出國報告(出國類別：國際會議)

參加第 10 屆生態系統與永續發展國際研討會

（10th International Conference on Ecosystems and Sustainable Development）

服務機關：行政院環境保護署綜合計畫處
姓名職稱：羅毓秀技士
派赴國家：西班牙
出國期間：104 年 5 月 30 日起至 6 月 7 日
報告日期：104 年 8 月 31 日

摘要

國際知名研究機構威塞克斯技術學院（WIT），近年來關注於環境保護、科技、永續發展等相關議題，進行許多研究，每年並召開國際會議深入探討。2015年第 10 屆生態系統與永續發展國際研討會在西班牙瓦倫西亞舉行，主要為針對生態系統、永續發展中不同層面的議題，提供科學界、工程界、經濟層面等專業人士建立共同的交流管道，進行研究和討論，該研討會歷年會議地點主要集中在西班牙、希臘、義大利、羅馬尼亞等歐洲地區，尤其重視永續發展議題，並希望藉由不斷更新的研究理論能有助與產業、政策等實務上結合。本次參與吸收各國論文提出者關切的議題及分析環境影響衝擊方法，探討國外永續發展趨勢，俾利本署境環影響評估發展後續施政之參考。

目次

一、出國目的……1

二、行程……1

三、會議地點及內容……2

四、會議參與情形摘述……7

五、心得與建議……12

附件 1　會議議程

附件 2　摘要論文

附件 3　其它會議相關資料

一、出國目的

生態系統與永續發展國際研討會係自 1997 年起針對永續發展之課題，包括環境管理、指標、政策等生態及環境議題召開國際會議，廣納各界對於環境永續發展的最新觀點與研究成果，可作為我國刻正檢討環境影響評估制度之重要參考方向。藉由本次同仁的參與瞭解國際為達成永續發展應用環境管理之技術、規劃及政策發展趨勢，並與其他國家經驗交流，作為我國永續發展思維下環境影響評估法制改進調整審議指標趨勢之重要參考。

二、行程

日期	地點	行程摘錄
5 月 30 日（六）至 31 日（日）	臺北-西班牙巴塞隆納	啟程
6 月 1 日（一）	西班牙巴塞隆納-瓦倫西亞	啟程
6 月 2 日（二）	西班牙瓦倫西亞	準備會議資料
6 月 3 日（三）上午	西班牙瓦倫西亞	研討會普利高津金獎頒獎典禮
6 月 3 日（三）下午	西班牙瓦倫西亞	研討會
6 月 4 日（四）	西班牙瓦倫西亞	研討會
6 月 5 日（五）	西班牙瓦倫西亞	研討會
6 月 6 日（六）至 7 日（日）	西班牙-臺北	返程

三、 會議地點及內容

西元 2015 年第 10 屆生態系統與永續發展國際研討會（10th International Conference on Ecosystems and Sustainable Development）於 2015 年 6 月 3 日至 6 月 5 日於西班牙瓦倫西亞 TRYP Valencia Ocean Hotel 舉行。

圖一、2015 年生態系統與永續發展國際研討會論文集

圖二、2015 年生態系統與永續發展國際研討會議地點西班牙瓦倫西亞 TRYP Valencia Ocean Hotel

本次會議專題研討分為九大議題，包括：永續發展規劃、生態系統模擬、永續發展研究、自然資源管理、政策、能源議題、永續指標監測及評估、市郊之自然資源、環境管理。共有來自世界 20 餘國近 150 人與會，我國僅本署派 1 人代表參加，會議論文發表數約 60 篇，分為 13 場分項座談會，並以 2 場次同步方式進行，並頒發生態系統學界著名的普利高津金獎，範圍非常廣泛，來自各國不同領域的專家學者就各種領域研究提出發表，會議議程詳如附件一。

圖三、2015 年生態系統與永續發展國際研討會報到

四、 會議參與情形摘述

本次會議專題研討分為九大議題，包括：永續發展規劃、生態系統模擬、永續發展研究、自然資源管理、政策、能源議題、永續指標監測及評估、市郊之自然資源、環境管理。大會並頒發生態系統學界著名的普利高津金獎，獲獎者為美籍華裔科學家、美國加州大學河濱分校終身教授 Larry Li，獲獎者演說特別指出，針對環境生態系統原本即具有自我調節的涵容能力，而經濟活動必須調節維持在生態環境的涵容範圍內，才不會造成環境污染。但是目前人類活動已導致了 60% 的生態系統被嚴重破壞，所以各國政府首先要瞭解生態系統的承受能力，其次必須控制污染排放總量不超過環境承載力，不能再沿用單一排放標準的線性管理，而是要將環境治理市場化，利用分析人類與生態系統間的相互關係，决定人類的社會需求和生態圈的和諧關係，由排污市場機制指標提出「生態金融」的理念，防止環境污染突破臨界點，才能維護生態系統的自我調節能力。

圖四、大會頒發生態系統學界普利高津金獎

圖五、普利高津金獎獲獎者發表演說

參考永續發展思維下，相關可納入環境影響評估法制改進調整審議指標之重要趨勢，故本次會議除參與本次會議主題之論壇外，亦參與多場次涉及政策座談會議，以下就各國針對其特性的政策和永續相關議題之探討摘要如下，其餘內容請詳見附錄二。

為規劃新型態大眾運輸系統之環境影響評估，義大利學者特別舉出其粒狀污染物屢屢超出限值的城市-帕多瓦，自西元 2007 年起開始推動電動大眾運輸系統，刻正進一步評估「甲烷巴士」大眾運輸政策，學者分析於相同的交通條件下，以甲烷全部取代或部分取代為雙燃料系統，以模式模擬其污染排放量、噪音、經濟及健康成本等層面影響之環境影響評估，提供作為政策決策參考基礎。

另與我國地理環境相似、自然資源有限的新加坡，因為高度工業化，

其面對永續發展的關鍵議題，研究機構則提出新加坡永續發展四大重要議題指標，作為永續指標的發展和確立，分別為：碳足跡、能源、水，及廢物管理與垃圾掩埋場，以規劃產品的溫室氣體排放量預測、發展潔淨能源、水資源政策及海上垃圾掩埋場進行研究，並以研究結果建議四大指標至2020年、2045年或2060年之目標期程。

巴西學者發表之透水鋪面成效分析及國家標準建議，係因巴西為防治疾病傳播政策及規劃永續發展目標，針對城市排水進行總體規劃，現已進行立法規範，近年來該國透水鋪面的使用比率雖已顯著地增加，但成效卻常因不正確的設計和施工，或缺乏適當的維護導致透水功能喪失，防治疾病成效不佳。故學者針對巴西透水鋪面國家標準進行分析，並建立設計、施工和維護之相關標準，提供作為政策擬定參考基礎。

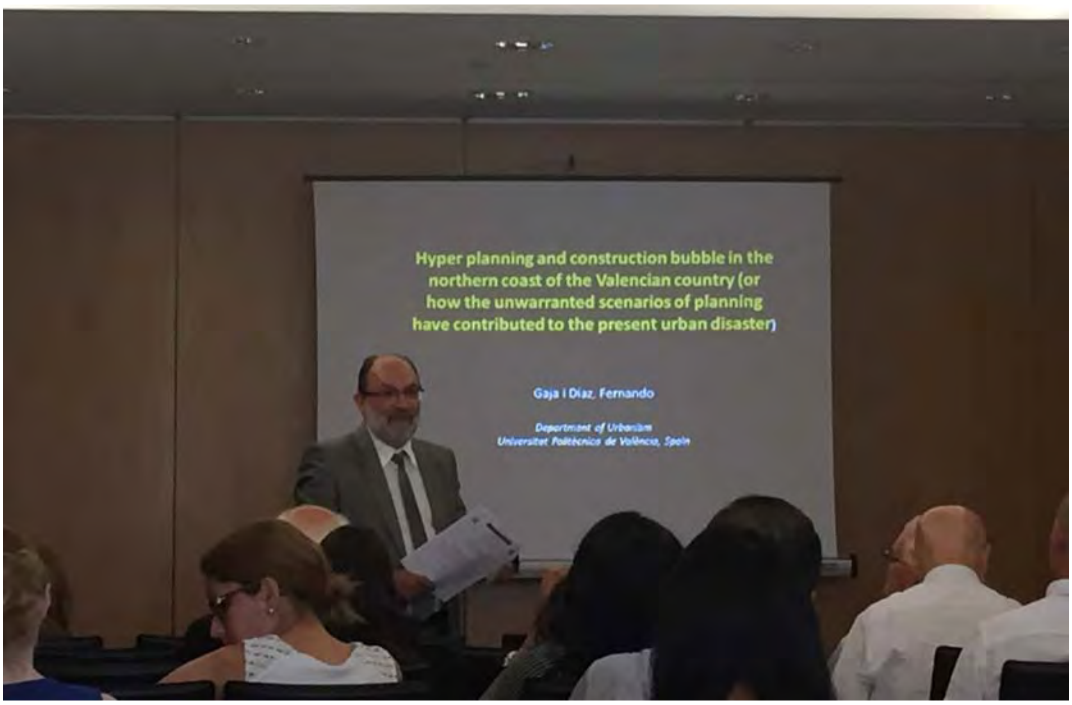
為了在複雜的環境效應中建立土地利用總體規劃和水資源管理之間的整合策略，以創造永續土地利用方案，西班牙學者針對該國格拉納達海岸研究，提出土地利用總體規劃和水資源管理整合，並建立閥值方案，作為一個方便的工具來限制在境內水利基礎設施影響的不確定性，幫助預測計畫可能出現的偏差和政策制定及決策。

為從廢棄物中創造價值，印尼詩都阿佐泥漿火山經常因泥漿噴發造成污染及影響周邊村莊。而該火山泥漿化學組成類似波特蘭水泥，故學者提出研究，將處理後的火山泥漿加以利用作為水泥替代材料。

考量世界各地建築設施的廣大需求消耗了大量的自然資源、水及能源，尤其在建築密度極高的香港，其對環境的影響更不應被低估，而綠色建材的選用將是必要趨勢，而香港綠色建築協會剛推出一個綠色建築產品標章計畫，規劃出可依建設項目及各種環境影響類別，選擇合適屬性的綠色建材方案，並建議與建築環境評估計畫整合，以提高城市建築設施環保

程度。

圖六、2015 生態系統與永續發展國際研討會情形



圖七、2015 生態系統與永續發展國際研討會情形

圖八、2015 生態系統與永續發展國際研討會情形

五、 心得與建議

（一） 永續發展建構於環境保護、經濟發展及社會公益三大基礎，本次會議多著重於環境保護及經濟發展面向，較少觸及社會公義層面，而我國自 83 年公布環境影響評估法、95 年發布作為政策環境影響評估工作推展主要依據的「政府政策環境影響評估作業要點」，規範各種開發行為及政策細項，在規劃階段應同時考量環境因素，發展迄今，無論是環境影響評估審議架構、專業之審查技術規範、多元化之公眾參與管道、審查結論及承諾事項落實監督，及政策環境影響評估之推動……等皆有相當之成果，尤其是首重資訊公開及公眾參與機制，建議本署未來應積極組隊參與國際會議，分享臺灣經驗，強化國際交流合作，提升我國環保形象。

（二） 我國環境影響評估法現在正面臨制度改革轉型時期，短期目標雖已藉由修訂環境影響評估法施行細則及環境影響評估作業準則，盡量加強目的事業主管機關權責，但在未來規劃長期改革目標，推動回歸各法律授與目的事業主管機關許可開發與否的權利時，將環境影響評估結果作為決定是否許可開發的考量因素之一，建議考量因素納入永續指標及市場機制，融入於個案或政策細項之整體評估的過程，並研訂適合我國的整體生態系統管理策略及措施，分析本土污染排放市場機制指標，結合生態金融理念，因應及預防環境污染突破臨界點，維護我國生態系統的自我調節能力，發展出符合永續發展趨勢，及符合我國本土環境屬性的第二代環境影響評估制度。

（三） 本次會議環境評估及政策議題，雖然不是對整體開發計畫環境影響評估方法進行討論，但對於各論文提出者關切的議題及環境影響衝擊的分析方法，可以看出國外發展的趨勢，即針對永續發展的迫切性，我國也應盡速

完成政府組織改造，成立環境資源部，結合生態環境、資源管理、污染防治及因應氣候變遷等面向，以達成環境永續發展的目標。

附件一、會議議程

CONFERENCE PROGRAMME

10th International Conference on
Ecosystems and Sustainable
Development

ECOSUD 2015

NOTES TO CHAIRMEN AND PRESENTERS

- Chairmen must be in their respective rooms 10 minutes before the start of their session to meet with the presenting authors.
- Authors must meet with the Chairman of their session 10 minutes before the start of the session.
- Authors must keep strictly to the time allocated for their presentation to ensure the smooth running of the programme.
- This programme is subject to last-minute alterations, please refer to the conference noticeboard for the most up-to-date information.

3 - 5 June, 2015

València, Spain

Organised by:
Universitat Politècnica de València, Spain
Wessex Institute of Technology, UK

Sponsored by:
WIT Transactions on Ecology and the Environment

Supported by:
International Journal of Design & Nature and Ecodynamics

Wednesday 3rd June 2015

14.30 **Keynote Address:**
Application of ecological models for assessment of sustainability
S. E. Jorgensen

Session 1: Sustainable development and planning (I) **Chairman: C. A. Brebbia**

15.00 **Invited:**
Hyper planning and the construction bubble on the northern coast of the Valencian countryside (or how the unwarranted scenarios of planning have contributed to the present urban disaster)
F. Gaja i Díaz 207

15.20 **Invited:**
The role of landscape aesthetics in the total economic value of landscape: a case study of Albufera Natural Park
V. Estruch-Guitart & M. Vallés-Planells 219

15.40 28 years into "Our Common Future": sustainable development in the post-Brundtland world
C. Y. Keong ORAL

Additional Presentation:

16.00 Enhanced biogas production from landfill leachate by low frequency ultrasound
C Can Yarimtepe, N Ayman Oz ORAL

REFRESHMENT BREAK

16.50 **Keynote Address:**
Ecology as a complex system
G. Rzevski

Session 2: Ecosystem modelling **Chairman: J. L. Miralles i Garcia**

17.20 **Invited:**
A theoretical model of the circuit of empty chemical containers from production to reuse
B. A. Larsen, Y. Villacampa, F. Garcia-Alonso, J. A. Reyes & P. Sastre-Vázquez 3

17.40 **Invited:**
Models to estimate the mechanical resistance to penetration in Argentine agricultural soils
J. M. Ressia, M. Cortés, Y. Villacampa & P. Sastre-Vázquez 13

18.00 Modeling and validating tritium transfer in a grassland ecosystem in response to 3H release
S. Le Dizès, H. Renard, F. Vermorel, D. Maro, C. Aulagnier, M. Rozet, D. Hébert & L. Solier 23

18.20 Environmental changes and temporal distribution of order Rodentia in North-East Brazil, and its link to the El Niño Southern Oscillation and drought in the region
G. Cruz Santos 33

END OF DAY 1

CONFERENCE DINNER

The conference dinner will take place during the evening. Please check the notice board or ask the Conference Coordinator for more information

Thursday 4th June 2015

PARALEL SESSION "A"

Session 3A: Sustainable development and planning (II) Chairman: S. E. Jorgensen

9.00	Improving the environmental performance of building facilities through a green building product labelling scheme *S. T. Ng & C. T. C. Wong*	243
9.20	Ecosystems and sustainable metabolisms *J. J. Galan Vivas, G. Peiro Frias & A. Fernandez Morote*	251
9.40	The concepts of planning and design in sustainable stormwater management *I. Tukiman, I. Zen & M. F. Musa*	263
10.00	Risk-oriented approach to long-term sustainability management for oil and gas companies in the course of implementation of investment projects *A. Domnikov, G. Chebotareva, P. Khomenko & M. Khodorovsky*	275
10.20	Effects of the Brazilian biodiesel certification in the relationship between the biodiesel industry and small-scale farmers *G. Marcossi, D. Ortiz & O. Moreno*	285

REFRESHMENT BREAK

Session 4: Sustainable development and planning (III) Chairman: E. Magaril

11.10	Energy strategies of industrial enterprises *L. D. Gitelman & M. V. Kozhevnikov*	297
11.30	Sidoarjo mud: creating worth from waste *M. F. Nuruddin, A. Fauzi Hasbi & M. M. Al Bakri Abdullah*	309
11.50	Integrating land use planning and water resource management: threshold scenarios – a tool to reach sustainability *M. I. Rodríguez, A. L. Grindlay, M. M. Cuevas & M. Zamorano*	231
12.10	The conservation of basins and the irrigation districts in Mexico *R. V. Lomeli & A. G. Nazario*	ORAL
12.30	Use of participatory development for sustainable tourism planning *S. Kask, T. Kull & K. Oru*	ORAL

LUNCH

Thursday 4th June 2015

PARALEL SESSION "B"

Session 3B **Chairman: G. Rzevski**

9.00 **Invited:**
Environmental tax as an instrument of economic stimulation to improve the quality of motor fuels
A. Golubeva & E. Magaril 149

9.20 Economics of ecosystem restoration: using derived demand to promote sustainable ecosystems
D. B. Rideout, D. Rossi & N. Kernohan 419

9.40 PQ analyses of a roof top solar PV: grid connected PV system pilot project in Indonesia
H. Suhana & N. I. Sinisuka ORAL

10.00 Considerations of user comfort in open spaces: lessons learned from the design of public spaces in the Eastern Mediterranean
A. Savvides ORAL

10.20 A remote sensing and GIS based spatial vulnerability model to support policy and decision making; A case study of St. Ives, UK
S. Vavias, T. R. Brewer, T. S. farewell ORAL

REFRESHMENT BREAK

Thursday 4th June 2015

PARALEL SESSION "A"

Session 5A **Chairman: P. Amrusch**

Part 1: Sustainable development studies:

14.30 **Invited:**
Effect of sediment load reduction in tidal entrance channels
A. J. Mehta, Y. P. Khare & K. Park 319

14.50 Sustainable development of the Russian Arctic regions
N. Didenko, D. Skripnuk, K. Kikkas & O. Seeleva 331

15.10 Relationship between community pride and participation needs in sustainable tourism development of Fishing Village: a case study of Samut Sakhon Province, Thailand
G. Pookaiyaudom 343

Part 2: Natural resources management (I)

15.30 Enhancing the traditional Mediterranean irrigation agroecosystems: a case study of the rivers Túria and Júcar (Valencia, Spain)
I. Martínez-Sanchis & M. J. Viñals 45

15.50 Assessment of urban landscapes management
M. A. Martínez Gimeno, J. Manzano, I. Balbastre Peralta & J. García-Serra 55

REFRESHMENT BREAK

Session 6A: Natural resources management (I) **Chairman: A. J. Mehta**

16.40 Fish landings in Barcelos, in the Middle Negro River Region, Amazonas
S. O. Inomata & C. E. C. Freitas 67

17.00 Problems of cadastral recording and assessment of lands in the Sverdlovsk region of Russia
I. Rukavishnikova 77

17.20 Dynamics of change in the peri-urban landscape of Huerta de Valencia: the case of La Punta (Valencia)
R. Temes & A. Moya 123

17.40 Resilience management of ecological services in National Parks: developing a new evolutionary approach
S. J. Pogue, J. A. Dearing, M. E. Edwards & G. M. Poppy ORAL

Additional Presentation:

18.00 Harnessing the latent sustainability – a postcolonial perspective
S. Sharma, S. Singh & I. Kularatne ORAL

END OF DAY 2

Thursday 4th June 2015

PARALEL SESSION "B"

Session 5B **Chairman: C. A. Brebbia**
Part 1: Policies

14.30	**Invited:** Environmental impact assessment of the employment of methane-run buses: a case study analysis for Padua, Italy *P. Amrusch, A. Tortella, A. Morini & F. Wirl*	431
14.50	Critical analysis of the Brazilian national standard for concrete permeable pavement *M. Marchioni, G. Becciu & C. Silva*	443

Part 2: Energy issues

15.10	Risks of systemic transformation in energy companies *L. D. Gitelman & M. V. Kozhevnikov*	357
15.30	Assessing the environmental impacts of 2nd generation (lignocellulosic) feedstock Under the energy-climate reference scenario using LUISA modelling platformi n EU-28 *C. Perpiña Castillo, C. Lavalle, C. Baranzelli, A. Barbosa, C. Jacobs-Crisioni & F. Batista e Silva*	367
15.50	Energy-efficient building with an integrated use of renewable energy sources in severe weather conditions *V I Velkin, S E Sheklein, A I Popov*	ORAL

REFRESHMENT BREAK

Session 6B: Sustainable indicators, monitoring and assessment **Chairman: J. L. Miralles i Garcia**

16.40	Developing and identifying sustainability indicators in the Singapore context *H. H. Khoo, A. W. L. Ee, Y. Wang, A. Adhitya, Y. S. Low, E. X. Y. Lim, C. K. Lee & R. B. H. Tan*	381
17.00	Sustainability in practice: integrated assessment to support policy and decision-making processes *A. Calleros-Islas & C. Welsh-Rodriguez*	393

Additional Presentations:

17.20	New technology for the recycling of aromatic amine waste products and salts of heavy metals into a multi-purpose non-toxic product *T. Yu. Grishchenko & I. S. Maslennikova*	457
17.40	Ecosystem based business model of smart grid *M. Lundgaard, Z. Ma & B. N. Jorgensen*	ORAL
18.00	Indicators to evaluate water sensitive urban design in urban planning *M. I. Rodriguez, M. M. Cuevas, F. Huertas, G. Martinez, B. Moreno*	ORAL

END OF DAY 2

Friday 5th June 2015

Session 7: Natural resources in peri-urban spaces **Chairman: G. Rzevski**

9.00 **Invited:**
Environmental management of peri-urban natural resources: L'Horta de Valencia case study
J. L. Miralles i Garcia 99

9.20 An approximate method for estimating water consumption according to tourist land use patterns: evidence from Gandía municipality (Spain)
R. Temes 85

9.40 Productive performance of small peri-urban farms using self-organizing maps and data envelopment analysis
A. P. S. Rubem, A. L. de Moura, E. de Oliveira, J. C. C. B. Soares de Mello, L. A. Alves & R. S. Tavares 133

10.00 Anthropic pressure and management of the municipal natural area of the Clot de Galvany, Elche, Spain
M. Vera Gonzalez , J. Navarro-Pedreno, J. C. Aranda & I. Gomez Lucas ORAL

Additional Presentation:

10.20 CO2 Emissions, Energy Consumption and GDP: Evidence from Iraq
J. Lee ORAL

REFRESHMENT BREAK

Session 8: Environmental management **Chairman: C. A. Brebbia**

11.10 Assessing the influence of restoration works on an artificialized river morphology
J. Botella, Y. Brizard, D. Chaisemartin & R. Nicolau 161

11.30 Environmental sustainability of the clementine production systems in Italy and Spain: an approach based on Life Cycle Assessment
B. F. Nicoló, M. C. De Salvo, C. Ramírez-Sanz, A. V. Estruch, N. Sanjuán, G. Falcone & A. Strano 173

11.50 Effect estimation of stem density and LAI on the evapotranspiration rate from forest stand
K. Tamai 195

12.10 EMAS – unfulfilled expectations and challenges associated with the planned publication of the new ISO 14001:2015
B. Szyszka & A. Matuszak-Flejszman ORAL

Additional Presentation:

12.30 **Invited:**
Occupation models in peri-urban areas: actions for orchard-city integration
S. Garcia-Ayllon 111

END OF ECOSUD 2015

We hope you have enjoyed the conference and look forward to seeing you at the next meeting in the series, have a safe and pleasant journey home.

附件二、摘要論文

Section 1
Ecosystem modelling

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A theoretical model of the circuit of empty chemical containers from production to reuse

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Abstract

This paper presents a theoretical model to evaluate the empty agrochemical packaging circuit used in the production of transgenic soya. In order for that, a model has been developed that analyzes the structure and causal relationships of the system. Thanks to this model, it will be possible to understand the retro feeding mechanisms in a time scale. Moreover, there has been shown a graphic representation of the dynamic system that starts in the yield process of the packaging, finishing with its re-use. The mathematical model generated is defined by a group of differential equations. These equations represent the change of the variables defined as level variables in time. The equations have been defined through flow variables that represent the yield rate use, discard and collection of packages. The theoretical model is close to reality and appropriate to simulate situations. During this period a theoretical model has been developed and in earlier stages planned sample taking is presented to obtain data to adjust the theoretical model proposed.

Keywords: model, chemical containers reuse.

1 Introduction

In Argentina, as in many other Latin American countries, there exists the development of activities that damage the environment as, for instance, the

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advance of the agricultural frontier where the election of the activity by the producers depends on market demands rather than land requirements. As a consequence of this, there is an exhaustion or deterioration of the land, an increase of erosion and desertification, water pollution and progressive loss of existing agricultural areas.

The technological package, consisting of genetically modified soya and direct seeding, which is used almost exclusively in Argentina, has enabled acceleration of agro-productive cycles. However, this technology uses a battery/set of agrochemicals, especially herbicides and insecticides, now added to fungicides and seed treatments (fungicide used in seed treatment) at a high cost. The genetically modified soya is agrochemical dependent. Its development is sustained based on ever increasing quantities of herbicides and insecticides, causing undesired effects on the environment.

Argentina, thanks to the transgenic soya went from being one of the “warehouses of the world” to become the “republic of the soya”. The use of soya, genetically modified to tolerate glyphosate-based herbicides, Roundup Ready System (RR) and Monsanto Company [1, 2] let uncontrolled fumigations. This fact has affected human and animal health, the environment and the cultivation for the feeding. The yield of soya has become a strategic monocrop basic for the yield structure of the nation but structurally weak and environmentally unsustainable. Among others, some of its negative effects analysed in this research it is worth to mention the problems generated by the direct seeding system (SD)-soya RR (Roundup Ready)-glyphosate, based on the massive use of traditionally, man has been considered as an entity separate from the environment, giving limited attributes leading to an overexploitation and depletion of systems and natural resources. This fact is closely linked to the development models over the last decades in the vast majority of developed and growing countries [3]. The fact is that, along history, man has been closely connected with nature but its conception about it has been changing, going from visions in which man protected nature to others where it was treated like a predictable and controllable system [4].

This relationship between man and nature is visualized in the development of the human activities on a concrete scenario, the *environment*, defined as “a space made of many elements: sun light, ground, air, water in all its means (rivers, rain, air moisture), big and small plants and animals, all types and sizes of buildings, artificial light, roads, air-conditioning, machinery, etc.” [4].

In this context, agriculture has transformed natural systems in agricultural systems or agro-systems, mainly characterized because of not being self-sustainable, their lack of diversity and resistance, being extremely dependent of the level of use and with short-term goals that make difficult the use of farming practices that tend to maintain a long-term production [5].

The *agriculturalization* process of the yield systems is a particular and common case of change of land use. On the one hand new agricultural areas are incorporated generating incomes to the yield system; on the other hand, this implies risks in the maintenance of the sustainability of the ecosystems and social systems [6]. It is important to analyse that neither the resilience [7] of the environment, the renovation ability of the nutrients or the substitution of labour by machinery among others are taken into consideration. The phenomenon of the soya is an example of an *agriculturalization* process characterised by a fast growing expansion of the cultivation of transgenic soya in detriment of other cultivations and land uses, generating the aforementioned effects. Due to this, Argentina is one of the countries that rapidly adopted the use of transgenic cultivations, generating a major technological change with environmental and human health related impacts. Due to this, it is important to do a permanent critical analysis of the situation and of the development and implementation of monitoring/control systems [8].

The soyalization process is characterized by the application of certain technology that involves the use of a large amount of agrochemicals; this lead to the utilization of over 200 million litres of glyphosate per year and to an increase in the use of biocides toxic for human health. The agrochemicals used comprehend a variety of chemical products with different absorption means, metabolism, kinetic elimination, action mechanism and toxicity. Despite the active principle, the formulas contain non-inert excipients and solvents since they influence the kinetic toxicity modifying some or all of their steps [9].

People can be more or less exposed to agrochemicals because of their jobs, accidents, food, etc. Due to this, despite the intrinsic toxicity of the agrochemicals, there have to be considered other factors that can increase or decrease the negative effects on man like: dose, means of exposition, age, sex [9].

A common goal in modern agriculture is to be able to control plagues that can affect cultivations in the most rational way. However, it is evident that integrated agriculture does not rejects the utilization of pesticides but underlines the efficient use of those. This way, to reach the goal of this research is it worth to question what to do with these recipients?

Firstly, we have to take into consideration that depending on its proper use they may not become a pollutant or won't be a toxic hazard for the user or for the public in general.

How to proceed then? Once that the pesticide has been loaded in the deposit of the machinery, it is important to give a good cleaning to the package incorporating washing water in the tool of pulverizing as well. This way, there is the financial advantage of using all the purchased product bringing to it its final destination, but avoiding contamination risks as well. Once it's been washed, we will proceed to make useless it through bottom perforation to avoid its potential reuse in any case. After that, it is necessary to contact the storing points that already exist in the region. These centres are linked to Officials Universities or private companies like cooperatives or trader centres. In these storing centres there the compacting process should be carried out to bring the packages to a recycling centre where they will be transformed in low environmental impact products like for instance, pipes for high voltage cables or optic fibre that will be buried underground next to public roads. It is important to realize that, contributing to give these dangerous rural residues a precisely controlled life cycle is the right thing to do. The proper re-use of these products will avoid further problems in benefit of the environment and all the population.

The main question of the research is: would it be possible to model the life cycle of empty agrochemical packages for transgenic soya yield? The authors have developed a first approach to the problem concluding that it is possible to model the life cycle of the empty packages generating a Forrester model [10, 11].

This model must be generated analysing the process from cradle to re-use.

2 Methodology

To achieve our goal a mental model was designed firstly, followed by a causal diagram and finally a Forrester model was developed [11–13], in order to define a group of differential equations to model the process.

It is a tool (fig 2) that shows the structure and causal relationships of a system that will help us to understand its mechanisms in a time scale. The basic elements are the variables or factors and the links or arrows. A variable is a condition, a situation, an action or a decision that can influence in or can be influences by other variables. Another elements are the arrows that represent the casual relationship between two of the variables. This influence can be negative or positive.

Forrester diagrams provide a graphical representation of dynamics systems quantitatively modeling the relationship between the parts by symbols corresponding to a thermodynamic interpretation of the system. It is a representation of the causal diagram in terminology that allows writing equations on the computer in order to validate the model observe the temporary evolution of the variables and do sensitivity analysis.

A feedback loop is a group of variables connected by causality or influence (negative or positive) that form a closed path starting with an initial value and ending with the same variable.

3 A theoretical model of the circuit of empty chemical containers

In the following figure 1 the mental model is shown. It is a mechanism that the mind uses to explain how the real world works. Due to the fact that some of the elements of reality are around us and not in our brains, a model should be developed to analyse the problems. One the mental model works, it proceeds to systematize some of its processes or components to increase the efficiency of the process, that is to say, the systematization of a process beginning with the mental model and then studying which parts can be systematized.

3.1 Modelling of the circuit of empty chemical containers

The following level variables are considered to explain the process of empty containers from its yield to its reuse:

1. Available containers: AC. Quantity of containers with their content, that is to say number of containers full with the product or chemical agriculture.

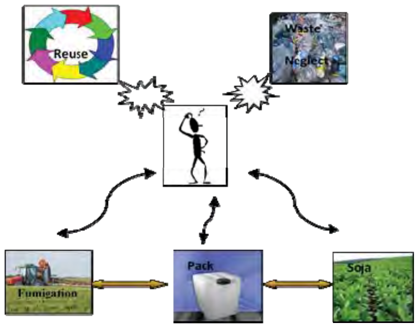

Figure 1: Waste or reuse.

2. Polluted containers: PC. Quantity of containers that don't contain remains of chemical agriculture used in the productive system.
3. Destroyed containers: DC. Quantity of containers destroyed by fire or burial.
4. Recycled containers: RC. Quantity of containers recycled through the triple washing.

The following flow variables are considered to explain the process of empty containers from its yield to its reuse:

1. Yield: Y. Quantity of full containers manufactured by unit of time.
2. Use: U. Amount of full containers used in the productive system by unit of time.
3. Destruction: D. Quantity of polluted containers that are destroyed, for unit of time.
4. Recycled: R. Quantity of polluted containers that become containers recovered, by unit of time.

Furthermore it is used the following auxiliary variables:

1. Yield Rate: PR. Amount of full containers manufactured.
2. Destruction rate: DR. Proportion of containers that leave the contaminated state and pass to the destroyed state.
3. Operational capacity of the machinery: OC. Number of acres that can be sprayed on Labor Day.
4. Duration of the workday: DW. Number of hours a day that can be sprayed.
5. Sequence of goods: SG. Number of operations required to perform the charging of the machinery.
6. Recipe Complexity applied: RC. The number of formulation components, i.e. the variable measures how many chemical components have the recipe.
7. Price of the empty container: PE. Market value of the empty container after being washed.

8. Distance to the collection center: DC. Number of kilometers until the nearest collection center.
9. Transport cost: TC. The cost of transporting empty containers to the collection center.
10. Surface available for seeding: SAS. Number of hectares available for seeding.

3.1.1 Sub-model area available for seeding

For the analysis of this problem a system dynamic model is proposed wherein it is possible to analyze the components of the route taken by packages containing glyphosate. This path relies heavily on the seeding area, so a sub-model is proposed to estimate the acres available for seeding and consequently make medical devices applications.

Two cycles are considered in the model. Cycle 1 represents a restriction of the system due to the availability of land. Cycle 2 is influenced by the amount of land available, less available land meaning increasing costs, causing crop profits to decrease and lower investment.

It is considered the following level variables:

1. Area for Seeding: AS.
2. Seeded area: SA.

It is considered the following flow variables:

1. Harvest 1.
2. Seeding: S.
3. Harvest 2.

In the sub-model it is considered as auxiliary variables:

1. Yield: Y.
2. Profitability: P.
3. Initial Area: IA.
4. New Area: NA.
5. Cost Seeding: CS.
6. Crop Yield: CP.

3.2 The Causal diagram and Forrester diagram

The causal diagram represents the causal relationship in the system. Also in the system a sub-model has been generated defining by the area available for seeding. The following figures 2 and 3 represent the causal diagrams that determine relationships for the general study of the system (figure 2) and the specific subsystem (figure 3).

Forrester diagram represented in the following figure 4 provides a graphical representation of the dynamic system. That is the relationship between the set of previously defined for the system model of the circuit of empty agrochemical variables, from yield to reuse, further comprising the subsystem defined by the available area for seeding.

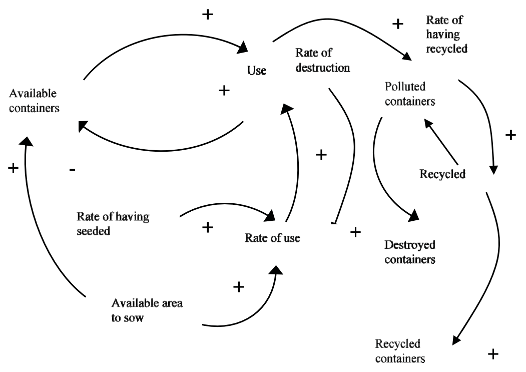

Figure 2: The causal diagrams of the system.

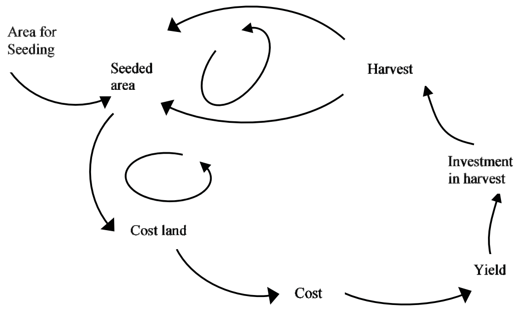

Figure 3: The causal diagrams of the sub-system.

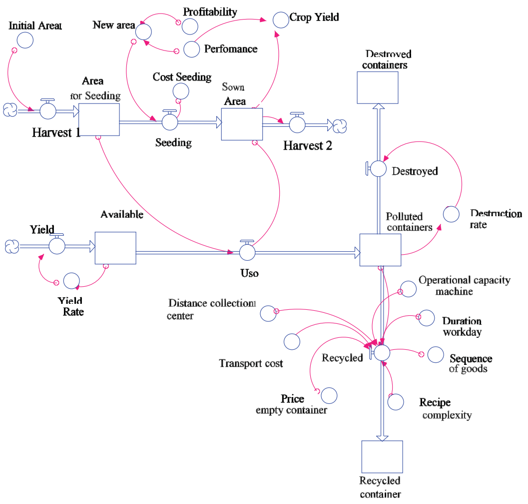

Figure 4: Forrester diagram.

3.3 Mathematical modelling

The state equations express the variation over time of the level variables and can be defined from the flow variables. Besides the flow variables can be expressed in terms of other variables.

The following state equations have been defined:

$$\frac{d(\mathrm{AC})}{dt} = Y - U$$

$$\frac{d(\mathrm{DC})}{dt} = D$$

$$\frac{d(\mathrm{PC})}{dt} = U - D - R$$

$$\frac{d(\mathrm{RC})}{dt} = R$$

Also, the following relationships or flow equations are considered:
Destruction = f (Polluted containers, Destruction rate)
*Destruction = Destruction rate * Polluted containers*
Recycled = f (Polluted containers, Operational capacity of the machinery, Recipe complexity applied, Transport cost, Distance to the collection center, Duration of the workday, Price of the empty container, Sequence of goods)
*Yield = Yield rate * Available containers*
Use =f (Area for seeding, Sown area, Available containers)

Or in an equivalent way:
Due to the fact that $D = f(PC, DR)$; $D = DR*PC$
$R = f(PC, OC, RC, TC, DC, DW, PE, SG)$
$Y = YR*AC$
$U = f(AS, SA, AC)$

Also, in the sub-model, the following state flow equations have been considered:

$$\frac{d(\mathrm{AS})}{dt} = H1 - S$$

$$\frac{d(\mathrm{SA})}{dt} = S - H2$$

4 Conclusions

A theoretical model has been defined for the study of the empty agrochemical container cycle, simulating a possible real situation. As is usual, the model does not represent the total reality but does give an approximation of it. The production of the Forrester diagram has made it possible to define a set of differential equations which study, over time, the variation of the level variables. To do this, initially, models for flow variables will have to be generated and analysed, making it possible for the evolution of level variables to be analysed and simulated over time. The study and modelling enables the quantification of the level variables as well as the simulation of their variations, enabling measures to be taken to discover in which levels an improvement in actions is needed. It is therefore possible to define sustainability indicators from the dynamic evolution of the system.

The authors, in their future investigations, and in coordination with the main representatives of the sector, will gather quantitative information for the defined variables in the theoretical model to study the dynamic behaviour of the system. This will furthermore enable the simulation of different scenarios and situations for the better management of the process and contribute to the sustainability of the system

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Moreover, obtaining experimental data will enable the adjustment of the theoretical model proposed in this work

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Models to estimate the mechanical resistance to penetration in Argentine agricultural soils

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Abstract

The mechanical resistance to penetration in agricultural soils varies with the water content of the soil.

Therefore the variation of soil humidity may mask the differences between treatments which were in the process of being evaluated. One way to avoid this problem is to make a correction in the humidity content of the soil. The aim of this study is to determine the ranges of variation in mechanical resistance due to the humidity and the depth for typical Argiudolls soils. The experimental data was obtained from four tests. The relation between the humidity, depth and mechanical resistance to the soil penetration was studied using several mathematical models.

The data were fit by equations with coefficients of determination ranging from 0.14 to 0.44.

Boundary conditions were assigned to adjust the equations. These conditions are referred at wet hard soil, dry and soft. In soils in Centro de la Provincia de Buenos Aires, Argentina, it is possible to explain part of the variability in the resistance to penetration of the soil by the humidity variability, apparent density, soil condition and depth.

The best model adjusted to the experimental data includes as independent variables: the condition of tillage, the depth and the apparent density.

Keywords: model, agriculture soil, mechanical resistance.

doi:10.2495/ECO150021

1 Introduction

As a consequence of soil degradation, a decrease in agricultural productivity is produced as well as damage to basic resources and ecosystems, which in turn leads to a loss of biodiversity due to changes in habitat both at a species and genetic level [1]. One of the main factors which cause physical deterioration of the earth is soil compaction [2]. Soil compaction is the collapse of soil structure and porosity due to load application. Besides causing a decrease in agricultural yield, this also leads to higher energy requirements in tillage and cultural labour, re-seeding, the need for higher doses of agrochemicals and more tractor and machinery passes, higher fertilizer use and inefficiency of machinery [3].

The resistance to soil penetration, along with apparent density are the two main parameters for determining the state of compaction in agricultural soil. Only when these two parameters have equal tendencies can we talk about soil compaction [4].

To measure the ground resistance to penetration, a cone penetrometer is used. This instrument has been standardised by the American Association of Agricultural Engineering under regulation ASAE S 313 [5] and, in Argentina under regulation IRAM 8063 [6]. The cone penetrometer has a cone and dipstick, both connected to a load cell and data storage unit [7]. Regulations stipulate two cone measurements, both of 30°: a large one of 20.27 mm in diameter and a smaller one of 12.83 mm in diameter. A penetration velocity of 30.5 mm s^{-1} has also been standardised. The force needed for penetration, related to the cone base surface, provides resistance to soil penetration data, in pressure units. The results of the profile evaluation are expressed in terms of cone index, which is the average taken from sufficient measurements to guarantee reliability of data [7].

Another soil parameter linked to the state of compaction is the apparent density, whose evaluation can be carried out by taking soil samples with a cylinder of known volume, drying said samples in a stove and later weighing them. The main problem with this method is the difficulty of taking a large number of samples without modifying them and the subsequent laboratory work this entails.

Currently, an indirect measurement of apparent density can be utilised by the attenuation of gamma rays, using a nuclear instrument. This will also usually give measurements of humidity present in the profile. Later, said instrument performs calculations to show and record data, directly such as the apparent density when dried [7]. However, this technique can prove difficult to implement owing to the high cost of the instrument and existing difficulties with manipulation of the nuclear instrumental equipment. Humidity is among the natural factors which have most influence on the resistance to penetration of agricultural soil, the link between the two being the main problem for obtaining comparable measurements of both. When humidity content is high, the earth sticks to the cone walls, slightly changing its geometry and, therefore, modifying the measurement registered by the instrument, likewise distorting the interpretation of penetrometry data [8].

In agricultural experimentation, the resistance to soil penetration is often used to compare treatments that differ in their humidity content (different tillage, different times of year, different soil stratums). In these circumstances, this

technique presents difficulties in clarifying if the value obtained is a product of compaction itself, or is caused by humidity content which may mask the effects of soil management in resistance to penetration.

Finding a clear mathematical link between the humidity and resistance to penetration will enable comparisons to be made in relation to uniform humidity, eliminating the ‘noise’ caused by differences in humidity. Different equations have been proposed for standardising resistance to penetration data as regards a common humidity, allowing a reduction in confounding effects, [9, 10]. However, it has been affirmed that, to do this, a good adjustment between resistance to penetration and humidity is necessary.

Lapen *et al.* [11] found that this adjustment is good for direct seeding soils but not for laboured soil. Yasin *et al.* [12], argue that the best connection between the cone index and humidity and apparent density is linear, while with the depth it is cubic, although they had to use an adjustment equation for each tillage treatment. The use of specific adjustments for each treatment involves the risk that the adjustment forms part of the specific effect in the tillage, which is what is being evaluated.

Paredes *et al.* [13], find significant regressions with R^2 between 27 and 61%. However, if this was really done with three humidity levels, only a limited index of data for one soil was included, up to 20 cm and without tillage treatments.

The objective of this study is to obtain general equations to enable resistance to penetration estimates, with a cone penetrometer, for agricultural soil in the central region of Buenos Aires, Argentina. Mathematical models which relate mechanical resistance to penetration, soil water content, apparent density, depth and soil condition are adjusted and compared.

2 Materials and methods

The study was undertaken with data from four tests, located in the vicinity of Cuidad de Azul (36°46’ latitude and 59°51’ longitude), Argentina, on three soils classified as typical Argiudoll, between the years 2004 and 2014. The tests included a control treatment, without decompacting, in direct seeding and, another two decompaction treatments. Information for each test is summarised in table 1.

2.1 Statistical analysis

Measurements were taken of gravimetric humidity (W), apparent density (AD) and cone index (CI). The measurements were taken at different stratum depths inside the soil profile (E). The form of measurement of the variables was the following:

- Cone index (CI): was determined using a cone penetrometer, constructed under regulation ASAE S 313, with digital information storage, which took samples every 25 mm. Each cone index value is the average of between 5 and 10 measurements.
- Apparent density (AD): was determined using the cylinder method and drying the soil in a stove until uniform weight was achieved.

Table 1: Characteristics of the tests.

Test	Group	Surface (m^2)	Treatment	Depth (cm)	n	Measuring/Time (month)
1	3	240	Control	0	267	3/11
			Paratill	35		
			Chisel	35		
2	3	240	Control	0	132	2/7
			Paratill	35		
			Chisel	38		
3	4	12,000	Control	0	816	4/36
			Paratill	30		
			Straight	35		
4	4	7,500	Control	0	240	2/12
			Paratill	30		
			Superficial	20		

- Gravimetric humidity (W): was determined in gravimetric form along with apparent density, drying the soil in a stove until uniform weight was achieved.
- Depth (E): in tests 1 and 2 depths of : 0–100, 100–200, 200–300, 300–400 and, 400–500 millimetres were used; in tests 3 and 4 depths of 0–100, 100–200, 200–300 y, 300–450 millimetres were used.
- Condition (C): results were classified, being grouped according to whether they had had decompaction treatment: with and without treatment.

The variation of the variables was studied: humidity (W), cone index (CI) and apparent density (AD) through different depths (E), in the combined results from the 4 tests. For this, variance analysis was performed, taking into account the depth factor (E). The averages were compared using the Duncan test of 5%. Moreover, taking CI as a dependent variable and X = W, X = AD and X = E as independent variables, the adjustment of the following models was studied:

1) *Linear:* $IC = b_0 + b_1 X$,
2) *Logarithmic:* $IC = b_0 + b_1 \ln X$,
3) *Inverse:* $IC = b_0 + b_1 / X$,
4) *Quadratic:* $IC = b_0 + b_1 X + b_2 X^2$,
5) *Cubic:* $IC = b_0 + b_1 X + b_2 X^2 + b_3 X^3$,
6) *Power:* $IC = b_0 X^{b1}$,
7) *ExpNoLn:* $IC= b_0 b_1^X$,
8) *Growth:* $IC = e^{(b_0 + b_1 / X)}$,
9) *ExpLn:* $IC= b_0 e^{b_1 X}$

With the objective of finding equations to estimate cone index values with adequate precision, multiple linear regressions were adjusted, taking condition, depth and apparent density as independent variables. Variables were selected with the Stepwise method.

3 Results

The study of the variation in variables humidity (W), cone index (CI) and apparent density (AD) through different depths shows the existence of a statistically significant effect between depths for the variables studied.

Thus, taking W variable as an example, there are only differences between levels if the letters are different, as can be seen in the table. For example, level 100 is no different from level 400, likewise 450 from 500, but a difference can be seen from level 200 (not having any common letters). By comparing the averages of these variables the results shown in table 2 and fig. 1 are obtained.

Table 2: Comparison of the mean, Duncan test, humidity (W), cone index (CI) and apparent density (AD) through different depths (E).

Depth	Mean (DA)	Stand. Dev.	Mean (W)	Stand. Dev.	Mean (IC)	Stand. Dev.
100	1.13 (a)	0.09	24.11 (ab)	4.45	947.63 (a)	674.64
200	1.23 (b)	0.08	25.22 (cd)	2.75	1847.47 (b)	1018.87
300	1.26 (c)	0.08	25.89 (d)	2.82	1910.43 (b)	1166.88
400	1.30 (d)	0.08	23.52 (a)	3.37	3334.08 (d)	1396.84
450	1.37 (e)	0.09	24.92 (bc)	1.88	1691.67 (b)	431.18
500	1.37 (e)	0.06	24.47 (bc)	2.48	2901.08 (c)	1263.86

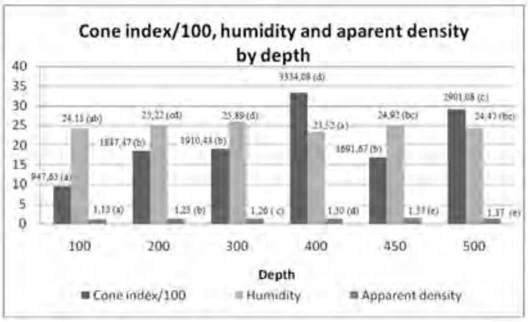

Figure 1: Average values of cone index, Duncan test, humidity and apparent density, at different depths.

The differences in humidity at different depths make the comparison of CI values at different depths difficult, in accordance with De Simone *et al.* [8].

In table 3 results obtained by adjusting the models with dependent variable Cone index (CI) and independent variable Humidity (W) are presented. In this table it can be observed that the models which presented greater R^2 are the linear, the quadratic and the cubic. In each one, it can be observed that, as is expected, the greater the water content, the lower the CI. None of the models analysed can be recommended for making CI estimations from soil humidity, due to the fact that very low R^2 values are obtained, explaining only 14.3% of the variability.

Table 3: Regressions: dependent variable (CI) and independent variable (X=W).

		Estimation of the parameters			
Model	R^2	b_0	b_1	b_2	b_3
1) *Linear:* $IC = b_0 + b_1 X$	0.141	4804.655	-124.672		
2) *Logarithmic:* $IC = b_0 + b_1 \ln X$	0.135	10652.671	-2793.158		
3) *Inverse:* $IC = b_0 + b_1 / X$	0.123	-698.981	58501.13		
4) *Quadratic:* $IC = b_0 + b_1 X + b_2 X^2$	0.142	3734.431	-32.134	-1.956	
5) *Cubic:* $IC = b_0 + b_1 X + b_2 X^2 + b_3 X^3$	0.143	3773.585	0.000	-4.832	0.06
6) *ExpNoLn:* $IC = b_0 b_1^X$	0.076	5802.955	0.944		
7) *Power:* $IC = b_0 X^{b1}$	0.071	82231.575	-1.273		
8) *Growth:* $IC = e^{(b_0 + b_1 / X)}$	0.064	6.148	26.535		
9) *ExpLn:* $IC = b_0 e^{b_1 X}$	0.076	5802.955	-0.057		

In table 4, results obtained for the case of adjusted regressions with dependent variable cone index (CI) and independent variable apparent density (AD) are displayed. In table 4 it can be observed that the models with greater R^2 are those of increase S and potential; however, none of the models analysed can be recommended for CI estimations as the R^2 values are very low, under 12%.

In table 5, results obtained for the case of adjusted regressions corresponding to dependent variable CI and independent variable E can be seen. From the observation of this table it can be deduced that the depth, adopting a model of increase S, would explain almost 30% of the cone index variation

This result concurs with that obtained from carrying out, for variable (CI), variance analysis with one factor: depth. As a result, although statistically significant, the predictive capacity of these variables, when they are taken in an isolated form, proves limited. In these variables, it should also be noted, that the depth of measurement has more influence over the cone index than the humidity or apparent density. In table 6, the models of equations obtained by the adjustment of multiple linear regressions, the adjustments and the estimates of their parameters, are shown.

Table 4: Regressions, dependent variable (CI) and independent variable (X=DA).

		Estimation of the parameters			
Model	R^2	b_0	b_1	b_2	b_3
1) *Linear:* $IC = b_0 + b_1 X$	0.024	-109.744	1450.283		
2) *Logarithmic:* $IC = b_0 + b_1 \ln X$	0.027	1292.947	1876.984		
3) *Inverse:* $IC = b_0 + b_1 / X$	0.030	3621.227	-2375.535		
4) *Quadratic:* $IC = b_0 + b_1 X + b_2 X^2$	0.042	-11610.164	20155.659	-7539.622	
5) *Cubic:* $IC = b_0 + b_1 X + b_2 X^2 + b_3 X^3$	0.042	-7912.088	10966.908	.000	-2043.538
6) *ExpNoLn:* $IC = b_0 b_1^X$	0.107	128.260	6.781		
7) *Power:* $IC = b_0 X^{b1}$	0.113	827.102	2.418		
8) *Growth:* $IC = e^{(b_0 + b_1 / X)}$	0.119	9.661	-2.990		
9) *ExpLn:* $IC = b_0 e^{b_1 X}$	0.107	128.260	1.914		

Table 5: Regressions, dependent variable (CI) and independent variable (X=E).

		Estimation of the parameters			
Model	R^2	b_0	b_1	b_2	b_3
1) *Linear:* $IC = b_0 + b_1 X$	0.112	961.948	2.814		
2) *Logarithmic:* $IC = b_0 + b_1 \ln X$	0.143	-2306.635	738.064		
3) *Inverse:* $IC = b_0 + b_1 / X$	0.161	2448.238	-145697.533		
4) *Quadratic:* $IC = b_0 + b_1 X + b_2 X^2$	0.158	-19.376	11.823	-0.016	
5) *Cubic:* $IC = b_0 + b_1 X + b_2 X^2 + b_3 X^3$	0.166	-1092.860	27.881	-0.082	7.96E-005
6) *ExpNoLn:* $IC = b_0 b_1^X$	0.206	743.536	1.002		
7) *Power:* $IC = b_0 X^{b1}$	0.263	46.120	0.628		
8) *Growth:* $IC = e^{(b_0 + b_1 / X)}$	0.297	7.877	-124.243		
9) *ExpLn:* $IC = b_0 e^{b_1 X}$	0.206	743.536	0.002		

Table 6: Models, adjustments and parameters.

Dependent Variable: Cone index				
R^2	Model	Variables	Coefficients	
			B	Tip. Error
0.141	1	Constant	3357.946	110.556
		Humidity^2	-2.628	0.170
0.262	2	Constant	2650.882	112.306
		Humidity^2	-2.712	0.157
		Depth	2.924	0.190
0.342	3	Constant	1544.033	134.590
		Humidity^2	-3.048	0.151
		Depth	15.024	0.924
		Depth^2	-0.022	0.002
0.370	4	Constant	987.287	148.959
		Humidity^2	-3.049	0.147
		Depth	15.061	0.904
		Depth^2	-0.022	0.002
		Condition	361.269	45.099
0.401	5	Constant	1576.351	159.979
		Humidity^2	-3.140	0.144
		Depth	16.544	0.898
		Depth^2	-0.022	0.002
		Condition	401.117	44.195
		Apparent density^3	-493.581	56.269
0.422	6	Constant	3367.831	292.324
		Humidity^2	-13.866	1.482
		Depth	17.281	0.888
		Depth^2	-0.023	0.002
		Condition	415.859	43.472
		Apparent density^3	-440.195	55.774
		Humidity^3	0.292	0.040
0.439	7	Constant	2032.165	349.313
		Humidity^2	-15.043	1.470
		Depth	41.299	3.663
		Depth^2	-0.121	0.015
		Condition	417.693	42.818
		Apparent density^3	-477.878	55.216
		Humidity^3	0.324	0.040
		Depth^3	0.0001	0.0001

Taking as independent variables: condition, depth, apparent density, and these elevated variables squared and cubed; an adjustment of multiple linear regressions explains 43.9% of the variability in the best cases. The tendencies are similar to those studied by Paredes *et al.* [13], and although the correlation values obtained have been less than those found by different authors in the bibliography [9–13], the sample universe was much broader. The use of a general correction factor which enables the standardisation of the cone index values to a uniform humidity, so as to be able to make comparisons between treatments and/or depths with different water content, therefore appears to be possible in this region.

4 Conclusions

In soil from the central region of the province of Buenos Aires, Argentina, it is possible to explain part of the variability in resistance to penetration by the variability of humidity, apparent density, condition of the soil and the depth at which it is measured.

In this work, defined models for mathematical equations which permit, with a cone penetrometer, estimations of the resistance to penetration in agricultural soil in the central region of the province of Buenos Aires, Argentina, have been generated. The models which relate the mechanical resistance to the penetration, hydrological content of soil, apparent density, depth and condition of soil, have been compared.

Moreover, in the region analysed, in accordance with the results obtained, the use of a general correction factor which enables a standardisation of cone index values to a uniform humidity content is possible, therefore making possible the comparison between treatments and/or depths with different water content.

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Modeling and validating tritium transfer in a grassland ecosystem in response to 3H release

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Abstract

In this paper a radioecological model for tritium transfer in a grassland ecosystem developed on an hourly time-step basis is proposed and compared with the first data set obtained in the vicinity of the AREVA NC reprocessing plant of La Hague (France).

Keywords: tritium transfers, process-oriented model, data acquisition and processing, grassland ecosystem.

1 Introduction

Tritium (^3H) is a major radionuclide released by the French nuclear facilities during normal operation, whether in gaseous or liquid waste discharges. Mainly released as tritiated water vapor (HTO) in the atmosphere, tritium can be readily integrated into terrestrial ecosystems through plant photosynthesis, and then follows the cycle of stable hydrogen (and hence water) throughout the food chain. To assess ^3H transfer into the environment for the calculation of human dose, it is important to develop models that are not only operational – i.e. based on a limited number of easily accessible parameters – but also tested against extensive sets of field measurements. In addition, among the many existing models in the literature, to our knowledge, there are very few models that predict ^3H transfer in terrestrial environment in response to discrete atmospheric releases from a nuclear facility.

The TOCATTA model developed at the Institute for Radioprotection and Nuclear Safety (IRSN) aims at estimating tritium (and carbon-14, ^{14}C) transfer in terrestrial ecosystems, in response to continuous or discrete atmospheric releases, or combinations thereof. The model was previously tested for ^{14}C by comparison with a set of field measurements - covering a two-year period - in the framework of the Validation of TOCATTA (VATO) study [1]. The main conclusion drawn from these comparisons has highlighted the need to develop an hourly time step model of ^{14}C transfer based more thoroughly on knowledge arising from plant physiology, soil science and meteorology [1]. Thus, by increasing the temporal resolution of the model, a new version recently developed, called TOCATTA-χ, can simulate the impact of intermittent ^{14}C releases occurring either the day or night.

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Regarding tritium, a previous study [2] has thrown light upon the efforts needed to produce more conclusive future modelling and experimental studies on ^3H transfer. First, in order to more realistically represent the fate of tritium in a plant exposed to acute variations in ^3H releases and meteorology, the TOCATTA-χ model previously developed to simulate ^{14}C transfers to pasture on an hourly time-step basis [3, 4] should be adapted to take account for processes specific to tritium, for example by integrating the water cycling within vegetation. Second, future experimental networks should cover all media (air, soil, rain, plant) and consider all forms of tritium and possible conversion reactions between these forms over time, along with controlled or at least constrained environmental conditions [2]. To achieve this (ambitious) goal, IRSN is setting up an *in-situ* laboratory on a ryegrass field plot closed to the AREVA reprocessing plant of La Hague, from 2013 to 2017, as was done in the past for the assessment of transfer of radiocarbon in grass [1]. More specifically, the main objective of this large-scale project is to better understand and evaluate transfer processes of tritium in several forms (HT, HTO) from the atmosphere (air and rainwater) to grass and soil. The hourly time-step model development is quite ambitious in that some of the required inputs are not sampled hourly. However, efforts are made to carry out high-frequency samples, such as ^{85}Kr measurements recorded every minute, from which it is possible to reconstruct atmospheric input data at an hourly time-step.

The goals of this paper are (1) to present the organization of the experimental design of the study dedicated to transfers of tritium in a grassland ecosystem, (2) to document the major assumptions, conceptual modelling and mathematical formulations of tritium transfers in soil-plant systems that have been implemented in the SYMBIOSE-3H model [4], and (3) to present the method used to reconstruct the atmospheric concentrations of HT and HTO on an hourly basis.

2 The IRSN experimental design

Because of the releases of ^3H in the atmosphere associated with normal operation of the AREVA NC La Hague nuclear reprocessing plant, the specific activity of ^3H observed in various environmental matrices located a few kilometers away from the discharge point is on average ten times higher than the natural background level. In addition, various studies have demonstrated the existence of persistent uncertainties on the transfer of tritium from atmospheric emissary to terrestrial ecosystem [5] such as grasslands – first essential links of a typical food chain of man. In this context, the experimental field set up by the IRSN 2km downwind from the nuclear fuel recycling plant of La Hague (AREVA NC) has been monitoring since June 2013 tritium concentration and transfer fluxes in/between environmental samples (air, rain, grass, soil) of a grassland ecosystem, together with meteorological parameters acquisition. The objectives of this experimental field are:

(i) to better understand the organically-bound-tritium (OBT) formation in plant by photosynthesis;
(ii) to evaluate transfer processes of tritium in several forms (HT, HTO) from the atmosphere (air and rainwater) to grass and soil;
(iii) to develop a model allowing to reproduce the dynamic response of the ecosystem to tritium atmospheric releases depending of variable environmental conditions.

So far, specific instrumentation and tests have been performed successfully in the laboratory and instrumentations (e.g. lysimeters) have been installed on the technical platform of the *in situ* laboratory. Since summer 2013, tritium activity measurements have been carried out in grass (monthly measurements of HTO, OBT), in air, rainwater, soil (daily measurements of HT, HTO) according to a specific sampling plan (see table 1). CO_2, H_2O fluxes between soil and air compartments are being measured as well.

Table 1: Sampling plan for the years 2013–2015.

Sample	Location	Frequency (days)	Analysis		
			HTO	HT	OBT
Air	*In situ* lab	30	x	x	
Air	*In situ* lab	2	x		
Rain water	*In situ* lab	2	x		
Plant	Permanent grass	15	x		x
Soil (0–20cm)	Permanent grass	30	x		x
Soil water	Permanent grass	2	x		
Plant	Lysimeters	15	x		x
Soil (0–20cm)	Lysimeters	30	x		x
Soil water	Lysimeters	30	x		

3 Modelling approach

3.1 Model main assumptions and characteristics

TOCATTA-χ is a dynamic compartment model developed at IRSN for managed (or unmanaged) productive pastures. The model is being implemented in the SYMBIOSE modelling platform to simulate ^{3}H (and ^{14}C) transfer in grassland ecosystems exposed to atmospheric ^{3}H (and ^{14}C) emissions from nuclear facilities operating under normal or accident conditions. The model was previously developed and tested on an hourly time-step basis for ^{14}C transfer to pasture [3, 4] and is under development for tritium to take into account acute variations in ^{3}H releases and meteorology. It has the following main characteristics and assumptions:

- The model is based on an hourly time-step;

- It is driven by monthly (and every two-days) atmospheric concentrations of tritiated water vapour (HTO) above the canopy and hourly weather input data for radiation, temperature, relative humidity, wind speed, and precipitation;
- The model integrates the day / night cycle of plant physiological behavior (photosynthetic uptake, respiratory loss, water and nutrient status, plant above-ground and below-ground dry matter production) derived from a simplified version of the PASIM (Pasture SImulation Model) process-based pasture model [6];
- The net photosynthetic production of OBT in plant parts is linked to the tissue free water tritium (TFWT) concentration in leaves, ignoring the OBT production during the night time [7]. It is a function of leaf CO_2 assimilation rate (net of respiration) derived from the biochemical Farquhar model [8] while the leaf area index (LAI) and the radiation scheme have been estimated in a quite simple manner [4];
- A physiological approach is used to integrate LAI and resistances in the calculations of exchange velocities at the leaf/air and soil/air interfaces;
- The model uses the same conceptual and mathematical modelling approaches as defined in SYMBIOSE [1]: the conceptual framework is based on the interaction matrix formalism (cf. section II.B), while the mathematical model is implemented as a series of first-order differential equations, defined for time-varying release conditions and expressing conservation of radionuclide activity for each compartment of the conceptual model. The time rate of change of the activity or concentration in a given compartment is mostly expressed by summing the different mass transfer fluxes coming in/out from/to other interacting compartments.

3.2 Conceptual model

The plant conceptual model in TOCATTA-χ comprises three compartments (table 2): (i) the substrate pool (i.e. sap), (ii) the shoot structural dry matter and (iii) the root structural dry matter. Other simplifications were made [3, 4]. For example, first neither the age nor the development stage of the plant are considered. Second, it is assumed only one layer inside the canopy. This affects both the radiation scheme and the photosynthesis computation [4]. Third, only the whole plant above the ground (i.e. the shoot biomass) along with the root have been considered, i.e. the stem, sheath, ear and laminae are not considered separately. Last, the pool of tritium in soil is assumed to be only tritiated water dissolved in soil pore water of the single soil layer. The soil HTO compartment is subject to loss because of root uptake. In addition, the processes of diffusion and migration in the soil are neglected.

3.3 Model test

TOCATTA-χ was previously tested against in situ data of ^{3}H activities measured in 2011 on the grass field plot located in the vicinity of the AREVA NC La Hague reprocessing plant [9]. However the model did not reproduce adequately the

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observed month-to-month variability; in particular, it overestimated OBT activity during the summer months. To cope with that matter, some processes have been identified to be further improved. Above all, an essential prerequisite for improving the model-measurements comparison is the reconstruction on a fine time scale (i.e. hourly) of dynamics of tritium concentrations in the atmosphere.

4 Reconstruction of atmospheric concentrations of tritium at an hourly time-step

4.1 Need to restore hourly dynamics in air and rain

As mentioned above, a good estimation of the atmospheric tritium concentrations to sufficiently high frequency levels (e.g. hourly) is an essential condition for ensuring the quality of model evaluation. Indeed hourly HTO concentration in air is required as input to the TOCATTA-χ model (atmospheric HT concentrations will also be required in the future). In addition exchange kinetics between the vapor in the atmosphere tritiated water (HTO) and tissue-free-water-tritium of the plant (TFWT) are very fast, of about half an hour (Belot *et al.* [10]). However the measurement results obtained for the atmospheric compartment, provided with a period of 2 days, do not allow accounting for the rapid changes in atmospheric concentrations and hence rapid exchange kinetics between HTO in air and TFWT. In addition, there is no direct way to sample atmospheric HTO on an hourly time basis.

Regarding tritiated hydrogen (HT), the environmental measurements are carried out at intervals of one month; it is possible to reconstruct hourly dynamics using Krypton-85 (^{85}Kr). Indeed, HT and ^{85}Kr are emitted into the atmosphere concomitantly and only by the two main chimneys UP2-800 and UP3. Since ^{85}Kr is a plume tracer, it could be measured at very high resolution (~1-minute sampling). The ^{85}Kr data were then used to downscale the monthly HT data to hourly time-step relying on a quantitative relationship between ^{85}Kr and HT release rates (see eqn. (1)), as was done in the past for long-term ^{14}C data. Consequently based on ^{85}Kr measurements every minute at 1.5-m above the plot and the actual ^{85}Kr and HT monthly discharge rates from the AREVA NC reprocessing plant, the atmospheric HT activity above the plot was estimated on an hourly basis from June 2013 to June 2014. Thus, instead of using an atmospheric dispersion model as input to TOCATTA-χ, we directly used the hourly activity of HT in air recorded at 1.5-m above the plot.

Unlike HT, tritiated water vapor (HTO) is emitted in the atmosphere not only by the two main chimneys (UP2-800 and UP3) but also by the emissaries of buildings D', STE2 and STE3 (fig. 1).

To reconstruct HTO concentration in air water vapor and rainwater on an hourly basis, it is thus necessary to take into account all sources using ^{85}Kr but also wind direction to take into account the possible influence of buildings D', STE2 and STE3.

Table 2: Conceptual model of TOCATTA-χ. Diagonal elements represent the compartments and off-diagonal elements are the processes included in the model. The processes written in italics are used in the mass conservation equation (to the dry matter plants).

SOURCE[a]	Gas dispersion (HTO)	Wet input (HTO, via precipitation) •Interception by soil	Wet input (HTO, via precipitation) •Interception by plant						
	AIR CANOPY[b]	Soil surface exchange (HTO)	Foliar diffusion (TFWT)				Photosynthesis		
		SOIL WATER[c]	Root uptake (HTO)						
			PLANT WATER[d]	Net formation (OBT)					
				PLANT DM[e]					
					Shoot structural dm[f]			*Ageing*	*Cutting (grass)*
						Root structural dm[g]		*Ageing*	Respiration
					Biological growth	*Biological growth*	**Substrate (sap)**[h]		
								REST PLANT[i]	
									SINK

[a] Tritiated water present in the atmosphere (air and water droplets). Specific releases would need to be defined for a given scenario; [b] Tritiated water vapour in the vegetation canopy atmosphere; [c] Dissolved HTO in the soil pores; [d] Tissue Free Water Tritium (TFWT) in grass above-ground parts; [e] Non-exchangeable Organically-Bound Tritium (OBT) in plant dry matter (DM); [f] Non-exchangeable Organically-Bound Tritium (OBT) in shoot structural dry matter (dm) of grass; [g] Non-exchangeable Organically-Bound Tritium (OBT) in root structural dry matter (dm) of grass; [h] Non-exchangeable Organically-Bound Tritium (OBT) in the substrate pool (equivalent to the sap); [i] The REST (OF) PLANT compartment includes all tissues constituting the plant, with the exception of the water in aboveground parts, sap and structural dry matter compartments, for example: water in plant root system, vascular system, etc. This compartment is not modelled.

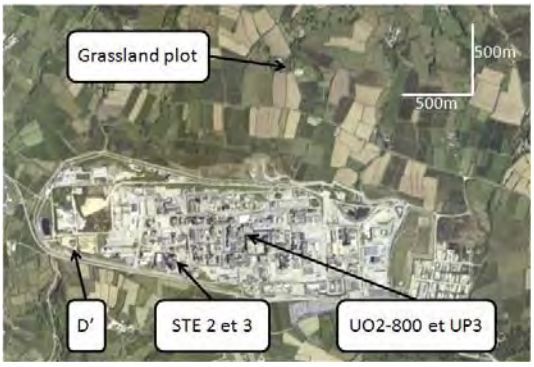

Figure 1: Position of tritium release points.

4.2 Reconstruction of HT concentration in air at an hourly time-step

HT and ^{85}Kr are released concomitantly from the same chimneys (UP2-800 and UP3), so the monthly concentration of HT measured in atmosphere is downscaled to hourly time-step according to the following equation:

$$C_c(HT)h_t = C_m(Kr)h_t \frac{C_m(HT)_m}{C_m(Kr)_m} \tag{1}$$

where $C_c(HT)h_t$, $C_m(HT)h_t$ are hourly air concentrations of HT and ^{85}Kr, respectively, calculated at an hourly time-step (Bq.m^{-3}); $C_c(HT)m$, $C_m(HT)m$ are monthly measured concentrations of HT and ^{85}Kr in air (Bq.m^{-3}).

4.3 Reconstruction of HTO concentration in air at an hourly time-step

HTO is partly released from the chimneys UP2-800 and UP3 and partly from the chimneys of the building D', STE2 and STE3; so two equations are used for reconstructing HTO through time.

4.4 Calculation of hourly concentrations above the plot coming from the chimneys UP2-800 and UP3

$$C_c(HTO_{UP})h_t = C_c(HT)h_t \frac{R(HTO_{UP})_m}{R(HT)_m} \tag{2}$$

where $C_c(HTO_{UP})h_t$ and $C_c(HT)h_t$ are hourly concentrations of HTO and HT (see eqn. (1)) in air calculated at time t and coming from the chimneys UP2-800 and UP3 (Bq.m^{-3}); $R(HTO_{UP})m$ is the monthly release of HTO in air coming from the chimneys UP2-800 and UP3 (Bq); $R(HT)m$ monthly release of HT (Bq).

4.4.1 Calculation of hourly concentrations above the plot coming from the chimneys D ', STE2 and STE3 (in the same angular sector, given a beating wind of 20°)

In most cases, $C_c(HTO_{UP})48h < C_c(HTO_{UP})48h$, so we have the following equations:

$$C_c(HTO_{AC})48h = C_m(HTO)48h - C_c(HTO_{UP})48h \tag{3}$$

$$C_c(HTO_{AC})h_t = C_c(HTO_{AC})48h \frac{fc_t}{\Sigma_1^{48} fc_t} 48 \tag{4}$$

where: $C_c(HTO_{AC})h_t$ is the averaged concentration of HTO in air calculated over 48 hours, coming from the chimneys D', STE2 and STE3 (Bq.m^{-3}); $C_c(HTO_{AC})48h$ is the hourly concentration of HTO in air calculated at time t and coming from the chimneys D', STE2 and STE3 (Bq.m^{-3}); fc_t is the weighing factor of atmospheric HTO concentration calculated at time t equal to discrete values (0 or 1) depending on wind direction (1 if wind direction is between 185° and 241°; 0 in other cases)

In the future, this weighting factor could be calculated with the laws of Gauss.

4.4.2 Calculation of total hourly concentration of HTO in air

The total concentration of atmospheric HTO at an hourly time-step is the sum of two sources of atmospheric tritium, i.e. that from the chimney UP2-800 and UP3 (see eqn. (2)) and that from the other three chimneys (eqn. (4)):

$$C_c(HTO)h_t = C_c(HTO_{UP})h_t + C_c(HTO_{AC})h_t \tag{5}$$

The hourly reconstructed dynamics of HT and HTO concentrations in the atmosphere are presented fig. 2.

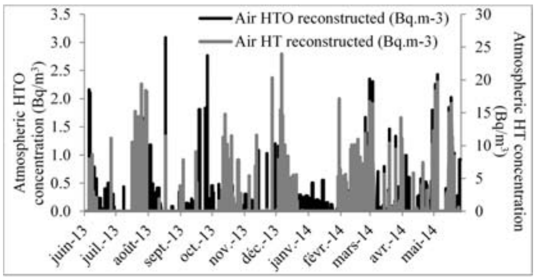

Figure 2: Atmospheric concentrations of HT (right axis) as estimated by the Krypton-85 methodology and atmospheric concentrations of HTO (left axis) as estimated from HT concentration and methodology explained in the text.

4.5 Reconstruction of HTO concentration in rainwater with an hourly time–step

Hourly concentration of HTO in rainwater depends on the concentration of HTO in air and intensity of precipitation. The calculation takes into account these two parameters in the calculation of the weighing factor.

$$C_c(HTO_{PL})h_t = C_m(HTO_{PL})48h \frac{fp_t}{\Sigma_1^{48} fp_t} \frac{\overset{n}{\Sigma_1} IP_t}{IP_t} \tag{6}$$

where: $C_c(HTO_{PL})h_t$ is the hourly concentration of HTO in rainwater calculated at time t (Bq.L-1); $C_m(HTO_{PL})48h$ is the averaged concentration of HTO in rainwater measured over 48 hours (Bq.L^{-1}); fp_t: Weighing factor of HTO concentration in rainwater at time t, i.e. the product of the concentration of HTO in air (Bq.m-3) and intensity of precipitation (mm.hr^{-1}); IP_t: Intensity of precipitations (mm.h^{-1}) for a given number n of precipitation.

5 Conclusion and perspectives

In the present study, gaseous releases of tritium from the AREVA NC nuclear reprocessing plant in normal operation can be intense and intermittent over a period of less than 24 hours. The TOCATTA-χ model previously developed to simulate ^{14}C transfers to pasture on an hourly time-step basis [2, 3] has been adapted to take account for processes specific to tritium. Previous model-measurements comparison studies [2, 9] had shown that TOCATTA-χ could be improved in terms of kinetics of tritium transfer and further tested against the extensive set of field measurements that has been obtained since 2013. In order to address the great number of factors that affect transfer processes of tritium (e.g. air and soil humidity, temperature, current and recent rainfall, season, growth stage etc.), the IRSN project is also carrying out high frequency (daily) sampling in air, rainwater and soil to reduce uncertainties in tritium transfer coefficients. Secondly, the results of this experiment will allow improving the TOCATTA-χ model accordingly.

As a prerequisite for performing further simulation runs and improving model evaluation, this article emphasizes the need to properly reconstruct hourly dynamics of HT and HTO atmospheric concentrations.

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Environmental changes and temporal distribution of order Rodentia in North-East Brazil, and its link to the El Niño Southern Oscillation and drought in the region

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Abstract

Between 1978 and 2010 in the Low San Francisco Sergipano ("LSFS") North-East Brazil ("NEB") region, there have been outbreaks of rodent plagues with an irregular temporal scale but in the same spatial scale, where rats have attacked the floodplain rice fields. Rats constitute a serious problem, insofar as they affect rice growing in this region causing massive economic losses. "El Niño" (EN) has a significant impact on animal communities and its effects on NEB are most often associated with years of drought throughout that region, which tested serious environment changes in the 1970s. The genera and species identified in the paper are Holochilus sicureus, which is predominant in the LSFS, Oryzomys sublavus, Rattus spp., and Nectomys sp. This comparative study of the plague years suggest that the temporal scale for the rat plague is related to the El Niño/Southern Oscillation (ENSO) years and climatic conditions in the dry season in the NEB region.

Keywords: floodplain, Holochilus, Low San Francisco Sergipano, Neópolis, Propriá, rodent outbreak.

1 Introduction

The index Southern Oscillation Index (SOI) [1] and its effects have often been linked with significant changes in animal behaviour [2–6]. Chilean scientists have shown the link between the El Niño Southern Oscillation (ENSO) event, the phenomenon known as "blooming desert" and the "rodent irruptions" ("ratadas")

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[5]. The "ratadas" have been associated with the ENSO event in the semi-arid regions of different South American countries such as Argentina, Bolivia, Brazil, Chile, Paraguay, Peru and Uruguay [5]. The effects of this oceanic and atmospheric coupling event referred to as SOI/ENSO have a big impact in the North-East Brazil (NEB) with the El Niño (EN) causing dry season with below-average precipitation, and La Niña (LN) contributing with precipitation [7–11]. Low San Francisco Sergipano (LSFS) is one of the sub-regions within NEB, and it has long been held as a natural example of interaction between river and floodplain systems. This sub-region actually underwent major environmental changes in the 1970s with a modification of the San Francisco (SF) river course triggered by the construction of the Sobradinho dam and reservoir [12–15]. As a result of this, the natural rice-growing floodplain areas were changed to an irrigated perimeter. Ever since the irrigated perimeter began operating in 1977, rodent outbreaks ("ratadas") have become usual on these floodplains [16]. This is a comparative study focused on the temporal scale between years of the ENSO event and rodents outbreak. It is suggested that rat plague is related to the years of ENSO; and the climate conditions in NEB during the dry season. This study makes a review of the literature linking ENSO events and "ratadas" in this region, and analyses the correlation between anomalies from oceanic-atmospheric regions ("OAR") and precipitation in the rice-growing floodplains in the LSFS for the years with rodent outbreaks.

1.1 Area of study and data

The PIB is a floodplain with a total area of 647.7 hectares. This region has an average annual temperature of 25.5°C and its mean annual precipitation (MAP) of 1.555 mm. The climate is sub-humid according to Thornthwait with two clearly defined seasons, resulting in a wet and relatively dry and warm [13–15]. In Propriá, the climate is "megathermic" semi-arid with MAP of 806.01 mm and an average annual temperature of 26.1°C [17]. Propriá is included within the semi-arid tropical zone and Neópolis within the sub-humid zone [13, 17].

In order to determine the correlation between the ENSO events, climatic conditions of the LSFS and rodent outbreaks, we analyse the monthly precipitation in a range of 10 non-sequential years in the same temporal scale in two different geographical zones of the LSFS floodplains areas which had recorded rat plagues: Propriá and Irrigated Perimeter Betume ("PIB")-Neópolis in the north NEB ("n-NEB"). Their rainfall was compared with the respective monthly anomalies for OAR categories in the Equatorial Pacific Ocean for the SOI [18] and the Niños Regions ("NR"): n1+2, n3, n4, n34 [19]. The most common correlation or predictability measurement, Pearson's coefficient (r), was introduced to assess the monthly precipitation anomalies of LSFS and OAR. The significance of the relationship was expressed in the probability value p at a linear correlation significance level of $p \leq 0.05$ and $p \leq 0.01$ (*95% and **99%). The software programme SPSS, version 19.0, was used for the statistical analysis. The comparison between the temporal scale characterised by the ENSO event, was checked against the National Oceanographic and Atmospheric Administration (NOAA) [20]. LSFS monthly precipitation data were provided by INMET and

CMRHSE [21] for the years 1978, 1982, 1983 and 1988 in Propriá 10° 12'49" S and 36° 50'28" [17], and Ascondir Station in Betume-Neópolis 10° 17' and 10° 24' S and 36° 36' 35 45 W [22] for the years 1993, 1998, 1999, 2005, 2009 and 2010. The 63 rice-growers from Betume were surveyed about the rodent plague in the LSFS floodplains before the environmental changes with one question: "Were there "Ratadas" before the PIB came into operation?" In this study, when MAP<800 mm, it is considered as years with much lower than mean annual precipitation (MLMAP) [23].

2 Results and discussion

In this study it was confirmed that: (a) the rat plague has been an irregularly occurring natural phenomenon in the LSFS floodplains; (b) an occurrence of rodent outbreak with losses for the growers of the flooded rice fields happened for the first time in 1978 after the environmental changes in the region; (c) in the LSFS 3 types of environmental changes were identified: (a) a physical change in the course of the SF River as a result of the construction of the Sobradinho dam in 1973, and it coming into operation in 1977; (b) changes in the use of the land with it traditional production system changing to irrigation system, and from one annual harvest to two; (c) and the three naturally occurring different land use stages during the year (river-floodplain, flooded rice-fields, and pasture) were reduced to solely rice-growing.

Of the 63 rice growers surveyed, 69.84% of them answered 'no' to the question about whether the plague had occurred prior to the environmental changes. The remaining 30.16% of rice-growers had no knowledge of the period prior to the environmental changes. "Ratadas" were actually observed in the rice-growing LSFS floodplains in 10 years of the last three decades since PIB came into operation (namely:1978, 1982, 1983, 1988, 1993, 1998, 1999, 2005, 2009 and 2010), table 1.

Table 1: Temporal scale for rodent outbreaks and ENSO event.

Plague	EN	LN	n-NEB	LSFS	LSFS mm
1978	weak	-	rainy	HMAP	1.127.4
1982	strong	-	rainy	MLMAP	780
1983	strong	weak	drought	MLMAP	484
1988	strong	strong	rainy	MLMAP	475
1993	neutral	neutral	drought	MLMAP	486
1998	strong	moderate	drought	LMAP	998.1
1999	moderate	moderate/strong	rainy	LMAP	1.035.8
2005	weak	weak	rainy	LMAP	1.460.1
2009	moderate	weak	rainy	HMAP	1.711.7
2010	moderate	strong	rainy	HMAP	1.715.6

Table based on [16, 20–22, 27, 28].

2.1 El Niño events and precipitation in the n-NEB and LSFS

In relation to the climatic conditions in the n-NEB the review of the literature has shown years with rainy seasons and severe drought in the n-NEB, table 1. The crossing point between the anomalies found in LSFS through the data corresponding to Propriá and PIB was identified as:(a) years with much lower than the mean annual precipitation (MLMAP) in 1982, 1983, 1988, and 1993; (b) years with a low mean annual precipitation (LMAP) in (1998, 1999 and 2005) and (c) years with a high mean annual precipitation (HMAP) – higher than the usual precipitation level in the LSFS region in 1978, 2009 and 2010 in table 1.

2.1.1 Statistical analyses between anomalies in OARs and LSFS

The correlation analysis of monthly anomalies between TSM (Temperature Sea Marine) of OARs and precipitation in LSFS floodplains identified four climatic conditions: (a) Association of correlations between SOI-NR $r<0$; NR-LSFS $r<0$ and SOI-LSFS $r>0$ in 1978 (EN-weak), and in 1982, with the EN (weak and strong) events in tables 1 and 2; (b) SOI-NR $r<0$, NR-LSFS $r>0$ and SOI-LSFS $r<0$ in 1983 with EN and LN (strong-weak) events; and in 1993 (a neutral year for the ENSO event in tables 1 and 2; (c) SOI-NR $r<0$, NR-LSFS $r>0$ and SOI-LSFS $r>0$ in 1988 (EN strong; LN strong), 1998 (EN strong; LN moderate), tables 1 and 2; (d) SOI-NR $r<0$, NR-LSFS $r>0$ and SOI-LSFS $r<0$ with years with both EN and LN episodes: in 1999 (EN-moderate and LN moderate/strong), in 2005 (EN weak-LN weak), 2009 (EN-moderate; LN-weak) and 2010 (EN moderate-LN strong) in table 1. Save for 1993, all the other years showing an occurrence of the plague were years of ENSO events.

2.1.1.1 Rodent outbreaks The plague first occurred in 1978, with neither the genus nor species being identified; in 1982–1983, rats were identified as Holochilus sp., Rattus spp. and Kerodon rupestris; 1988 had rodent irruption in the LSFS with neither the genus nor species being identified; in 1993, as Holochilus sciureus and Oryzomys sublavus; in 1998, the damage was caused by Holochilus sciureus; and in 1999, they were identified as Holochilus sciureus, Nectomys sp., and Rattus spp. by means of data collected in the field; finally, the damage was attributed to Holochilus sciureus in 2005, 2009 and 2010.

According to Santos [16], rodent outbreaks in the LSFS region result from the environmental impact caused by the changes experienced in the region. Before the environmental changes, during higher-water stages the river was a corridor for the aquatic species that entered the floodplains, thus functioning as a natural barrier against terrestrial animals such as infestations, and the productive system of this period had fishing as its basis. Instead, when the water returned to river, the lagoons became rice-growing fields with one annual harvest, and when the water level fell, the floodplains became grazing pastures. The traditionally established related to land use in this floodplain agro-ecosystem was almost lost.

Of the 63 rice-growers who answered the question posed, 69.84% – corresponding to those who lived in this region when the environmental changes took place – linked plague occurrence since 1978 to the introduction of PIB for

Table 2: Correlation analysis between TSMs of OARs and LSFS.

Years: TSMs/OARs and (r)	n1+2	n3	n4	n34	SOI-LSFS
1978 SOI-NR	-.597*	-.641*	-.315	-.606*	.486
NR-LSFS	-.694*	-.762**	-.302	-.476	
1982 SOI-NR	-.882**	-.862**	.312	-.863**	.171
NR-LSFS	-.432	-.424	-.300	-.359	
1983 SOI-NR	-.109	-.684*	-.720**	-.808**	-.308
NR-LSFS	.256	.163	.196	.141	
1988 SOI-NR	-.569	-.631*	-.742**	-.730**	.026
NR-LSFS	.102	.296	.188	.279	
1993 SOI-NR	-.459	-.257	.222	-.206	-.289
NR-LSFS	.251	.091	-.141	.055	
1998 SOI-NR	-.801**	-.924**	-.905**	-.926**	.133
NR-LSFS	.375	.155	.193	.100	
1999 SOI-NR	.296	-.300	-.776**	-.413	-.681*
NR-LSFS	-.500	.126	.800**	.346	
2005 SOI-NR	-.089	-.269	-.269	-.159	-.187
NR-LSFS	.463	.512	-.092	.213	
2009 SOI-NR	-.402	-.683*	-.716**	-.716**	-.248
NR-LSFS	.527	.118	.003	.006	
2010 SOI-NR	-.691*	-.862**	-.842**	-.880**	-.516
NR-LSFS	.706*	.771**	.757**	.761**	

rice growing, according to [24, 25]. The rodent outbreak appears as a natural and irregular disturbance in NEB [26], it suggests that an irregular outbreak of "ratadas" could be normal in this region in years with strong ENSO events (EN and LN).

Since the first confirmed rodent outbreak occurrence in the LSFS region in 1978, of the 12 years with strong ENSO events (1982–1983, 1987–1988, 1997–1998 (EN); 1988–1989, 1999–2000 and 2010–2011 (LN) [20], six of them (4 strong EN and 3 strong LN) were noted for plagues in LSFS (1982–1983, 1988, 1998, 1999, 2010) in table 1. Of these six years, three "ratadas" occurred in years

of extreme drought in the NEB region (1982, 1983 and 1988) [27, 28] and in 1993 been a year of extreme drought with neither ENSO event being identified, table 1.

Mares *et al*. [29] claim that animals from semi-arid areas are generally not well anatomically and physiologically adapted to bear the climate conditions which are typical of such periods. These animals could use microhabitats and shelters during drought periods, possibly developing their adaptation mechanisms as a solution in order to offset their physiological deficiencies [30]. Santos [16, 31] associated years of ENSO events with years of "ratadas" in LSFS. All of the above suggests that, during these very warm periods resulting from ENSO in LSFS semi-arid zones, these mammals seek refuge in the irrigated rice fields due both to the abundance of food and water, and the better temperature conditions. Furthermore, rice fields serve as a habitat for wild species and other animals, and river-floodplain as systems which cannot be separated [32, 33].

In relation to ENSO years, the results obtained from crossing point between the anomalies for OARs and LSFS were identified as: (a) SOI-LSFS r<0 (1983-MLMAP, 1993-MLMAP, 1999-LMAP, 2005-LMAP, 2009-HMAP and 2010-HMAP) with their respective precipitation levels, tables 1 and 2; (a.1) SOI-LSFS r>0: 1978-HMAP, 1982-MLMAP, 1988-MLMAP and 1998-LMAP; and (b) NR-LSFS with r<0 respectively for each region with data in (1978 and 1982) with (HMAP and MLMAP); and (b) NR-LSFS r>0 in years (1983-MLMAP, 1988-MLMAP, 1993-MLMAP, 1998-LMAP, 1999-LMAP, 2005-LMAP, 2009-HMAP and 2010-HMAP respectively in tables 1 and 2. According to Dos Santos *et al.* [34], if SOI-LSFS r>0, then there would be precipitation in the NEB and, conversely, a drought season would occur when NR-LSFS with r>0. However, it is possible for us to confirm HMAP in years with NR-LSFS for r>0 in 2009 and 2010.

With the exception of *Rattus spp.* [35], all the other confirmed genera and species identified by this study – in tune with the results obtained in other previous works – are native to the caatinga ecosystem in the NEB region. The genera and species identified in the study area according to the years of rodent outbreaks were: *Holochilus spp.*, *Kerodon rupestris* and *Rattus sp*. [36]; *Oryzomys sublavus* and *Holochilus sciureus* [37], and *Nectomys sp., Rattus spp.* and *Holochilus sciureusin* [16]. *Holochilus sciureus* is an autochthonous and predominant specie in the LSFS [37], and it is the most tropical rodent pest in South America [38]. The LSFS floodplains are a geographical zone situated between the coastline and the '*caatinga*' (semi-arid ecosystem) in the NEB [39], and Junk *et al.* [40] claim that plenty of organisms colonise this natural ecosystems and adapt to them, equipping themselves to survive during periods of drought.

There are two major natural resources that mark the Brazilian North-East region: the climate and the SF River, both of which have shaped major environmental, social and economic condition and decision in this region. It can thus be assumed that LSFS floodplain offers far less natural barriers after the environmental changes experienced in this region, with the ENSO event coming to exert a much larger influence, which in turn resulted in an increase of rodent outbreaks in the floodplains rice fields, with the subsequent considerable losses suffered by rice growers.

Finally, this study has shown that: (a) "ratadas" are a natural occurrence in semi-arid NEB zones, and they appear as a disturbance in LSFS floodplains as a result of the climatic condition in the region; (b) a strong link exists between the temporal scale for the ENSO event and the "ratadas" identified in different LSFS spatial scale; (c) in the specific case of the spatial scale examined here, only in one year (1993) was the association between the ENSO event and the "ratadas" not linked to that ENSO event – but severe drought occurred in the NEB region; (d) the temporal scale analysed for rodent outbreaks identifies years of ENSO events with MLMAP (drought), years with LMAP (below average precipitation) and years with heavy rains – HMAP (higher than usual precipitation) – in LSFS; (e) years with strong ENSO events were noted for drought in the NEB region with MLMAP or LMAP in the LSFS. On the whole, the study confirms the existence of a significant link between rodent outbreaks and years with ENSO, LMAP and MLMAP events in LSFS, and drought in the NEB.

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Section 2
Natural resources management

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Enhancing the traditional Mediterranean irrigation agroecosystems: a case study of the rivers Túria and Júcar (Valencia, Spain)

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Abstract

Since ancient times, agriculture has had a significant impact on ecosystems in the Mediterranean basin. Current cultural landscapes are a result of these historical activities and they are sites where traditional human knowledge is reflected in both tangible and intangible heritage assets.

The use of water for agriculture has always involved an understanding of the geographic space, hydrology management practices, and the engineering design of hydraulic devices such as small dams, weirs, irrigation channels, pools, or water mills, among other things. The intangible heritage is also especially relevant since the historical irrigation system provides the landscape with a structure characterized by orality, best practices, and traditional environmental knowledge.

However, this heritage is at risk due to its wide territorial spread and in some cases loss of functionality. Urbanization, unsuitable land usage and loss of production are also factors that can be mentioned.

This paper focuses on analysing the influence that the tangible and intangible heritage and the landscapes linked to the Rivers Júcar and Túria have on local development. The results indicate the existence of several resources with great cultural and recreational potential. They also continue to be key elements in the functioning of existing historical irrigation systems and, for this reason, these irrigation systems can still be considered fundamental drivers of the current sustainable development.

Keywords: territorial management, cultural landscape, hydraulic heritage, traditional irrigation system.

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1 Introduction and objectives

The Mediterranean basin is a semi-arid climate region where water resources are limited and irregular in both time and space. Therefore, historically, the freshwater ecosystems have been subjected to intense pressures from humans. In this context, the water management of the fluvial ecosystems, in all its intricacies (adaptations to the topography, geology, hydrology, climate, and biota), was the basis of agriculture, which gave way to farmed landscapes (agroecosystems) as a result of centuries of sustainable interaction between people and nature.

These traditional land use systems are still operational ('active living landscapes') and continue to provide valuable economic input. Moreover, nowadays, they are also considered cultural assets because of their historical features (archaeology, traditional buildings, distinctive settlements, local customs, and traditions) and the existence of intangible asset like Local Traditional Ecological Knowledge (TEK), also referred to as Local Ecological Knowledge (LEK), indigenous knowledge or ecoliteracy, that, according to Berkes [1] can provide lessons and insights in addressing the relationships between humans and nature. These systems are called 'Cultural Landscapes' and the UNESCO World Heritage Convention [2] defines them as "*the combined works of nature and humankind, that express a long and intimate relationship between peoples and their natural environment*". They often reflect specific techniques of sustainable land-use, taking into account the characteristics and limits of the natural environment they are established in. At the present time, 88 cultural landscapes are inscribed on the World Heritage List. The group of water management ecosystems includes the outstanding examples of the ancient Dujiangyan Irrigation System (China) constructed around 256 BC and still in use; the Shushtar Historical Hydraulic System (Iran), from the 5th century BC; the Canal du Midi (France), built between 1667 and 1694, which links the Mediterranean and the Atlantic ocean through 328 structures, and is one of the most remarkable feats of civil engineering in modern times. In Spain some age-old traditional irrigators' communities, such is the case of *Hombres Buenos de Murcia* (River Segura) and the *Tribunal de las Aguas de Valencia* (Valencia Water Court), which is studied in this paper.

The FAO has also approached this issue in order to safeguard and support these cultural heritage systems. Thus, in 2002 it started an initiative for the dynamic conservation of Globally Important Agricultural Heritage Systems (GIAHS) that promotes public understanding, awareness, and national and international recognition of these landscapes. Additionally, the European Landscape Convention, also known as the Florence Convention, recognizes the intimate and complex interrelationship between the natural and cultural heritage and the contribution of landscapes to European cultural heritage. This Convention highlights the contribution of the cultural landscapes to the consolidation of the European collective identity and sense of place.

Traditional Mediterranean land-use systems, which as proposed by Mata and Fernández [3] include historical irrigation systems, are a good example of these social-ecological systems with a high conservation value and high cultural

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diversity [4], where traditional management practices were part of an intermediate disturbance regime that has proven to enhance biodiversity [5].

In the framework of these cultural landscapes, the living farmed landscape category includes the 'traditional irrigation system landscapes' that are the focus of this paper. According to Leibundgut [6], the term 'traditional irrigation' implies the technical and organizational management of irrigation as practised in Europe before the introduction of modern techniques (sprinkling, drip irrigation) and the abandoning of old organizational structures (associations, common property regimes). Thus, it can be said that these traditional irrigation systems are derived from social and ecological systems that are interlinked and form complex social-ecological systems that co-evolve over time [7].

Historical water uses for agriculture involve an understanding of the geographic space, hydrology management practices, and engineering design of hydraulic devices. The intangible heritage is, as mentioned, also especially relevant since the historical irrigation system provides the landscape with a structure characterized by orality, best practices and traditional environmental knowledge.

Fluvial ecosystems have historically worked in agriculture. As a result of such activities, these traditional irrigation systems reflect tangible and intangible assets that endow the rural landscape with personality and identity and represent a valuable cultural heritage.

Leibundgut and Kohn [8] have listed at least 60 potential sites of traditional irrigation systems in Europe which deserve integral preservation. This list includes the Spanish Traditional Irrigation systems of the Valencian Rivers Túria and Júcar, studied in this paper, although they have not yet received official recognition. Only the River Túria partially enjoys the status of regional natural park (*Parc Natural del Túria*), and its intangible management structure (Valencia Water Court) is listed in the UNESCO World Heritage Convention as an intangible asset, as mentioned above. Therefore, this work intends to understand, appreciate and enhance the significance, as heritage elements, of the structures and features used in water management in these floodplain rivers in order to raise awareness about the need to preserve and protect them. This is important because there remain few traditional irrigation systems still in operation in Europe and without a prompt institutional response in just a few years it may be too late. Moreover, these traditional systems can be considered to be "learning laboratories" because they have resulted from advanced knowledge about sustainable techniques in land use. Additionally, protection of these traditional cultural landscapes can maintain or enhance natural values and biodiversity in the Mediterranean fluvial region.

Lastly, as Sabaté [9] points out, the new approach of the concept of territorial planning in the 21st century is focused on the nature-culture basis and that fits in perfectly with the idea of cultural landscape.

First, this paper presents a general overview of these two traditional Valencian irrigation systems (Fig. 1). It will then carry out a heritage assessment of the tangible and intangible landscape components. Finally, the paper proposes a legal framework of regional protection aimed at the conservation of this rich legacy, so

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that users, managers, local authorities, and Valencians in general can become aware of how to manage environmental assets in the pursuit of the common interest.

Figure 1: Location of the Rivers Túria and Júcar and their traditional water meadows.

2 Traditional Túria and Júcar irrigation systems

A large body of scientific literature and debate exist regarding the origin of the traditional Mediterranean irrigation systems in Spain [10]. It is well known that the Romans extended the agricultural legacy throughout the Spanish provinces, as proven by archaeological remains [11], and during the *Andalusí* period (9th–13th centuries) the irrigation system was intensified with a new territorial organization, which created a network of irrigation channels that allowed the wise use of water over an extensive area [12, 13]. After this, the Christians (13th–15th centuries) expanded and consolidated this legacy. Subsequent events, such as the discovery of America and the financing of waterworks by the bourgeoisie and by the monarchy, marked the arrival of new crops and increased production by encouraging the expansion of these traditional irrigation systems.

The irrigation systems analysed here are located in the Valencian region, in the downstream floodplains of the Rivers Túria (Fig. 2) and Júcar, just before they flow into the Mediterranean Sea.

Over the centuries, water management in these floodplains has yielded a wide range of heritage elements, which can be divided into three types: tangible assets directly linked to the hydraulic constructions, intangible heritage related to the

Figure 2: River Túria floodplain in the borough of Manises (Valencia).

legal, technical and administrative organizations and structures used in the irrigation assimilated to the concept of TEK, and traditional agroecosystem landscapes such as the water meadow systems. These buildings, engines, knowledge and landscapes are part of the history, customs and identity of the community they belong to, but they are also still in operation, being a vital element in the current regional economy.

From the hydraulic inventory carried out by Hermosilla [14], it can be noted that the main hydraulic heritage elements found in these water meadow systems are: engines for water distribution such as irrigation ditches and channels of different sizes, but also dams, weirs (Fig. 3), wells, reservoirs and ponds, waterwheels, watermills, gauge stations, small floodgate chambers, water dividers, bridges and public washing places. Some of them have individually achieved national or local legal recognition (*Bien de Interés Cultural* – BIC, *Bien de Relevancia Local* – BRL).

These rivers maintain their traditional organizational water structures: the Valencia Water Court, on the River Túria, and the Acequia Real del Júcar Irrigation Community, on the River Júcar. These traditional irrigation systems are mainly based on an orally-transmitted knowledge of water management techniques, rules and regulations, and social and cultural expressions.

The origin of the Valencia Water Court is unclear, but it most likely dates back to the Andalusí period. The court is composed of eight farmers from the irrigation communities which take their waters from the River Túria (Quart, Benàger-Faitanar, Tormos, Mislata, Mestalla, Favara, Rascanya and Rovella canals). Its jurisdiction is restricted to Valencia's Watered Land district. Specifically, it extends over 3471 hectares with a total of 11,691 members. The Court, acting as an executive body, resolves conflicts between irrigation water-users orally and publically at the gate of Valencia Cathedral every Thursday at noon. This court is included with the Spanish judicial system, with the same guarantees and legal value as any civil court, so that their verdicts cannot be appealed against before ordinary courts [15].

Figure 3: The Antella Weir on the River Júcar.

Moreover, the Acequia Real del Júcar was built by King Jaume I in the 13th century. On completion, its management came under the control of the royal officials, who gradually yielded attributions to the irrigators. In 1350, the *Ordenanzas,* the first regulations giving executive competencies to the irrigation community, were written. This institution currently consists of ten members who meet monthly to decide on water management and it also has its own local irrigation court to solve conflicts among farmers in a peaceful way.

The other heritage assets linked to these irrigation systems are their interesting cultural landscapes. Hydraulic devices and traditional knowledge of water management interact jointly with the natural environment over time, producing valuable water meadow systems on both rivers. These important agroecosystems are still lacking comprehensive legal protection as cultural assets.

All these tangible and intangible assets and landscape elements are directly related to the history and the identity of the society that has created and inhabited these lands, leaving a cultural print that is reflected in the territorial and social organization and the rich water heritage.

3 Results and discussion

The links between traditional irrigation system resources and environment and history have produced a series of strengths that show the values that they had in the past, but which are nowadays not currently known or valued. The increasing interest in the value of the water meadow systems for environmental (green corridors and healthy environment close to the urban areas) and socio-economic purposes (e.g. identity, sense of place, responsible tourism) justifies this kind of analysis. The case of the River Túria green corridor is already in operation [16], with more than a million visitors per year after the work carried out on restoration and public use in recent years.

Beyond the intrinsic values held by these traditional irrigation systems of the Túria and the Júcar, another assessment is also possible. By means of an enhancement process, some new actualities can take place in relation to resource and landscape protection, territorial planning, recreational uses and social awareness. In order to carry out an applied assessment of these resources, the following criteria have been selected: integrity, significance, fragility, representativeness, attractiveness, availability, feasibility and accessibility.

Integrity in a traditional irrigation system must be interpreted as a comprehensive set of facts and elements that allow the operational functioning of the system today. Thus, the hydraulic engines, functions, traditions and landscape must be fully preserved and protected.

These traditional irrigation systems can also be considered very significant and unique assets due to their outstanding environmental, historical, cultural and socio-economic values.

From the point of view of fragility, it may be noted that hydraulic devices are not fragile resources as they have survived to the present day thanks largely to the societies that guarantee their conservation. Nevertheless, the cultural landscape has a medium-high level of fragility and it presents symptoms of degradation on both rivers due to the impacts of actions by humans (e.g. abandoning of traditional activities, depopulation, lack of management and political will).

On the other hand, the traditional irrigation systems analysed here are highly representative and include all the typical attributes of these Mediterranean cultural landscapes.

The attractiveness of these landscapes is based on their scenic, aesthetic, emotional and perceptual features, supported by the intangible values manifested in the traditional ecological knowledge of their inhabitants throughout centuries. Typical Mediterranean gastronomy originating from on-site agriculture production is another value that increases its appeal.

Furthermore, the availability of resources in time and space is large because they are extensive areas enjoying good weather throughout most of the year.

The feasibility of these traditional irrigation systems refers to the enhancement of economic viability (assessment of cost and benefits, restoration costs, management and maintenance costs, as well as social benefits and stakeholder attitudes). The most important costs are those arising from environmental restoration work in certain points on the water meadow land, as well as some hydraulic construction.

There is good access to the assets because many highways and main roads run along the Túria and Júcar fluvial corridors, together with on-site multi-use rural trails. Other recreational facilities such as signage, tourism interpretative routes, and tourism services and transports are also available.

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4 Concluding remarks

After the application of these criteria for the recreational enhancement of these agroecosystems, findings highlight a great potential for public use initiatives. However, a problem arises that must be addressed, i.e. the need to legally protect the traditional irrigation systems as a whole under an appropriate category of protection such as 'Cultural Park'. Unfortunately, the Valencian regional laws do not include this category, and the existing ones (BIC, BRL) do not guarantee the appropriate conservation of these properties because no additional management tools are foreseen in these regulations. These assets are considered 'living heritage', as stressed at the beginning of this work, and they are in need of special management. Following Bray [17], the priority for heritage landscapes is not preservation but active cultural resources' management. The figure of 'cultural park' will be very useful not only to protect traditional irrigation systems but also archaeological sites and other cultural properties of a territorial nature which need active conservation.

Additionally, Sabaté and Lista [18], Eugster [19] and Bustamante and Parra [20] agree that smart heritage management is a key factor in economic development for local communities.

These agroecosystems are at risk of disappearance due to urban sprawl over farmlands; visual degradation of the landscape marked by the construction of unsuitable items (e.g. telephone and power lines, non-traditional buildings, hoardings and advertisements); the division or abandonment of the water meadow system and the elements it is comprised of; also the extension of infrastructures such as roads, railways or slopes that act as a rigid barrier; or unsuitable uses such as factories, storage areas and landfills. Additionally, the implementation of new irrigation technologies such as drip irrigation, without entering into the discussion of its advantages and disadvantages, are a threat to traditional irrigation systems, in terms of both their operation and their constructions. Active conservation and protection actions, and policy measures can prevent these threats, and wise public use can enhance the values of these outstanding traditional irrigation systems. They certainly deserve to be included in the UNESCO World Heritage List because of their significance, representativeness, uniqueness, and social values.

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Assessment of urban landscapes management

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Abstract

The paper is focused on making an integrated evaluation of hydraulic and energetic management in urban landscapes with the intention of detecting consumptions which are far from those recommended as best. The method is based on indentifying hydrozones inside plots and calculating their water needs. Additionally, an assessment methodology based on catch-can testing and quality irrigation indicators are proposed to appraise irrigation efficiency and uniformity. Finally, some energetic performance indicators for evaluating irrigation supply systems are defined. The protocol has been conducted in the gardens of the Universitat Politècnica de València (Spain) and a potential saving of 43% in water consumption could be achieved. Quality irrigation and energy performance was assessed and showed that the system is not operated under the optimum conditions.
Keywords: urban landscapes, irrigation efficiency, assessment, inventory, uniformity, water needs.

1 Introduction

Southern Europe ecosystems have high water requirements, which are not compensated by the scarce rainfall typical in a semiarid country like Spain. The irrigation needs in urban landscapes can reach a volume around a 9% of the total amount of water resources used in urban areas (INE [1]). Besides, most irrigation systems require energy to operate because they do not have enough elevation for

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supplying water by gravity. This leads to an important energy consumption ranging between 0.95 and 1.18 kWh/m^3 (Soto-García *et al.* [2]), with the environmental and economic impact that this involves. The main purpose in management tasks should be to save water because this aim will mean saving energy.

Management and maintenance of green areas is not always the desired. At the project level or in the early stages of garden management, facilities are built according to the theoretical conditions but with time, deficiencies and changes in vegetal species often arise and it is essential to detect and to correct them for achieving irrigation efficiency. The study is centered on assessing management of hydraulic and energetic resources in an integrated way with the intention of detecting consumptions which are far from those recommended as best. Besides, resource consumptions and irrigation uniformity are strongly linked by means of the relation flow-pressure and the emitter coefficients that determine emitters' performance. If there are any discrepancy in these parameters, quality irrigation and water and energy consumptions will be altered.

2 Materials and methods

2.1 Pilot site

The methodology developed in this document was conducted in the gardens of the Universitat Politècnica de València (UPV), Spain (39° 28' 54'' N, 0° 20' 37'' W, 7 m about sea level). The campus has 106,000 m^2 of landscaped area with more than 2300 trees. The garden has an irrigation system divided in two networks operated by two pumping units. The study is concentrated on the subnet called well two (w2) where there are 160 intakes and approximately 1400 emitters (sprinklers and diffusers). The irrigation network is operated by a centralized remote system that enables to establish irrigation scheduling by means of opening or shutting electrovalves than run groups of emitters.

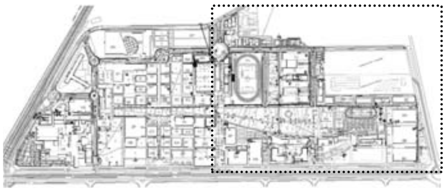

Figure 1: Pilot site. Subarea w2 highlighted.

2.2 Water needs for urban landscapes

The first step aims at saving resources is to calculate the precise water amount required by plants. Water saving is essential so the calculation has been formulated taking into account two important concepts: xeriscape and deficit irrigation (Burés [3]). Both of them are terms which promote an efficient irrigation under optimum water requirements.

The methodology chosen to calculate irrigation scheduling was the landscape coefficient method (Costello *et al.* [4]). It basically consists of obtaining landscape evapotranspiration (ET) by multiplying a landscape coefficient (K_j) and the reference evapotranspiration (ET_o):

$$ET = ET_o \; x \; K_j \tag{1}$$

where ET_o was calculated using Allen *et al.* [5] recommendations. Despite, this approach is the most frequent; there are several options for estimating ET_o like models used by Van Damm *et al.* [6] or Qualls *et al.* [7], among others.

Landscape coefficient is calculated from three factors: species (K_e), microclimate (K_{mc}) and density (K_d). These factors are used in the landscape coefficient formula as follows:

$$K_j = \; K_e \; x \; K_{mc} \; x \; K_d \tag{2}$$

In this work, for estimating landscape factors, it is recommended to use the guidebook called WUCOLS (acronym for Water Use Classifications of Landscape Species) developed by Costello *et al.* [4] and the reference document (Contreras [8]), for Mediterranean conditions. These coefficients are detailed in the Table 1 and they have been selected considering that vegetal species are adapted to semiarid conditions. Finally, water needs of landscape plantings (NR_r) can be estimated using following equations:

$$P_{ef} = 0.75 \; (P - 5) \tag{3}$$

$$FL = \frac{EC_w}{5 \; x \; EC_e - EC_w} \; x \; \frac{1}{L_e} \tag{4}$$

$$NR_r = \frac{NR_n}{E_a \; x \; (1 - FL)} \quad where \;\; NR_n = \; ET - P_{ef} \tag{5}$$

where P_{ef} is the effective rainfall (mm/day), P is the rainfall (mm/day), FL is the leaching fraction (-), EC_w is the irrigation water electrical conductivity (dS/m), EC_e is the saturation extract electrical conductivity (dS/m), L_e is the lixiviation efficiency (0.7), NR_n is the net water requirement (mm/day), ET is the landscape evapotranspiration (mm/day) and E_a is the irrigation system efficiency that is 0.8 for sprinklers and diffusers, and 0.9 for drippers. These factors have been defined for six hydrozones that simplified reflect usual conditions of urban landscapes. Coefficients are shown in the Table 1.

2.3 Uniformity irrigation measurements

The protocol assessment proposed is focused on reducing water and energy consumption. In the case of urban landscapes, it should be achieved by maximizing irrigation efficiency. This attribute can be computed as the ratio between the water used beneficially by plants and water applied in plots (Burt *et al.* [9]). This is a complex parameter to quantify; therefore, it can be obtained by

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Table 1: Coefficients to estimate water needs.

	Hydrozones	K_e	K_d	K_{mc}	E_a
1	Xerophytic plants + Drippers + Not shading	0.1	0.8	1.0	0.9
2	Intensive turf + Sprinklers + Not shading	0.6	0.8	1.0	0.8
3	Turf + Sprinklers + Not shading	0.4	0.8	1.0	0.8
4	Xerophytic plants + Drippers + Shading	0.1	0.8	0.6	0.9
5	Intensive turf + Sprinklers + Shading	0.6	0.8	0.6	0.8
6	Turf + Sprinklers + Shading	0.4	0.8	0.6	0.8

means of distribution uniformity. To quantify quality irrigation the catch-can method of uniformity testing was used. This assessment method is described by both the National Resources Conservation Service (NRCS) and the American Society for Agricultural Engineers (ASAE) (Micker [10] and ASAE [11]). The catch-cans were distributed on the turf area and around the plot to measure water losses in a square grid where approximately four cans were between sprinklers. In the UPV plots this distance was 2.5 m. The irrigation system was set to run for 20 minutes that is the usual irrigation time in the UPV, and then catch-can volumes were measured immediately following the test using an electronic scale. Water weighs were transformed to water depths and rainfall, and were represented spatially using an interpolation tool (IDW) from ArcGIS 10.1 [12].

The most of the irrigation schedules are determined for areas that receive less water in the plot. However, if it is applied excess water in order to there is enough water in dry areas, deep percolation and plant oxygen stress can occur. The goal of this second part of the assessment is to determine some indicator that detects these irrigation deficiencies from previous catch-can measurements.

2.3.1 Uniformity indicators

Uniformity of water distribution is a measure of the variability in application depth over a given area. Tree indicators have been used to quantify uniformity.

Coefficient of uniformity (CU): This indicator defined by Christiansen [13] has the strongest historical precedent in the sprinkler irrigation industry. It is defined as:

$$CU \; (\%) = 100 \; x \left(1 - \frac{\sum_{i=1}^{n} |x_i - x_m|}{n \; x_m}\right) \tag{6}$$

where x_i is the measured depth of water in equally spaced catch-cans on a grid (mm), x_m is the mean depth of water in all the catch-cans (mm) and n is the number of catch-cans used (-).

Distribution uniformity (DU): The uniformity for surface irrigation systems is commonly characterized by this indicator (Merriam and Keller [14]), defined as:

$$DU \; (\%) = 100 \; x \left(\frac{x_{lq}}{x_m}\right) \tag{7}$$

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where x_{lq} is the average depth measured in the low one-quarter on the catch-cans method (mm).

Scheduling coefficient (SC): This indicator is used to estimate how long the irrigation system must operate to wet the dry spots. It is defined as:

$$SC = \frac{x_m}{x_{ae}} \tag{8}$$

where x_{ae} is the depth of water in the driest continuous application area (mm).

2.3.2 Efficiency indicators

Apart from knowing water distribution in the plot, it is essential to assess which portion of irrigation is actually usable by the plants. For this, the following indicators are proposed:

Run time multiplier (RTM): This indicator (Ossa *et al.* [15]), provides an adjustment factor in order to compensate lack of distribution uniformity.

RTM is related to the lower-half distribution uniformity (DU_{LH}) in the following way:

$$RTM \; (-) = \frac{100}{DU_{LH}} \quad where \;\; DU_{LH}(\%) = 38.6 + (0.614 \; x \; DU) \tag{9}$$

Real irrigation system efficiency (E_{rs}): In this work, this indicator is adapted from [15] with the aim of comparing the irrigation water that is beneficially used for plant grown and the real water supplied in the plot. Here is proposed to calculate E_{rs} for a high water requirements period (test week) with the target to compare the real applied volume with the theoretical needed by plants. Another complementary indicator is defined, Δr, to value variations from $NR_{nw.}$

$$E_{rs} \; (\%) = 100 \; x \left(\frac{NR_{nw}}{NR_{apli}}\right) \quad where \;\; NR_{apli} = \; t_w \left({}^{\mathrm{x_m}}/_{t_{cc}}\right) \tag{10}$$

$$\Delta r \; (\%) = \frac{100 \; x \; NR_{apli}}{NR_{nw}} \tag{11}$$

where NR_{nw} is the net water requirement in the test week (mm), NR_{apli} is the net water applied in the test week (mm), t_w is the irrigation time in the test week (min) and t_{cc} is the irrigation time for each catch-can test (min).

To sum up this first part of the assessment, it is essential to highlight that the main purpose is to quantify the ratio between applied water and irrigation requirements and how the water distribution is. In this work are recommended some indicators but these coefficients could be changed by others because the most important is the goal and not the tools.

2.4 Energy efficiency characterization

In urban landscape irritation systems water is supplied by means of pressurized networks that carry important energy consumptions. Therefore, another important issue of the assessment is quantifying the pumping energy. For this, some indicators should be used to assess performance system. In this study, the proposed indicators are adapted from the official indicators of IDAE [16] and Abadía *et al.*

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[17], and they are very common in auditing process from agriculture irrigation networks. Three coefficients are defined:

General energy efficiency (EEG): This coefficient assesses the global efficiency of the irrigation network including the pump unit. EEG is given by

$$EEG \; = \; EEB \; x \; ESE \tag{12}$$

Pumping energy efficiency (EEB): This first factor represents the balance between the supplied energy by pumps (E_{su}) and the absorbed energy (E_{abs}). EEB is given by

$$EEB(\%) = \frac{E_{su}}{E_{abs}} \; x \; 100 \tag{13}$$

Both factors can be obtained by means of direct measurements in the system during a representative period of time. In particular, E_{su} for each period in which different intakes work simultaneously (shift) into the operating time is given by the following equation:

$$E_{su} \; (kWh) = 3.6 \sum_{i=1}^{n} \gamma Q_i H_i t_i \tag{14}$$

where γ is the specific weigh of water (9800 N/m^3), Q_i is the flow measured with a flow meter (m^3/s), H_i is the pressure measured with a pressure sensor (m) and t_i is the shift time (s).

The other component of EEB is E_{abs}. In this case, for each shift, the factor should be obtained measuring with a network analyzer. E_{abs} is defined as follows, including an energy value that considers a global efficiency of the pump. The equivalent equation is given by

$$E_{abs} \; (kWh) = 3.6 \sum_{i=1}^{n} \frac{\gamma Q_i H_i t_i}{\eta_{b_i} \, \eta_{me_i} \, \eta_{var_i}} \tag{15}$$

where η_b is the global efficiency of the pump, η_{me} is the electric motor efficiency and η_{vdf} is the variable frequency drive efficiency.

Energetic supply efficiency (ESE): This indicator represents the ratio between required supply energy at the system and real energy provided by the pumping. It is given by:

$$ESE \; (\%) = \frac{|\Delta E|}{ICE} \; x \; 100 \tag{16}$$

where ΔE is the energy balance of supply (m) and ICE is rate of energy charge (m) and if there is an only pumping source, this indicator is equivalent at head supplied by the pump, i.e., is the specific supplied energy by pumps (E'_{su}).

Particularly, ΔE quantifies the energy needed to satisfy, for each shift of the sequence, the head required by the most pressure demanding intake (H_{min}). The system works with an average head which is defined by the garden managers, in such a way, that irrigation requirements and uniformity irrigation are upper than a minimum recommended. The equation is the following, where V_j is the demander volume water for each shift and V_T is the total irrigation volume.

$$|\Delta E| = \frac{\sum_{i=1}^{n} V_j \,(Hmin_j)}{V_T} \tag{17}$$

The main objective of this last part of the assessment is analyze energy efficiency systems but other indicators and tools, like direct measurements in the pumping unit, could be used. This methodology could be considered a first approximation in the state of the system.

3 Results and discussion

3.1 Water needs for urban landscapes

In the UPV gardens, water needs were calculated following the proposed protocol and considering the weather conditions during 2013 obtained in an automated meteorological station located in the UPV campus. Results per hydrozones, compared with real water consumptions, are shown in the Table 2.

Table 2: Water needs for each scenario.

Hydrozones	Area	Percentage	NR_n	NR_r
	m^2	%	mm/year	mm/year
1	45,168	41.7	71	84
2	21,771	20.1	429	568
3	17,442	16.1	286	378
4	20,997	19.4	43	50
6	2,871	2.7	286	378
*Methodology consumption (mm/year)				Max: 568
Real consumption (mm/year)				998

*In the case study, the scenario called 5 does not exist.

The above results show the importance of adjusting irrigation dose to the strict requirements of the species planted depending on the microclimate in which they are installed. Water needs calculated using the methodology reaches a minimum saving of 43% if plots are irrigated with the volume from those more demanding. In another hypothetical scenario where water needs were weighted based on the representation of each hydrozone in the garden, the maximum saving could reach 77% consuming a total amount of 230 mm/year.

3.2 Uniformity irrigation measurements

Uniformity irrigation assessment was carried out in four plots of the UPV garden. Interpolated rainfall results (mm/min) are shown in the fig. 2. There are areas with high rainfall and others with an important deficit of water coverage. Usually these scarcity problems match up with emitters damaged.

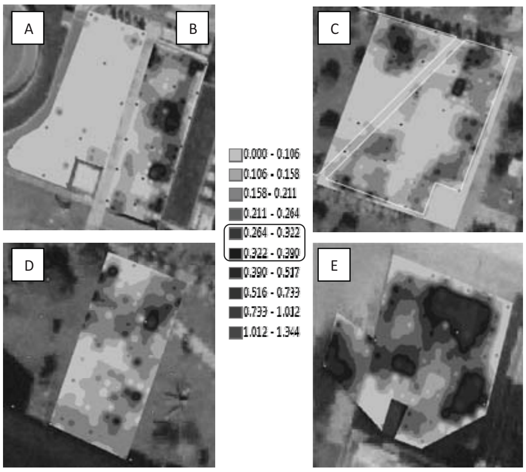

Figure 2: Interpolated rainfall (mm/min) registered in the UPV gardens.

Another problem detected is the presence of several flooded areas that even reach the outer limits of the garden. The main cause was vegetation and urban furniture interception with the water distributed by sprinklers. Besides, in sloped plots this effect generates water losses by run-off. It becomes clear that there are uniformity irrigation problems in every plot which must be solved to improve irrigation efficiency.

The assessment methodology was completed with the uniformity and efficiency indicators calculation. The reference values could be consulted in Ossa *et al.* [15] and Keller and Bliesner [18]. Results are showed in the Table 3.

These results show a deficient distribution, both DU and CU (except DU in the plot C) are under the recommended range. This irregularity was confirmed by means of the above assessment of interpolated rainfall. The indicator SC evinces that irrigation should be increased in every plot, and especially in the plot E about 65% to satisfy the less irrigated areas. The rise would mean overwatering other areas, so it is recommended to solve distribution and density emitters before increasing irrigation rates.

Table 3: Results of DU, CU, SC, RTM, E_{rs} and Δr for the studied plots.

Plot	Hydrozone	Area	UNIFORMITY	DU	CU	SC	EFFICIENCY	RTM	E_{rs}	Δr
	-	m^2		%	%	%		-	%	%
A	9	1092		39	33	13		1.60	207	-48
B	9	1724		56	45	65		1.37	57	+175
C	8	1897		62	31	8		1.30	130	-77
D	8	1797		57	56	21		1.36	92	+109
E	9	809		56	37	65		1.38	51	+196

Regarding to efficiency indicators, RTM in average could be considered acceptable in the majority of plots apart from the A. These results involves that the compensation time for increase irrigation uniformity is necessary but it is not excessive. Finally, in every assess plot, E_{rs} is outside of recommended range. The indicator Δr shows plots under and over irrigated compared with NR_{nw}. In conclusion, the irrigation is not uniform and therefore, being inefficient in the case study.

3.3 Energy efficiency characterization

Two consecutive days in a high necessity period have been studied. During these days, flow, pressure and power were registered. The unitary energy consumption obtained was 0.59 kWh/m^3. In addition, adapted indicators from IDAE were used to assess the efficiency system. For the 5th of June the EEB was 47.9% and the EEG was 23.9%. For the 6th of June the EEB was 42.6% and the EEG was 21.0%. The limit value considered acceptable for EEB is 45.0% and for EEG is 25%, IDAE [16]. Thus, EEB and EEG in both days are not acceptable. Therefore results show that the system is not operated properly under current conditions.

4 Conclusions

This work presents a methodology for assessing urban landscapes from the agronomic, hydraulic and energetic point of view. First, a group of recommendations base on the landscape coefficient method is suggested to calculate irrigation needs in several hydrozones. Results for w2 landscaped area in the UPV gardens showed a potential saving of 43% in terms of water. Then a serial of uniformity and efficiency irrigation indicators has been applied to evaluate irrigation quality. The assessment picks up damaged emitters and wrong spacing patterns. Finally, some energy performance indicators have been applied to assess the network operation. These results showed that EEG was not acceptable. To solve this problem, future works will be aimed on improving energy efficiency by optimizing irrigation scheduling.

Acknowledgements

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Fish landings in Barcelos, in the Middle Negro River Region, Amazonas

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Abstract

The purpose of this study was to gather information about fish landings in Barcelos, in the Middle Rio Negro region. Data were collected from fishing boats at weekends and from stalls where fish were processed and sold during the week. The results showed that in the period from February 2012 to January 2013, 56.0 tons of fish were landed and that average landings were 3.6 ± 2.2 tons/month and 1.1 ± 0.7 tons/month for fishing boats and for small boats with outboard motors, respectively. Pacu (subfamily Myleinae), aracu (family Anastomidae) and tucunaré (*Cichla* spp.) were the main species caught and accounted for approximately 50% of the landings. The Demeni River, Lake Anauali and Zamula streamlet were the most exploited fishing areas. Fishing boats exploited the lakes in the dry and flood seasons and the rivers in all seasons of the hydrological cycle, with a slight predominance in the falling-water season. Streamlets were also exploited by fishing boats in all the seasons apart from the flood season. Lakes were the preferred environment for small boats with outboard motors in the dry season. While rivers were exploited by these boats throughout the year, streamlets were exploited mainly in the rising- and falling-water seasons. There was a decrease in fishing effort in the flood season and an increase in the dry season. Average CPUE was 21.9 and 23.9 kg/fisherman/day for fishing boats and for small boats with outboard motors, respectively.

Keywords: exploited species, Negro River, fishing effort.

1 Introduction

Fishing is a traditional activity in the Amazon and has many unusual characteristics compared with fishing in other regions of Brazil, including the variety of species exploited, the amount of fish caught and the dependence of riverside communities on it as a source of income and protein [1].

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The Negro River provides a small proportion of the fish supply to major urban centers in the region, and it has been estimated that only 4.3% of the fish landed in Manaus comes from this river [2]. This figure is expected to decrease as a result of State Decree 22.304 dated November 20th, 2001, which limited commercial fishing in the Negro River basin to that needed to supply communities and towns along the stretch of river extending from the mouth of the Branco River to the border with Venezuela and Colombia.

However, fishing on the Middle Negro River is one of the main economic activities of the local population, who depend on it directly or indirectly for survival [3] as it provides an important part of their income and is also their main source of protein. In addition to subsistence and commercial fishing, leisure fishing and fishing for ornamental fish are also practiced in the region.

For a long time most of the wealth generated in Barcelos came from the exploitation of ornamental fish, which accounted for over 60% of the population's income. However, because of the decline in this activity in recent years as a result of competition with other regions of the Amazon and the contraction of the international market, many fishermen have migrated to commercial fishing and, more recently, leisure fishing [4].

Monitoring of fish landings and fishing effort is essential to gain an understanding of the extent to which stocks are being exploited and to support decisions related to fishery management [5]. Nevertheless, existing statistics on fish landings relate to the Solimões-Amazonas channel, and little is known about commercial fishing in blackwater rivers. This study, which is one of the first on fish landings in the Middle Negro River, therefore sought to gather information on fishing activity in the municipality of Barcelos by estimating the volume of fish landed and identifying the most important species, the environments in which fish were caught and the variation in fishing effort.

2 Materials and methods

2.1 Study area

The study covered the Middle Negro River region and focused on the municipality of Barcelos in the northwest of the state of Amazonas (Figure 1). The municipality covers an area of 122,475.73 km^2, making it the largest municipality in the state by area. It is located on the right bank of the Middle Negro River at a distance of 396 km in a straight line or 496 km by river from the state capital Manaus.

The Negro River basin is known for its high diversity of fish species, as well as its low stock biomass for individual species compared with whitewater rivers [6]. Some 950 species have been described, many of which are endemic. Notable among these is cardinal tetra (*Paracheirodon axelrodi*), which has been extensively exploited as ornamental fish and accounts for 80% of the volume of fish exported annually [7]. Barcelos is currently a popular destination for recreational fishing, and the region is estimated to receive some eight thousand tourists during the fishing season, which lasts throughout the low-water season, from September to March.

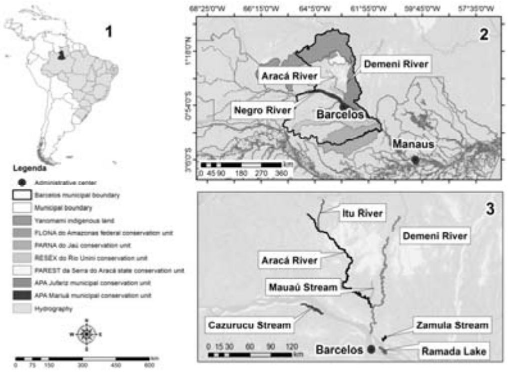

Figure 1: Maps showing the study area: 1) Map of South America showing Brazil, the state of Amazonas and the municipality of Barcelos; 2) Municipality of Barcelos, showing the Negro, Aracá and Demeni Rivers and Conservation Units; 3) Main fishing areas used by commercial fishermen in Barcelos.

2.2 Data collection

Data were collected with the aid of a structured questionnaire answered by stall owners and the person responsible for each boat between February 2012 and January 2013. The data for the fishing boats was collected at weekends while the data for stalls was collected during the week.

The information gathered included the fishing area, number of crew, date of departure and arrival, number of hours spent fishing, species caught, fishing devices used, total catch (kg) and price of first sale.

2.3 Data analysis

The data were kept in a spreadsheet and analyzed using descriptive statistics to calculate the frequency of occurrence and determine the measures of central tendency and dispersion of the data.

Monthly data on the water level in the Negro River (at the Barcelos hydrological station) were provided by the National Water Agency (ANA) and used to relate production to the annual hydrological cycle.

Fishing effort was calculated according to [8], which suggests that the best formula for determining fishing effort in the Amazon region is the number of

fishermen in the crew multiplied by the number of fishing days. Fishing effort and catch per unit effort (CPUE) were calculated separately for fishing boats and small boats with outboard motors.

Fishing patterns in terms of the type of boat used in each period of the hydrological cycle were identified using correspondence analysis and the STATISTICA program.

3 Results

3.1 Fish landings

Fish production in the study area serves two main markets: Barcelos and, primarily, the municipality of São Gabriel da Cachoeira, where it can be sold more profitably, possibly because of the greater purchasing power of the population.

In all, 167 fishing trips were recorded, with a total production of 56.0 tons (t) and a mean landing of 4.7 ± 2.2 t/month. The maximum landing was 9.2 t in October (dry season), and the minimum 2.5 t in May (flood season). Fishing boats landed an average of 3.6 ± 2.2 t/month, while the corresponding figure for small boats with outboard motors was 1.1 ± 0.7 t/month. The latter made the most landings (51.5%), but fishing boats caught the most fish.

The volume landed varied with the hydrological cycle and peaked in February (rising-water period) and September and October (dry period) (Figure 2). There was a sudden, abnormal drop in the volume landed in November because of problems with the factory that supplies ice, which led to a drop in the number of fishing trips.

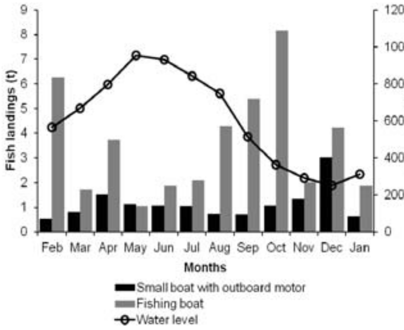

Figure 2: Monthly commercial fish landings in the municipality of Barcelos.

3.2 The main species landed

Twenty-two fish species or groups of species were landed in the municipality by commercial fishermen. Together, the three main species – pacus (subfamily Myleinae) (27.4%), aracus (family Anastomidae) (11.9%) and tucunarés (Cichla spp.) – accounted for approximately 50% of the landing frequency.

The species pacu, aracu, jaraqui and matrinxã are known locally as white fish and have greater commercial value, while other species sold, such as acará, tucunaré, traíra and piranha, are known as black fish and are less valuable.

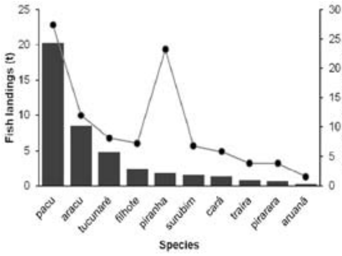

Figure 3: Landing weight and frequency for the main species landed.

Pacu alone was responsible for more than 20.0 t of the total landed. The largest monthly landings were observed when the water level in the river was at its lowest, between September and December, indicating that fish can be more easily caught during this period (Figure 4).

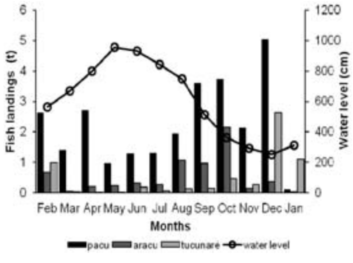

Figure 4: Landings of pacu, aracu and tucunaré in Barcelos.

3.3 Fishing areas exploited

The fishing fleet exploited 68 fishing areas in 39 rivers, 18 lakes and 11 streamlets (11). Of the rivers exploited, the Demeni River had the most fishing trips (24.8%), followed by the Aracá River (22.3%) and Itu River (20.7%). Lakes Anauali (37.3%), Ramada (31.4%) and Maxibeda (20.5%) were the most frequently exploited. The other lakes were exploited sporadically. Zamula (29.4%), Cazurucu (17.6%) and Mauaú (14.7%) were among the most frequently exploited streamlets.

In the correspondence analysis for the fishing boats (Figure 5), dimension 1 (eigenvalue 0.05181; 86.89% inertia) indicated that lakes were exploited during the dry and flood periods whereas the rivers were exploited throughout the hydrological cycle, with slightly more activity during the falling-water period. Streamlets were exploited in all periods except the rising-water period.

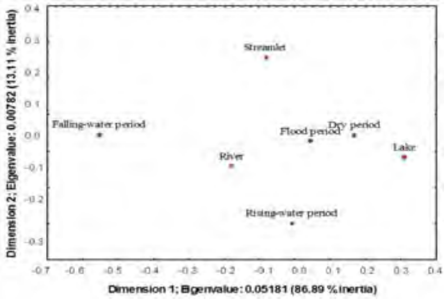

Figure 5: Correspondence analysis for the fishing areas used by fishing boats during the different periods of the hydrological cycle.

In the correspondence analysis with catch data for small boats with outboard motors, dimension 1 (eigenvalue 0.02623; 75.13% inertia) showed that the lakes continued to be the preferred fishing areas in the dry period, while rivers were exploited throughout the year. Streamlets were exploited mainly during the falling-water and flood periods (Figure 6).

3.4 Fishing effort and catch per unit effort

Fishing effort for fishing boats was inversely proportional to water level. Hence, the month with the smallest effort, which was coincidentally also the month with the smallest catch, was May, in the flood period (Figure 2). From June onwards,

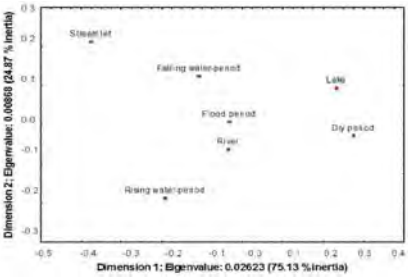

Figure 6: Correspondence analysis for fishing areas used by small boats during the different periods of the hydrological cycle.

fishing effort increased steadily as the water level dropped in the falling-water and dry periods (Figure 7). Fishing effort for small boats with outboard motors followed the same pattern, i.e. a large effort during the dry period, with a peak in December, and a small effort in the flood period, with the lowest value in June (Figure 7).

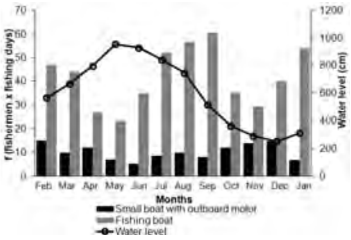

Figure 7: Fishing effort (f) for the Barcelos fishing fleet.

CPUE for fishing boats varied between 8.3 kg/fisherman/day in May (in the flood period) and 43.3 kg/fisherman/day in February (in the rising-water period). Mean CPUE was 21.9 ± 18.3 kg/fisherman/day. CPUE for small boats with outboard motors was 4.7 kg/fisherman/day in February (in the rising-water period) and 65.9 kg/fisherman/day in December (in the dry period). Mean CPUE was 23.9 ± 18.3 kg/fisherman/day.

4 Discussion

Other studies in whitewater rivers in the Amazon had already identified a relationship between water level and fish landings [9, 10]. In these studies the highest landings were observed during low-water periods associated with retraction of the physical environment, when fish are confined to open waters in lakes, making them easier to catch. The reduction in fish landings when water levels are higher and at the beginning of the falling-water period are common characteristics throughout the Amazon [11–13].

According to the interviewees, there are twenty-two species that are most frequently exploited by the fishermen. However, this number may in fact be larger, as several popular names mentioned in the interviews correspond to more than one species. Pacu, aracu and tucunaré were the most frequently caught fish in the study, corroborating the findings of [14] and [15] in the same area.

Monthly landing data for pacu showed that production was greater in September, October and December, when water levels are low. The increase in production in April may have been because pacu are often found in large shoals in this period, making it easier to catch them. The greater proportion of pacu and aracu in landings can be attributed to economic factors, which undoubtedly influence the choice of fish caught as both pacu and aracu are among the most prized and widely eaten fish in the region. A further possible factor is the use of gillnets, the main type of net used by the fishermen, as these are suitable for catching fish that migrate in shoals.

Tucunaré is one of the main groups of species exploited commercially and among the most important and widely eaten species during the summer, as well as one of the most popular types of fish among the population of the Middle Negro River. It is also one of the favorite species among leisure fishermen in this region [10] as it is attracted by bait and struggles when it is caught.

The importance of the Demeni River for local commercial fishing was readily apparent as this was the main river exploited. According to [14], the Demeni River is one of the most abundant in fish in the region, possibly because it is a whitewater river and therefore more productive than blackwater rivers.

The pattern of river usage during the flood period both by fishing boats and small boats with outboard motors is probably a result of the large number of shoals as it is during this period that various species of Characiformes migrate from the lakes to spawn in the main river channel. As fishing boats cannot enter the lakes during the dry season these vessels are used to store fish, while the small boats are more directly involved in catching the fish. This use of vessels for various purposes in the Solimões-Amazonas channel has already been described in [16].

Fishing effort is reduced during the flood period, unlike in the Madeira River, where fishermen in fishing boats and small boats with outboard motors increase fishing effort during the rising-water and flood periods to make up for the smaller yield during these less productive periods [17]. The reduction in fishing effort for vessels in Barcelos when the water level is higher may be related to dispersion of shoals, making it more difficult to catch the fish. This is because

when the average water level is high, although fish density is also high, catch efficiency is low and a greater effort is required to maintain yields. Therefore, during the flood period the fishermen reduce the number of trips as catches become smaller and do not cover the costs of the trips. During this period fishermen usually work jointly with a large fishing boat and make weekly or fortnightly trips or do other types of work.

The increase in fishing effort during the falling-water and dry periods may have been because the lower water level and consequent greater fish density make it easier to catch fish. The fishermen are aware of this empirically and therefore make most trips during this period, when they concentrate exclusively on fishing and make daily trips.

The values of CPUE found in this study were lower than those reported in [18] for the Middle Solimões River region (40.0 to 80.0 kg/fisherman/day) and in [19] for the municipality of Guajará-Mirim (65.0 kg/fisherman/day). However, they were similar to the values reported in [17] for Manicoré (22.9 and 20.6 kg/fisherman/day for fishing boats and small boats with outboard motors, respectively) and in [19] for Teotônio (26.6 kg/fisherman/day) and slightly above the values reported in [12] for Santarém (15.0 kg/fisherman/day).

5 Final considerations

In view of the preliminary nature of these results, further studies should be carried out to collect more data and generate a time series to corroborate the information presented here. Although preliminary, these data can be used as an initial basis for decisions related to fishery management in this region of the Middle Negro River.

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Problems of cadastral recording and assessment of lands in the Sverdlovsk region of Russia

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Abstract

The creation of a reliable system of land registration and valuation is a necessary condition for the further development of the real estate market in Russia. The purpose of this study is to analyse the currently existing problems in state cadastral registration and land valuation in the Russian Federation, both at the Federal and regional levels. In the present paper, information on the results of the cadastral valuation of land parcels in the Sverdlovsk region is presented. Based on an analysis of the data, it is possible to distinguish the following problems in this area: the imperfection of the methods of valuation and regulatory framework, the lack of accurate land boundaries: secrecy and opacity in the system of assigning information. The main stages of professional cadastral registration in the Russian Federation are reviewed. The approaches taken to determine the cadastral value of land according to Russian practices are discussed. It is shown that the cadastral value established can vary by several times according to the different valuation techniques employed. The possibility of challenging the results of an erroneous determination of cadastral value is demonstrated based on an analysis of legal precedents established in the Urals region. A conclusion is reached about the need to improve the methodological and legislative frameworks of cadastral valuation of land parcels as real estate. A number of possible paths forward are proposed and specific activities that should contribute to an improvement of the quality of land relations are outlined. It is proposed that regional experiences of cadastral assessment of lands can be used to support reform at the Federal level.

Keywords: cadastral recording, valuation of land parcels, cadastral value, assessment methods, State Real Estate Cadastre, land relations.

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1 Introduction

One of the main directions of the present stage of Russian economic development is to create a management system for the country's territories and to ensure its effective functioning. A prerequisite for sustainable development of the territory in a developing market economy is the provision of government guarantees supporting property ownership rights, including land. To solve this problem it is necessary to create a reliable system of recording and valuation of real estate – in the first instance, land.

2 The formation of professional cadastral registration in Russia

The formation of the professional cadastral recording and land valuation in Russia has been a relatively recent phenomenon in historical terms. At the beginning of the 20th century, Russian jurists considered using the Torrens system [1] for land registration. However, following the October Revolution in 1917, land was nationalised, i.e. declared to be national property. As a consequence, for several decades, land was actually public property and, as such, was not subject to taxation. Nevertheless, under the conditions of the planned economy, a need existed for a wide variety of information about land. In the Soviet Union, a system for regular land surveys was formed and successfully operated [2]. In accordance with the Decree of the USSR Council of Ministers, the registration of land users was conducted from 1955 onwards; the Land Cadastre of the USSR was formed on the basis of a summarisation of this data. The Land Cadastre of the Soviet period, approved in 1968, is a set of tables of data on land quality characteristics, differentiated by users. The Cadastre was provided with detailed information on agricultural lands and forest resources. However, information about land-based industry and populated areas was reproduced in simplified form and lacked objectivity [3].

In the 1990s, land relations in Russia – for that matter, the economic system as a whole – underwent significant changes. Land once again became the object of commercial exchange and subject to taxation. The period from 1991 to 2000 was characterised by high volatility. The disposal (transfer of ownership) of land was carried out at the behest of landowners without normative enactment by regulatory authorities. This resulted in a lack of fiscal information and an inability to properly identify and collect payments of land tax. Often there were boundary disputes, which could not be resolved in a civilised manner due to the lack of land registry information concerning land boundaries. It became necessary to modify and update the land legislation.

In 2000, a new law "On State Land Cadastre" was enacted. In accordance with this law, the Land Cadastre was defined as "a systematic set of documented information obtained as a result of state cadastral registration of land, concerning the location, purpose and legal status of the land of the Russian Federation".

It is worth noting that until 2008, the land cadastre is often regarded as one of the state cadastres of natural resources, amongst which are also included the forest

cadastre, water cadastre, mineral resources cadastre and wildlife cadastre. This approach can be considered as a legacy of the Soviet period when land, along with other natural resources, was considered to be public property. With the adoption of the 2007 Federal Law "On State Real Estate Cadastre", separate land, forest and water cadastres effectively ceased to exist. The functions of forest and water cadastres were partially fulfilled by the forest and water registries and partly moved to the State Real Estate Cadastre (SREC). All land cadastre functions were moved to the SREC.

Currently, the functions of organising a unified system of state cadastral registration of real estate and state registration of rights to immovable property and transactions thereof are assigned to the Federal Service for State Registration, Cadastre and Cartography (Rosreestr) [2]. The service is a division of the Ministry of Economic Development of the Russian Federation. State cadastral valuation of real estate, until recently, was one of the functions of Rosreestr; however, from 1st January 2013, it lost the corresponding authority. Now only the executive authority of the Russian Federation or the local authority may act for the customer of the work. Accordingly, funding for such work is made available from the regional or local budgets.

The outcome of the assessment consists in the cadastral value, which is taken into account at privatization of state or municipal property, and also serves as a basis for calculating land tax and determining rents paid for the possession and use of land, whether ownership is located at the state or municipal level. From 2014, the cadastral value of SREC entities in several regions of the Russian Federation started to be used as the basis for calculating property tax, replacing the property tax and land tax. There are plans to extend this experience to all subjects of the Federation. These facts impose high demands on the accuracy of determining the cadastral value of real estate property, including land.

3 The approaches for determining the cadastral value of parcels of land

Currently by cadastral value is understood market value of the real estate as determined by mass appraisal, or, if it is impossible to determine the market value using mass appraisal methods, the market value is determined individually for each property in accordance with the legislation concerning appraisal activity. By the mass appraisal of real property is understood the process of determining the value when grouping objects of evaluation with similar characteristics, in which mathematical modelling and other valuation techniques are used depending on the specific evaluation approaches taken [3]. However, some individual characteristics of properties included in the grouping cannot be ignored. Therefore, the value calculated by applying methods of mass appraisal, has a sufficiently high accuracy. In contrast, the market value determined individually for each concrete property takes into account all the possible factors that have an impact on the final value. Nevertheless, given the scale of the subjects of the Russian Federation, it is advisable to use mass appraisal methods of real estate evaluation, since this

method for determining cadastral valuations is considered to be less costly for the state.

4 Cadastral land valuation in the Sverdlovsk region

Information on the amounts and years of state cadastral valuation of different categories of land Sverdlovsk region is given in table 1.

Table 1: State cadastral valuation of land of different categories in the Sverdlovsk region (according to [4]).

Land category	Year of State cadastral valuation of land
Agricultural land	2000 – Round 1
	2006 – Round 2
	2011 – Round 3
Parcels of land for cottage building, gardening, included as part of agricultural land	2003 – Round 1
	2008 – Round 2
	2011 – Round 3
Land settlements	2002 – Round 1
	2007 – Round 2
	2010 – Round 3
	2012 – Round 4
Industrial land and other special purposes	2003 – Round 1
	2008 – Round 2
	2012 – Round 3
Land of specially protected territories and objects	2003 – Round 1
	2009 – Round 2
Water resources	2010 – Round 1
Forest resources	2003 – Round 1
	2008 – Round 2

Most often carried out by State cadastral land valuation (SCLV) in populated areas, primarily due to the frequent contestation of the value of parcels of land in this category.

The main reasons for such a state of affairs can be considered:

- stable market demand for land in this category,
- a significant change in the methodological framework used in different rounds of evaluation,
- imperfection and limited experience in applying the new assessment methodology.

The first round of SCLV in populated areas (2002) was carried out in accordance with the Methods of State Cadastral Valuation of Land Settlements (hereinafter – Methods); the second round (2007) was conducted in accordance with the Methodological Guidelines for State Cadastral Valuation of Land Settlements (hereinafter referred to as Guidelines). In this case, the procedure for determining the cadastral value of the land contained in the Methods varies considerably from that given in the Guidelines, namely [3]:

1. The Guidelines provide for the calculation of the cadastral value for the individual land parcel, while the Methods establishes a specific index of the cadastral value of land for each of the groups of types of functional use of land.
2. In place of the 14 types of functional land use given in the Methods, the Guidelines introduced 16 types of permitted uses of land. This change had a significant impact on the cadastral valuation of individual plots. For example, parcels of land intended to accommodate homes for individual residential development began to be referred to in the Guidelines as subsidiary smallholdings, whereas in the Methods they were referred to as land parcels for of agricultural use. This change caused a sharp rise in the price of land in populated rural settlement areas.
3. According to the Methods, the cadastral value of the land parcel should reflect the values of its most recent actual usage. According to the Guidelines, the value of land is determined by the principle of highest and best use; in this case, the criterion of the permitted usage of the parcel that maximises its value is selected.

In some cases, the approach taken in the Guidelines seems to us unnecessary, since it can sometimes lead to a situation in which the values of adjacent sections differ considerably, resulting in the owner of a parcel having a higher estimated value having to pay exorbitant taxes.

The use of the new methodological framework for the assessment in the second round, as well as a significant number of errors committed by cadastral engineers, has led to a substantial increase in land valuations and accordingly higher taxes. This has caused resentment in the general population and representatives of small and medium-sized businesses.

Calculated according to the results of SCLV 2007–2008, land tax in the Sverdlovsk region was the highest in the Russian Federation, with tax revenues exceeding levels five times that of other regions. This created the need for a third round of SCLV in settlements in 2010–2011. At the end of the third round of the cadastral valuation, certain types of land settlement valuation were significantly altered compared to the valuations resulting from the previous estimate (table. 2).

5 Challenging the state cadastral value of land parcels

The unreasonably high cadastral value of land has led to a saturation of cases appealing specific valuations in the court of arbitration. According to the Council of Municipalities of the Sverdlovsk region [5], in 2012, the Arbitration Court of the Sverdlovsk region received about 500 complaints, of which 98% were satisfied.

Table 2: Change (+ increase; - decrease) in the value of land after the third round of valuation of land in populated areas [5].

Parcels of land	Changes in the cadastral valuation, %
under multi-storey buildings	- 28
under low-rise and individual buildings	- 6
under office buildings	- 21
under shopping centres	+ 9
under garages and parking lots	+ 31
used: for the development of mineral deposits; for the construction of roads	+ 72

We will consider a few illustrative examples of court decisions relating to the reduction of cadastral value to the benefit of entrepreneurs. Examples of changes in cadastral value by the decision of the arbitration court of the Sverdlovsk Region are shown in table 3.

Table 3: Change (+ increase; - decrease) in the value of land after the third round of valuation of land in populated areas [6].

Enterprise – the plaintiff (the owner of the land)	Contested cadastral value of the land, mln RUB.	Cadastral value determined by the arbitral tribunal, mln RUB
Concern “Kalina”	86.23	21.6
Sports complex “Uktus”	423	110
Shopping and entertainment complex “Greenwich”	414	173

It can thus be seen that lawsuits contesting the cadastral value of land generally have satisfactory outcomes. However, it should be noted that the practice of returning overpaid land tax from the budget is not currently well established. This is due to an ambiguity in the interpretation of the regulations. It is evident that the laws governing cadastral valuation, as well as the methods used in the valuation of land settlements, are capable of further improved.

6 Other problems and challenges of cadastral recording and land valuation

Among the urgent problems manifested in cadastral registration, including in the Sverdlovsk region, should be included the problem of lack of precise land parcel boundaries.

Is important to note that from 1st January 2018, a ban comes into force (with no exceptions) on the disposal of land in respect of which there is no information about the location of boundaries [7]. This is reflected in the action plan “Improving the Quality of Public Services in the Field of State Cadastral Recording of Real Estate and State Registration of Rights to Immovable Property and Transactions Pertaining Thereto” (“roadmap”).

According to the data of the Federal Ministry of Economic Development, the funding of cadastral works to identify the exact boundaries of land will be made at the expense of regional and municipal budgets, as well as by grants from the Federal budget. The amount of funds for these works will be about 119 billion rubles.

Of no less importance is the need to find a solution to the problem of secrecy and lack of transparency within the system used to provide information about unused and already used lands. The presence of a significant number of administrative barriers in the sphere of land relations is a primary cause of corruption, based on which, for example, fraud associated with the illegal transfer of land from one category to another tends to proliferate. It should be noted that overcoming this problem is also related to the implementation of the action plan “roadmap”, which is based on the concept of the Federal target programme “Development of a Unified State System of Registration of Rights and Cadastre of Real Estate in the Years 2014–2019” (FTP), total funding of which will be 62,778 billion rubles, including 60,416 billion rubles from the Federal budget and 2,362 billion rubles from the budgets of the Subjects of the Russian Federation.

One of the most important results of the projected implementation of the “roadmap” and the Federal programme is the creation by 2018 the Unified State Register of Real Estate (EGRON) based on the combination of information from two sources: State Real Estate Cadastre and the Unified State Register of Rights to Immovable Property and Transactions Pertaining Thereto. The establishment of such a unified state information resource is highly desirable, as it would facilitate timely and rapid collection of data on real property, as well as reducing transaction risks in the property market.

7 Conclusion

The main problems in the sphere of state cadastral and land evaluation include the inadequacy of present valuation techniques and legislation; the lack of accurate land boundaries; and secrecy and opacity within the information system. Despite the existence of these problems, there is ongoing development within the institution of cadastral recording and valuation of lands. Improving the methodological and legislative frameworks of cadastral valuation will improve the quality of relations in the sphere of the real estate market of the country. In this case, it may be useful to refer to the experience of individual regions in the implementation of reforms at the Federal level.

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An approximate method for estimating water consumption according to tourist land use patterns: evidence from Gandía municipality (Spain)

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Abstract

This paper is a partial result of the research project, Strategies for Sustainable Regeneration in Tourism Settlements on the Mediterranean Coast (ERAM) of the 2011 National Research Plan of Spain. The research focuses on one of the 68 coastal towns of the Valencian Community Region (CV) representing more than 12.5% of the GDP. Although tourism is a fundamental economic strategy for many coastal cities, it is one of the main drivers of global environmental change and affects scarce water resources, including those in southern Spain.

This paper concerns a demonstration of the validity of an approximate method to estimate indoor–outdoor water consumption according to tourist land use patterns, and to provide quantitative information on water consumption in gardens and swimming pools as water-related leisure structures. The analysis combines water consumption statistics with population census and “Housing 2011”, and uses geo-data based on the SIOSE 2011 project, the CV05 cartography from the Valencian Cartographic Institute and the Spanish home-ownership registry. The results show the different tourist consumption due to land-use patterns and the validity of a method to approximate complete measurement of all coastal municipalities in CV.

Keywords: tourism water consumption, sustainable regeneration, touristic destinations, touristic indicators, Valencian community.

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1 Introduction

Along the Spanish coast, on the strip of 500 m, are situated around 500 municipalities, belonging to 23 different provinces of 10 different regions and two autonomous cities. This administrative reality makes the management of the Spanish coast extremely complex, due to the multiple political measures and expectations that are around it. In each one of these regions and autonomous cities, reality is far different as it is the proportion of territory that is part of the strip of 500 meters of coast. According to SIOSE 2009 data (System of Information regarding the Occupancy of the Land in Spain) [1] until today the most disorganized system of geographic information about uses and occupancy of the land done homogeneously for the entire Spanish territory, it is in this littoral strip where the major and most important expansions have been occurring during the last few decades in Spain. Inside the artificial covering of the SIOSE, updated in 2009, the mixed urban land occupies 88,493 ha, where 32,725 are downtown or first expansion areas (*ensanche*), in other words, continuous land with dense and high construction, and 55,768 are discontinuous land or expansive urbanism. The discontinuous land is an area with a lower density of population than the continuous land, it occupies a larger area and generates higher maintenance costs of infrastructure. The Valencian region has always been characterized as being a territory with middle size cities with a mainly compact urbanism, typical of the European Mediterranean cities. However since the 1990s, a high increase of extensive expansion, mainly on the coastal area, has transformed most of the littoral landscapes and generated important transformations [2].

1.1 The Valencian touristic model

Inside this strip of 500 meters the main activities are leisure, tourism, and second residencies, the tourism industry being the one representing, according to the IMPACTUR (2007) [3] report, the 13.2% of regional GDP, meaning 76% of the total amount of services exports and 4% of total investment. However, the Valencian touristic model also has its singularities. Instead of choosing a professional model of touristic production in close relationship with the territory, the Valencian region, as the Murcian region and Andalucía, following real estate interests and inertia of the economy, has configured a touristic model where environment treatment and services are just secondary factors [4, 5].

Without a doubt the touristic leadership of the region comes from the immense unregulated accommodation; more than 2.6 million beds in residential dwellings, with a potential touristic use and discontinuous occupancy that are conditioning how Valencian tourism operates. Inappropriately named “residential tourism”, it is one of the most important industries of the Valencian region regarding investments, rent and, most of all, employment. For its part, the legal offering given by hotels and registered littoral apartments, represent a similar number to the existing on the province of Madrid regarding bed numbers, a situation that would be much lower if we do not take into account Benidorm, focus of foreign and local tourism in Western Europe offering integrated and competitive touristic services as its Tourism Index shows in 2006–2013: 2733–2944 [5, 6].

Moreover, in a territory not characterized by its abundance in water resources, the consumption of the touristic industry is a first line subject to deal with. As Rico Amorós states [7] an analysis of the units of water consumption associated with the touristic activities is essential to value the environmental and socioeconomic efficiency model of the Valencian urban-touristic territorial development.

1.2 General objectives and structure of the work

This paper’s main objective is to define an indirect method of evaluation and measurement of water consumption of the touristic offer (official and unregistered) based on a common behavior that will, therefore, permit its application to the 474 kilometers of coast and 21,327 ha of Valencian coast strip.

To do so, it is vital to attend to the different manners of territorial implementation of these activities, especially regarding hotel and residential occupancy, comparing the efficiency of drinking water management in low and high density urban models. This paper follows a line not yet studied by other investigations that have also evaluated the real consumption of touristic spaces [7, 8] and takes some data and information from these studies about estimated consumptions of each type of settlement.

The study is based in Gandía, one of the touristic municipalities with the greatest dynamism of the Valencian region. The area of “Playa de Gandía”, where this investigation is focused, has 7 kilometers of littoral and an area of 700,000 square meters of fine and white sand. It also has an estimated accommodation infrastructure of 95,000 beds that makes it one of the 5 most visited touristic destinations of the Valencian region (after Benidorm, Valencia, Alicante and Peñiscola).

With this source of geographic framework, the study establishes a comparison between the results of water consumption obtained from measurements and indirect sources (cartography and average estimations of consumption) and data obtained from real consumptions given by the water supply company of Gandía (“Aguas de Valencia”).

The methodology applied, therefore, is quantitative with the use of secondary sources that are compared with real measurements. The main secondary sources are the home-ownership registry (Cadaster) from the Spanish Housing Ministry, the cartography CV05 from the Valencian Institute of Cartography, the Population and Housing census of 2011, and the project SIOSE 2011. The graphical representation and the measurements have been done with the ArcGis software (Geographic Information System GIS).

2 Territorial and chronological frame of reference

The distribution of tourism demand in the Valencian community highlights that, despite the various diversifying trends of recent times, the Valencian tourism system – from a territorial perspective – lies essentially in the conurbation of the littoral structured by large infrastructures such as CN-340, AP-7 from ‘Vinaròs’ to Valencia and the CN-332 between the regional capital and ‘Pilar de la Horadada’, that have acted as the main catalysts of the urbanization process.

Inside this littoral structure we find Gandía, a municipality with a population over 75,000 inhabitants, although with a variable population that gives a total of 100,000–120,000 inhabitants. This gives Gandía the condition of the seventh largest city by population numbers and one of the most important of the region, due to its history and also its proximity to the limits of Valencia and Alicante. Furthermore, Gandía is one of the main touristic destinations of Spain, multiplying its population by three, to almost 320,000 residents, during the summer.

Our work focuses attention on the most touristic area of the municipality: Playa de Gandía, with an area of over 226.5 ha and formed by the Census Areas (SC) SC4613104003 and SC4613104005.

Figure 1: “Playa de Gandía”. Census Areas (SC).

To guarantee an adequate homogeneity and coordination for the comparison of data, the year 2011 has been taken as the reference year. Thus the population data as well as the home-ownership data and the measurements of the real consumption given by “Aguas de Valencia” are analyzed for the same period.

3 Settlement touristic patterns

In Spain there are no statistical data on the total urban suppliers at a local scale, nor data differentiating the consumption by housing type or buildings related to the touristic and leisure industry. For its part, although there are some public cartographic products of an excellent quality, it is not possible to make an automatic evaluation of the regulated and unregulated tourism from them. Together with these limitations, we should add two more difficulties. On the one hand, although the regulated offering is identified with a common architecture typology of the Spanish coast (hotel or apartment-hotel) that is usually present as one or more multifamily buildings, the unregulated offering has a major diversity. We should at least differentiate between the apartments used as multifamily buildings and the single family buildings (Table 1). Also, season, or the grade of intensity of use of accommodation during the year, is another factor to take into consideration when water consumption is estimated, although it affects the regulated offering as well as the unregistered one.

Table 1: Typologies of touristic settlements.

	Multifamily Buildings				Single Family Buildings
Official tourism	Hotel	Hotel-apartment	Hostel	Apartments	_
Unregistered tourism	Apartments				Apartments
Residential dwelling	Housing				Housing

As can be seen in Tables 2 and 3, the studied district is an area where the unregistered offering of touristic spaces prevails over the official sites, mainly due to the existence of apartments in multifamily buildings. If we take percentages, 83% of the offering is characterized by the unregistered model, 8.7% by the official tourism concentrated mainly in hotels and hotel-apartments; and 8.3% by permanent residential occupancy of the area.

Table 2: Distribution of the official and unregistered offerings.

Census	Total	Official tourism*	Non official tourism**+ Residential dwelling
Number	Accommodation	Nº of rooms	Accommodation
Total	**50,332**	**4,795**	**45,537**
SC 4613104003	20,322	2,739	17,583
SC 4613104005	30,010	2,056	27,954

**Hotel, apartments; **Residential dwelling, unregistered tourism, empty dwelling.*

Table 3: Detail of the first residence and unregistered offering.

Census	Residential dwelling	Unregistered tourism	Empty dwelling
Number	Accommodation	Accommodation	Accommodation
Total	**4,528**	**44,518**	**1,019**
SC 4613104003	2,864	16,796	786.9
SC 4613104005	1,664.1	27,722	232.2

3.1 Method for measurement of tourism uses

With regard to the different types of tourism uses, we have employed the home-ownership cartography to be able to approximate the real use of leisure space. This cartography, with a 1:500 scale, is the most precise one with a national coverage so it is consistent with the systematic method that we propose to use in this study. Although the procedure used allows distinction between single family residences and the multifamily buildings and guarantees the distinction of the land use for hotel and hotel-apartment buildings, it is impossible to distinguish between what we consider residential dwellings and unregistered tourism. To obtain the data, we have used statistical differentiation based on the percentages of residential dwellings and unregistered tourism offered by the Census of Population and Housing 2011. Thanks to these data we have been able to classify the accomodation units from which we will calculate indoors consumptions.

Figure 2: Types of land use according to city planning.

The outdoor consumption measurements have been undertaken by evaluating two types of water consumption – surface irrigation of green areas and filling and maintenance of swimming pools.

For the measurements of the green areas using a systematic method that would be useful afterwards for other coastal municipalities, we have been working on false color IRG or close infrared orthophotos from the Valencian Institute of Cartography. The infrared radiation or IR radiation is a type of electromagnetic and thermal radiation that, thanks to the sensibility of the films used for obtaining these pictures, can be taken. These photographs are sensitive to green, red and infrared, instead of blue, green and red, and therefore the visible colors for the human eyes are modified producing the characteristic colors of these photographs.

Regarding the measurement of the areas used as pools, the procedure has been much easier because the data has been directly obtained from the CV05

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cartography from the Valencian Institute of Cartography that covers the entire region and distinguishes with enough quality the perimeters of three zones.

Table 4: Area outdoors.

Census Tract	Built up area (m^2)	Pools area (m^2)	Garden area (m^2)
Number	790 plots	281 pools	612 plots with gardens
Total	**1,124,240**	**38,006**	**140,370**
SC 4613104003	506,758	17,119	42,963
SC 4613104005	617,482	20,887	97,407

4 Estimation of population and water consumption indoors and outdoors

The estimation of population as well as the consumption of water in the touristic area requires precise explanation, because there are different options to evaluate the figures. In both cases, the approximation undertaken has been based on the report by Hof and Schmitt [8].

4.1 Estimation of population and year

We have selected two possible scenarios of tourism impact on the area. First, a calculation of the official population which represents minimum population (Table 5):

Table 5: Official population.

Census tract	Census population 2011	Hotel seats	Monthly capacity utilization factor (Hotels)	Official population
Number	Inhabitants	Number of beds		
Total	**5,403**	**4,795**		**8,064**
SC 4613104003	3,221	2,739	**55.49**	3,221
SC 4613104005	2,182	2,056		2,182

Official population = official census data + ((hotel beds + apartments beds) × (monthly capacity utilization factor)).

Second, a calculation where the potential population represents a maximum, reflecting the maximum residential population plus tourists in second homes and in non-declared units (Table 6):

Table 6: Potential population.

Census tract	Unregistered tourism*	Hotel accommodation	Monthly capacity utilization factor (Hotels)	Potential population
Number	Accommodation	Number of beds		
Total	**44,828**	**4,795**		**44,828**
SC 4613104003	20,880	2,739	55.49	20,880
SC 4613104005	23,948	2,056		23,948

Potential population = ((no. of apartments + no. of flats + no. of single residential houses) × (average household size)) + ((hotel beds + apartments beds) × (monthly capacity utilization factor)).
*(no. of apartments + no. of flats + no. of single residential houses) × average household size.

The average household size is 2.58 persons according to INE (2013) and the capacity utilization factor includes monthly percentage of open hotels and tourist apartments and their utilization factor according to "Encuesta de ocupación Hotelera (2011)" [9]. The resulting water consumption figures are compared with findings from other studies in similar climates and contexts [7, 10].

4.2 Estimation of indoor, outdoor and per capita water consumption for different of domestic water uses

As the Hof and Schmitt report mentions [8], other studies in similar climates and contexts have shown that analyses of domestic water consumption have to take three variables into account for explaining model patterns: per capita consumption indoors (dependent on household size, seasonality of inhabitancy and capacity utilization of tourist accommodation), and outdoor water consumption for garden irrigation and swimming pool maintenance [11, 12].

The following sections outline the methodology to determine each of the variables for domestic water consumption analysis.

4.2.1 Indoor water consumption: official tourist accommodation in hotels, hotel-apartments and hostels

In Table 2 we summarize the data related to the number of hotel beds in the studied area. We already know that water consumption is directly related to the hotel category [11]. Taking the previous report as a guide, we can use an average monthly consumption, depending on the category, the ones shown in Table 7, and calculate the monthly indoor consumption of the official tourist offering.

4.2.2 Indoor water consumption: official tourism and unregistered tourism in multifamily and single family buildings

Similar to the previous case in Table 2, we summarize the data related to the number of "No official tourism" existing in the studied area. Based on the Rico-Amoros *et al.* work [11], we can estimate the consumption per inhabitant and day depending on the type of settlement and calculate the indoors monthly consumption of the unregistered tourism offer in:

Table 7: Water consumption in hotels according to category.

Hotel category	Census tract (Number of beds)		Average consumption per bed occupied (l/p/d)*	Monthly capacity utilization factor (Hotels)	Water consumption per month (m^3)
Total	SC 4613104003	SC 4613104005			**24,182.3**
1 Star	158	_	174	55,49	453.62
2 Star	32	_	194		102.43
3 Star	1,059	2,056	287		14,751.08
4 Star	1,490	_	361		8,875.19

*Source: Rico-Amoros *et al*. [11].

Table 8: Water consumption in unregistered tourism.

	Capacity of accommodation per Census tract		Av. C (l/p/d)*	Water consumption per month (m^3)
Type	SC 4613104003	SC 4613104005		105,234.83
Multifamily apartments	7,755	9,021	142	101,409.91
Single family apartments	338	261	150	3,824.91

*Source: Rico-Amoros *et al*. [11]. Average consumption per seat occupied (l/p/d).

4.2.3 Outdoor water consumption: pools

To estimate pool water consumption, evaporation will be taken into account by square meter of pool area and filling. In this case we have followed the estimations made by Hof and Schmitt [8]:

$$w_{Pool} = \dot{n}_{average} * a_{Pool} * days + a_{Pool} * \text{average pool depth} * 1000/12 \qquad (1)$$

where w_{Pool}: sum of pool water evaporation loss and filling of pool (litres per month); $\dot{n}_{average}$: average water quantity evaporated from a pool in Gandía (5 liters per square meter per day); a_{Pool}: pool area (square meters); average pool depth: 1.5 meter.

Table 9: Water consumption in pools.

Census tract	Pool area (m^2)	W $_{Pool\ per\ month}$(m^3)
Number	281 pools	
Total	**38,006**	**10,452**
SC 4613104003	17,119	4,708
SC 4613104005	20,887	5,744

4.2.4 Outdoor water consumption: garden irrigations

Water availability for garden irrigation has been established following the references present [12]. In this case it is a study undertaken for irrigation systems of private gardens in suburban Barcelona, although we have considered wider intervals of the approximation, because the climate is much dryer in Gandía. With this information, we will take as a reference value: 12 l/m^2/week. Doing so the results obtained are shown in Table 10:

Table 10: Water consumption in gardening.

Census tract	Garden area (m^2)	W $_{Pool\ per\ month}$ (m^3)
Number	612 plots with gardens	
Total	**140,370**	**6,738**
SC 4613104003	42,963	2,062
SC 4613104005	97,407	4,676

5 Conclusions

The objective of this study is to establish a systematic method applicable to the Valencian touristic coast that would allow the estimation of indoor and outdoor water consumption. Table 11 compares values of estimated and real measurements.

Table 11: Water consumption comparisons.

	W_G p/m (m^3)	W_P p/m (m^3)	W_C Unregistered tourism(m^3)	W_C official tourism (m^3)	T_{Tw} p/m (m^3)
Total	**10,985**	**10,452**	**105,235**	**24,182**	**150,854**
SC 4613104003	3,362	4,708	49,037	14,446	71,553
SC 4613104005	7,623	5,744	56,198	9,736	79,301
	E_{WC} p/m (m^3)		R_{WC} p/m (m^3)	Difference (m^3)	%
Total	**150,854**		**178,697**	**-27,843.02**	**-15.58**
SC 4613104003	71,553				
SC 4613104005	79,301				

As a conclusion to our work we will highlight some ideas:

- The method considered, when compared with real measurements, gives a 16% error. It can be considered acceptable because it is caused by the following factors:
  - The real measurements (R_{WC}) given by the firm "Aguas de Valencia" (2,144,368 m^3/year in 2011) warns about the impossibility of filtering the data of industrial and commercial consumption. Therefore we start

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from the basis that the measurements we have used are higher than the values we wish to estimate.
  - On the other hand, the estimated measurement (E_{WC}) works with monthly average use in apartments and hotels. If this estimation was done for the period of a year using monthly data, the result would be more adjusted.
  - We have detected some errors on the identification of unregistered tourism in the home-ownership data used in the study. These errors give a lower number of beds than existing in the area. Thus, a correction of home-ownership data would improve the results.
  - The identification using false IRG color or close infrared orthophotos, although it is a quick way to count surfaces, requires an important adjustment. In areas where there are reflected shadows, green areas are not detected.
- As additional improvements, a validation should be done based on several municipalities to prove that the deflection obtained is homogeneous, or that there are different local deflections.

This report is a first step supported by specialized references in the path to achieve a better and more effective control of water consumption in large regions such as the CV.

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Section 3
Natural resources in peri-urban spaces

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Environmental management of peri-urban natural resources: L'Horta de Valencia case study

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Abstract

L'Horta de Valencia is a peri-urban agricultural space with recognized values as a heritage: historic, cultural, agricultural, economic, landscape and natural resource. Across Europe, there are only six similar landscapes according to the DOBRIS report of the European Environment Agency (1998). Many studies and authors show their values. This historical zone has been irrigated, since the Medieval Age, by seven channels of Túria's river, and irrigation water is managed by specific organization of seven irrigation communities, one for each channel, with a historical Court of Waters. UNESCO named the Court of Waters as a World Heritage. The surface of the irrigation zones historically was very extensive with about 23,000 ha. Today there are about 12,000 ha. There have been several attempts to plan and protect this area and landscape, but so far, none has succeeded. The last attempt was in about 2006 by the Territorial Action Plan to Protect Horta of Valencia, finalized in 2010 but not approved. Meanwhile, the urbanization of agricultural areas has continued. In fact, this situation occurs as a result of management problems. Protection of anthropic spaces requires maintenance of existing economic activities, particularly, but not only, agricultural activities. Stakeholders expect more income from urbanization processes. Therefore, the main problem to execute any plan with success is the management of agricultural space to maintain economic activities associated with the agricultural landscape. This paper analyzes the behavior of stakeholders and structural causes that explain the failure of Horta planning and propose management systems to generate objective conditions in order to maintain this exceptional landscape.

Keywords: territorial management, agricultural heritage, peri-urban zones, regional planning.

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1 Introduction

Valencia's Horta has a very special landscape. It is a very fertile land around Valencia City. This area is irrigated by a system of seven canals that distribute water – Túria River (*Quart, Benàger i Faitanar, Tormos, Mislata, Mestalla, Favara, Rascanya i Rovella)*. The origin of the city is Roman. The origin of the canals may be Arabian but we do not know this for certain.

Figure 1: Metropolitan area of Valencia with urban areas in red. Origin: ICV, SIOSE, 2011[1].

From the Medieval Age, the irrigation problems between farmers has been argued in the Water Court (*Tribunal de las Aguas)*. Even today, the Water Court dispenses justice every Thursday at the door of the Apostles of Cathedral. All processes are exclusively oral and judgments are enforced by the verbal agreement of farmers who submit to the court. In 2009, the Water Court of Valencia was declared World Heritage by UNESCO as an intangible heritage.

The historical area of fertile land or irrigated land was very extensive, about 10,000 ha [2]. Today, more than half of this area had been transformed into urban land. Besides this historic agricultural area, there exists another irrigation area, since the XIX century, with a surface area of about 10,000 ha. These agricultural soils are of exceptional quality and are very lacking. The Valencian Community, with about 23,000 km^2 of surface area, in 1998 have only 3.9% of this surface area with similarly agricultural quality. As a reference, in 2006, the surface of urban areas in Valencian Community was 4.86% [4].

Note that the climate in Valencia is Mediterranean: hot and dry. Irrigation water in Valencia comes from two sources: the Túria River, the only river that exists in this area, and especially groundwater. With these conditions, the earth gives 3 or 4 crops a year.

Figure 2: Detail of Valencia and surrounding area in 1944. Origin: Historical National Topographic Map of Spain, 1:50,000 original scale.

The farmers of this area have a specific cultural heritage created by historical experience. The special landscape *of L'Horta de València* has special values as a cultural heritage, historical heritage, anthropic landscape, architectural heritage and hydraulic world heritage and, of course, for its agricultural activity [5].

In 1995, the European Environmental Agency published a report [6] about European landscapes which identified only 6 places in Europe with this type of landscape, two of them in Spain – Valencia and Murcia.

From 1978, when democracy was implanted in Spain, there have been many attempts to plan and manage this peri-urban area, but to date, all have failed. Therefore, gradually, this space has become a benchmark for the effectiveness or failure of environmental policies.

2 Objectives

Many authors have studied this space from different viewpoints. This paper analyzes the structural causes that explain why, today, despite the social and scientific recognition of values of this space and the very extensive legal framework for environmental protection, it has not been possible to plan and manage use in this special space.

Figure 3: Image of irrigated land of L'Horta de Valencia.

3 Historical attempts to planning and management of peri-urban Valencia's Horta

In 1946 the first metropolitan plan of Valencia, *Plan General de Ordenación Urbana de Valencia y su Cintura,* was approved*.* In 1957 a major flood occurred. The Spanish government decided to change the route of the Túria River via the south of Valencia (South Solution) and build a new channel through which to divert water in case of new floods. For this reason, the metropolitan plan was revised and a new plan was approved in 1966, *Plan General de Valencia y su comarca adaptado a la solución Sur* (General Urban Plan of Valencia and the surrounding area adapted to South Solution).

The first plan was oriented to conserve agriculture, to produce food in autarchy scenario (from the end of the Civil War in 1939 to the beginning of the open economy in 1959).

The second plan was elaborated to the situation of a real estate boom (period 1959–1972) and very intense changes in economy. The agricultural sector was becoming less important. During this time, the environment is not considered important and all historical heritage or natural resources can be destroyed, if necessary, to allow for the increase in income and economic progress. The metropolitan plan of 1966 had urban expansion and infrastructure promotion around the city as objectives.

Finally, in the 1970s, a popular movement for conserving natural spaces or natural resources around Valencia such as L'Albufera Lake, Saler beach or L'Horta historical agricultural land was born in Valencia. At that time, the government promoted a project of tourist city in the coastal zone of El Saler, near to Albufera Lake. The objective of this project was similar to the La Manga case [7, 8]. Many scientists, NGOs and people in general, protested against the project and, in addition, requested protection for natural spaces and historical agricultural land. Maybe this movement was the first ecological movement in Spain.

In 1978, the actual democratic constitution in Spain was approved. The Albufera Lake and El Saler coastal zone were protected. Urban development in these zones was stopped, but not in agricultural land.

In 1978, the new democratic constitution was approved. According to it, legislative powers in urban and regional passed to the new regional governments. In 1988, a new metropolitan plan, the *Normas de Coordinación Metropolitana del Area Metropolitana de Valencia* (Coordination Metropolitan Rules for Metropolitan Area of Valencia) was approved. This was a new metropolitan plan to establish land reservation for: infrastructures (especially transport), regional public facilities and protected areas. According to this plan, an important part of agricultural land was protected but not everything. These metropolitan rules were implemented by *Consell Metropolità de L'Horta* (L'Horta Metropolitan Council).

In 1999, the Metropolitan Council was removed due to a conflict of interest between the metropolitan organization and municipalities.

Municipalities wanted to be free to promote urban development in its municipal boundaries during the time of the 1997–2007 housing boom. At the same time, in 2000–2001, a new popular movement promoted an act, by system of "popular legislative initiative" for protecting historical agricultural land [9]. The initiative collected around 118,000 signatures, 10% of the electoral roll in the area. The Act was rejected by regional parliament, but a new metropolitan plan to protect agricultural land was initiated after many years [10].

In figure 4 you can see agricultural land (green), urban zones (red) and other uses (white) in Valencia in 2000 with boundary of new plan and boundary of *L'Horta* region. The initial strategy, in 2007, to intervene in agricultural land was based on the popular Act proposal [11]:

- Regional planning: Territorial Action Plan for protection of L'Horta de Valencia
- Socioeconomic agricultural plans and rural tourist plan
- *Horta* Act and creation of a Management Entity to protected area

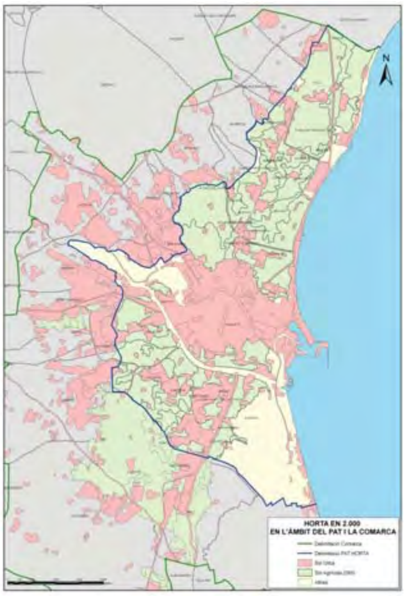

Figure 4: Agricultural land in Valencia in 2000.

Finally, in 2011, the plan was finalised but not approved. Never started working about complementary instruments: agricultural plan, rural tourist plan, Horta Act and Management Entity.

4 Causes of continued failure

Why? Why has it not been possible to conduct intervention projects? Why, despite all the time passed, did any of the instruments of intervention not run?

We can identify three essential unresolved contradictions in our society that you can see in figure 5.

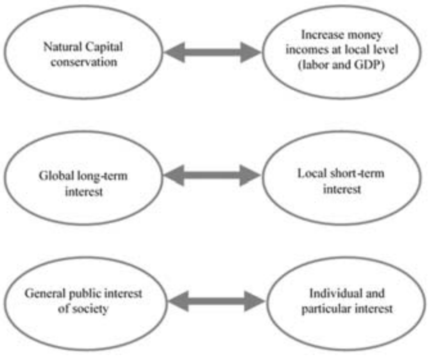

Figure 5: Essential unresolved contradictions.

The causes for the failure of the intervention in agricultural land of *L'Horta*, which are explained below, are an expression of some of these contradictions.

4.1 Interest of land owners to increase income by sales of land for building

In the last period of real estate boom in Spain and Valencia, during 1997–2007, prices of protected agricultural land to change protection and build on, went up to 180 euros per square meter. Therefore, a normal plot of 3,000 m^2 could be sold for 540,000 euros. In this situation, in general, the farmer wants to sell their land. The land prices to build on is always much higher than its price for agriculture [12].

Farmers, in general, want to increase their income and don't want protection for their land. They think that if society wants to conserve the natural capital of agricultural land, society must pay for the conservation. Conservation cannot be at the expense of the farmers. This question justifies management systems, as an ecological tax to pay for the conservation by land stewardship contracts, for example.

However the high price of land was produced by a speculative process. In fact this is one of the causes that has produced the current economic crisis in Valencia and Spain [13, 14]. Facts have proved that this high value market price of land to build on produces a tendency to destruct the natural capital. In addition, the land market to build does not generate economic progress but debt, because the market value is only an expectation value. It is necessary to revise the theory of property of land to build.

4.2 Interest of municipalities to prepare land to build

Since the 1975 Land Act in Spain, municipalities can obtain significant income from urban development. In the period of real estate boom, 1997–2007, many municipalities promoted urban development to increase income [15]. In addition, local governments often serve request of owners, real estate developers, builders and homebuyers.

The period of government in democracy is short, 4 years in Spain. So local governments prefer to increase income in the short-term, serve local interest in the short-term but particularly interest versus general public interest to conserve natural capital in the long-term.

Therefore, it is necessary to revise governance to guarantee long-term public interest.

Figure 6: Landscape of L'Horta around Valencia City.

4.3 Low profitability of crops

Farmers always say that agricultural prices are very low. However, the agricultural land in Valencia is always in production. It is an extensive land made up of small farms with intensive production. On the other hand, ecological agriculture and landscape conservation implies conditions. For example, it is not compatible with the cultivation under plastic. For all these reasons, it is necessary to use new management systems to finance landscape conservation.

This situation is contradictory with the global situation of food speculation [16]. From a strategic standpoint, the Valencian society should preserve and maintain a natural resource that, globally, is increasing in appreciation

On 20 December 2013, the four Basic Regulations and the Transition Rules were published in the Official Journal of European Union [17]. The new Common Agricultural Policy (based with three strategic aims: food security; quality, value and diversity of food; and employment [18]) will help to improve the situation.

4.4 Inadequate distribution of the costs of sustainability

If society wants to conserve the landscape in quality conditions as a green infrastructure for citizens [19], society must pay the added costs. Peri-urban space of *L'Horta* is not only an agricultural historical land, it is also a big open space for the enjoyment of citizens and a good landscape for rural tourism. Accordingly, society and rural tourism activities should help to finance landscape conservation.

5 Conclusions

Conventional systems for regional planning and management are ineffective and insufficient to act on the current real situation of historic farmland of Valencia. Conventional systems cannot successfully solve current contradictions in order to guarantee a better future for society.

In fact, peri-urban agricultural spaces of Valencia are a symbol of precious natural and cultural goods. An example of very intense conflict between todays interests over tomorrows interests. A laboratory which tests new instruments to search guaranteed natural resources for the future.

The experience of Valencia suggests a list of structural changes to act successfully in peri-urban spaces of natural resources. Strictly, these structural changes or new social rules must be realized in regional constitution or state constitution. It is only possible to pilot experiences by law only.

5.1 Revised property theory about the ground to build on

Current property theory was born in the XVIII century. However, current environmental problems are much more important and current technology is very different. Today the property registration is digital, we can see all the plots of Spain on-line and we can distinguish between the ground and the underground.

On the other hand, we must remember that, as in the XVIII century, the only source of wealth is labor [20]. The work of workers and organized labor in companies. From the work, society produces goods and services to consume. Therefore, we can establish a basic social and economic principle: every worker or company must receive economic compensation for the goods and services it produces.

Nevertheless, to ensure that this principle is efficient, it must also meet its corollary: no worker or company must pay nothing for goods and services that no one has produced.

In the case of land, we have two goods: the ground and the underground. The ground is the surface of land that is used for agricultural activities. The underground is the geological material under the ground. The ground is improved by farmers. The underground is natural goods that no one has produced. When a building or public work is constructed, the ground is removed to cement in the underground. That is, the owner is really the owner of the land but not the owner of the underground or not the owner of geographic coordinates.

Therefore, land for building must be public and so the speculative land market for building on will be removed. In this situation, land value is according to agricultural use and expected urban uses cannot influence the price of land. Thus, speculative land prices would not be cause for the destruction of natural resources.

5.2 Revised governance system: administrative organization and environmental power

Current administrative organization cannot guarantee environmental interest in the long-term. Usually, the protection of natural resources was realized by an act, but all acts can be changed when legislative power changes. In Spain, legislative power chooses executive power for four years. New legislative power can always change protection laws.

It is necessary to have another power, an environmental power, to guarantee environmental interest in the long-term. Remember when the theory of the three powers created at the time of the French Revolution (legislative, executive and judicial), environmental problems were not considered. Therefore, society organized by these three powers do not guarantee public environmental interest and therefore does not guarantee long-term environmental interests.

This new power must be independent of legislative, executive and judicial powers. It should operate under the principle "political protection and technical custody". That is, natural resources protection must be a legislative democratic decision but, once natural resources have been protected, the environmental power will have the custody of those protected resources as a function. In this situation, unprotected natural resources or territory can only be possible by resolution of environmental power. In other words, democratic legislative powers take decisions about protecting resources or areas for the long term, but the responsibility of the management of it corresponds to other institutions. This environmental power must also realize environmental reports for environmental impact process and strategic environmental assessment.

The function of environmental power will be equivalent, in the environmental field, to the role of the European Central Bank in the economic field. If European Central Bank have as a function guaranteed monetary equilibrium or guaranteed assets measured by currency, environmental power must be an institution for guaranteed natural heritage for the long-term. Therefore, we can name this power or institution as a Natural Capital Bank [21]. The Governing Board of this institution shall be elected by a system to ensure its independence from the executive and legislative powers.

On the other hand, in Spain we have about 8,000 municipalities. Many of them with very little population. In this current situation, with a very developed transport system, the geographic scope more appropriate to fixed uses is the functional area or metropolitan area, not municipal area. For this reason, we need governance revision. Rethink local administration, functional area for each level of administration and their different competencies for managing public services.

5.3 Translate to society the cost of sustainability

The need of sustainability produces a cost for today, for more benefits tomorrow. These costs should be distributed among the beneficiaries of environmental services. If general society is the beneficiary, then she should bear the cost.

Management systems, as ecological tax, can be used to finance land stewardship contracts. The contract can regulate agricultural use conditioned to landscape quality and the commitment to not develop urban in exchange for an annual payment.

However, in the future, if agricultural land will be transformed for building or public works construction, then the contract will not be fulfilled and the developer must return all payments with interest. Of course, this cost must be borne by the urban developer or public world developer. This cost increases the final price of the building or public work. It is a way to pass the cost of sustainability to the product price: building or public work.

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Occupation models in peri-urban areas: actions for orchard-city integration

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Abstract

The model of urban development in settlements based on sprawl growth systems generates a strong problematic in terms of resource consumption. The management of these environments located between city and the countryside is complex, especially due to the difficult cohabitation between real estate development and agriculture. Water rights, land distribution, urbanistic regulation, etc. are elements to evaluate in order to establish real diagnoses about which must be the future of these territories. This paper presents the orchard of Murcia, an illustrative case study of anarchic urban development (a peri-urban area largely influenced by its traditional irrigation system). With the help of geospatial analysis systems, they will be raised as orchard-city integration models to enable an ordered growth of the urban plot, allow the survival of smallholder agriculture and minimize the impact on the landscape.

Keywords: peri-urban areas, sprawl growth, urban management, rural studies, land transformation.

1 Introduction

The management of peri-urban areas is a field that is gaining increasing interest in the context of scientific research (see [1–3] for example). The sprawl model of growth in cities is a rising phenomenon that encompasses a varied case mix, especially in large megacities of emerging countries with high growth rates [2], where the scale of work reaches the regional level. In such areas, called peri-urban territories, agricultural soil transformation processes and landscape impacts generated by changes in land use and the complex management that commonly suffer these "mixed territories" [3], are particularly interesting.

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Within this subject, it is very interesting as a learning element for the development of today's emerging cities the retrospective analysis of ancient European cities of Spain. In these cities, the transformation process of the territory has already internalized dozens of years with changes in economic, political or strategic cycle. A case of particular interest from the point of view of peri-urban areas management is the so called "Huerta de Murcia", a vast agricultural area around the Segura River that lies between Murcia and Alicante in south-eastern Spain (Fig. 1).

Figure 1: Territorially homogeneous agricultural area associated with the Huerta de Murcia. Source: Google Earth.

If it is focused on the territory belonging to the Region of Murcia, there is a field of study of more than 10,200 hectares (Fig. 2), similar to the whole metropolitan area of cities such as Madrid or Barcelona. This area around the city of Murcia has been traditionally called "the orchard of Europe" due to traditional agricultural capacity of the land, watered by the Segura River. This irrigation system is composed of various interrelated elements: water uptake, its driving by irrigation ditches and the land terracing to irrigate intensively, used since the middle ages (Fig. 3).

This environment is undergoing an intense transformation process for last decades. The strong housing growth and spread of the city has gradually generated a mixed suburban territory where coexist agricultural and urban uses. In this sense, one of the main indicators of the current situation is the impact on the landscape and the resources and infrastructure consumption. The consequences of this process will be discussed in this study, proposing the basis for the establishment of solutions.

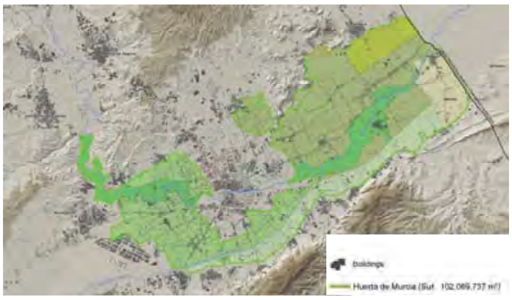

Figure 2: Geographical scope of the Huerta de Murcia.

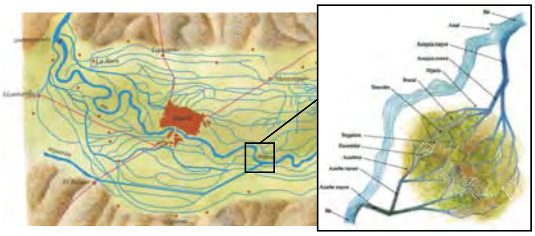

Figure 3: Operation of traditional irrigation in the orchard since the Middle Ages.

2 Urban retrospective analysis of the La Huerta de Murcia

The city of Murcia is suffering since 30 years an acute phenomenon of sprawl growth. 60% of its population is located outside the town centre, which generates a chaotic urban plot that has been invading the traditional orchard space anarchically. This phenomenon has been extensively analyzed from the perspective of geography (see for example [4, 5]), but there are scarce scientific publications related to an analysis of the transformation of territory from the point of view of urban planning and landscape.

The result of this transformation process can be observed analyzing retrospectively the evolution of the agricultural land in the Huerta of Murcia in the last 50 years. If a comparative GIS analysis of agricultural land transformation is done (Fig. 4), it can be observed the gradual replacement of traditional irrigation network formed by water ditches and small agricultural holdings, for a complex urban plot lacking many of the most basic sewerage services.

Figure 4: GIS analysis study of traditional irrigation network in the orchard.

If we perform a GIS analysis on a large scale over the entire territory of orchard it can be seen that the population growth of 8% compared to the rest of the region does not correspond with an increase of over 22% of urban land (Table 1).

Table 1: Evolution of population and land transformation of the Huerta of Murcia vs. the whole Region of Murcia. Source: [5].

	1950	1960	1970	1981	1991	2001	2011
Land transformed							
Huerta de Murcia	526	1,079	1,886	2,782	3,931	6,156	7,832
Region of Murcia	4,861	6,415	8,579	10,515	14,806	28,252	54,673
% HdM/Region	10.82	16.81	21.98	26.45	26.55	21.78	14.32
Population							
Huerta de Murcia	260,023	297,806	304,522	371,237	432,851	491,290	551,119
Region of Murcia	755,850	803,086	832,047	955,487	1,045,601	1,190,379	1,335,792
% HdM/Region	34.40	37.08	36.59	38.85	41.39	41.27	41.25

This situation can be checked at the municipal level, where it is observed that there has been essentially a process of land transformation by sprawl growth between 1980 and 2007. Looking at Fig. 5, it can be seen how the growth of the affected municipalities by the metropolitan area of the city of Murcia and its orchard have a consumption rate much higher than other municipalities of the Region of Murcia and Alicante.

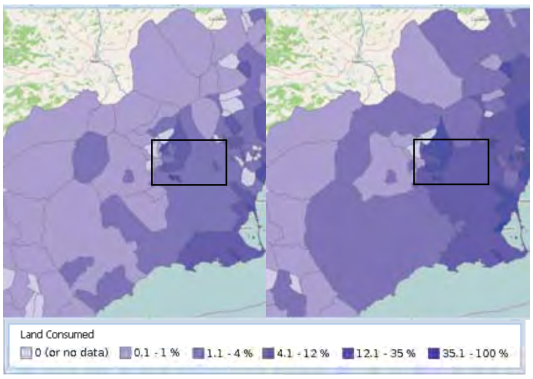

Figure 5: Land consumed by municipalities in 1990 (left) and 2007 (right) in the Region of Murcia (black box corresponding to influence area of Huerta de Murcia). Source: [6].

If it is analyzed in detail over the last 50 years the behaviour of the transformation evolution of agricultural land into urban land, repetitive patterns of conduct are observed (Fig. 6):

- Systematic piping of the traditional irrigation ditches and natural waterways
- Generation of unconnected frames associated urban to rural roads (different performance in the east and west side of the orchard)
- Progressive fragmentation of agricultural plots (weathering of property) accompanied by breaking new ground plots (different behaviour in the east and west side of the orchard)

Considering the progression in the evolution of land use, orchard trend models can be set about the future occupation of the territory obtaining the following trend analysis (Fig. 7):

- Strangulation of urban development to the east by the existence of the barrier that generates the A-7 highway
- Strong urbanizing growth northward caused by the resort phenomenon and the infrastructural expansion of the city
- Formation of scattered settlements in the environment of the western orchard and filling of the interstitial spaces in the eastern orchard
- “Sandwich effect” on the south by the natural growth of the city urban plot combined with the urban development of the industrial outside districts.

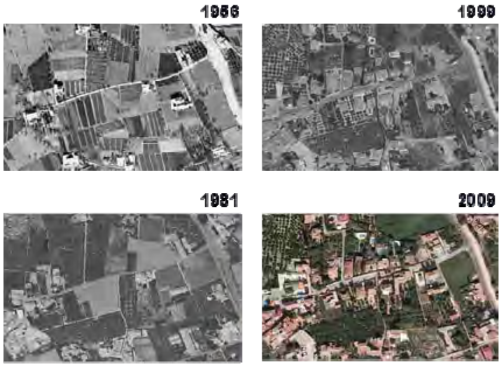

Figure 6: GIS evolution of a set of plots in the Huerta de Murcia. Source: [6].

3 SWOT analysis and diagnosis

It can be imagined therefore sufficient evidence on a different behaviour between the east and west orchard, which must be demonstrated. Analyzing two statistically significant portions of both spaces they can be diagnosed pathologies and trends of both environments. For this, it has been selected in the study the most interesting features of land transformation, the structure of property and infrastructure provision thereof (Table 2).

Looking at the analysis of the western sample it can be deduced that the territory has almost completely abandoned its productive agricultural facet to provide support for a kind of anarchic city-garden. Comparing the two samples, one can see that while the western orchard land has a rate of built soil higher than 10%, in eastern orchard this value is just over 3%. Besides, the impact of roads and paths is three times higher as a result of the increased urbanization. Furthermore, although the agricultural surfaces of both samples are not very different, the area of cultivated land at the time of analysis is much higher in eastern orchard.

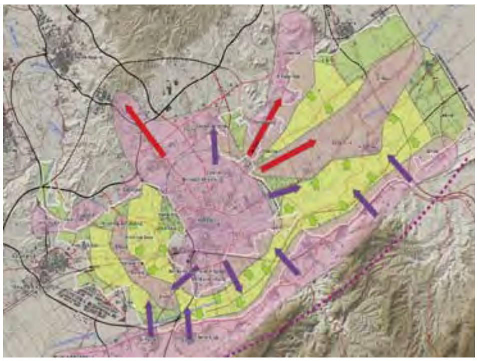

Figure 7: Trend analysis of the Huerta de Murcia.

Table 2: Data from the two samples analysed.

Sample 1 (West orchard)			Sample 2 (East orchard)	
Analyzed surface	654,387 m^2		Analyzed surface	654,387 m^2
Artificial surface	67,165 m^2		Artificial surface	18,263 m^2
Agricultural area	523,632 m^2		Agricultural area	597,372 m^2
Number of houses	743		Number of houses	108
Average size of plots	1,600 m^2		Average size of plots	12,200 m^2
Transformation rate 1956–1981	12.5%		Transformation rate 1956–1981	11.7%
Transformation rate 1981–2007	67.3%		Transformation rate 1981–2007	37.6%
Road length	9,673 m		Road length	4,836 m
Cultivated land	217,812 m^2		Cultivated land	486,785 m^2

This may be explained as a result of the existing property structure, which makes that the estimated average holding in eastern orchard is almost ten times the western one. This has allowed during the period of major transformation of the soil (1981–2007), the East orchard to maintain some of its original essence. In the case of West Orchard, farms have become too small, been unattractive for cultivation, and gradually reconfiguring the territory in a more residential area (Fig. 8).

Based on this analysis it can be performed the following SWOT diagnosis highlighting the strengths, weaknesses, opportunities and threats that currently owns the Huerta of Murcia (Table 3).

Figure 8: Urban configuration in western orchard (left) and eastern orchard (right). Source: [7].

Table 3: SWOT diagnosis.

WEAKNESSES	- High complexity - Low legibility and *imageability*: suburban fringes - Low landscape quality in the nuclei and access to populations - High fragility of the areas of highest landscape quality - Low contribution of landscape to the competitiveness - Lower contribution from the daily landscape to quality of life
THREATS	- Loss of the magnificent landscapes of orchard - Growing of suburban fringes - Reduction of readability and low *imageability* and identity - Tendency to *aterritoriality*
STRENGTHS	- The existence of the mountain ranges in good condition - The wealth of contrasts (Huerta, forest, semi-desert in wadis) - The existing vegetation: the geomorphological variety run great interest as potential asset - The orchard as a landscape identity and the existence of the already executed river buttes
OPPORTUNITIES	- Rethinking the orchard as an identity preserving landscape speck structural axis of the river as an overall approach to the metropolitan landscape - The restatements that forces the economic crisis may allow the consideration of landscape as a key element of competitiveness - Improving the quality of life of citizens by improving urban landscape - The landscape strategy in the region, instrument implementation of the European Landscape Convention

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4 Proposals for improvement

From the SWOT analysis conducted they can be considered various defensive, offensive, proactive and reactive strategies (growth-share matrix) and some actions to promote agricultural activity for orchard-city correct integration [8]:

Table 4: Strategic SWOT analysis.

	STRENGTHS	WEAKNESSES
OPPORTUNITIES	**Offensive Strategies:** - River buttes as a strategic elements, linked through lanes and channels form a network of pathways between the soft hills and Huerta - Setting priorities for recreational/productive use/ urban growth in low and middle river stretch	**Proactive Strategies:** - Enhancement of the structural elements of the landscape (paths, viewpoints) as a tool for solving landscape deficits - A green belt of mixed uses as an opportunity for a hierarchy and consistency of services to different mesh use
THREATS	**Reactive Strategies:** - Preservation of existing trees and vegetation in the fight against desertification - Integration of orchard in regional tourism as a living reality and transformation in a moment of fashion urban agriculture and local food production	**Defensive Strategies:** - Urban planning discipline - Reorientation of urban land use regime and orchard urban corridors - Identification of opportunities for rural plot rearrangement respects traditional landscape frame

From the socioeconomic point of view, these strategies can be translated into actions in order to promote the competitiveness of the orchard and its differentiation in economic activity:

- Creating a quality brand of orchard products of Murcia.
- Consolidation of local circuit's sale of direct selling.
- Development of organic agriculture with high added value for foreign markets.
- Incorporate all associated with these products experience: recipes, tourism (B&B).
- General help on the marketing and production: Agricultural Orchard Park.
- Lost or abandoned orchards mismanaged, leasing companies.
- Create a land bank to be sold to third parties.

Having seen the importance of ownership structure and the average size of plots in the development of the orchard, the proposal for an orchard bank is very necessary to avoid the fragmentation of ownership and consequent urbanization unstructured of landscape [9]. Promoting the sale of abandoned orchard plots for rental by individuals or associations could been articulated through this tool, because despite the fall in the rate of urbanization after the bursting of the housing bubble in Spain, who require some land to develop agriculture have actually real trouble acquiring land:

- The owners have no interest or need to sell their land.
- The soil is generally under strong speculation.
- The creation of a market for rural-agricultural land is essential to ensure a future in the industry.

The only way to generate a reliable market floor is through an entity endorsed by the government itself (Fig. 9).

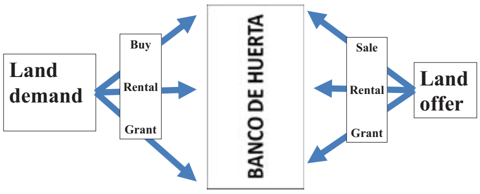

Figure 9: Operating of the Orchard land bank.

Thus, this instrument would permit to retake much of the farming loss in last decade and preserve from urbanization the undeveloped plots that are currently in danger of falling into the hands of speculative processes (Fig. 10).

Figure 10: Plots with higher than minimum area to build without building in 2014: area to preserve.

5 Conclusions

La Huerta de Murcia is an environment of high cultural and landscape value closely associated with the identity of Murcia. Based on a GIS analysis was conducted a SWOT diagnosis that has allowed to highlight the current pathologies and trends in the area of orchard. This diagnosis has established various strategies for western orchard (converted into a highly urbanized city-garden, with widespread loss of agricultural activity and atomized ownership structure) and eastern orchard (less dysfunctional due the larger size of their plots but with significant endowment problems and streamline in its infrastructures and significant danger of speculative processes).

To catalyze these strategies have been proposed various socioeconomic measures, including the implementation of a land bank in the orchard. All these measures will require being channelled through important urban planning regulations and modifications that should be addressed in two stages:

1. Development of integrated studies characterizing the orchard:
    - Special urban development plans for Huerta recovery, contemplating improvement and enhancement of irrigation network, generating tourism and scenic routes, establishing visual windows and vectors connecting garden spaces.
    - Development of special infrastructure plans to streamline service networks.
    - Mobility studies to reduce vehicle access to certain routes/paths.
2. Adaptations in the General Urban Plan of Murcia municipality, applying the results of the studies:
    - Temporary limitation of the transitory building regime.
    - Moratorium on the development of particular sectors of building land Huerta to develop comprehensive plans.
    - Complete and set clear limits to the growth of developable land in Murcia environment and districts.
    - Reorder buildable urban land especially in western orchard, to allow visual landscape windows.
    - Implement setbacks especially in urban land of eastern orchard, to allow visual landscape windows.
    - In general, adopt specific regulations for construction in orchard area.

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Dynamics of change in the peri-urban landscape of Huerta de Valencia: the case of La Punta (Valencia)

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Abstract

This paper is a partial result of a wider research project that attempts to assess the changes in the urban and peri-urban fabric soils of the municipality of Valencia from 1944 to 2004. The research presented focuses on the analysis of the nature of the changes and the dynamics of these over time in the area of *La Punta*, a town administrated by the city of Valencia (Spain) and located in the district of *Quatre Carreres*. The methodology is based on the analysis and measurement of changes in land structure, in the land use, in the occupation of building and in the forested areas presented in the traditional structure of non-urban roads. The key to measure such changes have been the use of the Cadaster of 1929–1944; 1972; 1989; orthophoto collections from the Valencian Regional Library and evolution of mapping from the SIOSE. The most outstanding results refer to the surprising resilience of some elements of the structure of the *Huerta de Valencia* and the discovery and identification of "landscapes" (plural) result of the different dynamics of change.

Keywords: urban transformations, resilience, GIS, Valencian community, Huerta de Valencia.

1 Introduction

Probably the Huerta of Valencia is one of the most rich and complex historical landscapes of the Valencian region due to its spatial morphology as well as by its architecture density, spaces and footprints that have been accumulated during centuries until today. This is due, most of it, because of its situation next to the biggest city of the old Valencian Kingdom and capital of the Sharq al-Andalus

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during the Muslim period which has produced a long and intense relationship between the urban and rural world that have been absolutely influenced by its long history [1]. A history that starts on the VIII century with the Muslim's peasants who designed and constructed the first hydric systems, found the first towns – the andalusi farmsteads – where they settled and constructed the first roads to connects the new towns with the main city. Time after, the feudal conquer of the XIII century brought a new model of social coexistence and power that produced a deep reconstruction of the landscape of the Huerta. It would be on the XIX century when, following the Bourgeois Revolution, different social and economic transformations take place that ended up modifying the agriculture landscape and beginning a new period of its history that lasted until our days, with a total rupture of the landscape by wide highways and roads and the progressive disappearance of the Huerta due to the actual urbanization and industrialization process. All these changes are perfectly explained and argued on the studies of Guinot [1, 3] and Guinot and Castell [2].

Therefore, we must say that there have never been a Huerta speaking from a single entity but a different number of Huertas, a reflection of the society that managed, grew and transformed every part of it. Geographically, the historical Huerta of Valencia is formed by eight organized hydric systems: seven of them are part of the "Tribunal de las Aguas de Valencia" (canals of Rovella, Favara, Mislata-Xirivella, Quart-Benageber-Faitanar, Tormos, Rascanya and Mestalla) and the Royal Canal of Montcada. Also, on the limits of its historical hydric perimeter, there have been for centuries, and at least during the middle Ages, other small communities and institutions such as the "Comú de Monperot", the "Comú de Rafalterras" or the delegation of "Francs i Marjals" of the Valencia City Council, which was created on the XIV century together with small and abundant number of irrigation wells on the area of the Northern Huerta as well as on the South. All of them situated on the limits of the irrigation organized by communes and the areas of marshes.

1.1 General objectives and structure of the work

In this study the objective is to do an evaluation and analysis of the transformations that have been produced from 1944 to 2014 on a delimitated area of the historical Huerta of Valencia. More specifically, we will analyze the evolution of the last 70 years of an area known as "La Punta", integrated on the medieval irrigation system as a prolongation of the canal of Rovella [4]. "La Punta d'en Silvestre" was situated on the eastern limit of the medieval "Franc i Marjals", spaces dedicated to feed cattle and where, during the first part of the XIV century, were done sanitation operations changing the path of the left water from the irrigation system of Favara and Rovella towards the Guadalaviar (nowadays the river Turia). On this area, the abuses on the agriculture space of the Huerta have been intense and constant since the 1940s acquiring some important increment at the beginning of XXI century (the interval from 2004 to 2014 was the largest road network increased (13.25%) and decreased the anthropic not use (-12.21%). Its actual situation, confined between the South Boulevard of the city, the V-15 and the V-30, and its closeness to areas of last urban expansion and development such as the “Ciutat de les Arts i de les Ciencies”, the partial development plan of “Les Moreres” and the ZAL area, creates a complicated situation for the agriculture space. Besides all these, time have demonstrated the capacity of resiliency of this space that invites to believe on its preservation despite the abuses that has had to face.

1.2 Method of cartographic coordination

The methodology used to do this study has been one of comparative analysis of cartographies managed by a Geographical Information System (GIS) and already used on other studies and reports done by the authors [5]. The primary sources for the reconstruction of the agriculture divisions of the land during the periods 1944, 1972, 1989, 2004 and 2014 have been the historical cartography base of the Cadaster. The Cadaster source has been the only one that, systematically and during the last 70 years, has done a precise and accurate description of each one of the urban and rural pots of the city. This information is, therefore, one of the most complete and trusty sources of information when facing a systematic analysis of a wide area. But, to be able to do this restitution, fist was needed the collection and digitalization of the cadaster collections used. These are divided on 4 groups, depending to a spatial reconstruction and two different regulation situations on paper and the last series digitally collected.

Despite the quality with which the Cadaster Service has been reconstructing its plot maps along its lifetime, it is inevitable that after trying to overlay the information of different periods of time, some little deformations occur due to the accumulation of different type of errors. The immediate strategy of establishing a comparison of a same section of an area on different periods of time usually faces important problems that reduce the quality of the final results. To solve it, we have followed a specific strategy overcoming two of the main problems of the cartography.

1.2.1 The vertical an inverse coordination of the cartography

To be able to do a correct comparison of the different periods, we have done, on the first place, a chronological inverse reconstruction of the mapping to guarantee the correct coordination of the cartography. This means start from the 2014 cartography and going back to the one done in 1944. We had the digital reconstruction of the plotting of Valencia of 2014 facilitated by the Web Assistance of the Spanish Cadaster [6]. With this vectorised plotting, and previous geo-position and digitalization of 1989, 1972, and 1944 cartographies, each period was vectorised. To do so, a process of, as we call, cartography coordination was done which is just a verification of relations between the cartographies of different periods, taking as support points the existing constructions or invariable points that assure the comparison of the period sequence studied. The coordination of the cartographies is not a simple process of drawing with a more or less precision of the different maps regarding different periods of a same territory, as can be understood. It is a vertical reconstruction of a cartography series that searches for buildings appearing on the different periods of time of the studied sequence.

1.2.2 The inevitable deformation of the cartography

As we have already commented, the cartographic work of different periods of time usually brings different levels of quality that difficult the comparison of the maps. These distortions can hardly be solve by an automatize process. By doing so we are in risk of eliminating façades linings, building peculiarities or widening of streets that show variations during the study period. This is the reason of the costly and delicately process that must be done for the reconstruction of a coordinated cartography, usually accompany with a continuous consultation of complementary information to be able to understand the real situation. This process of identification is not absent of errors that must be taken into consideration to evaluate the level of exactitude of the base of the study for the analysis.

1.2.3 Addition of complementary data

It has been added to the restitution the height of each of the constructions, allowing a calculation of the total available construction area for each one of the periods. Due to the lack of information regarding qualitative data, we have used the geometrical data of the elements to obtain the areas and the available construction area. Three different types of areas have been classified: roads and facilities infrastructure, buildings and plots. The first two are what we called anthropic lands and the rest of the surfaces have been classified as portions: farm land or farming plots (one the constructions, roads and primary transportation network have been eliminated). But we are aware that the agricultural land is a creation of a human transformation, and therefore anthropic, we have preferred to keep a differentiation between the agricultural land and the rest.

2 Development of the work

The area of study has been limited so it covers which administratively is, inside the city of Valencia, the district of La Punta, where there is information about the 70 years analysis. The total area is about 592 ha which represent comparably around four times the Valencia’s downtown area. The spatial coordination restitution of all the elements of the maps allows a time comparison of the cartographies, detecting the changes and transformations. The coincidence of the vertexes permits topological calculations of intersection and cutting, obtaining new geometries that limit the three types of land previously quoted.

For each one of the periods studied, a first calculation has been made regarding the surface occupied by connection and facilities infrastructures. The results are shown in Table 1.

The constructed areas have been calculated using the same procedure, doing the subtraction of plots by using the restitution of the building as base layer. On the reconstruction process the building’ heights have been consulted which, including the surface area, allow us to calculate the final available construction area for each period. The result is shown in Table 2.

Table 1: Road network and equipment (surface).

Year	Surface (sq. m)	%
1944	439,958	8.43
1972	857,508	16.43
1989	1,114,957	21.36
2004	1,544,340	29.59
2014	2,235,652	42.84

Table 2: Edification and potential development.

Year	Road net. (sq. m)	%	Potential development (sq. m)
1944	213,014.09	4.08	299,922.57
1972	257,738.57	4.94	354,838.70
1989	358,964.19	6.88	478,277.69
2004	409,988.67	7.86	632,731.59
2014	355,843.67	6.82	491,155.50

Finally, we calculate the existing agriculture plotting on each of the periods, as a result of subtracting the area occupied by constructions from the agricultural surface. This land is equal to the traditional production area of the Valencia’s Huerta on the area of La Punta district. The result can be seen in Table 3.

Table 3: Portions.

Year	Portions (sq. m)	%
1944	4,566,154.27	87.49
1972	4,119,940.41	78.94
1989	3,745,96478	71.78
2004	3,264,682.83	62.55
2014	2,627,297.20	50.34

We can see how on each period of time a remarkable increase of land area dedicated to roadways and connection infrastructure as well as to facilities have been occurring. This increase has been produced basically by reducing the portion of agricultural land. We can also see how the areas dedicated to constructions grow up, except on 2014 when a reduction on the constructions area and built areas occurs. This is a consequence of diverse factors. On the one hand, on the south and southeast areas of La Punta, a large extension of land is urbanized so it can shelter the Logistic Activities Area (ZAL in Spanish), although after 10 years from the demolition of the last “barraca” nothing has been built on it. On the other hand, a great increase can be seen on the area dedicated to the purifying plant but, as the previous example, no constructions have been done to add constructed area. On the next graphics we can see the evolution of land uses.

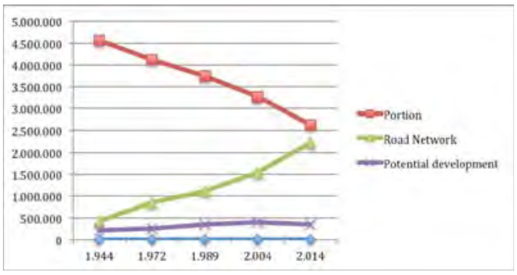

Figure 1: Land use graphic.

If we do a detailed study of the transformations by periods of time (Table 4) (Figure 2) we can make different comments of each case. On the one hand regarding the last period studied (2004–2014), the shortest one, where the major transformation intensity of the land has occurred. Its magnitude is 50% higher than the period before it (1989–2004) and doubled if we compare it to the period 1944–1972, even though this last period is identified as the era of urban development. If the transformation rate of approximately 60 ha every 10 years is maintained, in 40 years the 262.7 ha of agriculture land existing today would be consumed. Regarding available construction area, after what we have exposed on the previous parts of this report, a “fictitious effect” of stagnation is produced due to the no development of the ZAL area next to Valencia’s harbor and the expansion of the purifying plant.

Table 4: Land use changes (sq. m).

Period	Portions	Road network	Potential development
1944–1972	-446,213.86	417,549.79	44,724.48
1972–1989	-373,975.63	257,449.16	101,225.62
1989–2004	-481,281.95	429,383.11	51,024.48
2004–2014	-637,385.63	691,312.58	-54,145.00

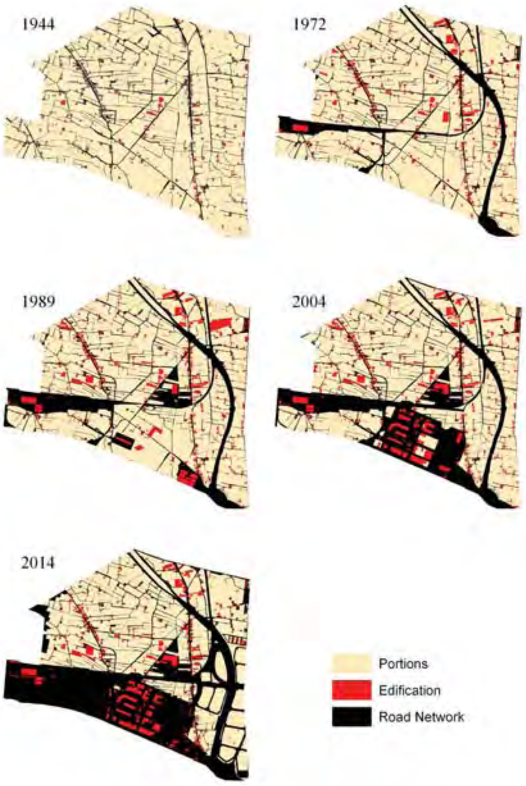

Figure 2: Map evolution of "La Punta".

On the other hand, if we focus on the period of lower transformation intensity of the last 70 years, we will choose the 1972–1989 period. It is in this interval when the area receives new infrastructures, such as the railway and the south highway constructed during the 1970s. It is, therefore, a period of accessibility improvements on the district of La Punta, converting it into a future candidate for the construction of new facilities of the city, such as MercaValencia (logistic market place), the purifying plant or RENFE's railroad workshop. This effect can be seen on the high available construction area that it does characterize this period of time if we compare it with the previous and following ones.

Another effect that is interesting to be highlighted, as can be seen on Figure 2, is the process of quick anthropization that is occurring from the south of the studied area. The accumulation of large facilities or service spaces, as well as the artificial division created by large infrastructures, have drawn a completely different scenario from the original situation of the paths and networks of the Huerta that were developed for hundreds of years. The no attention and inconsiderateness towards the district of La Punta can be seen graphically through the comparison of the figures shown. The level of degradation is significant on the landscape of the Huerta, although the resiliency of this territory is remarkable because, despite all the abuses that have been committed, it maintains its irrigation system, the farming areas, traditional pathways, etc.

3 Conclusions

With a studied perspective of the last 70 years of the history of the Huerta of the district of La Punta, we can affirm that the major transformations developed on the area have occurred during the last 10 years. This has happened regarding magnitude as well as speed and aggressiveness, the most intense of it. If the rate of transformation done during the last decade is maintained, in less than 40 years this territory will disappear and the historical Huerta with it.

On the last 70 years the district of La Punta has suffered a loss of Huerta's surface close to 200 ha, a surface a little larger than the downtown area of Valencia. Despite the intensity of this transformation, La Punta has shown a high level of resiliency by keeping, overcoming adversities, its irrigation system, traditional paths, crops, etc.

The area of La Punta has progressively being transformed into a storing land of large infrastructures facilities of the city of Valencia: purifying plants, ZAL area, RENFE's railroad workshops. This collection of uses on the area shows the consideration as an empty plot of the area of Huerta, not taking into consideration any historical-heritage value existing on its structure and configuration.

It is necessary to apply and start to implement the Territorial Action Plan of the Valencian Huerta that, with an integral vision of the entire Valencian agriculture system, gives a use and a functionality to each part of the area. Not doing so, the weakness shown on the defense of some small portions of the independent Huerta will condemn it to its progressive disappearance or an inevitable degradation.

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Productive performance of small peri-urban farms using self-organizing maps and data envelopment analysis

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Abstract

In this paper, we aim to analyze the productive performance of plots cultivated by family farmers. We use an alternative Data Envelopment Analysis (DEA) approach to calculate the relative efficiency of such plots. Notwithstanding, DEA's basic assumption includes the homogeneity of the production units under analysis. Herein, as the chemical composition of the soil varies considerably among plots, directly influencing their fertility, and, thus, their productivity levels, the plots shall be grouped into homogeneous clusters first. For that, we use Self-Organizing Maps, based on their comparative advantages to other methods. Then, the relative efficiencies of plots within each cluster will be assessed using separate DEA models. Nonetheless, a direct comparison among the scores of plots from different clusters is not feasible, because the relative efficiency of a production unit can solely be compared to those inserted in the same set of analysis. Hence, to overcome such inconvenience, we further apply a technique that allows compensating for the non-homogeneity of plots. The results indicate that, when countervailing the effects of the chemical composition of the soil, the plots with favorable conditions do not necessarily present better productive outcomes.

Keywords: sustainable development, data envelopment analysis, efficiency analysis, peri-urban spaces, self-organizing maps.

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1 Introduction

Since 2006, the Family Agriculture Project in Strip of Ducts (or PAF Ducts – the acronym in Portuguese) is an agricultural occupation strategy for the peri-urban areas that overly Petrobras refinery pipelines. The area, located in the municipality of Nova Iguaçu, Rio de Janeiro, Brazil, was divided in plots of 1,000 m² each. Each one assigned to a particular family.

The activity developed meets some ecological concerns and focuses primarily at the cultivation of fruits, tubers and vegetables. The farmers cultivate about 50% of the total area of each plot, while the other part is alternately intended for fallow. The average labor force employed is two workers per year. All plots make use of electrical energy and have a catchment basin for manual irrigation. Besides, technical assistance and inputs are offered at equitable basis.

The objective of this study is to evaluate the productive performance of such plots, in accordance to some criteria, which aim at great stability (i.e. less seasonal variation) in production, large variety of items produced and high volume of products offered for sale. For that, we use an alternative approach that combines Data Envelopment Analysis (DEA [1]), Self-Organizing Maps (SOMs [2]) and a compensating algorithm proposed by [3].

The option for DEA was grounded on its ability of dealing with multidimensional problems and various units of measurement. Nevertheless, DEA models assume the homogeneity of the production units under analysis (the plots). However, in a preliminary analysis, it was identified that the chemical composition of the soil varies notably among the plots, influencing their fertility, and, thus, their productive levels. Therefore, the plots needed to be grouped in homogeneous clusters firstly. For such purpose, we use SOMs based on their comparative advantage to other clustering methods [4]. Next, the relative efficiencies of the plots within each cluster will be calculated using separate DEA models.

Due to the disjointedness of the clusters formed, a direct comparison among plots from different clusters is not feasible, once the relative efficiency of a production unit can solely be compared to those units inserted in the same set of analysis. To surpass such inconvenience, we will further apply the algorithm of [3] to compensate for the non-homogeneity of the plots.

Section 2 brings a review of DEA´s use in agricultural activities. In section 3, we present the methodology used herein. Section 4 describes the application to the problem under analysis. In section 5, we present the results derived. Section 6 discusses the results in terms of the chemical composition of the soil. Finally, in section 7, we present some conclusions and a few suggestions for future work.

2 DEA's application in agriculture

Since the early 1990s, DEA has become widely used in the evaluation of relative efficiency in different areas [5]. The agricultural activity represents a field where the application of DEA models is quite fruitful. Classic DEA models [1, 6] were used to analyse the relative efficiency of energy consumption in the agriculture by [7]. In [8], the production relative efficiencies and productivity changes of

agricultural cooperatives were measured using DEA and the Malmquist index. In [9], the beef cattle production was examined using a unitary input DEA model combined to relative efficiency measures generated by the inverted DEA frontier. In [3], DEA models were used to compare the performance of farms cultivated with different technologies, and an algorithm for calculating the relative efficiency scores taking into account such non-homogeneity was proposed. In [10], the performance of producers were analysed, using SOMs and cross-evaluation DEA models. In [11], a unitary input model was used for the evaluation of intercropping.

Here, as [9, 11], we apply a unitary input DEA model, but unlikely we use SOMs to cluster the production units and allow the homogeneity in the subset to be evaluated by each DEA model. In this sense, our proposal differs from [10], which used the DEA cross-efficiencies as inputs to the SOMs procedure for *ex-post* clustering. Additionally, we apply the algorithm developed in [3] to enable the direct comparison of plots from different clusters.

3 Methodology

The methodology applied herein comprises three sequential steps. First, we use SOMs [2] to segregate the plots and assure their homogeneity in terms of the chemical properties of the soil. Second, we use a separate DEA model for each cluster, and evaluate the relative efficiency of each plot within the cluster. Finally, we use an algorithm [3] to countervail for non-homogeneity among plots.

3.1 Self-organizing maps: fundamental aspects

Although there exist several methods that evaluate the similarity between a set of units to create homogeneous subsets (clusters), we opted for SOMs. In the literature, we find some works [10, 12] that discuss the combined use of SOMs and DEA models.

SOMs represent a type of neural network, i.e. computer models of artificial intelligence that incorporate certain capabilities of the human brain, where sensory inputs are represented by topologically organized maps [12]. Particularly, SOMs emulate the unsupervised learning by considering neuron neighborhood, whose structures are arranged in grid. The most used topology is the interconnected two-dimensional one, where the neurons are represented by rectangular, hexagonal or random grid knots of neighbor neurons [12].

SOMs procedure comprises three processes. In the competitive process, each neuron is initialized with a vector of inputs, and then the neurons compete to become active. The choice of the winner neuron is usually based on the Euclidean distance, as performed here. Next, the winner has its weights adjusted to respond to the stimulus (synapse), and a cooperative process between the winner and its topological neighbors is simulated, so that the neighbors receive adjustments as well. The topological neighborhood is normally defined by a Gaussian function, as herein. Finally, the adaptive process takes place by the adjustment of the synaptic weights, considering that the learning rate decreases over time to avoid that new information compromise the knowledge accumulated.

In synthesis, SOMs yield a topological mapping, segregating the input data based on their similarities. Comparatively to other neural networks, SOMs present the advantage of transforming patterns of high-dimensionality in discrete maps, usually single or two-dimensional. For further insights, see e.g. [12].

3.2 Data envelopment analysis

3.2.1 Basic concepts

DEA is a non-parametric method based on mathematical programming that calculates the relative efficiency of a set of production units using multiple inputs (resources) and producing multiple outputs (products). These units are known as decision-making units (DMUs). In DEA, the basic premise is homogeneity of the DMUs. Here, as the DMUs (plots) in the set of analysis do not operate in similar environments (due to differences in the chemical conditions of the soil), we use an alternative DEA approach to overcome the lack of homogeneity.

Each DMU's relative efficiency score is optimized, by comparing the resources used and the quantities produced to the levels of the others. The result is an efficient frontier. The DMUs lying on the frontier are efficient (score of 100%); the others are inefficient (score of less than 100%).

The most used DEA models are: CCR [1] and BCC [8]. The first assumes constant returns-to-scale, while the latter works under variable returns-to-scale, replacing the axiom of proportionality by convexity. These models present equivalent formulations (envelope and multipliers), which provide the same efficiency scores for each DMU, as they are dual problems. Traditionally, there are two possible radial orientations for such models: input orientation, which seeks to minimize the resources while the production levels remain fixed; and the output orientation, which implies the increase in quantities produced while the resource levels remain unchanged.

3.2.2 Unitary input DEA model

In this study, as every agricultural plot in the set of analysis operate with quite similar inputs, we use the DEA model with a unitary, constant and single input, wherein the input denotes the very existence of the DMU. The unitary input avoids the mathematical inconsistencies that arise in a model without inputs. We apply the approach of [13], in which the CCR and BCC models are equivalent, and use an output orientation. The linearized unitary input DEA model, output-oriented, in the envelope formulation, herein applied, is given by the following linear programming:

$$\text{Max } h_o \tag{1}$$

$$\text{s. t. } \sum_{k=1}^{n} \lambda_k y_{jk} \geq h_o y_{j0}, \forall j \tag{2}$$

$$\sum_{k=1}^{n} \lambda_k \leq 1 \tag{3}$$

$$\lambda_k \geq 0, \forall k. \tag{4}$$

In eqns. (1)–(4), h_o denotes the inverse of the relative efficiency of the DMU under analysis (DMU$_o$); y_{jk} is the *j*th output (*j* = 1, ..., *s*) of DMU$_k$ (*k* = 1, ..., *n*); and $\{\lambda_k\}$ and is the individual contribution of each DMU in the formation of DMU$_o$'s target. In fact, this model resembles a multi-criteria additive model, where the alternatives (DMUs) assign weights to each criterion (outputs), ignoring any judgment of an eventual decision-maker.

3.2.3 Homogenization technique

Although the literature comprises several proposals to overcome the lack of homogeneity [14, 15], we follow the line of action (as in [3, 12, 16]) that applies handicap factors to compensate for the DMUs non-homogeneity.

The assumption is that, after grouping the DMUs into homogeneous clusters, the efficient DMUs of each cluster equally share good management practices. Nonetheless, these DMUs do not present scores of 100%, when compared to DMUs from other clusters, due to different exogenous conditions that characterize each particular cluster. Thus, comparisons among clusters shall be done by taking into account solely the efficient DMUs of each cluster. This comparison allows identifying the cluster that benefits from exogenous variables to compensate the disadvantaged clusters, giving a prior benefit to those DMUs under disadvantage.

Differently from [12, 16] that apply the handicap factor to the inputs and outputs, respectively; we follow [3] that corrects the relative efficiency measures directly. The algorithm herein applied obeys the following steps.

(1) Cluster the DMUs in homogeneous groups.
(2) Run a specific CCR model for each cluster, and select the efficient DMUs.
(3) Run a CCR model with the efficient DMUs from step 2.
(4) Calculate the average relative efficiencies of the DMUs from step 3, separated in their original clusters.
(5) Run a CCR model with all DMUs in the set of analysis.
(6) Use the average relative efficiencies of step 4 as a compensating factor to the relative efficiency measures of the disadvantaged clusters, by dividing each DMU's relative efficiency score found in step 5 by the average relative efficiency of step 4 assigned to its original cluster. If any value obtained is greater than one, we need to perform the corresponding normalization.

The compensated relative efficiency scores are those derived in step 6.

4 Application and results

In the following, we apply the methodology described in section 3 to the evaluation of the agricultural plots of PAF Ducts. The data refer to year 2012.

4.1 Step 1: clusters definition

We start choosing the environmental variables to be used as input vectors in the SOMs procedure. Based on the chemical composition of the soil of the plots in the set of analysis, we selected the variables: potential of hydrogen (pH); potassium content (K); percentage of organic matter (OM); base saturation (BS); and boron content (B). Such variables are widely recognized as relevant to express the fertility of the soil. Table 1 exhibits the input data used to initialize the SOMs procedure, which come from a research conducted by the Center of Analysis of the Federal Rural University of Rio de Janeiro, in May 2012.

Table 1: Input data used for SOMs procedure.

Plot	pH	K (ppm)	OM (%)	BS (%)	B (ppm)
P3	7	107	26.4	90	0.12
P6	7.4	26	19.1	100	0.25
P7	7.6	36	18.3	100	0.21
P9	7	43	17.4	91	0.12
P10	7.2	29	15.9	100	0.21
P11	7.1	31	19.1	96	0.17
P12	7.3	31	16.6	96	0.12
P15	7.3	60	20.0	98	0.17
P26	7.1	95	20.9	95	0.12

We used the software MATLAB® version 7.10.0, and opted for a hexagonal topology to the grid, as it showed good results and represents a usual practice among experts. Then, we tested different grid dimensions to determine the best arrangement of clusters. We restricted the tests to the (2x1), (3x1) and (2x2) grids, to assure a minimum number of plots in each cluster for the DEA analysis. Table 2 shows the cluster configurations, according to the grid dimensions tested.

Table 2: Clusters formation, according to the grid dimension tested.

Plot	Dimension		
	(2x1)	(3x1)	(2x2)
P3	2	3	4
P6	1	1	1
P7	1	1	1
P9	1	2	2
P10	1	1	1
P11	1	2	2
P12	1	2	2
P15	1	2	3
P26	2	3	4

The (2x2) grid yields four clusters, one formed by a single plot (P15). As we will apply a separate DEA model to each cluster, a comparison of this plot (which originates eight DMUs, as later explained) with others would be impaired, without the application of the homogenization algorithm used herein. Once this is not a limitation to our approach, we opted for the (2x2) grid dimension, because it better distinguished the lack of homogeneity among the plots (i.e. generated a larger number of clusters).

4.2 DEA modeling

To evaluate the productive performance of the plots, primary data were gathered on the availability of items put for sale at weekly fairs. In 2012, the production activity was concentrated in the period from February to October. This occurred mainly due to the climate conditions in the region.

The dataset comprises the agricultural items offered, listed in accordance to the amount put for sale by item, and the average prices (in Brazilian Real – R$) practiced by each of the nine plots comprised in the analysis. Thereby, our unitary input DEA modeling was designed with two outputs: the variety of products available for sale (y_1); and the estimated revenue based on the average price of products (y_2). The "variety of products" is the amount of different items available for sale for each DMU (combination plot-month). A large variety of items denotes a better performance of the plot in an effort to meet the market's needs, as well as a greater ability to deal with seasonality. The "estimated revenue" is the amount of product available for sale multiplied by the average selling price of each product. This value was used as the actual revenue data were not available, and it standardizes the production of distinct items in monetary units as well, thus making possible the sum of the production from different crops.

As the output data were collected monthly, we apply the model to the period from February to October 2012, and pool all observations together in the analysis, through a longitudinal data approach, as done in [17]. This is one of the ways to increase the number of DMUs [18], since we regard the same plot as a distinct DMU in different months. Thence, the DMUs are each plot-month combination (i.e. "P6-Feb" is a different DMU from "P6-Mar"). The assumption is that the technology and the environmental conditions remain stable over the period of time concerned, what seems fairly acceptable to our case study. Otherwise, we would need to use, e.g. the Malmquist index [19] instead.

In the analysis, we solely take into account the plot-month combinations with non-nil outputs, totalizing 68 DMUs, which are distributed among the four clusters defined by the SOMs procedure. As a deterministic method, DEA does not depend on a large number of observations for the validity of its application, unlike statistical approaches. In such sense, the number of DMUs in each cluster (varying from 25 to 8) meets the minimum advised by [20].

4.2.1 Step 2: evaluation of DMUs within each cluster

The linear program used to compute the relative efficiency of each DMU through our proposed unitary input DEA-CCR model is obtained by replacing the values of the outputs above defined in the general formulation of subsection 3.2.2, eqns. (1)–(4), provided that a separate model is run for each one of the four clusters previously defined.

For that, we applied the software SIAD [21] version 3.0 (available at http://www.uff.br/decisao/Siadv3.zip), and calculated the relative efficiency scores of each DMU, in relation to the others belonging to the same cluster. These results are shown in table 3. We may observe that, in the whole set of analysis, seven DMUs were 100% efficient within their own cluster (two in C1, two in C2, two in C3, and one in C4, as marked in grey). Notably, five out of the seven cluster-efficient DMUs refer to plots operating in August.

Table 3: Relative efficiency scores for each DMU in relation to the others in the same cluster.

C1		C2		C3		C4	
DMU	Eff	DMU	Eff	DMU	Eff	DMU	Eff
P6-Feb	13.3%	P11-Feb	15.4%	P15-Feb	30.9%	P3-Feb	42.3%
P7-Feb	46.7%	P12-Feb	15.4%	P15-Mar	42.5%	P3-Mar	73.1%
P6-Mar	56.7%	P9-Mar	30.8%	P15-May	100.0%	P3-Apr	80.8%
P7-Mar	76.7%	P11-Mar	65.4%	P15-Jun	44.8%	P3-May	73.1%
P6-Apr	33.3%	P12-Mar	34.6%	P15-Jul	100.0%	P3-Jun	61.5%
P7-Apr	63.3%	P9-Apr	23.1%	P15-Aug	70.8%	P3-Jul	76.9%
P10-Apr	53.3%	P11-Apr	51.3%	P15-Sep	74.6%	P3-Aug	100.0%
P6-May	93.3%	P9-May	69.2%	P15-Oct	45.2%	P3-Sep	65.4%
P7-May	73.3%	P11-May	88.5%			P26-Sep	7.7%
P10-May	56.7%	P12-May	53.8%			P3-Oct	88.5%
P6-Jun	73.3%	P9-Jun	65.4%				
P7-Jun	70.0%	P11-Jun	57.7%				
P10-Jun	36.7%	P12-Jun	34.6%				
P6-Jul	93.3%	P9-Jul	84.6%				
P7-Jul	90.0%	P11-Jul	88.5%				
P10-Jul	36.7%	P12-Jul	69.2%				
P6-Aug	100.0%	P9-Aug	100.0%				
P7-Aug	100.0%	P11-Aug	98.8%				
P10-Aug	43.3%	P12-Aug	100.0%				
P6-Sep	83.6%	P9-Sep	53.8%				
P7-Sep	84.2%	P11-Sep	67.5%				
P10-Sep	26.7%	P12-Sep	61.5%				
P6-Oct	80.1%	P9-Oct	61.5%				
P7-Oct	76.7%	P11-Oct	50.0%				
P10-Oct	40.7%	P12-Oct	50.0%				

4.2.2 Steps 3 and 4: cluster of efficient DMUs

Next, we separate the 100% efficient DMUs of each cluster in a cluster of efficient units, and apply the same unitary input DEA-CCR model previously used to these seven DMUs (step 3). From the scores obtained, we calculate the average scores of the DMUs in the cluster of efficient units, taking into account the other efficient units from their original clusters (step 4). These results are shown in table 4.

The fact that only the DMUs from cluster C1 got a score of 100% in the cluster of efficient units suggests this is the only cluster operating in optimal environmental condition, while the others show soil disadvantages that negatively affect their productive outcomes, despite any other managerial inefficiencies.

DMUs "P6-Aug" and "P7-Aug" were deemed as 100% efficient because they individually exhibit the best ratio at each one of the partial productivity measures, i.e. the largest revenue and the widest variety of items produced, respectively. This is a well-known and widely reported feature of DEA models [22].

Table 4: Relative efficiency scores for the DMUs in the cluster of efficient units and the average scores by the original cluster.

Original cluster	DMU	Score in this cluster	Average by original cluster
C1	P6-Aug	100.0%	100.0%
	P7-Aug	100.0%	
C2	P9-Aug	86.7%	80.6%
	P12-Aug	74.5%	
C3	P15-May	60.0%	56.7%
	P15-Jul	53.3%	
C4	P3-Aug	87.5%	87.5%

4.2.3 Steps 5 and 6: overall evaluation of DMUs by countervailing the lack of homogeneity among clusters

In the following, we apply the same unitary input DEA model to all the DMUs comprised in set of analysis (step 5), and refer to this as the “all-units” model. Then, starting step 6, we use the reciprocal of each average relative efficiency score from step 4 (cluster of efficient units) as a compensating factor for each disadvantaged cluster (C2, C3 and C4). For that, we multiply the compensating factor assigned to each cluster by the relative efficiency scores found to each DMU in step 5 (all-units model) taking into account its corresponding original cluster.

As the compensating procedure resulted in two relative efficiency scores greater than one, we had to perform the corresponding normalization, dividing the scores so far obtained by their maximum value. Therefore, all DMUs in cluster C1 had their relative efficiency scores reduced in relation to those calculated using the all-units model, while the relative efficiency scores of the DMUs from the other clusters have all increased.

Table 6 displays the DMU’s relative efficiency scores calculated using the all-units model, as well as their compensated (after the normalization) scores. After the compensation and subsequent normalization, “P9-Aug” was the single 100% efficient DMU, which was originally allocated to cluster C2, where it was 100% efficient as well (see table 3).

From the results in table 6, we may deduce that the plots P10 and P26 were those that faced the worst managerial practices. The data analyzed suggest that fertilization intended to complement and elevated levels of K and OM in P10, and B in P26, may contribute to the increase of productive outcomes. Another relevant aspect is that most farmers shall make efforts to maintain good levels of production along the year, not solely during May, July and August.

5 Conclusions

This study provided an evaluation of the productive performance of family farms of PAF Ducts project. In the analysis, we used a unitary input DEA model combined to the SOMs procedure, to set homogeneous clusters, in accordance to criteria related to soil fertility. Furthermore, we applied an algorithm that enables to compensate for the non-homogeneity of the plots. So that, a direct comparison among the relative efficiency scores from different clusters became possible.

Table 5: Relative efficiency scores calculated by the all-units DEA-CCR model, as well as the compensated normalized scores.

Cluster	DMU	All-units model	Compensating algorithm	Cluster	DMU	All-units model	Compensating algorithm
		Eff	Eff			Eff	Eff
C4	P3-Feb	36.7%	39.0%	C3	P15-Jun	26.7%	43.8%
C1	P6-Feb	13.3%	12.4%	C4	P3-Jul	66.7%	70.8%
C1	P7-Feb	46.7%	43.4%	C1	P6-Jul	93.3%	86.8%
C2	P11-Feb	13.3%	15.4%	C1	P7-Jul	90.0%	83.7%
C2	P12-Feb	13.3%	15.4%	C2	P9-Jul	73.3%	84.6%
C3	P15-Feb	16.7%	27.4%	C1	P10-Jul	36.7%	34.1%
C4	P3-Mar	63.3%	67.3%	C2	P11-Jul	76.7%	88.5%
C1	P6-Mar	56.7%	52.7%	C2	P12-Jul	60.0%	69.2%
C1	P7-Mar	76.7%	71.3%	C3	P15-Jul	53.3%	87.5%
C2	P9-Mar	26.7%	30.8%	C4	P3-Aug	87.5%	93.0%
C2	P11-Mar	56.7%	65.4%	C1	P6-Aug	100.0%	93.0%
C2	P12-Mar	30.0%	34.6%	C1	P7-Aug	100.0%	93.0%
C3	P15-Mar	23.3%	38.3%	C2	P9-Aug	86.7%	100.0%
C4	P3-Apr	70.0%	74.4%	C1	P10-Aug	43.3%	40.3%
C1	P6-Apr	33.3%	31.0%	C2	P11-Aug	74.9%	86.4%
C1	P7-Apr	63.3%	58.9%	C2	P12-Aug	74.5%	86.0%
C2	P9-Apr	20.0%	23.1%	C3	P15-Aug	40.0%	65.6%
C1	P10-Apr	53.3%	49.6%	C4	P3-Sep	56.7%	60.2%
C2	P11-Apr	43.3%	50.0%	C1	P6-Sep	83.6%	77.8%
C4	P3-May	63.3%	67.3%	C1	P7-Sep	84.2%	78.3%
C1	P6-May	93.3%	86.8%	C2	P9-Sep	46.7%	53.8%
C1	P7-May	73.3%	68.2%	C1	P10-Sep	26.7%	24.8%
C2	P9-May	60.0%	69.2%	C2	P11-Sep	56.7%	65.4%
C1	P10-May	56.7%	52.7%	C2	P12-Sep	53.3%	61.5%
C2	P11-May	76.7%	88.5%	C3	P15-Sep	20.6%	33.8%
C2	P12-May	46.7%	53.8%	C4	P26-Sep	6.7%	7.1%
C3	P15-May	60.0%	98.5%	C4	P3-Oct	76.7%	81.5%
C4	P3-Jun	53.3%	56.7%	C1	P6-Oct	80.1%	74.5%
C1	P6-Jun	73.3%	68.2%	C1	P7-Oct	76.7%	71.3%
C1	P7-Jun	70.0%	65.1%	C2	P9-Oct	53.3%	61.5%
C2	P9-Jun	56.7%	65.4%	C1	P10-Oct	40.7%	37.9%
C1	P10-Jun	36.7%	34.1%	C2	P11-Oct	43.3%	50.0%
C2	P11-Jun	50.0%	57.7%	C2	P12-Oct	43.3%	50.0%
C2	P12-Jun	30.0%	34.6%	C3	P15-Oct	26.7%	43.8%

In addition, it was found that both the relative efficiency and the maintenance of the soil fertility in the plot result from the interaction of several variables related to the chemical composition of the soil. Among the variables analyzed, it was found that the levels of pH, K, B, OM and BS were those that greatly contributed to the promotion of relative efficiency. This suggests that the proper soil management helps the sustainability of the agricultural activity, fomenting the preservation or even increasing soil fertility.

Table 6: Average scores using the within-cluster model and the compensating (normalized) algorithm per plot, month and cluster.

Plot	Average scores		Month	Average scores	Cluster	Average scores	
	Within cluster	Compensating algorithm		Compensating algorithm		Within cluster	Compensating algorithm
P3	63.8%	67.8%	Feb	25.5%	C1	64.1%	59.6%
P6	69.7%	63.2%	Mar	51.5%	C2	59.6%	58.4%
P7	75.7%	70.3%	Apr	47.8%	C3	63.6%	61.7%
P9	54.3%	61.0%	May	73.1%	C4	66.9%	54.8%
P10	42.0%	39.1%	Jun	53.2%			
P11	64.8%	63.0%	Jul	75.7%			
P12	52.4%	50.7%	Aug	82.2%			
P15	63.6%	54.8%	Sep	51.4%			
P26	6.7%	7.1%	Oct	58.8%			

Remarkably, the definition of clusters, through the SOMs, combined to the use of the DEA model, proved very promising. Besides, it corroborated the connection between the levels of the chemical elements present in the soil composition and related to its fertility with the relative efficiency in agricultural activity. We believe the methodological integration proposed herein may contribute to the improvement of the management of family agriculture with ecological concerns, as it may effectively be employed to assist small farmers in the decision-making process (e.g. what to plant, how many varieties, when to start etc.).

A possible extension for this work consists of using the so-called dynamic clustering [23] combined to the DEA model, replacing the (static) clustering method applied herein. By doing this, although indirectly, an overall comparison among all DMUs can be made, even in the clustered model, provided that no cluster is disjoint in relation to all the others.

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Section 4
Environmental management

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Environmental tax as an instrument of economic stimulation to improve the quality of motor fuels

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Abstract

Carbon dioxide (CO_2) is a main component of organic fuel combustion, and its increased concentration in the atmosphere causes negative impact assumed to be associated with its contribution into the global climate change. CO_2 emission is correlated both with fossil fuel consumption intensification and with toxic substances emissions in the process of fuel combustion, thus indirectly characterizing the general dynamics of pollutants impact upon environment.

Motor transport is one of the major consumers of oil products. Within this context, the search for the ways to reduce CO_2 emission from motor vehicles is a priority problem for the global commonwealth.

Taking into account that tax stimulation is one of the most effective instruments of influence on oil-refining companies, an urgent task is to improve the existing tax system to reduce carbon dioxide emissions.

The aim of this work is to substantiate a model and a method to calculate an environmental tax for motor fuel considering not only environmental classes of fuels being used but also the carbon dioxide emissions in the process of their combustion.

The authors have proposed a mechanism for economic stimulation of reduction of carbon dioxide emission from motor transport. A dependence of CO_2 emission on motor fuels qualitative characteristics has been disclosed and a methodological approach to calculate the environmental tax for fuel has been found. The proposed methodological approach can be used for improvement of the current system of oil products taxation in order to create incentives for manufacturers of oil products to produce environmentally-friendly fuels.

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Keywords: CO_2 emission, economic stimulation, oil product taxation, motor transport, motor fuel, environmental tax.

1 Introduction

The increase in anthropogenic emissions of carbon dioxide (CO_2) leads to global changes in environmental conditions and reserves of natural resources that create an integrated environmental-economical challenge for contemporary human society. Vehicle fleet currently exceeding one billion of motor cars is one of the main consumers of oil products and, as a consequence, emitters of CO_2 in the world. Fuel and energy resources consumption relates to the principal indicators of the civilization development level, and at present the expanding industrial production and global growth of the vehicle fleet are resulting in the increasing rate of the fossil fuel resources depletion. Carbon dioxide emission can be seen as an indicator of oil-related fuels consumption and its reduction is one of the priority problems of sustainable development. However, at present there is no integral mechanism of economic stimulation to reduce CO_2 emissions by motor transport. This negatively affects management of negative impact of the emissions and causes ineffectively increased consumption of motor fuels.

Effective application of economic mechanisms stipulated by the Kyoto Protocol is hampered in this case due to the specific character of the greenhouse gases emission inventory for automobiles. At the same time, environmental taxation is a promising tool of economic stimulation within the framework of resources-saving practice and environmental management [1, 2], it is possible to use it in order to establish incentives for reduction of carbon dioxide by motor vehicles.

2 Mechanism of economic stimulation to reduce CO_2 emissions by motor transport

The implemented analytical research has enabled the authors to propose their scheme for improving the economic stimulation of measures aimed at reduction of CO_2 emissions by motor transport (fig. 1).

In specific conditions of different countries of the world the priority directions of motor transport CO_2 emissions reduction can differ. In Russia such a direction is the improvement of the quality of produced gasoline and diesel fuels (this would lead to their specific consumption decrease and, consequently to the annual consumption decrease). For a number of countries the priority is the increase of the number of motor vehicles using alternative fuels.

Dynamics of motor fuels consumption by motor vehicles and corresponding dynamics of CO_2 emissions, as well as environmental-economical damage associated with the rapid growth of the global vehicle fleet during recent decades demonstrate the necessity of forming an effective mechanism of economic stimulation for motor transport CO_2 emission reduction. On the basis of the conducted analytical research the authors propose the mechanism structure shown in fig. 2.

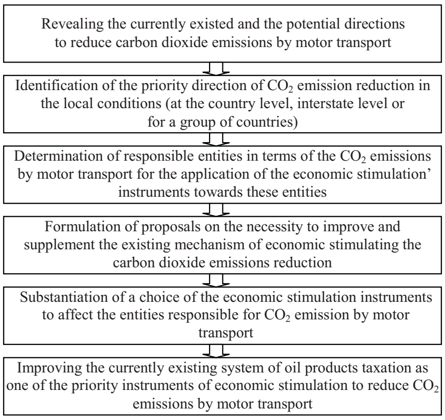


Figure 1: Scheme of the improvement of economic stimulation to reduce CO_2 emissions by motor transport.

Systematization of the main groups of measures on carbon dioxide emission reduction and directions of their implementation carried out by the authors enabled to reveal responsible entities in terms of the CO_2 emission by motor transport for the application of the economic stimulation' instruments towards these entities (owners of motor vehicles, car manufacturers, and motor fuel producers), including methods of taxation, in order to get the target outcome, and to differentiate possible instruments of economic stimulating in respect of these responsible entities [1].

3 Application of taxation instruments for stimulation of reducing carbon dioxide emissions

The world practice of economic incentives for carbon dioxide emissions reduction possesses an experience of the taxation instruments usage with respect to owners and producers of motor vehicles. The most advanced and efficient system for taxation based on the CO_2 emissions by the used cars, with increased fuel consumption, exists in the UK [3], where car owners pay road tax, calculated according to the vehicle environmental class considering carbon dioxide emissions; since March 2011 they have to pay also for the engine capacity [4].

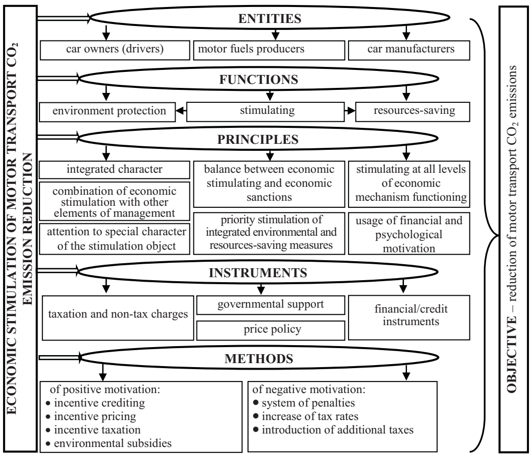


Figure 2: Mechanism of economic stimulation to reduce carbon dioxide emissions by motor transport.

EU Regulation No 443/2009 [5] sets requirements to new cars registered at the EU territory in terms of CO_2 specific emission. The Regulation stipulates for certification of motor vehicles in respect of CO_2 emissions and charges for exceeding by producers of the permissible volume of CO_2 emission.

It should be noted that quality of fuel used in motor transport critically affects the carbon dioxide emissions by vehicles [6–9], this requires special attention to the problem of tax regulation of fuels quality.

Fiscal regulation of oil and gas complex which, on the one hand, should secure a stable increase of the budget income and, on the other hand, should create incentives for investments and techniques of the most advanced world level, is the most significant factor of sustainable economic development of oil industry and as a whole the countries of the world, as well as it is a factor of motor transport sustainable development.

The issue of the improving fuel quality is being solved differently in different countries. The fuel producers in the countries of the first group are taxed extraordinary high (more that the half of retail price of fuel). This group comprises Turkey, as well as France, Germany, Finland – almost the whole of Europe. The other group consists of countries with relatively low taxes for oil companies (about 20%) (USA). Countries of the third group (Ecuador, Nigeria, Malaysia, Bolivia, Indonesia, Syria, Argentina, and countries of the Gulf) act conversely: they grant subsidies from the budget for fuel production thus securing low prices.

The cost of fuel in the USA includes excise, environmental tax, special taxes, and, in addition, local taxes of individual states.

Taxes on fuel vary in different EU member-states but, in general, they include excise (the Netherlands)/tax on fuel (in Germany it depends on environment-friendly properties of fuel: fuel type, sulfur content, in Sweden it involves tax on carbon and power consumption), tax on road exploitation (Norway), tax on added value, and transport tax [10].

European Union program “20–20–20” stipulating for 20 per cent reduction of carbon dioxide by the EU countries, 20 per cent decrease of their GDP power intensity, and increase of the renewable power sources’ share in power balance up to 20% by 2020 [11, 12], aimed at introduction of two taxes on the power: a tax on CO_2 emissions associated with motor fuel combustion for the purposes of heating and a tax on power content in motor and heating fuels that is to replace current taxes and excises charged on physical volumes of energy carriers [11].

Currently acting systems of fuel taxation do not enable to differentiate taxation depending not only on fuel environmental class but also on the CO_2 emission amount which can considerably differ within the given quality category.

According to the authors, an environmental tax calculated on the basis of the main tax rate depending on the fuel environmental class and the additional tax rate, which depends on CO_2 emission due to the motor fuel combustion, can be an effective instrument of stimulating the fuel quality improvement [1].

In the process of practical implementation of the environmental tax it is necessary to take into account that gas produces considerably less carbon dioxide emission per power unit in comparison with gasoline and diesel fuel, consumption of the gas fuel is to be increased due to its higher environmental properties, considerable available reserves of natural gas, and potential of associated petroleum gas processing. Thus, gas fuels (natural gas (methane-ethane) and liquefied gas (propane-butane) are to be exempt from environmental tax.

4 The model and method of the calculation for the environmental tax on motor fuel

The authors propose the following universal model for an environmental tax on fuel:

$$T_{el_{ij}} = R_{ij} \cdot W_{ij} = \left(R_m + R_{ad}\right) \cdot W_{ij}\,, \tag{1}$$

where $T_{el_{ij}}$ is the value of environmental tax on the i-th type of fuel (gasoline/diesel fuel) of the j-th environmental class, monetary units; R_{ij} is the

rate of an environmental tax on motor fuel, monetary units/t; W_{ij} is the weight of the sold i-th type of fuel of the j-th environmental class, t; R_m is the main rate of the environmental tax on the i-th type of fuel of the j-th environmental class, monetary unit/t, depending on the fuel environmental class; R_{ad} is an additional rate of the environmental tax on the i-th type of fuel, monetary units /t, to be determined depending on CO_2 emission amount in the process of the fuel combustion.

Motor fuel quality and CO_2 emission in the process of its combustion to the considerable degree are determined by its density which is an easily measured and controlled indicator of the oil product quality.

Values of relative density, as a rule, are used to characterize fuels (table 1).

Table 1: Density of gasoline and diesel fuel of different categories of quality [13].

Indicator	Gasoline			Diesel fuel		
	Quality category			Quality category		
	1	2	3	1	2	3
density at 15°C kg/m^3	715–780	715–770	715–770	820–860	820–850	820–840
ρ_{15}^{15}	0.716–0.781	0.716–0.771	0.716–0.771	0.821–0.861	0.821–0.851	0.821–0.841

Relative density (ρ) is a dimensionless quantity, which value is equal to the ratio of true density of the given substance to the true density of a reference substance taken at the certain temperatures.

It is necessary to note that reduction of the fuel density within the limits of the given category of quality does not require any additional investments and is determined by the temperature range of distillation of gasoline and diesel fractions in the process of petroleum refining [5, 6].

Considering the direct linear connection between carbon dioxide emissions and the fuel density [6–9], it is possible to define an additional rate of the environmental tax in accordance with the fuel density.

It should be mentioned that the diesel fuel production is considerably cheaper in comparison with gasoline in terms of oil refining: production of gasoline, besides distillation of crude oil, requires the expensive processes of isomerization with hydrofining, reforming with hydrofining, catalytic cracking with hydrofining, and alkylation. Production of diesel fuel requires only crude oil distillation and hydrofining. Ratio of prices at the oil products market does not correspond to the ratio between production costs and is caused rather by oil companies’ gambling with growing demand for diesel fuels. Thus, with taking into account lower cost and higher volume of production, higher CO_2 emission both per ton of fuel and per unit of power obtained in the process of fuel combustion, an additional rate of the environmental tax for diesel fuel should be higher than for gasoline [14].

To stimulate decrease in density of the motor fuels in production it is expedient to set a zero additional rate for gasoline of minimal density.

When setting the analogical additional rate for diesel fuel it is necessary to take into account: 1) though diesel fuel specific consumption during vehicles’ exploitation is less (25%) than that of gasoline due to higher effectiveness of diesel engines one had to take into account considerably higher total emissions in case of diesel fuels [7]; 2) in case of the diesel fuel combustion the CO_2 emission per power unit is higher than in case of gasoline due to less (in comparison with gasoline) calorific value and higher per cent content of carbon in the fuel; 3) cost of diesel fuel production is substantially lower than that of gasoline. Consequently, the minimal additional rate on diesel fuel is not to be zero and is to be set considering higher carbon dioxide emission in relation to gasoline that has the minimal density.

According to the proposed approach the minimal additional tax rate is to be set for gasoline and diesel fuel with the minimal permissible values of density. In general the formula for the environmental tax additional rate (2), considering the motor fuel density, can be written as follows [1]:

$$R_{ad} = C_{CO_2} \cdot \left(W_{CO_{2i\rho}} - W_{CO_{2_{i\min\rho}}}\right), \tag{2}$$

where C_{CO_2} is the cost of CO_2 emission unit regulated at the state (interstate) level, monetary units/t; $W_{CO_{2_{i\rho}}}$ is CO_2 emission caused by combustion of the i-th motor fuel (gasoline/diesel fuel) of the given density sold by the fuel producer, t/t; $W_{CO_{2_{i\min\rho}}}$ is CO_2 emission in case of combustion of the gasoline with minimal density, t/t.

Total sum of the environmental tax on motor fuels will be:

$$T_{el_{ij}} = \sum_i \sum_j W_{ij} \cdot (R_m + R_{ad}) = \sum_i \sum_j W_{ij} \cdot \left(R_m + C_{CO_2} \cdot \left(W_{CO_{2_{i\rho}}} - W_{CO_{2_{i\min\rho}}}\right)\right), \quad \text{monetary units} \tag{3}$$

where W_{ij} is the fuel weight calculated for transactions recognized as a taxation object over the period to be considered, motor fuel of the i-th type (gasoline/diesel fuel), j-th environmental class, t.

Carbon dioxide formation during fuel combustion (W_{CO_2}) depends on the carbon content in it:

$$W_{CO_2} = 0.01 \cdot C \cdot \frac{44}{12}, \text{ fuel t/t,} \tag{4}$$

where C is the carbon content in fuel, %.

The carbon content in motor fuel depends on the relative density [7, 14] and is to be determined according Craig formula [7, 14]:

$$C = 74 + 15\rho_{15}^{15}, \text{ \%,} \tag{5}$$

where ρ_{15}^{15} is the motor fuel relative density.

Then the dependence of carbon dioxide formation in the process of gasoline and diesel fuel combustion on their density can be calculated:

$$W_{CO_2} = 0.01 \cdot (74 + 15\rho_{15}^{15}) \cdot \frac{44}{12} = 0.55 \cdot (4.93 + \rho_{15}^{15}), \text{ t/fuel t} \tag{6}$$

With taking into account the shown calculated dependencies of CO_2 emission on the fuels density and minimal values of the permissible density we obtain the formula for calculating the additional rate of environmental tax:

$$R_{ad} = C_{CO_2} \cdot (0.55 \cdot (4.93 + \rho_{15}^{15}) - 3.105) = C_{CO_2} \cdot (0.55\rho_{15}^{15} - 0.394), \quad \text{monetary unit/fuel t} \tag{7}$$

where 3.105 is the carbon dioxide formation in the process of combustion of the gasoline of the minimal permissible density (ρ_{15}^{15} = 0.716), fuel t/t.

Taking into account all the above the environmental tax total sum will be:

$$T_{el_{ij}} = \sum_i \sum_j W_{ij} \cdot (R_m + R_{ad}) == \sum_i \sum_j W_{ij} \cdot \left(R_m + C_{CO_2} \cdot \left(W_{CO_{2_{i\rho}}} - W_{CO_{2_{i\min\rho}}}\right)\right) = \\ = \sum_i \sum_j W_{ij} \cdot (R_m + C_{CO_2} \cdot (0.55\rho_{15}^{15} - 0.394)), \text{ monetary unit} \tag{8}$$

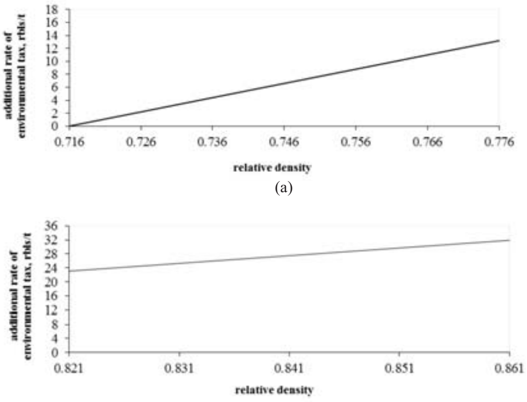
where W_{ij} is the weight of motor fuel of the i-th type (gasoline/diesel fuel), j-the environmental class, t, in terms of transactions recognized as a taxation subject over the period under consideration.

For Russia the authors consider the cost of a CO_2 emission unit equal to 400 rubles/t (according to [15]). With the use of the proposed formula the dependence of the substantiated environmental tax additional rate on the motor fuel density has been calculated (fig. 3).

Implementation of the proposed environmental tax will create an indicator for oil-refining enterprises in their transition to production of fuels with the decreased density and higher quality category. On the other hand, implementation of the proposed environmental tax that takes into account dependence of CO_2 emission on the fuel density and the fuel environmental class will enable to affect economically on the carbon dioxide emission reduction and the fuels quality improvement, this will improve the environmental situation and reduce consumption of scarce motor fuels.

In the all-Russian scale in view of the current annual volumes of fuels production, taken according to [16], the replacement of the fuel excises by the environmental tax can lead, according to authors’ estimations, to an increase of the annual tax deductions up to 2.4 billion rubles.

Besides, transition from maximal density motor fuels production to minimal density fuels will enable to reduce CO_2 emissions resulting from combustion of gasoline and diesel fuel by 3 million tons, gasoline consumption can be reduced



(a)

(b)

Figure 3: Dependence of the environmental tax additional rates on the motor fuels density: (a) gasoline; (b) diesel fuel.

by 442 thousand tons, and diesel fuel consumption can be reduced by 532 thousand tons. Assuming the average producers' gasoline price in 2014 was 23 rubles, and diesel fuel price was 22 rubles (according to [17]) the authors estimated the annual economic effect only due to reduction of the motor fuels consumption equal to more than 22 billion rubles.

The authors consider it expedient to apply the principle of non-tax charges for negative impact upon environment with respect to the environmental tax: environmental tax on the minimal density fuels should be paid from production cost of the fuel to be sold, while for the fuels with higher density it should be paid from the profit. The environmental tax on fuels should be paid on the spot of sale (import) of such commodities. It will be useful to distribute the income generated by the environmental tax for two purposes: formation of the road fund (the funds allocated for the roadway covering rehabilitation) and nature-protective measures, in proportions necessary for the problems solution over the given period and the given region in accordance with these purposes.

Such a direction of funds expenditure responds to negative environmental consequences of motor transport use, i.e. wear of roadway covering and emissions of the fuel combustion products including carbon dioxide (and other pollutants: as it was mentioned earlier, total air pollution correlate with CO_2 emissions from fuel combustion).

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5 Conclusion

Implementation of the environmental tax on motor fuel as an instrument of economic stimulation for the oil resources rational consumption will enable to raise the oil-refining companies' interest to implement measures aimed at improvement of the produced fuel environmental characteristics. This will improve the quality of oil products, will reduce fuels consumption and CO_2 emissions by motor transport (at the current state of the vehicle fleet), and will improve the environmental situation in megalopolises.

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Assessing the influence of restoration works on an artificialized river morphology

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Abstract

The Glane River is a French stream highly artificialized. It displays 20 transversal structures inducing rupture in the continuity. In the context of the Water Framework Directive, several restoration works have been scheduled between 2014 and 2016. A station in the head of the watershed including 3 successive weirs intended for removal has been selected for evaluating the river response to incoming changes. A specific methodology has been applied in order to assess the morphological evolution of the stream. It includes regular measurements of transversal and longitudinal geometric key values, and granulometric composition. The serial of measurements made before the first removal have helped to highlight reductions of sediment and biological communities continuity across the linear implied in the study. Particular degradation among diversity of hydraulic profiles and size classes of substrate have been identified in areas between weirs. The gradual decrease of the hydrological dynamics and the proportion of lotic fish species from downstream to upstream were observed.

The first weir removal was conducted in July 2014, inducing direct release of large amounts of fines from the reservoir. Campaigns have been made between 3 and 5 months after the beginning of works upstream and downstream of the removed structure. A gradual deposition of fine sediments has been observed downstream while their withdrawal from the reservoir resulted in the emergence of coarser material. The most significant observation of these mid-term measurements is the channelization of the upstream linear in parallel with the reduction of the bed width and augmentation of lotic profiles encountered.

Keywords: weir removal, morphology, sediment transport, dynamic profiles, habitats, stream response.

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1 Introduction

Small dams found in streams are considered as an ecological issue by their local impact on natural environment. Although of modest size, they induce similar impacts to those of bigger ones, accentuated by their presence in great number over linear. Impacts generated by these structures on aquatic environments involve several fields of study such as status of biological communities, nutrient dynamics, or morphology [1, 2]. In this article, work is focused on sedimentary, river morphology, habitats aspects and their relationship.

A stream is a complex environment, based on a delicate balance between all its parameters. Modification of one of them will influence the evolution of the whole system. Evolution of the stream sedimentary behaviour is one of the key points of this balance. So, one of the main impacts generated by the presence of a transversal obstacle is the physical barrier of sediment transfer along the river. Upstream of the weir a global phenomenon of sediment deposition is observed due to the decrease of water velocity [3]. Downstream of the structure, deficiency in new material and increase of velocity induced erosion with a channel incision [4], until equilibrium or non-erosive structure was reached.

The imposition of lentic profiles upstream of the structure [5] leads to a lack of riffles and lotic portions in the area of influence. This lack of flowing profiles diversity induced degradation of habitat quality [6].

Concerning old structures, an artificial balance was established in the river and it is important to consider any stream restoration operation as a disturbance and a reconfiguration of an environment at equilibrium [7].

Morphological changes induced by removal operation of a transversal structure take place during the first year after works [8]. Observations made during and after operations are generally transitions of the upstream pond to lotic systems with a quick transport of accumulated sediments upstream to downstream [4]. The drying of lateral areas where vegetation rapidly grows, and decrease of bed width upstream of the removed weir are also observed [9]. While the characteristics of the transport dynamics within the system are specific to each steam, there is generally a reduction in fine sediments in the upstream area, discharged on a linear more or less extended downstream [3].

Few studies deal with the removal of small transversal structures, and most of them are focused on operations performed on large rivers and high dams. Thus, the temporal and geographical scales of disturbances related to the presence or removal of small dam are still poorly known. These small structures are mainly considered as a local disturbance with poor impact on the whole river. Nevertheless, presence of numerous and close weirs as observed in many rivers, generate a greater impact and global disturbance of the stream easily perceptible [6].

The purpose of this work was to follow the removal operation of a weir located in the head of watershed of a highly artificialized French stream: the Glane River. The work is focused on the evolution of morphology and habitat characteristics of the upstream and downstream linear at both short and medium term. A methodology used by the French water national office (ONEMA) has been adapted to our needs and applied to reflect in the most accurate way the geometry of the river. We also mainly based our analysis on the work of Malavoi and Souchon [10] concerning grain-size and habitat parameters.

2 Methods and material

2.1 Study area

The Glane River is located in the Haute-Vienne area in the center of France. The river displays 26 transversal obstacles, resulting in a global stepping rate of 16.2% over its 43 km. Restoration operations have been programmed on 16 of these structures between 2013 and 2016.

The study area (Fig.1) has been defined at the head of the watershed .It includes three weirs displayed consecutively on a 1 kilometer long linear. In July 2014, the middle weir was removed. The previous weir is the Aval Rabaud, ranging from 0.9 to 1.3 meters in height. It underwent the complete deletion of the artificial part, until the bedrock natural obstacle. The reservoir upstream of the structure benefited during the works phase of the filling of a lateral annex (Fig. 2).

Figure 1: Study area. Each dot represents a transversal structure.

Figure 2: Planned removal of Aval Rabaud weir.

2.2 Methodology and analyses

On the study site, 4 different areas have been defined:

- Zone 1 downstream of the group of structures ;
- Zone 2 between the downstream weir and Aval Rabaud ;
- Zone 3 between Aval Rabaud and the upstream weir ;
- Zone 4 upstream of the group of structures.

Longitudinal profile was also made by the measurement of bed altitude along the river. Measurements have been performed every 10 meters using an infrared leveller (Fig. 3).

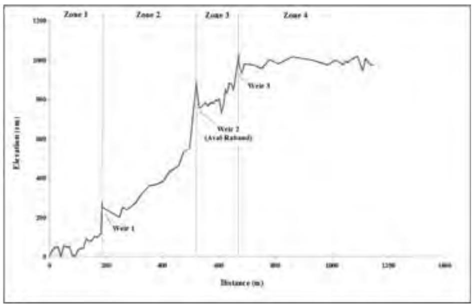


Figure 3: Longitudinal profile of study area.

The monitoring of solid particles transport has been performed upstream and downstream using:

- turbidity measures realised by autonomous probes (Exowater, EXO2)
- and TSS realised by filtration through 0.45mm nitrocellulosic membrane. Water samples were obtaining using automatic samplers (Sigma, 900p).

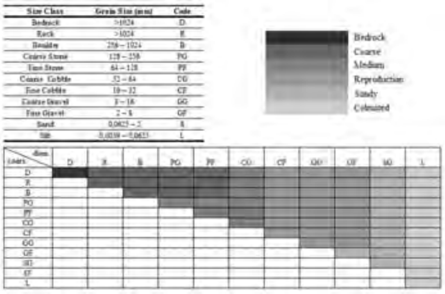
Two measurement campaigns have been realised before and after removal work. Frequency of measurement has been fixed to 1 hour.

Along the river, transversals transects has been defined every 10 meters. For each of them, it has been noted:

- A description of banks (materials, nature of the habitats, thickness and type of side vegetation and presence of lateral erosion);
- Immerged bed width and full bed width (limit of overflowing);
- Flow profiles encountered (rapid, riffle, shallow lotic, shallow lentic, deep lentic);
- Local grain size and water depth every 1/10 of immerged bed width. Two grain sizes were described, one for dominant and one for coarser substrate.

Application of this methodology for a 6 meters full bed width river over a 150 meters linear took half a day for 3 persons.

Habitats were assessed by the particle size noticed in the bed substrate. In this work, a grid based on the works of Malavoi and Souchon [10], and Frissel *et al.* [11] was used to distinguish 6 different habitats.



Size Class	Grain Size (mm)	Code
Bedrock	>1024	D
Rock	>1024	R
Boulder	256 – 1024	B
Coarse Stone	128 – 256	PG
Fine Stone	64 – 128	PF
Coarse Cobble	32 – 64	CG
Fine Cobble	16 – 32	CF
Coarse Gravel	8 – 16	GG
Fine Gravel	2 – 8	GF
Sand	0.0625 – 2	S
Silt	0.0039 – 0.0625	L

Figure 4: Grain size exploitation and habitats grids.

For the initial state all the fourth zones have been characterised.

After the removal of "Aval Rabaud" weir, only zones 2 (330 m) and 3 (150 m) have been described. Zones 1 and 4 have been protected from the work by the presence of upstream and downstream wears.

Pre-removal campaigns have been conducted between 10 and 4 months before the beginning of works and post-removal campaigns between 3 and 6 months after.

3 Results and discussion

Measurement campaigns performed before the weir removal have shown a highly impacted environment. Longitudinal profile highlighted a strong fragmentation of study site as evidenced in Fig. 3 by slope breach. Modification of natural slopes is also noticeable, with a flatten slope upstream weirs. The presence of sediment-filled reservoir directly above the weirs can explain the slope decrease.

Regards to flow profile (Fig. 5), gradual augmentation of lentic profiles throughout upstream progression can be observed. Impact of weirs 2 (between zones 2 and 3) and 3 (between zones 3 and 4) were clearly noticed on upstream flow profiles. In fact, an increase of lentic profiles can be noticed between zones 2 and 3 (10%) and between zones 3 and 4 (50%). The influence of weirs seems stronger in zone 4 with a configuration favouring stagnation and sediment retention (86.7% of lentic flow). However, weir 1 (between zones 1 and 2) seems to have lower effect on flow profiles. Rapid and riffle decrease in favour of shallow

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lotic profile and deep lentic profile appears but fraction of lentic profiles keeps close to 20%. This slight influence can be attributed to the advanced degradation state of the weir.

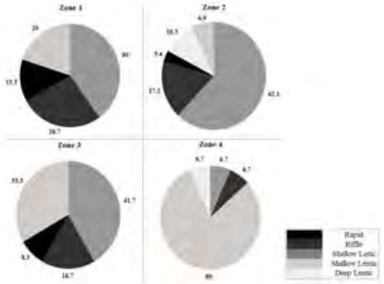

Figure 5: Flow profiles before removal.

Habitat study shows the consequence on sediment transport of the increase of lentic profile observed below (Fig. 6). Downstream to upstream, the increase of fine substrate (sandy and colmated) less favourable to life can be noticed: zone 1: 36.1%; zone 2: 32.4; zone 3: 71.1, and zone 4: 95.8%. One more time, impact of weir 1 is clearly less problematic than the 2 others. In comparison to zone 3 and 4, zone 1 and 2 downstream of Aval Rabaud, present a greater diversity in available habitats. All habitats are present at percentage located between 10 and 30%.

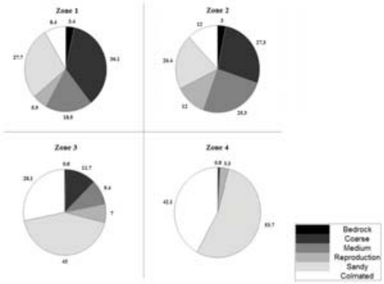

Figure 6: Habitats before removal.

Fish communities inventory has been conducted by the Haute-Vienne fishermen association during October 2013. Inventory has not been conducted in zone 3, due to the reduced linear (150 m) in this sector not enabling completion of the measures. However the field surveys combined with previous observations leave few doubts that fish communities are under-represented on this particular zone. Structure of communities pointed out the strong fragmentation of the ecosystem. Zone 2 (constrained area of 330 m between weirs 1 and 2), despite presenting diversity of habitats and flow profiles (Figs 5 and 6), contains a weak biomass (302 g/m^2). Contrary to the previous, zones 1 and 4 show high biomass (up to 1500 g/m^2). These differences can be attributed to the part of river disconnected: zone 1: 7.5 km; zone 2: 0.3 km; zone 4: 3.5km.

Figure 7: Fish biomass (g/100m²). Comparison between zones 1, 2 and 4.

The removal of the Aval Rabaud weir has been conducted the 24th of July 2014 at 9:00 am (first arrow on Fig. 8(b)) and ended the 25th at 11:00 am. The first phase (2 hours) corresponded to the depletion of the weir and the rest of times being dedicated to modelling of the reservoir above: filling of the lateral annex and channelization.

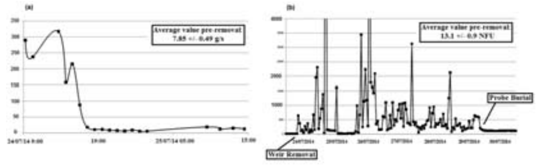

Figure 8: (a) Suspended matter (g/s) and (b) turbidity (NFU) during and after removal directly downstream of the structure.

As expected, a strong release of fine sediments from the reservoir to the river downstream was observed (Fig. 8). Visual observations during and after the works showed a transfer of sediments far away downstream beyond the limits of the study area. This strong discharge (300 g/s) occurred immediately after the beginning of the operation and took place over a period of 9 hours (Fig. 8(a)). The behaviour of suspended matter flux observed on Fig. 8 is due to the operation of weir destruction and the work of an excavator directly in the riverbed.

Even though the suspended sediments discharge only took place during the first day of the operations, the measure of turbidity by the probe placed bottom of riverbed recorded a bed load phenomenon occurring in the days following the removal (Fig. 8(b)). Analysis of turbidity variations over the first days after operations highlighted this phenomenon throughout 6 days before the burial of the probe under sediments (second arrow in Fig. 8(b)). It is therefore likely that the extent and duration of the sediment discharge is currently underestimated mainly concerning bed load occurring a long time after work.

The types of habitat and the flow profiles observed in zones 1 and 4 have not been highly influenced by the removal of the middle weir number 2 due to the persistence of the two others. Thus only zones 2 and 3 have been prospected in post-removal campaign. Results show the short/medium term evolution (few months after work) of the study site in response to the erasing of weir 2.

In zone 2 the strong sediment discharge observed in Fig. 9, has led to a net increase in fine substrate over the entire area (twice as great). In zone 3, transport of fines downstream has resulted in the emergence of coarser material, mainly boulders. Yet fine sediments remain the dominant substrate (65%). The presence of a natural barrier remaining after the work (waterfall generated by bedrock) creates a reduced retention area. Moreover the persistence of weir 3 upstream blocks the charge in coarser sediment. These two reasons contribute to maintain the domination of fine substrate in zone 3.

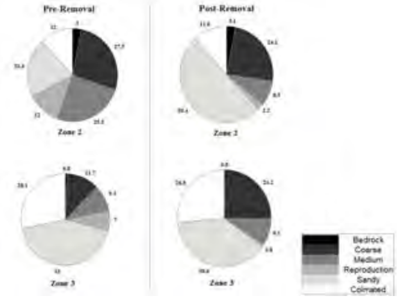

Figure 9: Habitats before and after removal in zones 2 and 3.

Flow profiles have radically changed, showing a shift to a mostly lotic environment in comparison with the slow-flowing facies observed during pre-removal campaigns. In zone 3, the restoration of the reservoir upstream of weir (filled of lateral annex, channelization and stabilization of banks), leads to a decrease in bed width. The same decrease and a channelization have also been observed upstream on a non-artificially modified linear, demonstrating the resumption of natural evolution. In zone 2, the discharge of sediment and the increase of fine substrate induce a slightly decrease of lotic profile (dominant one) but the diversity of flow is maintain. Thus elimination of weir 2 has not serious issue on flow profile downstream but improves greatly upstream one.

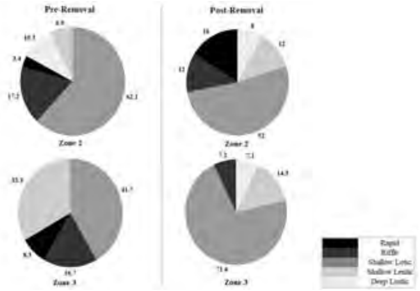

Figure 10: Flow profiles before and after removal in zones 2 and 3.

4 Conclusion

The pre-removal campaigns suggested a strong influence of weirs on river equilibrium (flow, habitat, fishes).

Fish inventories showed that the impact on the communities is linked to the fragmentation of ecosystem more than to the diversity of available substrates. Indeed results have shown that the sections exhibiting less biomass are the most limited one in terms of linear length. It seems therefore reasonable to say that the removal of the 2 structures inducing the re-connection of 12 km of river, will lead to a great improvement for fishes community in term of variety and biomass.

Morphological measures showed that every area directly above a transversal structure is largely disturbed. It has been observed a significant decrease in habitat diversity and quality from downstream to upstream. The succession of closely located obstacles induces retention of fine sediments leading to the progressive clogging of the upstream substrate.

The smoothing of the slope in upstream areas caused the dominance of lentic dynamics.

The removal operation caused a strong release of fine sediments retained over the years upstream of the weir. This discharge has uncovered several boulders upstream, and contributed to incision of bed and channelization.

Upstream of the deleted weir a reduction in the bed width is observed. Part of this evolution is due to artificial changes made during the work. Nevertheless, beyond this area the stream presents a channelization due to re-establishment of fluvial dynamics. In this section the stream dynamics have increased, returning to a more natural behaviour.

However, a few months after removal the evolution of the stream does not show any apparition of medium sized sediments such has cobbles and gravels essential to reproduction and development of lotic fish communities. The cause here is the presence of the upstream weir blocking any sedimentary renewal. Thus, the elimination of the structure is only a step to re-naturing of site and the levelling of the near weir upstream is necessary to the success of the rehabilitation project.

The negative effect of the operation expressed by a high release of fine sediment downstream contributed to the degradation of local environment quality. Nonetheless, such input seems not sufficient to permanently damage downstream area. Moreover, it is believe that the seasonal increase in flow rates will transport these particles further downstream. The area will then return to its previous good state.

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Environmental sustainability of the clementine production systems in Italy and Spain: an approach based on Life Cycle Assessment

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Abstract

The first step towards a sustainable agriculture is to know the impacts that it generates. Although this is a complex task, since the environmental impact of agriculture depends not only on the production system (e.g. conventional or organic) and farmer practices, but also on the production site (soil and climate conditions). The aim of this study is to assess the environmental impact of clementine production farming systems (conventional, CFS, and organic, OFS) in Italy (Calabria region) and Spain (Comunidad Valenciana) through Life Cycle Assessment (LCA). The functional unit to which the results were referred was 1 hectare (ha^{-1}). The system boundaries considered were from "farm gate to farm gate", which included the production of the machinery, fertilizers and pesticides and also the field operations. The study is based on one year of primary data, collected from surveys of 19 Italian and 23 Spanish farmers. Ten impact categories were assessed by CML2001 and USEtox methods. No significant differences were found between CFS and OFS in both countries and the impacts present a high variability depending on the farm. In CFS the fertilizers production is the stage most impacting in almost all categories (Global Warming Potential: Italy 92% – Spain 89%; Acidification: Italy 91% – Spain 80%) with the exception for the Ecotoxicity in which field operations have a great contribution (Spain: 97%; Italy:

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78%). Regarding OFS, no stage contributes specifically to all the impacts. The main difference between Italian and Spanish organic farms arises in the Ecotoxicity category. In Italy the stage with the greatest contribution is the production of fertilizers (87%), whereas in Spain it is the field operation (95%). In general, the impacts generated by OFS are lower than for CFS. The LCA results of this study allow identifying those agricultural practices that can help to reach a more environmentally sustainable agriculture.

Keywords: life cycle assessment (LCA), citrus crops, comparative assessment, environmental performance.

1 Introduction

Agro-ecosystems are big producers of significant impacts on the principal environmental compartments (air, water and soil) producing greenhouse gasses and other emissions. Nowadays, farms should be planed and managed in accordance with criteria that lead to eco-friendly practices to reduce the environmental pressure. Therefore, a sustainable agriculture is now clearly an objective recognized and indispensable to achieve the sustainability criteria by the application of methods and techniques, which identify the environmental hotspots of the agricultural processes and to improve their environmental performance.

The worldwide production of citrus fruit, in 2012, was 131.28 million of tons, with a planted area of 8.79 million of ha^{-1}. In Europe, the main citrus fruit producing countries are Spain and Italy, with 318,700.0 ha^{-1} and 146,294.0 ha^{-1}of citrus fruit respectively [1]. The largest citrus area in Spain is *Comunidad Valenciana*, with 178,361 ha^{-1} in 2010 of which 37% was Clementine with a production of 1.181 millions of tons [2]. In Italy, after Sicily, the second region with the largest citrus surface is Calabria with 35,185 ha^{-1}, of which the 35.61% were Clementine [3] with a production of 4.952 millions of tons [4]. Taking into account the great surface of citrus in these regions and the impacts generated by agriculture, reducing the environmental impact of this crop presents a goal to be achieved.

But farmers need information about the causes of environmental impacts in order to promote environmentally sound agricultural production. Life Cycle Assessment (LCA) methodology has proved to be a valuable tool for the environmental evaluation of farming systems. LCA is a compilation and evaluation of the inputs and outputs and of the environmental impacts of a product system [5]. Some agricultural LCA studies have assessed specific agricultural production systems, including oranges [6–8]; others have compared systems such as conventional versus organic farming [9, 10]. Although those studies have addressed the differences between the farming systems regarding environmental impacts, the results from LCA studies are affected by different sorts of variations. In fact, some studies [11, 12] have highlighted the variations between the farms or scenarios within the same type of production system, even within the same region. A way to tackle this variability is to define representative systems and to quantify the uncertainty linked to the variability by using Monte-Carlo analysis [13]. Another option is to study each farm separately, since it can help us to differentiate

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results among farms and also to define the potential for improvement of environmental impact management in individual farming enterprises. As Mouron *et al.* [11] state, the promotion of environmentally sound farming is not only a question of choosing a farming system (e.g. organic vs. integrated farming) but an understanding of the system specific management influence is crucial.

In this study, a comparative analysis of two cropping systems, organic and conventional, in two different production site, Comunidad Valenciana and Calabria Region, has been conducted by the LCA methodology in order to highlight the differences and to identify those agricultural practices that can help to reach a more environmentally sustainable agriculture.

2 Materials and methods

2.1 Life Cycle Assessment

The LCA methodology, according to ISO guidelines [14, 15] has been used in this comparative analysis in order to quantify the environmental impacts produced in the cultivation stage of clementine. LCA is an environmental sustainability tool that comprises four main phases defined by the ISO standards: goal and scope definition, inventory analysis, impact assessment and interpretation.

2.1.1 Goal and scope definition

The main objective of the study was to compare organic and conventional clementine production systems in the Comunidad Valenciana and Calabrian Region.

The functional unit (FU) is the reference unit to which the system's input and output are related [16]. In this study, the FU chosen is 1 ha of clementine at the farm gate.

The study is based on one year of primary data corresponding to the season 2009–2010. Input and output data have been collected directly by questionnaires and interviews with farmers. The study has examined 43 clementine farms, 23 Spanish and 19 Italian. From the 23 Spanish farms are located in Comunidad Valenciana, 12 correspond to organic production (OFS_{Sp}) and 11 are conventional (CFS_{Sp}) have been considered. The Italian farms are in the Calabria Region, 9 carry out organic farming (OFS_{It}) and 11 are conventional (CFS_{It}).

According to Bentrup [17], LCA studies do not always cover all life cycle stages of a product, but can be restricted to defined parts of it, for example in so-called "cradle to gate" or "gate to gate" studies. In this study, the system boundary considered was from "farm gate to farm gate", which included the use of the machinery, the production of fertilizers, pesticides and fuels, the field operations, as depicted in fig. 1. Irrigation and transport of fertilizers and pesticides were excluded due to lack of data. The machinery manufacturing was excluded because machinery is mostly rented. Thus the use of the machinery is higher that if it was used only by one farmer. Furthermore, a study carried out by Frischknecht *et al.* [18] shows that the production of capital goods for agriculture contributes to cumulative energy demand whereas the contribution to other impact categories is not significant.

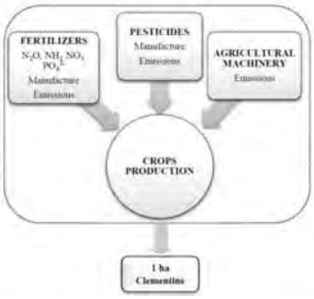

Figure 1: System boundaries of the clementine crop.

2.1.2 Life Cycle Inventory (LCI)

Life cycle inventory (LCI) analysis involves the collection of data defined by the materials and energy used in the system, emission to air, liquid effluents and solid wastes discharged into the environment [19].

Data regarding the resource consumption and emissions produced during the fertilizers and pesticides manufacture were taken from the Ecoinvent 2.1 database, [20]. The procedure suggested from Audsley *et al.* [21], was used to calculate the data of those active ingredients not included in Ecoinvent database. Regarding the mineral oil, used as insecticide, the manufacturing process of the kerosene in Ecoinvent 2.1 has been considered due to its similar properties.

For the manufacture process of those inorganic fertilizers not included in Ecoinvent 2.1, and the organo-mineral complex considered as inorganic, the data suggested from Patyk and Reinhardt [22], have been used.

Data on tractor emissions have been calculated from Ecoinvent database, while emissions from weeding machine manual has been obtained according to Oficina Catalana de Canvi Climàtic [23].

The application of fertilizers generates emissions that have been calculated. To estimate N_2O emissions the IPCC Guidelines [24] were followed. To estimate NH_3 emissions, the amounts of both ammoniacal nitrogen and organic fertilizers were obtained from the register of fertilizers suggested from MAGRAMA [25] and Organozoto fertilizzanti SPA [26]; then NH_3 emissions were calculated from the method suggested by Bentrup *et al.* [27]. NO_3 and PO_4^{3-} leaching was calculated according to MARM [28], and Nemecek and Kägi [29], respectively.

To calculate the fate of pesticides the general model of Hauschild [30], has been used to estimate the pesticide fractions arriving to the environmental compartments (soil, plant, surface- and groundwater). This fraction depends on both the physical and chemical properties and the degradation rate of the pesticide. These properties have been found in the following databases: Pesticide footprint

[31], EU Pesticide Database [32], OSU Extension Pesticide Properties Database [33] and The Pesticide Manual [34]. Furthermore, a Leaf Area Index (LAI) of 6.04 has been taken into account [35] for the deposition of the pesticide on crops plants and field soil. The fraction that reaches the surrounding environment (drift off the field) has been calculated taking into account both the surface water and the surface area for both countries. A surface area of 2,320,000 ha^{-1} in the Valencia province and of 1,510,000 ha^{-1} in the Calabria Region, and a water surface of 23,216 ha^{-1} and of 2980 ha^{-1} respectively, has been considered.

2.1.3 Life Cycle Impact Assessment (LCIA)

The purpose of the LCIA phase is to translate the environmental burdens quantified in the LCI into the related potential environmental impacts (or category indicators) [19]. To this aim Gabi 6.0 software [36] was used. The impacts assessment has been calculated by using a midpoint approach including the classification and characterisation steps. Ten impact categories have been considered: Global Warming Potential (GWP 100 year, measured as kg CO_2 eq), Acidification Potential (AP, measured as kg SO_2 eq), Eutrophication Potential (EP, measured as kg PO_4^{3-} eq), Abiotic Depletion (ADP elements, measured as kg Sb eq), Abiotic Depletion (ADP fossil, measured in MJ), Ozone Layer Depletion Potential (ODP, measured as kg CFC-11 eq) and Photochemical Ozone Creation Potential (POCP, measured as kg Ethene eq) according to CML2001 method [34]. In addition, Ecotoxicity, Human toxicity carcinogenic and Human toxicity non-carcinogenic expressed in CTUe (comparative toxic units) and CTUh have been calculated according to USEtox method [37].

3 Results interpretation

The environmental performance of the conventional and organic clementine farming systems for the two countries summarized in table 1, as mean values (M) and standard deviation (SD) for each impact category. No greatest differences have been found between CFS and OFS in both countries and the impacts show a high variability depending on the farm.

As can be observed, the Spanish farms show higher variability, particularly the organic farms. This is due to the heterogeneity of the agricultural practices, in fact, different levels and kind of chemical and organic fertilizers, pesticides and machinery are used. In the case of Italian farms, both organic and conventional show more homogeneous practices and consequently the impact results present lower variability.

Figs 2 and 3 show the impacts generated by each production process stage in the Spanish and Italian CFS. The most impacting stage in almost all categories is the fertilizer production (GWP100: CFS$_{Sp}$ 89% – CFS$_{It}$ 92%; AP: CFS$_{Sp}$ 80% – CFS$_{It}$ 91%; ADPelements: CFS$_{Sp}$ 81% – CFS$_{It}$ 48%; ADPfossil: CFS$_{Sp}$ 93% – CFS$_{It}$ 96%; ODP: CFS$_{Sp}$ 93% – CFS$_{It}$ 98%; POCP: CFS$_{Sp}$ 90% – CFS$_{It}$ 93%; Human Toxicity cancer: CFS$_{Sp}$ 97% – CFS$_{It}$ 100%; Human Toxicity non–cancer: CFS$_{Sp}$ 83% – CFS$_{It}$ 93%) with the exception of the Ecotoxicity and EP categories in which the field operations have a great contribution (Ecotoxicity: CFS$_{Sp}$ 97% – CFS$_{It}$ 78% and EP: CFS$_{Sp}$ 49% – CFS$_{It}$ 40%). Pesticides manufacturing presents an important contribution to ADPelements for the two countries (CFS$_{Sp}$ 18% – CFS$_{It}$ 52%).

Table 1: Mean values and standard deviation for each impact category for clementine production. Conventional Farming System Spain (CFSSp) and Italy (CFSIt) – Organic Farming System Spain (OFSSp) and Italy (OFSIt).

Impact categories [Units]	Conventional				Organic			
	CFS $_{Sp}$		*CFS $_{It}$*		*OFS $_{Sp}$*		*OFS $_{It}$*	
	M	SD	M	SD	M	SD	M	SD
GWP 100 yrs [kg CO_2 eq]	1.37E+04	1.06E+04	2.87E+04	2.83E+03	3.57E+03	5.48E+03	2.80E+03	1.71E+03
AP [kg SO_2 eq]	1.10E+02	1.03E+02	2.61E+02	2.59E+01	1.94E+02	3.05E+02	8.69E+01	4.14E+01
EP [kg PO_4^{3-} eq]	4.30E+01	2.75E+01	8.01E+01	8.55E+00	4.69E+01	5.50E+01	2.24E+01	8.07E+00
ADP elements [kg Sb eq]	1.17E-02	7.37E-03	9.01E-03	6.12E-03	4.62E-04	1.23E-03	3.17E-04	3.86E-04
ADP fossil [MJ]	1.26E+05	1.16E+05	3.05E+05	3.04E+04	2.86E+04	5.98E+04	2.90E+04	1.62E+04
ODP [kg CFC-11 eq]	7.30E-04	5.86E-04	1.56E-03	1.62E-04	1.17E-04	3.17E-04	4.96E-05	7.20E-05
POCP [kg Ethene eq]	5.08E+00	5.02E+00	1.32E+01	1.30E+00	1.42E+00	2.57E+00	1.88E+00	9.98E-01
Ecotoxicity [CTUe]	9.41E+05	5.40E+05	3.39E+05	1.45E+05	9.18E+04	3.17E+05	2.54E+03	3.29E+03
Human toxicity cancer [CTUh]	4.36E-04	4.57E-04	1.12E-03	1.20E-04	7.04E-05	2.29E-04	3.42E-05	4.94E-05
Human toxicity non-cancer [CTUh]	2.15E-03	1.77E-03	4.63E-03	5.07E-04	4.50E-04	9.64E-04	5.06E-04	2.71E-04

The impacts generated in the OFS are presented in figs 4 and 5. The results show that the main difference between Italian and Spanish organic farms arises in the Ecotoxicity category. In Spain, the 95% of the impact is produced in the field operation stage, while in Italy the 87% is caused by the fertilizers. The impacts generated by the machinery present the following percentages: GWP100: OFS$_{Sp}$ 18% – OFS$_{It}$ 51%; AP: OFS$_{Sp}$ 3% – OFS$_{It}$ 14%; EP: OFS$_{Sp}$ 3% – OFS$_{It}$ 13%; ADPelements: OFS$_{Sp}$ 6% – OFS$_{It}$ 17%; ADPfossil: OFS$_{Sp}$ 32% – OFS$_{It}$ 69%; ODP: OFS$_{Sp}$ 6% – OFS$_{It}$ 0%; POCP: OFS$_{Sp}$ 45% – OFS$_{It}$ 79%; Ecotoxicity: OFS$_{Sp}$ 0% – OFS$_{It}$ 13%; Human Toxicity cancer: OFS$_{Sp}$ 1% – OFS$_{It}$ 3%; Human Toxicity non–cancer: OFS$_{Sp}$ 35% – OFS$_{It}$ 75%. As in the CFS, the fertilizers manufacturing present higher impacts in almost all categories, in particular, in the ODP category for both countries the values are significantly higher (OFS$_{Sp}$ 80% – OFS$_{It}$ 97%). Finally, the pesticide stage contribute to the production of impacts in the AP (36%) and ODP (15%) categories, only in Spain. In general, the impacts generated by OFS were lower than those for CFS.

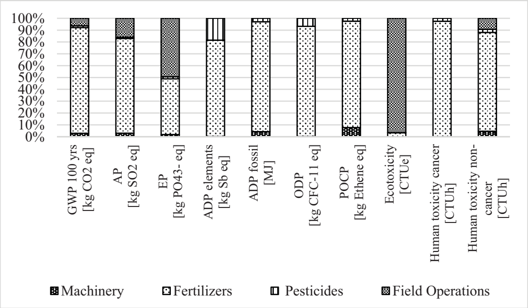

Figure 2: Impacts per production stage in conventional clementine production in Spain.

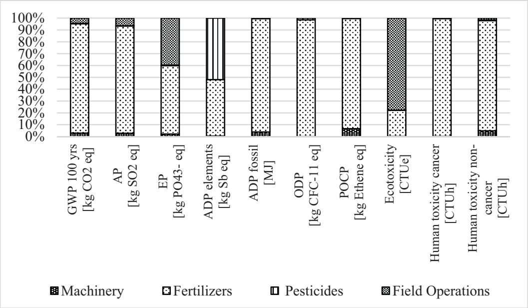

Figure 3: Impacts per production stage in conventional clementine production in Italy.

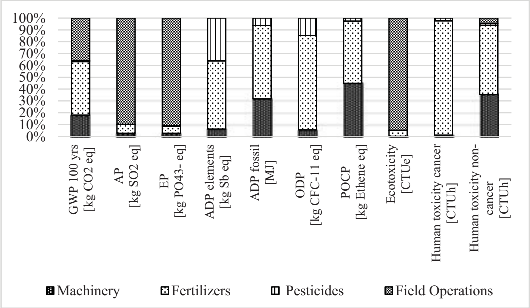

Figure 4: Impacts per production stage in organic clementine production in Spain.

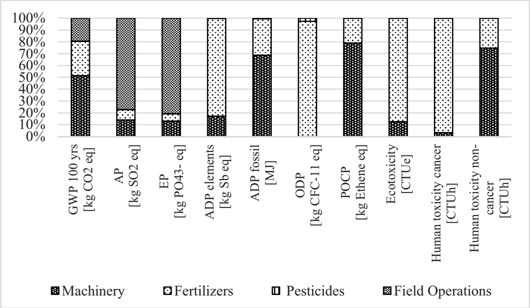

Figure 5: Impacts per production stage in organic clementine production in Italy.

4 Discussion

The environmental performance obtained by comparing organic and conventional cropping systems in Spain and Italy shows small differences between both production areas for the impact categories selected. This phenomenon it is likely due to similar pedoclimatic conditions that conducted to comparable agricultural techniques and similar biocenotic processes. However, although the mean results show comparable performances, the Spanish farms show a higher variability in the impact results, due to a higher adaptation of cultivation techniques to the individual farm, as a consequence of more advanced farm management techniques.

De Luca *et al.* [10] performed a similar study in Calabria region but findings are not comparable because they used an end-point LCIA method (Ecoindicator 99) which expresses the environmental impacts from a damage oriented perspective. Pergola *et al.* [9] analyzed the production of lemons and oranges in Sicily region taking into account the whole life cycle of the orchard (50 years). These authors used the same impact assessment method as the one in this study and chose, however, five impact categories (AD, GWP100yrs, PO, AA, EU). When partitioning the total results for one production year, impact values are lower, this is due, among other reasons, to the influence of the planting and growing phase, in which the lower quantity of inputs applied reduces the mean value of the impact per year.

Dwivedi *et al.* [38] analyzed the production of orange juice in Florida, considering a farm cradle to industry gate system boundary. Results are related to 1893 L of Not-From-Concentrate orange juice. Considering an average production of 45 t oranges/hectare and comparing results in term of GWP, the average value of 303 g CO_2/kg clementine for the Spanish conventional farming system is similar to Dwivedi's result (312 g CO_2/kg orange). Contrariwise, the Calabrian conventional farming system generates around 637 g CO_2/kg clementine. This value is mostly due to the higher quantity of fertilizer spread, which represents the most impacting operation for CFSIt. The reduction of the fertilizer dose could improve the environmental performances of these farms.

5 Conclusion

In this study the importance of the variability of management practices has been analyzed. The results show how, independently of the farming system, a proper management enables to generate both relatively low environmental impacts and costs contributing to the aim of sustainability.

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Effect of drought stress on mungbean (*Vigna radiata* L.) under arid climatic conditions of Saudi Arabia

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Abstract

Water limitation is undoubtedly a critical environmental constraint hampering crop production in arid and semiarid areas. The present study was conducted to assess the water deficit stress consequences of yield components and water use efficiency (WUE) in mungbean. A field experiment was conducted at Educational Farm, Crop Production Department, College of Food and Agriculture Sciences, Kind Saud University, Saudi Arabia during 2012–2013. The trial was comprised of four irrigation intervals viz. (3, 5, 7 and 9 day intervals) as well as three mungbean genotypes; Kawmay-1, VC-2010 and King. The experiment was arranged under split plot design with irrigation as the main plot and genotype as subplot treatment, and replicated thrice. Plant height, 100 seed weight, biological yield, seed yield, harvest index and WUE were recorded at harvesting. Results revealed that a decrease in irrigation had significantly hampered all the studied parameters except WUE. The differences found among mungbean genotypes were significant. Whereas irrigation-genotype interaction was significant for seed yield, harvest index and WUE. Plant height, shoot weight and biological yield were recorded as non-significant for irrigation-genotype interaction. The minimum irrigation interval (3 days) produced the maximum values, while VC-2010 comparatively performed best under low irrigation levels. It is concluded that mungbean may be successfully adopted under the Saudi Arabian climate, but it needs frequent irrigation. However, genotypic variations are a hope to developing improved varieties with a higher WUE.

Keywords: mungbean, irrigation intervals, water use efficiency, genotypes, yield.

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1 Introduction

Drought is a meteorological term and is commonly defined as a period without significant rainfall. Drought stress changes the biochemical and physiological reactions, pigment composition and morphological characters of plants [1, 2]. In arid and semiarid regions, water deficit is a major crop restraining factor. Limited amounts of water, low and irregular rainfall, and hot summers promote drought stress which are the world leading intimidations that should be considered [3, 4]. Water scarcity and increasing demand create an urgent need for improved irrigation management to maximize the efficiency of available precious water resources. The development of new irrigation scheduling such as deficit irrigation is one of the options available to increase per unit yield [5]. However, the yield response of the crop to deficit irrigation must be in an investor's knowledge [6]. Both over-irrigation and deficit irrigation are economically unsuitable. Over-irrigation wastes water, energy and labour, it may also lead to water-logging, nutrient leaching and low yields while drought stress can cause severe yield reduction [7]. Hence an accurate and wise use of irrigation has been suggested for arid and semiarid regions.

Mungbean or green gram (*Vigna radiata* L.) is an annual grain legume, widely spread in Asia and an important component of many major cropping systems [8]. Fresh or dry mungbean seed can be used as a whole or may be processed to bread, noodles, porridge, soups, snacks or even ice-cream [9]. It's a fat free, protein rich meat replacer especially for vegetarians, and in addition it contains a variety of minerals and vitamins [10]. It can be used as intercrop or a cover crop in-between two cereal crops due to its short growing period (80–90 days) [9, 11]. It can be grown under limited amounts of water and poor soil fertility. It is also a valuable green manure, can produce a huge biomass (7.16 t/ha) [12] and contributes a lot of nitrogen to soil ranging from 30 to 251 kg/ha [13, 14]. Mungbean straw and by-products are fairly good and valuable feed for sheep and goats [15], cattle [16], poultry [17] and fish [18]. Mungbean does not require a large amount of irrigation water (600–1000 mm/year rainfall) and is also capable of tolerating drought stress [9] as it has a well-developed root system including taproot and deep lateral roots for the absorption of water when limited in availability [8]. Some of the experimental studies believe that drought stress has no effect on mungbean as it is a drought tolerant crop. However, a few studies have been undertaken to investigate the negative effects of drought stress on the growth, physiology, yield and yield components of mungbean [19, 20].

Drought resistance is a complex quantitative trait, involving interactions of many metabolic pathways related to stress-resistant genes. One strategy to reduce the effect of water stress on crop yield is to use drought tolerant genotypes and is a good management of irrigation water supplies. This assertion was supported by Siddique *et al.* [21], who reported that for the purpose of crop production, yield improvement and yield stability under water stress conditions, development of drought tolerant varieties is the best option. Crop plants are usually under stress at one time or another and plant species able to withstand such stresses have great economic potential [22]. Use of drought tolerant species is one of the effective strategies used to cope with water deficit stress wisely, as some plants species are able to withstand such stresses [21–23]. The proper application of deficit irrigation practices can generate significant saving in irrigation water supplies [21, 24]. Among field crops, groundnut, soybean, common bean and sugarcane have shown proportionately less yield reduction under continuous but lower drought stress than the relative evapotranspiration deficit imposed at certain growth stages. The present study was designed to identify the yield potential of promising mungbean genotypes under a controlled deficit water supply.

2 Materials and methods

2.1 Experimental site

The field experiment was conducted at Educational Farm, College of Food and Agriculture Sciences, King Saud University, Riyadh, Saudi Arabia during summers 2012–13. The experimental site was located in tropical arid at 24.72°N latitude, 46.63°E longitude and almost 600m altitude. This region has a hot desert climate, an extremely hot summer, approaching 50°C occasionally and with only 10 to 17 percent humidity. The city experienced very little rainfall and a number of heavy dust storms in the summers.

2.2 Plant materials

Three mungbean genotypes were selected for the current experiment from 20 genotypes previously evaluated by, Field Crop Group, Plant Production Department, College of Food and Agricultural Sciences, in a series of experiments conducted under the title of "introduction of new crops under Saudi Arabian condition". This selection was based on yield and yield component characters. In the present study the following three genotypes have been selected:

Table 1: Mungbean genotypes and origin.

Number	Genotype name	Origin
V_1	Kawmay-1	Egypt
V_2	VC-2010	Thailand
V_3	King	China

Healthy seeds were sorted out mechanically and treated with 0.1% sodium hypochlorite (NaOCl) for 5 minutes then washed with distilled water. Air dried seeds were then measured by an electric balance to maintain the weight of seeds for each treatment and packed for each pot separately.

2.3 Soil analysis and preparation

Before commencement of the field experiment, soil samples were taken from 30–60 cm depth for physical and chemical analyses according to the methodology described by Cottenie *et al.* [25] and But [26]. Results revealed that the soil site was sandy-clay-loam in texture with electrical conductivity 1.4 dS/m^{-1}. The seedbed was prepared according to the recommendations of the Ministry of Agriculture, Saudi Arabia. The soil was ploughed twice and divided into plots, subplots, paths and borders. Phosphate fertilizer was applied as calcium superphosphate (15.5% P_2O_5) by the rate of 200 kg/ha and potassium fertilizer as potassium sulphate (48% K_2O) @ 150 kg/ha while nitrogen sulphate (20.6% N) @ 50 kg N/ha was applied in three split doses.

2.4 Field experiment:

The field experiment was arranged under the split plot design according to Gomez and Gomez [27] with three replications. The experiment included 36 experimental units, four drought stress levels imposed as the irrigation interval (illustrated below in Table 2) as main plots and three genotypes V1 (Kawmay-1), V2 (VC-2010) and V3 (King) in subplots. Each subplot had dimensions 3m x 2m with 6 m^2 total area. Seeds were planted manually in 10 cm apart hills while row to row distance was kept at 50 cm. Fifteen days after sowing, hoeing and thinning were done to eradicate weeds as well as 3 seedlings per hill were maintained. The same amount of water was applied at every irrigation (about 400 m^3/ha), which was previously determined based on field capacity. The amount of irrigation was regulated by using a "gauge meter". The soil moisture content was measured by a "moisture probe meter" (MPM-160-B) based on water volume percentage (%) for each treatment. Drought stress treatment was started three weeks after sowing. Amounts of irrigation water supplied over the growing season were calculated and are presented below (Table 2).

Table 2: Irrigation plan, interval and total amount of irrigation.

Treatment number	Irrigation interval (days)	Number of irrigations	Amount of irrigation (m^3/ha)
I_1	3	30	12000
I_2	5	18	7200
I_3	7	13	5200
I_4	9	10	4000

2.5 Observations

At harvesting; Plant Height (cm), Shoot Dry Weight (ton/ha), Biological Yield (ton/ha), Seed Yield (kg/ha) and Harvest Index were measured according to standard protocol. Water use efficiency (WUE) (kg/m^3) was computed according to the following equation formulated by Bos [28].
WUE_b = Biological Yield/Seasonal water use

2.6 Statistical analysis:

The data obtained was subjected to the statistical analysis suggested by Gomez and Gomez [27] and wherever the treatment differences were found to be significant (F-test), critical differences were worked out at the five per cent probability level. Means were compared by using the Least Significant Difference test (LSD), with a 0.05 level of significance, which was developed by Steel *et al.* [29].

3 Results and discussion

Water deficit stress is one of the most rapidly increasing threats to agricultural production. Limited amounts of water, increasing demand and deterioration of available water reservoirs are the fundamental factors to be considered. Efficient utilization of this precious agricultural input is one of the most cost-effective options for arid and semiarid regions. The present study disclosed that irrigation interval and genotypic differences were highly significant while genotype by irrigation interaction was found to be highly significant for seed yield, harvest index and WUE, while plant height, shoot weight and biological yield were found to be non-significant (Table 3).

Table 3: Analysis of variance summary for mungbean genotypes under water deficit stress.

Sources of variations	Shoot weight (ton/ha)	Harvest index (%)	Plant height (cm)	Seed yield (kg/ha)	WUE $_b$ (kg/m^3)	Biological yield (ton/ha)
Irrigation(I)	3.73**	467.31**	881.30**	1,843,053**	0.505**	6.23**
Genotype(G)	11.89**	64.05**	181.57**	213,659**	0.163**	5.79**
I x G	0.19ns	5.80*	11.56ns	8,956**	0.009*	0.055ns
CV (I x G)	14.57	12.51	10.68	2.84	9.37	12.56

*, and **:F-test significant at $P \leq 0.05$, and $P \leq 0.01$, respectively. ns, not significant.

Irrigation was recorded as highly significant for all study parameters. However, biological yield was recorded as statistically similar for I_1 and I_2. Irrigation frequently resulted in descending order $I_1>I_2>I_3>I_4$ for shoot weight, HI, plant height, seed yield; however, WUE showed a reverse trend, it has been recorded as increasing when water deficit stress is increased (Table 4). This may be the result of hampered physiological processes under deficit water conditions. These findings were in line with the results of Mogotsi [9], who reported that seed yield and WUE of mungbean were affected by the irrigation amount. The genotypic variations in mungbean are have shown varied behaviour under similar water conditions. Kawmay-1 performed excellently for plant height, VC-2010 lead in biological yield, seed yield and WUE; whereas for harvest index both were statistically similar. The "King" genotype was statistically similar to VC-2010 for shoot weight and biological yield. The minimum irrigation interval and maximum amount of water applied have produced better yields under the arid climatic conditions of Saudi Arabia. However, conclusively, VC-2010 performed better under all water deficit condition. Siddique *et al.* [21] and Bibi *et al.* [22] reported similar results and concluded that genotypic differences within a species have remarkable potential for crop improvement under water stress conditions.

Table 4: Mungbean genotypes performance under water deficit stress in Saudi Arabia.

Irrigation	Shoot weight (ton/ha)	Harvest index (%)	Plant height (cm)	Biological yield (ton/ha)	Seed yield (kg/ha)	WUE $_b$ (kg/m^3)
I_1	4.78 A	18.86 A	48.77 A	6.14 A	1129.2 A	0.511 C
I_2	4.73 A	11.33 B	44.59 B	5.59 A	623.1 B	0.777 B
I_3	4.51 AB	05.27 C	37.55 C	4.89 B	256.9 C	0.941 A
I_4	3.98 B	02.65 D	26.15 D	4.22 C	115.2 D	1.058 A
LSD	0.653	1.8950	0.8225	0.25	21.050	0.1271
Varieties						
Kawmay-1	3.76 B	10.99 A	43.71 A	4.45 B	515.78 B	0.697 C
VC-2010	4.97 A	10.74 A	36.49 B	5.82 A	671.56 A	0.927 A
King	3.78 A	06.87 B	37.60 B	5.36 A	406.01 C	0.841 B
LSD	0.565	1.8572	1.71	0.26	6.16	0.0666

Biological yield is the outcome of plant health and growth. The present study revealed that the mungbean genotype, Kawmay-1 produced the maximum biological mass when under the highest and most frequent irrigation application (Table 5). The harvest index, a quick expression of economic production, was led by the I_1 x Kawmay-1 and I_1 x VC-2010 pairs respectively while the genotype "King" had the minimum harvest index when under the lowest irrigation (I_4) (Table 5). The harvest index of the expressed parameters viz. physiological and genetic components as well as genotypic variations x environmental interaction, are affected by water deficit stress. The Kawmay-1 genotype produced the maximum plant height and biological yield under I_1 while "King" stood highest in shoot weight. However, almost all other combinations overlap one another for these parameters. Although growth was recorded as non-significant it was found that, in G x I, I_4 consistently hampered the growth of all three mungbean genotypes (Table 5). Plant height, biological yield and shoot weight are the indirect measure of the vegetative health of plants which are vulnerable to environmental stresses and based on genome properties. Seed yield is the most desired character of farmer's interest in field crops and considered as the economic outcome of farming. The VC-2010 genotype in combination with I_1 was recorded as having the highest seed yield followed by Kawmay-1 and "King", respectively, under the same irrigation conditions (Table 5). Here again the gradual increase in water deficit conditions regularly reduced the seed yield for all three genotypes. These findings corroborated the results reported by Hao *et al.* [23] who stated that irrigation stress may reduce the mungbean seed yield and affect WUE. WUE: the major object of this research and the aggregate of all physiological, genetic and phonological mechanisms of plants under certain situations was recorded as highest for VC-2010 and I_4 combination followed by Kawmay-1. A clear distinction can be seen in different interactions for WUE efficiency (Table 5); it has increased as the amount of seasonal irrigation water decreased, and is an area for future study. Shirvan and Asgharipur [19] and Ranawake *et al.* [20] are in support of the present findings. A plants response to unusual stresses is simultaneously a mixture of the multidisciplinary networked correlation among different plant processes and genetic combinations.

Table 5: Genotype-irrigation interaction summary of mungbean under the Saudi Arabian climate.

Interaction I x G	Shoot weight (ton/ha)	Harvest index (%)	Plant height (cm)	Biological weight (ton/ha)	Seed yield (kg/ha)	WUE $_b$ (kg/m^3)
I_1 x Kawmay-1	5.09 AB	22.04 A	55.94 A	6.64 A	1146.9 B	0.45 G
I_1 x VC-2010	5.10 AB	19.78 A	43.73 BC	5.43 BCD	1306.6 A	0.55 FG
I_1 x King	5.18 A	14.78 B	46.66 BC	6.35 AB	934.2 C	0.52 FG
I_2 x Kawmay-1	3.87 CD	12.53 B	49.30 B	4.53 DE	583.6 E	0.65 EF
I_2 x VC-2010	5.16 AB	12.85 B	41.74 CD	6.17 AB	784.4 D	0.86 CD
I_2 x King	5.17 AB	08.60 C	42.75 BC	5.90 ABC	501.3 F	0.82 CD
I_3 x Kawmay-1	3.84 CD	06.10 CDE	41.46 CDE	4.22 EF	254.2 H	0.65 DE
I_3 x VC-2010	5.01 AB	07.21 CD	35.26 E	5.52 BCD	394.3 G	1.06 B
I_3 x King	4.68 ABC	02.49 EF	35.92 DE	4.93 CDE	122.1 I	0.97 BC
I_4 x Kawmay-1	3.27 D	02.28 F	28.16 F	3.47 F	78.4 IJ	0.87 CD
I_4 x VC-2010	4.61 ABC	04.10 DEF	25.24 F	4.93 CDE	200.9 H	1.12 A
I_4 x King	4.08 BCD	01.59 F	25.06 F	4.26 EF	66.4 J	1.07 B
LSD	1.13	3.71	3.42	0.53	12.32	0.13

4 Conclusion

The present study revealed that mungbean could be successfully cultivated in a Saudi Arabian climate. However, deficit irrigation is a serious limiting factor. Mungbean biological yield, seed yield, shoot weight, plant height, harvest index and WUE were affected by the amount of irrigation. Although water deficit stress has hampered the yield and yield components of mungbean. However, the VC-2010 genotype has performed better under all irrigation levels and may be used for further research and varietal development programs.

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Effect estimation of stem density and LAI on the evapotranspiration rate from forest stand

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Abstract

The estimation model was constructed to estimate the evapotranspiration and canopy interception from the forest stand using the parameters showing the forest structure such as stem density, tree height and leaf area index. This model is expected to have the ability to estimate the effect of forest management such as stem thinning and leaf amount control. Comparing the calculated rate by this model and the observed rate in previous studies, the model can estimate the evapotranspiration and canopy interception. The effect of air temperature rise on the potential water resources was also estimated. Its decrease ratio was calculated to be around 11–13%.

Keywords: Penman–Monteith equation, roughness length, zero plane replacement.

1 Introduction

It has been one of the major topic in Japan to adapt the forest management such as stem thinning or leaf amount control for purpose of water resource management. It is said for strong dry season does not exist in Japan on the other hand, soil drought is usually not the limitation of transpiration in Japan. When soil drought limitation of the transpiration is not recognized, the amount of potential water resources defined to be annual precipitation minus annual evapotranspiration is used as the index of water resources for any forest stands (e.g. Sawano [1]). In this strategy, the estimation of evapotranspiration rate is very important to estimate the amount of potential water resources. Moreover, it is necessary to estimate the evapotranspiration using the parameters showing the forest structure such as stem density, tree height and leaf area index. If so, we

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can estimate the amount potential water resources for each forest stand, or predict the effect of forest management on the amount of water resources.

Some methods are proposed to estimate the evapotranspiration rate from the forest stands using the forest micro meteorological data (e.g. Monteith [2], Shuttleworth and Calder [3]). However, most of them do not use the parameters showing the forest structure such as stem density, tree height and leaf area index. Thus, it is difficult to estimate the changes of evapotranspiration rate by forest managements, such as stem thinning or leaf amount control in direct.

Among the parameters using in Penman–Monteith equation (Monteith [2]), roughness length and zero plane replacement show the exchange efficiency of vapor between forest canopy and atmosphere, and surface conductance shows the stomata openness. Nakai *et al.* [4] reported the dependency of roughness length and zero plane replacement on stem density and tree height. Moreover, Stewart [5] proposed the equation to estimate the surface conductance that surface conductance and leaf area index are in the proportional relation. As the feature of evapotranspiration phenomenon from forest stands, canopy interception process to evaporate the intercepted rain water from the canopy surface to the atmosphere is important (Mulder [6]). The calculated values with Penman–Monteith equation means the canopy interception when g_c is fixed to be infinity. Moreover, Teklehaimanot *et al.* [7] reported the equation to show the relation between canopy interception rate and stem density.

In this paper, the estimation model for evapotranspiration rate is constructed using the parameters of stem density, tree height and leaf are index, by connecting the previous studies. The constructed model can predict the change of evapotranspiration and potential water resources by forest management such as stem thinning and leaf amount control.

2 Model

Evapotranspiration is consisted with transpiration and canopy interception loss. When canopy is dry, trees transpirate through stomata. When canopy is wet with rain, water evaporates from the canopy surface to the atmosphere.

2.1 Transpiration

Transpiration rate was calculated using the Penman–Monteith equation as eqn (1) proposed by Monteith [2]:

$$\mathrm{lE} = \frac{\Delta \mathrm{R_e} + \rho \mathrm{C_p} \delta \mathrm{q}\, \mathrm{g_a}}{\Delta + \gamma (1 + \dfrac{g_a}{g_c})} \qquad (1)$$

where lE is the transpiration rate, R_e is the effective radiation, g_c is the surface conductance, g_a is the aerodynamic conductance, ρ is the air density, δq is the vapor pressure deficit, C_p is the specific heat of air at constant pressure, and Δ is the slope of the saturation vapor pressure at air temperature, γ is the psychrometric constant.

The value of g_a was obtained from eqn (2):

$$g_a = \frac{\kappa^2 u(z)}{\left(\ln \frac{z-d}{z_0}\right)^2} \tag{2}$$

where u(z) is the wind speed, z is the wind speed observation height, d is the zero plane replacement, z_0 is roughness length, and κ is the von Karman constant.

Eqns (3) and (4) is the approximation formula showing the dependency of z_0 and d, respectively, on stem density (d_s; stem ha^{-1}) and tree height (h; m), derived from the figures in Nakai *et al.* [4].

$$\frac{z_0}{h} = 0.2007 \exp(-0.0003 d_s - 0.0001) \tag{3}$$

$$\frac{d}{h} = 0.2327 \ln(d_s) - 1.1859 \tag{4}$$

Stewart [5] proposed the eqn (5) as following for surface conductance:

$$g_c = \alpha \, \mathrm{LAI} \, f(S) \, f(\delta q) \, f(T) \, f(\delta\theta) \tag{5}$$

where LAI is the leaf area index, S is the solar radiation, T is the air temperature, δθ is the soil moisture deficit, and f represents the functions of each of the environmental variables; α is a constant.

f(S), f(δq) and f(T) are used as eqns (6)–(8), respectively, proposed by Komatsu [8].

$$f(S) = \frac{1180S}{1000 + 180S} \tag{6}$$

$$f(\delta q) = \frac{EXP(-0.569\delta q)}{EXP(-0.569)} \tag{7}$$

$$f(T) = \frac{39(T-5)}{25(T+9)} \tag{8}$$

The unit of S, δq and T in these equations are W m^{-2}, kPa and °C, respectively.

As strong dry season does not exist in Japan, soil drought is usually not the limitation of transpiration in Japan. Thus, f (δθ) is fixed to be 1 in this paper. α is also fixed to be 12.36 in this paper.

2.2 Canopy interception

The calculated rate by eqn (1) with g_c to be infinity can be regarded as canopy interception (lE_i). On the other hand, Teklehaimanot *et al.* [7] reported the relations between dens and lE_i as eqn (9).

$$lE_i = \frac{8.6 \times 0.026 d_s}{8.6 + 0.026 d_s} \tag{9}$$

Combined with both, potential rate of lE_i was calculated with eqn (10) in this study.

$$lE_i = \frac{\Delta(R_n - G) + \rho C_p \delta q \, g_a}{\Delta + \gamma} \frac{8.6 \times 0.026 d_s}{8.6 + 0.026 d_s} \tag{10}$$

However, larger water than precipitation (P) cannot be intercepted by canopy, lE_i rate was judged to be equal to P, when calculated potential rate of lE_i was larger than P in a calculation unit time.

2.3 Calculation method

The necessary data to calculation are precipitation, effective radiation, solar radiation, air temperature, vapor pressure deficit and wind speed as weather condition, and stem density, tree height and leaf area index as forest stand situation.

The model was constructed for stem density and leaf area index to be input individually, to estimate the effect by forest management such as stem thinning and leaf amount control. However, this paper focuses on the model construction and their calculation ability, not on the effect estimation of forest management. Thus the relation between stem density and leaf area index was settled as Figure 1 in this study. H is also fixed to be 12.6m in this paper. Thus evapotranspiration was defined to be the amount of vapor passing up through the 14.6m height plane from forest canopy to atmosphere.

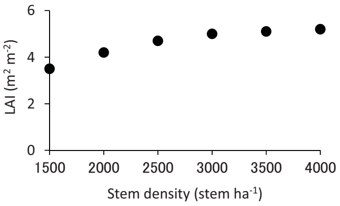

Figure 1: The values of stem density and Leaf Area Index (LAI) used in the model calculation.

3 Site description and observation method

The weather condition hourly data was observed in the Main weather station of Takaragawa Forest Watershed Experimental Station located in central Japan (36° 51' N, 139° 01' E, ASL 861m) in May–October 2011 to be no snow period. The amount of precipitation was 1,267.0 mm in this period. Figure 2 shows their monthly averaged or integrated values. The observation height of sensors are 6.5m for wind speed, 5.59m for net radiation and solar radiation, and 4.82m for air temperature and relative humidity.

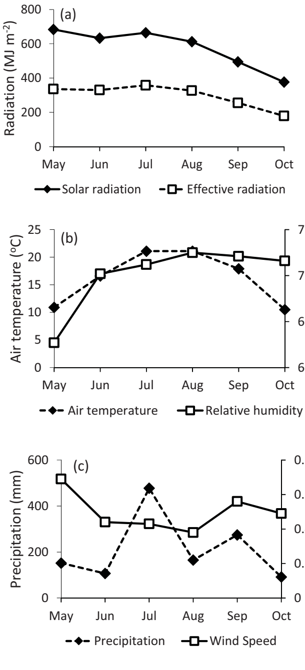

Figure 2: Average or integrate monthly weather data used in the model calculation observed in Takaragawa Forest Watershed Experimental Station in May–October, 2011. (a) Integrated monthly solar radiation and effective radiation, (b) Average monthly air temperature and relative humidity, (c) Integrate precipitation and average wind speed.

Additionally, the change of lE and potential water resources were estimated in this paper with the vertical air temperature by the global warming effect. The vertical air temperature was 4°C higher than T observed in Takaragawa in each hour. The value of relative humidity was not changed. However raised air

temperature cause to increase the value of VPD in calculation. The raised temperature to be 4°C derived from the A1F1 scenario of global warming.

4 Results and discussions

4.1 The rates of evapotranspiration and canopy interception

The evapotranspiration and rainfall interception between May and October are calculated to be 480–580mm and 210–220mm, respectively, in the range of stem density to be 1500–4000 number ha^{-1} (Figures 3 and 4). As the amount of P was 1267.0mm in this period, percentages of the lE and lE_i over P were around 38–46% and 17%, respectively. These values and percentages are compared with the previous studies derived from the observation of lE and lEi between May and October in Japanese forest.

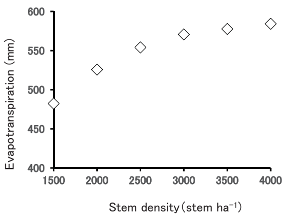

Figure 3: Calculated evapotranspiration in each stem density.

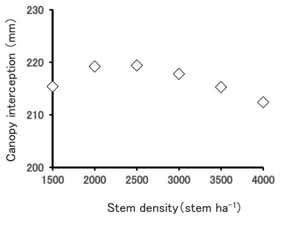

Figure 4: Calculated canopy interception in each stem density.

Kiryu Catchment (34° 58’ N, 136° 0’ E, ASL 190–255m, Area 5.99 ha) is covered with evergreen coniferous forest consisted with Japanese red pine (*Pinus densiflora* SIEB, et ZUCC) and Japanese cypress (*Chamaecyparis obtuse* SIEB et ZUCC). Suzuki [9] reported the rates of lE derived from the method of the short time period water budget using observed precipitation and discharge water volume from the catchment, and lE_i derived from the tank model. Tank model is consisted with tanks corresponding to canopy and stem of trees. From the balance of each tanks based on the observed P, lE_i was estimated. Summing the average monthly rates between May and October, 1972–1976 reported by Suzuki [9], lE, lE_i and P were 514.0mm, 199.2mm and 1,185.0mm, respectively. Percentages of the lE and lE_i over P were around 43% and 17%, respectively.

Yamashiro Catchment (34° 47’ N, 135° 51’ E, ASL 190–260m, Area 1.6 ha) is covered with secondary deciduous broad leaved forest. Most dominant species is oak (*Quercus serrata* Thunb. Ex Murray). Abe *et al.* [10] reported the monthly rates of lE derived from the method of the short time period water budget, and lE_i derived from the difference between observed P and observed precipitation on the forest floor. Summing the monthly rates between May and October, 1989 reported by Abe *et al.* [10], lE, lE_i and P were 564.0mm, 139.6mm and 1,181.0mm, respectively. Percentages of the lE and lE_i over P were around 48% and 12%, respectively.

The calculated rates by the model constructed in this paper are almost equal to those reported by Suzuki [9] and Abe *et al.* [10]. Thus it can be judged that the model have the ability to estimate the lE and lE_i properly.

4.2 Changes of evapotranspiration and canopy interception by forest management

Next, the differences of lE and lE_i among the different d_s are compared with the previous reports by Kubota *et al.* [11] and Nobuhiro *et al.* [12]. Hitach Ohta Experimental Watershed (36° 34’ N, 140° 35’ E, ASL 310–340m Area 0.88 ha) is covered with Japanese ceder (*Cryptomeria japonica*). The stem thinning was performed in 2009 from 2,229 stem ha^{-1} to 1,113 stem ha^{-1}. Kubota *et al.* [11] and Nobuhiro *et al.* [12] reported the changes of lE and lE_i, respectively, before and after stem thinning.

Kubota *et al.* [11] estimated lE before and after stem thinning derived from the water budget and paired catchment experiment and reported that lE after thinning was reduced to around 80% of before thinning. The calculated lE by the model were 554.0mm and 482.3mm at 2,500 stem ha^{-1} and 1,500 stem ha^{-1}, respectively. The latter is around 87% of the former. The decreased percentage calculated in the model is less than that in Kubota *et al.* [11] derived from the observation.

On the other hand, Nobuhiro *et al.* [12] reported that the percentage of through fall over the precipitation increased from 70–75% before thinning to 80–90% after thinning. Rain water reaches to a forest floor by 2 ways, through fall (pass through between the canopy) and stem flow (run down on the stem). In general, the volume of through fall is much more than stem flow. For example, Abe *et al.* [10] reported the percentages of through fall and stem flow over the precipitation to be 80% and 7%, respectively, in Yamashiro catchment. Under the assumption that stem flow can be ignored, the report by Nobuhiro *et al.* [12] can be interpreted that the percentage of lE_i over P decreased from 25–30% before thinning to 10–20% after thinning. The calculated lE_i by the model were 219.4mm and 215.4mm at 2,500 stem ha^{-1} and 1,500 stem ha^{-1}, respectively. The percentages of lE_i over P were around 17% in both d_s, much less than that reported by Nobuhiro *et al.* [12] derived from the observation. Thus, it is judged that the model constructed in this paper has to be improved to estimate the change of canopy interception.

4.3 Effect of global warming on evapotranspiration and potential water resources

Figure 5 shows the increase rate of lE calculated by the model due to that T in Takaragawa rises 4°C in observed weather data in Takaragawa. In the range of d_s to be 1,500–2,000 stem ha^{-1}, the increased rate of lE was around 72–83mm in May–October, 2011 caused that T rises 4°C.

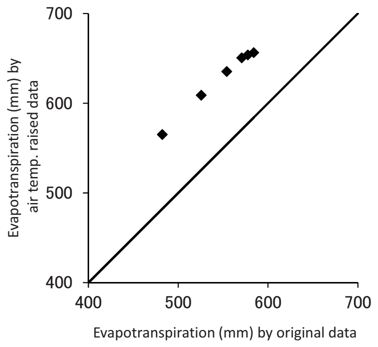

Figure 5: Comparison of evapotranspiration rate calculated with the original weather data and 4°C raised air temperature data. Solid line shows that both rates are equal.

The potential water resources is defined to be the difference between P and lE. Thus the increase of lE leads the decrease of potential water resources. In the present situation using the original observed weather data in Takaragawa, potential water resources are estimated to be around 615–715mm. In case using the warming weather data that T rises 4°C, potential water resources decreased to be around 540–630mm (Figure 6). The decreased ratio was calculated to be around 11–13%.

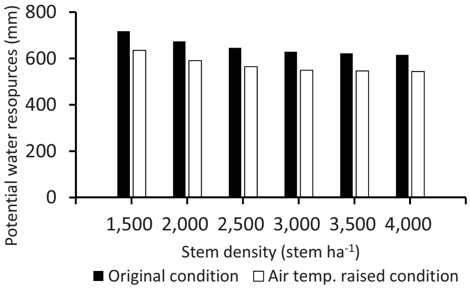

Figure 6: Comparison of potential water resources in case of original condition and raised air temperature condition.

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Section 5
Sustainable development and planning

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Hyper planning and the construction bubble on the northern coast of the Valencian countryside (or how the unwarranted scenarios of planning have contributed to the present urban disaster)

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Abstract

The northern coast of Valencia, previously left out of the development of mass tourism, hoped to join the manna that had arrived with the construction boom of 1996 to 2007 in Spain. Along with the desire to overcome the hurdle of seasonality, the construction, which has become known as Golf Resorts, began to take place. We will study the role played by what is called "hyper planning" (extremely oversized proposals) and the role of Public Administration in giving support to those operations in order to explain why none of them has successfully been finished.

Keywords: construction bubble, planning, golf resorts, ecological impact, scarce resources.

1 Introduction: the cycle of construction hyper-production

From 1996 an unparalleled construction bubble was unleashed in the Spanish State only to abruptly burst in 2007 with the mortgage *subprime* crisis. Although the focus of this paper is not to analyse the causes of this phenomenon, on which there is abundant analysis, [1], we must indicate briefly that this emergence was made possible through the combination of very diverse reasons: economic, social, political, policy, including the hypertrophy of the construction sector itself, and especially the availability of cheap and abundant funding. However, few studies have considered the role played by urban planning with their oversized proposals. The aim of this present work is to highlight the contribution of urban planning to the real estate *tsunami* of the northern coast of Valencia. In particular we will study

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a specific type of development known as *Golf Resorts,* a combination of a golf course and a residential area of high density. These operations have an impact on those semiarid and very vulnerable lands that we cannot afford.

2 The last frontier, the northern coast of Valencia: Orange Blossom Coast

The northern coast of Valencia comprises 16 municipalities with just 378,000 registered inhabitants (2011), of which almost half live in the capital of "administrative province", a sparsely populated region with a low density (91.1 inhabitants/km^2), whose coast (161.7 km. out of a total of 644) is also the least urbanized [2]. This area has remained outside the phenomenon of European mass tourism. The only exception is that of Benicàssim, a destination mostly occupied by domestic and even local tourism.

To overcome this situation of stunted development, the label "*Costa del Azahar"*, The Orange Blossom Coast, was launched. However, its impact has been very limited, despite the fact that out of the 16 coastal municipalities all but La Llosa (the smallest one with just 951 inhabitants) were declared *"Tourist Towns"* [3]. We will not examine the reasons for this backwardness, but we must emphasize that until the outbreak of the housing bubble this area had a sagging tourism development. With the construction boom, it seemed that its hour had finally arrived, but the proposals made for this last frontier can only be described as excessive, a sample of hyper-planning: *"Regardless of the political colour of the municipalities, from south to north, different companies have presented PAI* (the legal instrument equivalent to detailed plan) *to develop between 35 and 40 million square meters, with the construction of 12 new golf courses in addition to the three existing ones, and that will entail the construction of 40,000 new homes. Environmental experts have warned about the impact of these projects"* [4].

2.1 Golf as an alternative to the problem of seasonality of tourism

In Valencia, as in the whole Spanish State, tourism is a central economic activity. To give an idea and summarily illustrate its importance, in 2012 it accounted for 10.9% of GDP and employing 11.9% of the workforce [5]. Yet it has a serious and unsolved problem: seasonality, linked to what is known as the "sun and beach" tourism. This dominant model coexists with others: inland, nature, congress and tourism, but they represent a small minority. To try to overcome the problem of seasonality, one alternative has been proposed: to promote golf. In the *"prodigious decade"* golf was presented as the ultimate solution, to avoid seasonality and combine tourism with the real estate boom: tourism, golf and brick all together. This proliferation of project of golf courses, always combined with a residential area, formed this typology and is identified as the Golf Resort.

2.2 Golf on Mediterranean, semi-arid climate

Golf is not a suitable sport for an ecosystem such as the Mediterranean one, a semi-arid coastal territory, with annual average rainfall that was in 2003 of 388 mm. [6]. To have a comparative idea, we must point out that the Cantabrian coastline exceeds 2,000 mm annually [7] and in what we could identify as the "European Golf" territory, is at least twice [8].

Water is the great handicap for golf in an environment such as the Mediterranean seaside, where it is a scarce resource. This sport requires conditions that do not exist in an ecosystem such as the Valencia coast. Its huge areas of prairies are conditioned by a critical factor: irrigation. How much water does a golf course situated in northern coast of Valencia needs? The estimates vary considerably. "*Ecologists in Action"* estimates an average annual consumption of 10,000 m3/hectare, the equivalent of a town of 8,000 inhabitants [9]. WWF/ADENA increases it to 12,000, while Greenpeace raises it to 15,000. The total consumption of the 380 existing golf courses in the whole State in 2013 would stand for 14 million m^3, i.e. the equivalent need of a population of 4 million people [10]. Along with the pressure on water resources, there exists other equally not negligible impacts on the construction of a golf course: the occupation of between 60 and 100 hectares (for an 18 holes course), the removal all the original vegetation (shrub, tree and herbaceous) after application of a plough of about 30 cm deep and the introduction of alien species; the strong impact on the fauna, flora, landscape, soil, runoff; the loss of biological connectors and corridors between natural areas; groundwater contamination; human pressure coming from increased traffic, noise; the massive use of pesticides and fertilizers. Without ignoring that despite what is stated by law, the use of treated water for irrigation instead of recycled sewage waters is widespread. A sport that has been justified by reclaiming the breaking of seasonality problem, the generation of revenues from elite tourism, but as it has been proved, the golf itself is not profitable; to make it economically viable it has been invariably accompanied by a real estate development: the Golf Resort [11].

2.3 Golf Resorts on the prodigious decade

Throughout Valencia there are in currently a total of 36 golf courses in operation, of which only three are in the northern region. All three were developed before the last real estate boom; the oldest one is the *Club de Golf Costa Azahar*. It opened in 1960, an almost urban club, just 6 km away from the centre of Castelló. It is a small course with nine holes, intended for a local user, nothing to compete with the Golf Resort model. For foreign tourism and as an integrated Golf Resort, only the *Panorama Sant Jordi Golf* can be taken into account, opened in 1995, with 18 holes (80 hectares) it was designed by Bernhard Langer. Situated in between is the *Club de Campo Mediterráneo* Golf in Borriol with 18 holes, dating from 1978.

But when the building frenzy broke out, projects for Golf Resorts arose everywhere. The Association of Golf Courses of Castelló added to the other five to the existing three on the project: the Benicàssim Golf (to be opened in 2008–2009), the Doña Blanca Golf (2008–2009), Sant Gregori (2008–2009), Xilxes

Golf (2009–2010) and finally the Marina d'Or Golf with undated scheduled inauguration. Not one of these projects has been successfully completed.

2.4 Stages in the process of construction or space n build

Since the passing of the Urban Activity Regulatory Law (LRAU) in 1994, all development plans of a certain magnitude must be carried out by processing an instrument called PAI (Integrated Action Program). In its processing four stages can be distinguished: planning, management, urbanization and building. The first one just requires the approval of planning documents, but does not involve any physical transformation of the ground, nor of the legal structure of land ownership. In the management phase (usually by rearranging plots, or by expropriation) there are changes in the legal structure of the allotments, although no physical alteration of the land. In the third one, with the implementation of the development, physical reality is altered, soil, landscape are transformed. The result of this process is to obtain plots that are now legally available for building. In the last one, the physical process of constructing the resort community is concluded with the building under the conditions established in the plan. This distinction in stages is extremely important from both an economic and a legal point of view. The first two (planning and management) require minimal investment from developers, making sense to the fact that they are eager to push through these plans even in circumstances of crisis, because they may consolidate rights so that their initiatives acquire a certain degree of legal irreversibility. The turning point from an economic point of view comes with works of urbanization. There the promoter must make investments that by far exceed those required at the "paper" stages of this phase. As we will see, this is where projects are stalled when confronted with a depressed economic cycle.

3 Study cases

3.1 Golf Sant Gregori (Borriana): do not count your chickens before they are hatched

The plan for Golf Sant Gregori in Borriana covers a total area of 255 hectares, which includes a golf course of 73 hectares, a future extension to another one (Sant Gregori II), a residential resort with 6,000 homes and a marina (Santa Barbara), affecting some 30 hectares. This land is protected in the EU Natura 2000 Network, from the mouth of the Millars River to the natural spot of the *Clot de la Mare de Deu.* It is a disproportionate, excessive project, with an initial budget 105 million euros [12].

Although in 2000 the initial proposals had already been submitted, we can consider that the project actually begins on the 17th of January 2005 with the approval of the plan for the area (Sector SUR-T-1) and with the simultaneous granting of the concession to urbanize to the company "Gestión y Construcción de Obras Públicas", despite the fact that in October that corporation did transfers its rights to another one, "Urbanización Golf Sant Gregori", a pool of the largest local

construction enterprises (GyC, Ballester and Lubasa). In late 2006 the urban plan had already been approved. Everything was ready for the launching of the works, and in fact in 2007, a promotional video painted a picture without any shadow of doubt; idyllic, a reliable business, a scenario of progress and social welfare [13]. But coinciding with the bursting of the construction bubble procedures underwent an abrupt stop. Until 2010 the rearranging of plots into a new land subdivision will be not resolved, to be finally enrolled in Public Register the following year, in an atmosphere of unbridled euphoria, fed from official sources, with forceful statements such as that *"this new thrust to the Sant Gregori PAI places Borriana, along with Torreblanca Doña Blanca Golf PAI, at the forefront of the development of large residential and tourist projects in the province of Castellon. Only two PAI are currently following their normal processing and are in such an advanced point*" [14].

But the reality was quite different, and in early 2012 some owners, mainly minority shareholders, claiming the context of crisis, requested the temporary suspension of the project [15]. Seizures began for those who could not face the first instalment of urbanization works, and even the City Council having difficulties to meet that payment was forced to put for sale two of its plots [16]. Nevertheless, Bankia who had become the main partner through having to foreclose on the part of the developer (Golf Sant Gregori SA) continues in September 2012 to publicly express their willingness to maintain and continue the project. This is quite a surprising standing since the same entity had withdrawn simultaneously from other, the Doña Blanca Golf de Torreblanca, in which it was also involved [17]. Useless statements that do not prevent that in mid-2014 difficulties could be concealed and that the bank, nationalized and bailed since May 2012, and owning nearly 69% of the shares of the project, formalized before the City Council a request for suspension of two years for the operation, and the return or reduction of the guarantee, even though the latter appeal was denied [18].

Why did the project stop and fail? There are a variety of reasons: financial difficulties, the bursting of the housing bubble, its slow processing, and a late start in 2005. It should be highlighted that the role played by civic and social opposition, especially from ecologists groups. Indeed the project occupies a very sensitive and valuable area from an ecological point of view (from *El Clot de la Mare de Deu* the mouth of the Millars). In view of the failure of the operation, the environmental association GECEN *(Grup per a l'Estudi i Conservació dels Espais Naturals)* requests on the 17th of May 2014 to disqualify the area as developable land and its regeneration [19]. But, against all odds, the municipal government, adopting a stubborn attitude did not withdraw the initiative. And that's it; today the project has no viability at all. In the meantime, the search for new international investors, *"Two investment groups interested in Golf Sant Gregori*" [20] groups which finally did not appear, and after twelve years of negotiation, the 27th of December 2012, the majority shareholder (Bankia) transferred the ownership and the management of the operation to SAREB [21], widely and better known as the "Bad Bank". SAREB (Acronym in Castilian for Management Company for Assets Arising from the Banking Sector Reorganisation) is a joint company, public (45%) – private (55%), founded in November 2012, during the bailing of financial

institutions, in order to help clean-up the Spanish banking sector and, more specifically, the banks with problems due to their over exposure to the real estate sector. SAREB has finally received the so called "toxic" real estate assets, without any chance in normal market. Financial institutions that had assumed them as a result of foreclosures transfer them to the SAREB who proceeds to its liquidation, avoiding bankruptcy of the former banks, but assuming losses which funded at 45% from by public budgets. This move was a foretaste of its inevitable liquidation, in which again losses will be largely assumed by a public entity, as well as the original minority landowners who embarked on a speculative venture doomed to failure. End to a chimera that should never have risen.

3.2 Doña Blanca Golf (Torreblanca): the milkmaid and her pail

The project to build a resort with golf course in the municipality of Torreblanca, known and advertised as "Doña Blanca Golf" administratively starts on the 16th of May 2003 with the approval of a Plan that covers the sectors IV, VII, VIII, IX and X, and the grant of the concession to urbanize to the company "Urbanizadora Torremar SA." We are dealing with a macro project for a municipality whose population in that year was only of 5,238 inhabitants, and where according to the 2001 Census there were 3,679 dwellings (1,802 primaries, 1,222 secondary and 616 empty ones). The figures speak for themselves in their excesses: a total of 191 hectares located on the coast, invading again land of high ecological value, with the inevitable golf 60 hectares (described as the "green lung") and 4,319 homes (245 single family homes, 106 bungalows and 3936 apartments) plus 3 hotels, shopping malls, sports facilities and green areas, with an initial budget that exceeded 52 million euros [22].

To ease the processing, and thus give a better legal coverage, all political parties unanimously approved a new Master Plan in 2009 [23]. With the housing bubble already burst, a significant and revealing fact of social consensus that such operations got in the middle of the brick fever even afterwards. Against all logic, the chimera did continue, supported by the Provincial Government who generously funded in February 2011 a stand at the MIPIM, Cannes real estate fair, seeking international investors [24]. Its President had to recognize and affirm that if *there are no investors who can promote our projects we have to go and look for them wherever they are.* Simultaneously, in an exercise of foolishness extolled to the press continued to maintain that *if all deadlines are accomplished, before the end of this year the machines could start to work (...) Torreblanca strengthens its commitment to implementation of this flagship project that also would be the first to be built in the province since 1995, when a golf course opened Sant Jordi.* In September 2011 the deadline for submission of applications to execute the works of urbanization was opened [25] and in June 2012 the work is awarded to a joint venture company made up by Renos and Pavasal [26]. But just three months after the developer controlled now by Bankia (who, as in the case of Sant Gregori, again had to seize and substitute the original developer) requested suspension for two years [27]. To enmesh even more all the process, in May 2013 the City Government had to cancel the concession of the works when the existence of commercial links between the developer and the builder were proved, something that prohibited by law [28].

At all costs and against all logic, the Torremar developer (with now Bankia acting as the majority shareholder) tried to pressure the City Council to continue backing the operation, but finally it was the concessionaire itself who in February 2014 did notify to the municipal government its willingness to abandon the project [29], including a bizarre proposal to let the local authorities themselves becomes the developer, and run the project [30]. But it was not a toll free proposal, an act of atonement for the excesses committed, but rather of a poisoned present, since the assignment included a clause by which the company recovered the deposit of over 8 million euros that for legal reasons had been previously deposited [31]. Forced by circumstances, the City Council in July 2014 cancelled the concession [32]. And again the story is over: the project stalled, the concession annulled, while environmental groups claim the cancellation of the whole project [33], and the owners, both Bankia and the small landowners facing losses from a grandiose project that should never have been started. This retells the story of milkmaid: the jar is broken and the milk poured.

3.3 Marina d'Or Golf: the bigger they come, the harder they fall

The project for Marina d'Or Golf, also known as Mundo Ilusión (World Illusion), is the most ambitious of all Golf Resort that have arisen in Valencia, pure hubris: no less than 1800 hectares, 7 large themed hotels (400–660 bedrooms), 3 golf courses (one designed by Greg Norman, another by Sergio Garcia and a 9-hole golf school course), shopping areas, dining and entertainment, the largest spa in Europe, a ski track, an artificial beach, all set to recreate different parts of the world; in short 55,806 hotel rooms and 33,000 tourist homes. A "Holiday City", as its promoters have labelled, for 220,000 inhabitants, which would make it the fourth largest city in Valencia. Everything begins in the eighties when his promoter, Jesus Ger, finds one of the few pieces of unspoilt coastline left in the northern counties, and develops some small real estate operation, a prelude of things to come after the construction boom. The existing resort of Marina d'Or consists of five hotels, about 15,000 apartments, holiday parks, a spa, over twenty restaurants, themed events built north of the town of Orpesa, on the beach on a strip less than a mile wide between the railway coast and the coast, land that was considered as developable in the eighties. A preview of what was going to be Mundo Ilusión, sharing the same strategy: to overcome seasonality, the Achilles heel of the sun and beach tourism, by means of a wide range of leisure offer (spas, golf, skiing, and theme parks).

This mega-operation overflows the municipal boundaries of Orpesa extending into the adjacent Cabanes. From an Administrative point of view the Plan (PAI) began in 2005, but its final approval by the Autonomous Government of Valencia did not come until April 2010, amid numerous social and legal disputes, and various delays. Late and ephemeral approval resulting from the housing and economic crisis took its toll on the group. Soon after, in May 2011, the developer was declared insolvent and the entire operation paralyzed. But unlike the two previous golf resorts, this initiative has not finished in the hands of a financial

entity or transferred to SAREB and is now in a kind of frozen state, a latent or dormant threat.

4 By way of conclusion: a house of cards

Not a single Golf Resort proposed in the northern regions of Valencia has been completed. Throughout the text we have seen the reasons for those failures. We shall now highlight the costs and impacts of these failed endeavours.

The ecological impact. The Golf Resorts reflect an unsustainable pattern of consumption of resources (especially water), an unfeasible option, unnecessary, with unacceptable environmental costs.

Urban planning, far from protecting and preserving the environment, the landscape and the territory has contributed, in no small measure, to feed the construction bubble, being largely responsible for what happened, and its own discredit (the so-called *wild Urbanism)*

Political costs: Public Administration has been serving the interests and preferences of the promoters *(Urbanism à la carte)* forgetting and ignoring its main mission: to improve the lives of citizens.

Economic costs: a large proportion of failed projects have ended up in the hands of the SAREB. This implies that they will be sold off or liquidated at public expenses, but economic losses not only affect the Public Administration, or the construction companies. They have also cause harm to many smallholders who were dragged to a non-existing "Dorado."

Future strategies: local councils (and a part of the society that supports them) seem not to have learned the lesson, and they continue to bet on what we call the boa strategy; wait and see, until digestion occurs, until the huge stock of buildings and urbanized land is sold, to resume business as usual. Absurd and disproportionate projects, guided by the myth of growth are nowadays simply frozen, waiting for better times, but have not been formally abandoned, cancelled for good, forever and ever.

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The role of landscape aesthetics in the total economic value of landscape: a case study of Albufera Natural Park

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Abstract

Aesthetic enjoyment can be considered as part of the Total Economic Value (TEV) of landscape. The main purpose of this study is to estimate the relative importance of landscape aesthetics in the full value of Albufera Natural Park (Valencia, Spain). The Analytic Multicriteria Valuation Method (AMUVAM) is applied with the aid of a set of experts that include local and external stakeholders. AMUVAM is a combination of two established techniques: analytic hierarchy process (AHP) and discount cash flow (DCF). According to the experts, existence (EV) and bequest values (BV) are the most important in this landscape, followed by indirect use values (IUV). Aesthetic enjoyment (AE) represents 7% of the TEV in Albufera Natural Park and 24% of the EV in Albufera Natural Park (€176 million). Results reveal distinct patterns in the valuation of TEV and EV. In this way, together with the average, a range of values which shows the different sensitivities of society is provided.

Keywords: analytical hierarchy process, economic value, landscape valuation, multi-criteria decision making, wetland.

1 Introduction

Landscapes can be viewed as spatial human–ecological systems that perform a wide variety of functions that are, or can be, valued by humans for economic (productive), sociocultural, and ecological reasons (Termorshuizen and Opdam

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[1]). While most of these benefits are not captured in conventional market-based economic analysis (de Groot [2]), it is nevertheless important to have an assessment of the monetary values of the full set of goods and services provided by landscapes. This paper focuses on the valuation of landscape aesthetics, as a component of the Total Economic Value (TEV) of landscape.

With regard to the economic valuation of aesthetic quality, a field that began in the 1970s (Price [3]), the most frequently used methods are revealed preference and stated preference (Oueslati and Salanié [4]). Revealed preference techniques are based on people's actual behaviour in real markets, in relation to the consumption of particular goods (e.g. Kong *et al.* [5]). The focus of these methods is to estimate the economic value of landscapes at a certain moment, in order to provide information to policy makers to justify preservation or allocation of resources. The second category, stated preference methods, focuses on change involving both negative (e.g. Price [6]) and positive (e.g. Hynes *et al.* [7]) impacts on landscape. Such methods assume that there is no related market for landscapes, but that a hypothetical market can be constructed. Unlike revealed preference, stated preference methods include non-use values and are addressed to changes in valuations of landscapes, rather than to the valuation of landscape "*per se*" (Moran [8]).

Concerning the natural resources management point of view, not only is important to know the absolute value of a certain service (e.g. aesthetic enjoyment) but also to consider all the benefits provided by a certain landscape and their relative importance. While the first issue is tackled by the methods described above, the second is not. This knowledge can help decision makers in two ways: on the one hand, to define the objectives of public interventions and resource allocations; on the other hand, to inform and make people aware of the values of various benefits provided by a landscape.

In this way, the focus of this work is on the relative importance of landscape aesthetics in the full value of Albufera Natural Park (Valencia). For this purpose, a method different from the ones cited above is applied. This method has been used in the economic valuation of environmental assets such as Pego-Oliva Wetland (Aznar *et al.* [9]). Nevertheless, its application to the valuation of aesthetic enjoyment is new. The way AMUVAM tackles the problem of valuation differs from that of the most commonly used methods of landscape valuation. Economic value of non-market benefits under AMUVAM is obtained indirectly, by comparing the relative degrees of importance ascribed to different types of landscape values. Respondents are asked to state the importance of each of the components of the Total Economic Value (TEV) by comparing them by pairs, considering aesthetic enjoyment as part of the TEV.

2 Methods

Based on multi-criteria analytical techniques, AMUVAM enables to determine TEV, the relative values of components of TEV and the relationship between values that lack an associated market (and hence a market price) and values that do have a market price.

In AMUVAM, it is assumed that the known value of some of the components of TEV may be used to derive the values of the remaining components, such as the aesthetic value. Hence, it allows to assess (i) the relative importance and (ii) the monetary values of all the components of the TEV (direct (DUV), indirect (IUV), option/quasi-option (OV), existence (EV) and bequest values (BV)) and the disaggregated values within these components.

Two techniques are involved in AMUVAM: the analytic hierarchy process (AHP) and discount cash flow analysis (DCF). AHP, the method developed by Saaty [10] which has been broadly used in different fields (e.g. Chow and Sadler [11]), is implemented to obtain the relative weights of the TEV components, while DCF (IVSC [12]) is used to determine the economic values of the services associated with direct use (DUV).

The aesthetic value of a landscape may be considered one of the values that comprise its TEV. Although this aspect of a landscape's value may be conceived as a use value rather than a non-use value (Swanwick *et al.* [23]), in this work, following previous authors (e.g. Costanza *et al.* [13]; de Groot *et al.* [14]), aesthetic enjoyment is viewed as an existence value.

2.1 Site description

The current work was developed in the Albufera de Valencia wetland. This wetlands area, of 21,000 hectares, located in eastern Spain, 10 km from the city of Valencia, has been included in the RAMSAR Convention since 1990 and in the SPAs since 1991 and is protected under the designation of Natural Park. Moreover, due to its natural, cultural and aesthetic value, it has become a source of identity for the population of Valencia (Sanchis [15]).

Three main ecosystems compose Albufera de Valencia: the lake, the marshland and the sandbar. The name Albufera originates from the Arab term al-Buhayra (small sea), which references the lake that is the central element of this landscape. This lake originated from an ancient gulf that became enclosed as a result of sediments that were deposited into it from two rivers (Turia and Jucar River), forming a sandbar that separated the lake from the sea. The extent of the lake has changed over time, due to the development of agriculture, especially rice, which was introduced into the area in the 18th century. Today, the surface of the lake is approximately 2,800 hectares.

2.2 Definition of the TEV components

According to Barbier [16], the value of a wetland is derived from its assets, flows and attributes. Assets, also called products, goods or stocks, are those components which are directly exploitable by humans and provide an economic benefit. Flows or services refer to the ways in which ecosystem processes contribute to human well-being. They usually refer to environmental regulating services (flood control, erosion prevention …), but also to recreational and cultural benefits derived from nature. Hence they involve material and immaterial benefits for humans. Nowadays, both goods and services are included under the umbrella of ecosystem services (MEA [17]). With regard, to the third concept, attribute, it refers to those components of a wetland that have value because they induce certain economic uses or they have value in themselves (e-g. biodiversity, cultural heritage). Taking into account these components of a wetland value, Barbier [16] proposed the concept of TEV, which distinguishes between use and non-use values. The TEV components and their associated goods, services and attributes for the case study of Albufera Natural Park (Table 1) were based on previous work on economic valuation of wetlands, on the study area and on the discussion with experts (Gómez-Limón and Arriaza [18]) that would also take part in the weight assignment stage (Section 2.3).

Table 1: Components of Total Economic Value in Albufera of Valencia. DUV: direct use values; IUV: indirect use values; OV: option, quasi-option values; BV: bequest values; EV: existence values.

VALUES	ACTIVITIES AND/OR FUNCTIONS
DUV	Rice, hunting, fishing
IUV	Support of other ecosystems, flood control, coastal stabilisation, groundwater recharge, retention of nutrients, recreation
OV	Possible future uses (direct and indirect); value of information in the future
EV	Biodiversity; cultural heritage; aesthetic enjoyment
BV	Bequest value

2.3 Weight assignment of TEV components by experts

In this step, AHP (Saaty [10]) is implemented in order to obtain the relative weights of TEV components and EV components from a group of experts. They must have a deep knowledge of the area and represent the different points of view on the wetland.

Experts weight components at two levels (Figure 1). They start weighing TEV components (level 1) and then, they weigh EV components (level 2). The survey starts with a brief explanation of the goal of the work and the meaning of the different types of values. Then, experts are asked to compare TEV and EV components by pairs. This comparison is implemented in two steps. First, they decide which of the two components the most important is. The question posed to the participants is the following: *of the two values being compared, which is considered more important by society with respect to the overall value of Albufera Natural Park?* Second, they express the intensity of importance, using the scale of comparisons shown in Table 2. According to how close are the elements compared in importance, one can use the different values of the fundamental scale.

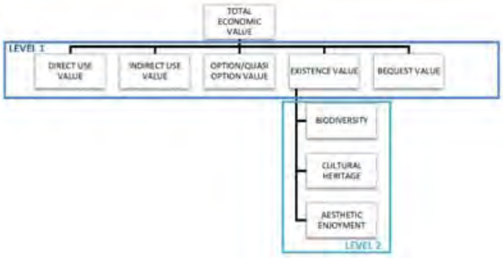

Figure 1: Diagram showing TEV and EV components compared in the survey.

Table 2: The fundamental scale for pairwise comparisons. Source: Saaty [10].

NUMERIC SCALE	DEFINITION	EXPLANATION
1	Equal importance	Two elements contribute equally to the property or criterion
3	Moderate importance	Experience and judgment slightly favour one element over another
5	Strong importance	Experience and judgment strongly favour one element over another
7	Very strong importance	Experience and judgment very strongly favour one element over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation

Their answers are used to obtain the comparison matrices. There are as many matrices as consulted stakeholders. The consistency ratios (CR) are then verified, and eigenvalues are calculated. Finally, the geometric mean of the eigenvalues is calculated (Saaty [10]) to obtain the weights of the various TEV and EV components.

For this study, the set of experts included local and external stakeholders representing the key topics of the area, in terms of exploitation and conservation of natural resources. Experts were representatives of: Albufera Technical Office, in charge of the Natural Park management, Valencia Regional Agricultural department, Valencia Regional Environmental departments related to natural environment and landscape sections, farmer trade associations, irrigation community, fishing community, rice cooperatives, ecologist associations and university lecturers specialised in landscape planning, botanic and phitotecnics.

In this study, TEV weights were derived from the responses of 43 experts conducted during two surveys, a previous one in 2005 (25 experts) and another in 2012 (18 experts). EV weights were obtained from the 18 experts consulted in 2012. The incorporation of the data obtained in a previous study in 2005 allowed the comparison the values of TEV components.

2.4 Calculation of the pivot value

This stage aims to obtain the economic value, called the pivot, of a TEV component. The DUV is usually the pivot because it associates economic functions with market values. The pivot value is based on both present and future revenues derived from the exploitation of these resources. DCF is a method of valuation based on the revenues an asset generates over a period of time (IVSC [12]).

This method assumes that the economic value of an asset corresponds to the present value of the sum of the future revenues derived from this asset. In this way, the present value of future expected net cash flows is calculated using a discount rate which converts a future monetary sum into present value. In this case, the pivot value is derived from rice, hunting and fishing activities. First, the annual revenues derived from the incomes and expenditures of these three activities are calculated. Then, following Evans [19], this cash flow is updated applying a 3% tax (Eq. 1).

$$DUV\ value = \frac{Cash\ flow\ of\ the\ services\ provided\ by\ DUV}{Discount\ rate} \tag{1}$$

2.5 Calculation of the TEV and its related components

The hypothesis behind the TEV as the sum of its partial components is implicit in this stage. Since the TEV is not considered a market value, but an indicator of the value of an environmental asset, the sum of its partial values may be seen as an estimate of its real value (Adamowicz *et al.* [20]; Hanley *et al.* [21]; Colombo *et al.* [22]).

Once the pivot is known, the values of the other TEV components (IUV, OV, EV, BV) are estimated, using the eigenvalue determined through the AHP method, so that the relative weights of the TEV components are defined (Eqs (2)–(5)). The TEV of the environmental asset is then determined by adding up all the partial values (Eq. (6)). The value thus obtained indicates the total economic value of the Albufera landscape. Then, the value of each EV component (biodiversity, cultural heritage and aesthetic enjoyment) is derived from their weights and the known economic value of the EV (Eqs (7)–(9)).

$$IVvalue = \frac{DUV\ value}{DUV\ weight} \times IVweight \tag{2}$$

$$\frac{O}{OV} value = \frac{DUV\ value}{DUV\ weight} \times \frac{O}{OV} weight \tag{3}$$

$$EV\ value\ =\frac{DUV\ value}{DUV\ weight}\times\ EV\ weight \tag{4}$$

$$BV\ value\ =\frac{DUV\ value}{DUV\ weight}\times\ BV\ weight \tag{5}$$

$$DUV\ value\ +IUV\ value\ +O/OV\ value\ +EV\ value\ +BV\ value \tag{6}$$

$$B\ value\ =\ EV\ value\times\ B\ weight \tag{7}$$

$$CH\ value\ =\ EV\ value\times\ CH\ weight \tag{8}$$

$$AE\ value\ =\ EV\ value\times\ AE\ weight \tag{9}$$

2.6 Analysis of expert valuations

Once average values are obtained for the TEV and EV components, this stage focuses on the analysis of the differences among the weights assigned to these components by the experts. For this purpose, first a cluster analysis is implemented and, then, a variance analysis is applied in order to check if there are significant statistical differences among the groups.

Cluster analysis produces hierarchical groups of items based on distance measures of dissimilarity or similarity. The variables used are, firstly, the components of TEV and, secondly, the components of EV. Euclidean distance is used to calculate the distance between two items and the clustering method is the method of average linkage between groups (SSPS Inc.).

Significant statistical differences among the groups derived from cluster analysis of TEV components are estimated through t-test. It compares sample means by calculating Student's t and displays the two-tailed probability. TEV components are considered the dependent variables whereas the variable obtained from cluster analysis is the independent variable. Variance analysis (ANOVA) is applied for EV components. In particular one-way analysis is implemented which produces a one-way analysis of variance for an interval-level dependent variable by one numeric independent variable that defines the groups for the analysis. EV components are assumed the dependent variables and the variable derived from cluster analysis is the independent variable. Post hoc analysis which tests for comparisons of all possible pairs of group means or multiple comparisons is Bonferroni t test. This test is based on Student's t statistic and adjusts the observed significance level for the fact that multiple comparisons are made.

3 Results

3.1 Calculation of the TEV components

The survey was carried out in August, September and October of 2005 and in October 2012 with completion time for the survey averaging 25 minutes. The pairwise comparisons made by the experts were used to calculate the eigenvalues, which indicated the relative importance, from the experts' points of view, of each

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TEV component. 34 consistent matrices, whose CRs did not exceed 10%, were used to calculate the aggregated eigenvalue, which was estimated by calculating the geometric mean of the eigenvalues and was normalised by addition (Table 3).

Table 3: Aggregated and normalised eigenvalues.

TEV	WEIGHTS OF TEV COMPONENTS		
	Cluster 1	Cluster 2	Global
UDV	0.0636	0.3285	0.1375
UIV	0.1216	0.2620	0.1882
OV	0.0489	0.1307	0.0822
EV	0.4358	0.1107	0.2979
BV	0.3300	0.1681	0.2942

Table 4 shows incomes and expenditures associated with these activities. After updating the calculated cash flow to account for a 3% tax (Evans [19]), the estimated DUV in Albufera was €333 million. With regard to the TEV, Table 5 shows the global value and the values corresponding to the two groups derived from cluster analysis.

Table 4: Incomes and expenditures (€) related to direct use values.

	INCOMES	EXPENDITURES	CASH FLOW
Rice	49,645,706	40,001,538	9,644,168
Hunting	598,564	390,902	207,662
Fishing	306,595	154,920	151,675
Total	50,550,865	40,547,360	10,003,505

Table 5: Albufera economic value according to the aggregated weights assigned by experts.

TEV	VALUE IN 1,000 €			VALUE FLOW IN 1,000/YEAR		
	Cluster 1	Cluster 2	Global	Cluster 1	Cluster 2	Global
UDV	333,450	333,450	333,450	10,003	10,003	10,003
UIV	637,931	266,014	456,593	19,138	7,980	13,698
OV	256,673	132,632	199,410	7,700	3,979	5,982
EV	2,285,896	112,423	722,540	68,577	3,373	21,676
BV	1,730,864	170,609	713,700	51,926	5,118	21,411
	5,244,814	1,015,127	2,425,694	157,344	30,454	72,771

3.2 Calculation of the EV components

Founding on the geometric mean of the 15 consistent matrices and the EV estimated in the preceding section, the economic values of the EV components (biodiversity (B), cultural heritage (CH) and aesthetic enjoyment (AE)) were calculated. Table 6 shows the relative importance of these three components and Table 7 shows their economic value for the whole group and for the three groups derived from cluster analysis. The assessed value of aesthetic enjoyment in Albufera Natural Park is €146 million ranging between €86 and €186 million.

Table 6: Weights of EV components. B: biodiversity; CH: cultural heritage; AE: aesthetic enjoyment.

EV	WEIGHTS OF EV COMPONENTS			
	Cluster 1	Cluster 2	Cluster 3	Global
B	0.6229	0.7741	0.1047	0.5529
CH	0.1272	0.1130	0.6370	0.2035
AE	0.2499	0.1130	0.2583	0.2436

Table 7: Existence value according to the aggregated weights assigned by experts.

	VALUE IN 1,000 €				VALUE FLOW IN 1,000 €/YEAR			
EV	722,540				21,676			
	Cluster 1	Cluster 2	Cluster 3	Global	Cluster 1	Cluster 2	Cluster 3	Global
B	450,070	559,304	75,650	399,487	13,502	16,779	2,269	11,985
CH	91,922	81,618	460,258	147,068	2,758	2,449	13,808	4,412
AE	180,548	81,618	186,632	175,985	5,416	2,449	5,599	5,280

4 Discussion

This work has shown how AMUVAM method can provide knowledge about the importance of the aesthetic value of landscape in comparison with the other components of the TEV. According to the results, the aesthetic value of landscape corresponds to 7% of the TEV and 24% of the EV in Albufera Natural Park (€176 million).

However, the statistical analysis of expert weights also reveals the existence of distinct patterns in the valuation of TEV and EV components. These differences in weight assignment may be attributed to the existence of different interests and attitudes towards the valued asset. This finding is in agreement with previous authors working in the field of land management who have reported differences in

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weight assignment among different expert groups (Chow and Sadler [11]). In this way, this study provides, together with the average value, a range of values that reflect the different sensitivities of society for the TEV and its components.

Regarding the TEV, cluster analysis suggests two different patterns – environmentalist and utilitarian – which show significant statistical differences for all the components of the TEV (Table 5). The utilitarian group (cluster 1) gives a higher importance to use values which represent 72% of the TEV. While non-use values correspond to 77% of the TEV according to the environmentalist group (cluster 2). According to this analysis, the TEV of Albufera Natural Park ranges between €1,015 and €5,244 billion.

With regard to EV, three different groups have been identified (Table 7). The first and the second cluster are similar in terms of the importance assigned to biodiversity and cultural heritage. But they differ on the value of aesthetic enjoyment. The weight of aesthetic enjoyment in the first cluster (25%) is twice as high as in the second cluster (11%). Whereas the third cluster is similar to the first one in terms of the weight of aesthetic enjoyment (26%), but it is very different to the other two groups in biodiversity and cultural heritage values. Hence, results suggest that the weight assigned to aesthetic enjoyment ranges between 11% and 26% of the EV, which corresponds to 3.56% and 7.61% of the TEV.

Despite the lack of consensus in the importance of the different components of the TEV, it is noted that all the TEV components receive similar weights in both surveys (2005 and 2012) except for the BV. Unfortunately, this comparison could not be conducted for the aesthetic value, since no data about the EV components was collected in 2005.

5 Conclusions

AMUVAM methodology has been applied to determine the importance of aesthetic enjoyment in the full value of Albufera Natural Park. According to this work, the average value of aesthetic enjoyment in Albufera Natural Park corresponds to €176 million and its range is between €82 and €187 million. This range of values corresponds to the different patterns of valuation identified in this study which reflect the diversity of sensitivities within society with regard to the components of TEV.

The results obtained from AMUVAM may be useful in more objectively prioritising future environmental initiatives by enabling to select those initiatives with greatest impact on the aspects most valued by society. It may also contribute to a better allocation of investments and subsidies, to better align the objectives of such expenditures with the importance attached to those objectives by society.

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Integrating land use planning and water resource management: threshold scenarios – a tool to reach sustainability

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Abstract

The relationship between water and territory has been determined throughout history by the successive construction of water infrastructures. From the first agricultural canals to the present day, water networks have transformed the territory, favouring the creation and development of human settlements, but also resulting in severe impacts. The complexity achieved by these networks and its environmental effects require the establishment of coordinated strategies between Land Use Planning and Water Resource Management, to generate sustainable land use scenarios. In this sense, threshold scenarios are proposed as a convenient tool to limit the uncertainty and determine the impacts of water infrastructures on the territory, helping with decision making and anticipating possible deviations from the plans' forecasts. In this paper a study on the coast of Granada (Spain) is presented. It shows the importance of including threshold scenarios in an integrated water resource management, as a tool that can be used in the strategic environmental assessment to evaluate territorial integration in water management.

Keywords: *land use planning, integrated water resource management, threshold scenarios, sustainability.*

1 Introduction and objectives

Throughout history, water management models have been based on principles that have evolved with the needs and challenges of each location and time. Traditionally water was considered as a factor of production and an unlimited resource, which allowed the growing demands on that water be satisfied through

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the construction of hydraulic infrastructure, creating expectations of growth which were translated into greater demands *ad infinitum* [1]. This unsustainable process has caused the deterioration and depletion of water resources, as well as a growth rate greater than many territories could support [2]. For this reason since the 1980s a more rational management of water has been demanded, which considers water as an eco-social asset. This change of perspective has been represented fully in the bibliography. There are many references that allude to this under different appellatives; 'hydraulic culture' against 'hydrologic culture' [3], 'supply driven ethos' against 'demand management ethos' [4], 'period of water development' against 'period of water management' [5], 'traditional planning' against 'integrated resource planning' [6], 'supply management era' against 'demand management era' [7], 'a time of resource exploitation' against 'a time of changing focus' [8].

These new principles involve the need to carry out water management from a more integrated and less segmented focus, in which all the disciplines meet and that in one form or another are represented in the problems of water. Thus in the 1990s 'Integrated Water Management' was being explored [9–11] as a methodology to join all these variables in a new form of managing this most valuable resource, which became incorporated into the Water Framework Directive [12], relating to the need to carry out an integration of territorial and hydrological policies.

Currently many references exist that confirm the application of these new principles [13–15], however, the majority of them continue to hold sectorial views, as so many of the authors call attention to the lack of consideration of territory in this new model [16–18]. Neither the water management plans nor the territorial management plans have given sufficient response to territorial needs [19, 20], to a certain extent, due to the absence of specific mechanisms in the Water Framework Directive that affect the instruments of territorial planning [21]. This has meant that sectorial approaches have continued to be perpetuated, resulting from the competitive compartmentalization between management administrations [23]. This deficiency implies a challenge for contemporary society and defines the principle objective of this paper, to contribute to the integration between Land Use Planning and Water Resource Management, beyond the different understandings of the administrations that manage them, and to foster their interdependence wherever possible. In this way, the Directive on Strategic Environmental Assessment [24], a tool for the environmental evaluation of plans and programs, could be utilized as a legal framework for the evaluation of the integration of territory in Water Resource Management.

2 Hypotheses

Despite reaching a general consensus on the need to undertake an Integrated Water Management approach which is integrated with Land Use Planning, the basic principles of this integration have not been clearly defined [25]. The first consideration to take into account is that these principles lack universality, indeed that the factors vary according to the characteristics of the region; the natural environment and the intensity of the water problems, the human resources, the institutional capacities, the peculiarities of the public and private sector, the cultural aspects [26]. However, there are a series of common elements in most of the territories, that structure the relationship between Land Use Planning and Integrated Water Management [27, 28], and therefore define the hypotheses of this paper. The first of these relates to the investment between *infrastructure and growth*. It is clear that the creation of infrastructures has a great influence on the territory, as the provision of new services generates an expectation of development which enables potential growth, and then limits it when it has reached levels higher than those available. This is clearly demonstrated both with transport as well as hydraulic infrastructures, as an increase in accessibility and/or availability of water generates a development of activities in the environment of the newly supplied areas [29, 30]. The second hypothesis is based on the fact that *the forecasted growth in water management plans is usually lower than the actual growth*. This normally occurs because irrigated areas end up being completely utilized, despite this growth not being planned [18, 31, 32]. The third and final hypothesis explores the *environmental impacts* that this excess of growth produces on the territory, causing sometimes irreparable damage (over-exploitation of aquifers, erosion, contamination of water, etc.) [33–36]. One of the principle environmental impacts is the water deficit, as the water requirement exceeds the projections, and therefore, the existing water availability. This fact generates a social demand for water that usually culminates in the creation of new hydraulic infrastructures, culminating in "a vicious circle" that continually creates more impacts on the territory [1, 18, 21] (fig. 1).

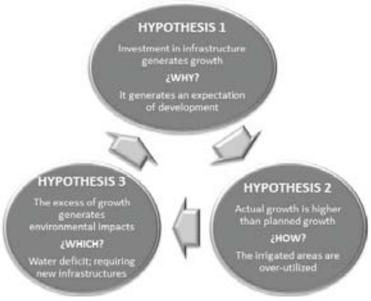

Figure 1: Hypotheses and circle of unsustainability.

These interrelationships define the principle objective of this paper; to determine a tool which allows control of the growth produced and breaks this cycle of unsustainability prevalent, even today, throughout all Mediterranean countries [21].

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3 Methodology

Starting from the defined hypotheses, the methodology used comprises of analysing each one in a pilot region, with the objective of detecting the water-territorial interactions that prove to be crucial for the definition of a tool to control growth. The zone chosen as a field study was the coast of Granada, in the region of Andalusia, southern Spain (fig. 2). In this zone, the water-territorial relationships have been very strong throughout its history, and the huge growth produced in recent years makes it a location where it is perhaps even more necessary, if that is possible, to develop tools that allow the generation of sustainable scenarios [18, 21, 31]. Thus, the regional administration has developed the 'Territorial Plan for the area of the Costa Tropical of Granada', the principle objective of which has been to establish the framework of reference for the sustainable organization and development of Granada's littoral, with the aim of guaranteeing and making compatible the preservation of environmental and territorial resources, with socio-economic progress and the improvement of the quality of life for its inhabitants [37]. With an area of 23.87 km^2; this region has an irregular hydrological cycle, a high environmental quality and diversity, large infrastructural development and elevated current and future water demands (all the hypotheses are fully represented). It is a territory totally involved in the process of transformation after the improvement of the principle infrastructures, both transport and hydraulic, whose potential for future development is based fundamentally in agriculture and tourism [37].

Figure 2: Coast of Granada location.

Despite all of the above, there is a recognition that the Plan has not responded to the new demands and problems of the region, consequently it has established a series of strategies aimed at territorial integration, re-evaluation of economic activities and the prizing of natural, cultural and scenic resources. However, this document lacks concrete proposals that provide limits to the uncontrolled growth produced in the region in the last 50 years which has perpetuated an unsustainable water management model.

3.1 Investment in hydraulic infrastructure to generate growth

The pluviometric variability, typical of the Mediterranean regions, has always necessitated hydrological planning to be based on the management of extreme phenomena (droughts and floods) and, therefore, the construction of many hydraulic infrastructures to store, retain and control the water [38]. Furthermore, the mountainous geography of the area generates fast flowing run-off and does not allow for the 'natural storage of water' which consequently encourages the use of unregulated water resources [39], so that water management becomes a far more complex task. Thus, the inadequate availability of water combined with the limited natural regulation of water, has promoted the creation of multiple hydraulic infrastructures that have allowed the storage, retention and control of the water resources, increasing its availability and allowing the development of the territory [40]. However, counter-intuitively, this phenomenon has not resulted in a reduction of the water scarcity, but rather the complete opposite. In the Andalusian hydrographic basins, a significant increase in the availability of water resources in recent years has paradoxically led to a greater water deficit [18, 21]. Specifically, on the coast of Granada, the estimation made by the Hydrological Plan indicates a deficit of 4 Hm^3 in 2015 and some 7 Hm^3 in 2025 [41]. The successive investments in the hydraulic infrastructure have produced an occupation of the adjacent areas in a manner at times uncontrollable [42]. Fig. 3 shows how the construction of irrigation channels to heights of 50, 100 and 200 metres, has almost completely determined the growth of agriculture in the zone, over-utilizing the irrigated areas and generating a massively significant environmental impact on the territory [43].

Figure 3: Evolution of the growth of agriculture and its relationship to the hydraulic infrastructure on the coast of Granada.

3.2 Growth is greater than anticipated

As the Plan demonstrates, the growth of the agricultural area on the coast of Granada has been spatially determined by the development of the hydraulic infrastructure, generating an expectation of growth which has meant that 99% of areas able to be irrigated are currently being irrigated (DHCMA, 2010), and that the water deficit is ever greater. This growth has not been linear, but rather, as Malisz pointed out, "*… the process of territorial expansion is of a terraced or stepped character that is not continuous, but rather that occurs in jumps coinciding with the creation of the infrastructures …*" [44]. In the case of the coast of Granada, these jumps have coincided with the creation of a succession of irrigation channels that have functioned as triggers for growth approximately every 10 years (fig. 4).

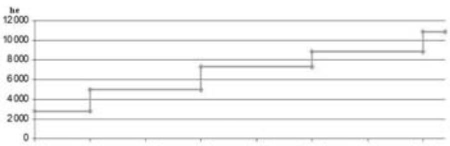

Figure 4: Increase of the irrigated area in relation to the creation of the hydraulic infrastructure on the coast of Granada.

These stepped jumps, generally unplanned, have meant that the growth forecasts in the plans have been completely exceeded in reality. In Andalusia, the forecasts made by the various plans have been considerably less than the actual growth produced (fig. 5), generating a significant water deficit which is causing serious problems in the region (environmental, economic, social) [31].

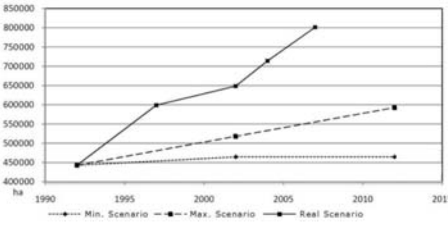

Figure 5: Growth forecasts and real growth of irrigated areas within Andalusia [45].

3.3 Growth without planning generates impacts on the environment

On the coast of Granada agricultural use is the principal consumer of water in the region. In fact, this demand accounts for almost 90% of the total demand [40]. Thus an increase in the irrigated area in relation to that forecasted in the plans can imply serious environmental problems relating, amongst others, to the quantity and quality of the water [43].

On the coast of Granada, in 2003 the possibility of building a new channel to the height of 400 metres was established, which would supply new irrigated areas [46]. The current economic crisis has paralyzed this process, at least for the immediate future. As a result of this, a prediction has not been carried out on the territorial consequences that this new infrastructure could create. It is therefore necessary to establish coordination strategies between Land Use Planning and Water Resource Management that use the hydraulic infrastructures as a tool to re-balance the territory, and not, as has happened in this region, as an enablement to its imbalance [21].

Hence, a basic principle of coordination between both plans must be to limit the territorial uncertainty that the creation of an infrastructure would generate, by means of the creation of a 'Threshold Scenario' that quantifies the maximum growth that this infrastructure could cause, as well as the associated demands that would be produced. Utilizing this forecast of maximum growth, an evaluation must be made as to whether the expected growth would imply an acceptable risk for the affected territory or not. If the growth follows historical trends it could follow that the creation of this infrastructure would generate more damage than benefit, which may lead to its construction being rejected. So, using this tool, it would be possible to avoid the recurring phenomenon of recent years, where growth has always exceeded the forecasted scenarios, causing serious, mainly irreversible, environmental impacts.

In the case of the coast of Granada, after developing the Threshold Scenario associated with the creation of the infrastructure proposed in 2003 [21] (fig. 6), it can be seen that the increase of irrigated area that it could produce would be some four times higher than that generated in recent infrastructural jumps (fig. 7), causing a water deficit of almost 50 Hm^3 [21]. The information generated by this Threshold Scenario would prove indispensable when deciding on the advantageousness or otherwise of this infrastructure, as well as for establishing preventative measures if the construction is finally completed. In this way, the maximum demands would be limited and programmes could be established that augment the available water resources (improve the efficiency of networks, water re-use, desalination) and generate a strategic reserve against a possible increase in consumption. This would avoid the 'improvisations' that are produced when demands exceed forecasts, which generally lead to the use of subterranean resources when surface resources are insufficient. This has generated the over-use of most coastal aquifers throughout the Mediterranean, many of them already irreversibly so [47].

Figure 6: Threshold Scenario associated with the channel from the height of 400 metres on the coast of Granada.

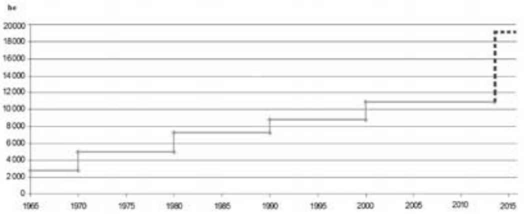

Figure 7: Agricultural growth corresponding to the Threshold Scenario associated with the channel from the height of 400 metres on the coast of Granada.

4 Conclusions

According to the study, the increase in the availability of water through construction of hydraulic infrastructure as a response to the growth of demand, has not affected a decrease of the water deficit, but rather to the contrary, it has caused an unsustainable situation that is having serious environmental consequences. This has happened because the growth forecasts in the plans have been totally exceeded by the actual growth, leading to a 'water shortage' that has established a considerable fragility in the territories and has caused serious conflicts over water usage. Therefore it is necessary to establish strategies of coordination between Land Use Planning and Water Resource Management, which enable sustainable scenarios to be generated, putting an end to this recurrent phenomenon. Thus, the creation of 'Threshold Scenarios' facilitates the quantification of maximum growth that can be generated and the evaluation of the advantageousness of constructing new infrastructures, limiting the uncertainty and risk generated by the expectation of growth in a territory, and establishing preventative methods that avoid future mismanagement of the water resource. In this way, the planning of the hydraulic infrastructures are carried out without forgetting that they are a crucial element in Land Use Planning and that they play an important role in the development of regions, thus helping to improve the future sustainability within territories.

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Improving the environmental performance of building facilities through a green building product labelling scheme

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Abstract

The environmental impacts caused by the prodigious demand for building facilities around the world should not be underestimated as construction projects consume a great deal of natural resources, water and energy. To help save the ecosystems and achieve the global vision of sustainable development, the construction industry has an indispensable role to play. Of various approaches to reduce the environmental burdens of construction facilities, the use of green building materials is considered a crucial aspect. Yet, it is not easy for construction stakeholders to select the most suitable green building materials for a construction project. What is needed is a transparent and credible scheme to evaluate and compare the greenness of building products. In Hong Kong, a green building product labelling scheme has just been launched by the Hong Kong Green Building Council. A major characteristic of this green building labelling scheme is that it enables construction stakeholders to differentiate the level of greenness of building materials and products based on various environmental impact categories. By integrating the green building product labelling scheme with the building environmental assessment schemes such as LEED, the overall environmental performance of a building can be easily delineated. In this paper, the salient features of the green building product labelling scheme in Hong Kong are presented and the way to capitalise on the scheme to enhance the environmental performance of building facilities in the city is discussed.

Keywords: sustainable construction development, green building material, green label, environmental impact.

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1 Introduction

Building facilities are essential to a city as they do not only provide dwelling space for inhabitants but can also support its economic development. With continuous growth in population and exacerbated urbanisation, the demand for building facilities is expected to increase for the years to come.

Despite that, the construction of building facilities can be detrimental to the environment [1] as it consumes large quantity of different building materials. UNEP [2] estimated that the construction industry is responsible for about 40 per cent of the overall environmental burden. The most common environmental impacts caused by the consumption of building materials include resource depletion and effect to the eco system and human health [3].

Nowadays, more and more clients, designers and end-users are aware of the adverse environmental impacts brought by construction materials [4]. Apart from reducing the amount of materials in a building materials through design optimisation and/or greater use of recycled materials, greater adoption of green building products is gaining popularity.

While many manufacturers have great expectations on the niche market of green building materials and invested heavily in improving the environmental friendliness of their products, the greenness of some building products remains ambiguous to construction stakeholders [5].

In some countries, green or eco labelling schemes have been developed to promote green products. These schemes fall short in providing a comprehensive coverage of building products considering the diversity of materials used in a construction project. Besides, the existing green or eco labelling schemes do not allow decision-makers to differentiate how green the products are. This would impede the construction industry's opportunity to significantly uplift the environmental performance of building facilities.

In Hong Kong, the Hong Kong Green Building Council has launched a Green Building Product Labelling (GBPL) Scheme in January 2015. The GBPL scheme aims to provide a transparent and credible platform for evaluating and comparing the life cycle environmental friendliness of building products.

In this paper, the essential features of the GBPL scheme *viz*. the product coverage and assessment mechanism are first highlighted and the potential application of the scheme to improve the environmental performance of building facilities is exemplified.

2 Product coverage

In the initial phase of the GBPL scheme, fifteen building products which are commonly used in building facilities in Hong Kong as well as representing the highest environmental burden are included. These fifteen building products are categorised into four distinctive categories, i.e. structure and façade, interior system, finishes, and mechanical and electrical (fig. 1).

In determining which building products should be incorporated in the first stage of the GBPL scheme, a thorough analysis of the building project was carried out.

This involved a systematic examination of the amount of materials used in a series of capital projects in the city. The frequency of replacement of the building products based on a fifty year building life as well as the material wastage at the construction stage were taken into account when assessing the amount of materials needed in the selected projects.

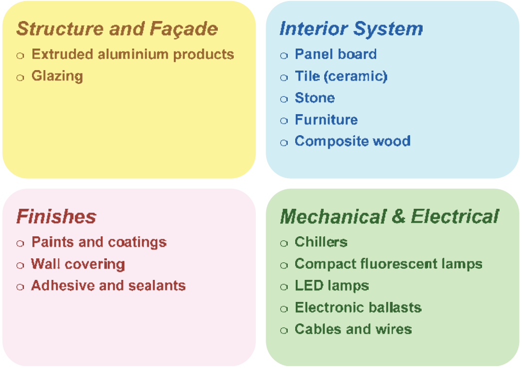

Figure 1: Building products covered in the GNPL scheme.

To better understand the environmental impacts of various building products, commonly environmental inventories were used. Through which, the quantity adjusted environmental impacts could be computed to establish which are the most predominant building products from the environmental performance's perspective. Given the potential environmental impacts brought by building services components, analyses were conducted by referring to their energy consumption throughout the building life cycle.

Analogous to other similar studies, the findings of the current study shows that reinforcement bars, copper, aluminium, tiles and concrete are the greatest contributors of environmental burden in building projects. As for the building services components, chiller, compact fluorescent lamp and electronic ballast deserve much attention due to their energy consumption and extensive usage.

3 Assessment mechanism

A life cycle assessment approach is adopted to determine the environmental impacts brought by a building product. However, as the characteristics of each building product vary, the impact categories of individual product could exhibit

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some variances. For instance, paint and coating products shall be assessed by referring to their serviceability, hazardous substances, toxicity, biocides, heavy metals, environmentally hazardous substances, carcinogenic substances, ozone depleting substances, and volatile organic compounds.

While some assessment criteria are similar to other green or eco labelling schemes around the world, the standards can be different especially when the building facilities and their usage in Hong Kong is not the same as other cities. Therefore, a series of focus group meetings were conducted to establish the most suitable standards for each of building product. Besides, relevant international and local standards or regulations were reviewed to ensure that the requirements are in line with the trend.

Another major distinction between the GBPL scheme and other existing green or eco labelling schemes is that the criteria are divided into core and non-core ones. Since the core criteria represent absolute minimum environmental standard of a building product, only those materials which can satisfy all the core criteria will be awarded a label under the GBPL scheme. For instance, recycle content is one of the core criteria for extruded aluminium products.

The non-core criteria, however, demonstrate whether additional efforts have been directed to improve the environmental friendliness of the product. This should help differentiate how green the product is. As a result, additional scores will be awarded if the product can meet any of the non-core criteria. Table 1 shows the scoring regime under the GBPL scheme.

Table 1: An example of core and non-core criteria and scoring regime.

	Criteria	***Basic Score***	***Bonus Score***
Core	Volatile organic compounds	10	
	Lower than the limit specified (Table 2)		5/10
	Carcinogenic substances	10	
	Heavy metals	15	
	Serviceability	10	
	Product information	5	
	Maximum sub-total for core criteria:	*50*	
Non-core	Environmental management system		5
	Packaging requirement		5
	⁝		⁝
	Ozone depleting substances		5
	Maximum sub-total for non-core criteria:		*50*
	MAXIMUM TOTAL SCORE:	**100**	

To facilitate manufacturers and verification bodies report and validate the environmental impacts of a building product in a transparent and equivocal manner, the detailed requirements pertinent to each criterion are provided in the assessment guideline (Table 2). More importantly, the score corresponding to each criterion is shown so that manufacturers can estimate how green their product is.

Table 2: Limit of volatile organic compound and associated scores.

	Score		
	10 (basic)	+5 (bonus)	+10 (bonus)
Paint/coating type	Interior		
	VOC limits (g/L) (include water and tints/colourants)		
	Minimum requirement	*Higher standard*	*Highest standard*
Matt (≤ 10 gloss units)	50	25	10
Semi-gloss/gloss (≥ 15 gloss units)	80	40	10

There are altogether five different grades under the GBPL scheme ranging from 'platform, 'gold', 'silver' and 'bronze' to 'green' (fig. 2). The level of label to be awarded depends on the satisfaction to the scoring regime (see Table 1 for example). A product which satisfies all the core criteria would result in 50 marks and it is eligible for a 'green' label under the scheme. If the product satisfies all the requirements of the core and non-core criteria, extra marks of up to a total score of 100, which would lead to the award of a 'platinum' label.

Figure 2: Different levels of green labels.

4 Improving Buildings' Environmental Performance

As explained earlier, the environmental performance of building facilities depends not only on the energy consumption at the operational stage, but also a careful selection of building products as the opportunity to reduce the environmental burden would diminish once the facility is built. The problem is aggravated when the use of inferior materials may pose health hazards to the occupants.

Through the GBPL scheme, clients and designers can select green building products of different environmental friendliness to commensurate their goal in contributing to environmental conservation and protection. While some countries or cities like Hong Kong offer incentives to promote green construction, e.g.

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granting gross floor area concession, it is necessary to see how to integrate the GBPL scheme with the existing mechanisms in appraising green buildings.

The ability to differentiate building products into various degrees of greenness makes the GBPL scheme extremely useful and handy as it can be linked to the existing building environmental assessment schemes like the Leadership in Energy and Environmental Design (LEED) in the United States, Building Environmental Assessment Model (BEAM-Plus) in Hong Kong, etc.

Of various possible approaches, one can improve the material aspects of the existing building environmental assessment schemes by assessing the labelled green building products used in the project. The more the labelled green building products are used and the higher are the green labelling grade of the selected materials, the higher score on the material aspects can be achieved. This together with the incentivising programme should promote a greater uptake of green building products.

Clients and design team members can also specify the use of labelled green building products. For instance, for those building products which are hazardous to the environment and/or human health, at least those having awarded a 'silver' green building product label can be used. This should help change the behaviour of the construction industry and ensure the manufacturers are moving towards the production of greener building products.

From the perspective of the buyers and end-users of the building facilities, they may be more prepared to move in to a property with better environmental quality. With the aid of the GBPL scheme, buyers and end-users can delineate the environmental friendliness of the building. Through which, the demand for green buildings would increase.

5 Conclusions

A GBPL scheme which can differentiate the level of environmental impacts of building products has been introduced in this paper. The scheme adopts a life cycle assessment approach whereby the environmental impacts instigated by various stages of production including raw material extraction, transportation, processing, fabrication, installation, operation, reuse, recycling and disposal are taken into account.

Fifteen commonly used building products have been carefully selected after reviewing the amount of different building materials used in construction projects and the environmental impacts of those materials. Assessment standards have been developed to help manufacturers and validation bodies compile and verify the information for the award of a green building product label. By referring to the core and non-core criteria and the level of green label awarded, one can easily differentiate which building product of the same category is greener than the other so as to facilitate decision making.

Improving the environmental performance of building facilities is the duty of all stakeholders. From the clients and designers' point of view, specifying the use of green building products can ensure that the building is safe for occupancy and causing minimal disruption to the environment. With a greater demand for green building products, manufacturers should invest more in research and development for new materials and new production process to minimise the environmental burden. The government should play a proactive role to encourage the construction of green buildings in particular the use of green building products, and incentivising and educating the industry to go green should be built into a country or city's policy.

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Ecosystems and sustainable metabolisms

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Abstract

The Strategic Plan for the Calderona Mountain Range (Valencia, Spain) covers an area of 200 km^2 including 5 municipalities located at the northern edge of Valencia's Metropolitan Area. The Plan deals with a wide diversity of aspects, being ecology and sustainable development their common denominators.

Thus, the analysis of the different territorial layers (forestry, agriculture, natural environment, urban planning, landscape, heritage, tourism and public use, mobility and infrastructures, and economic activity) was developed from an ecological and sustainability focused point of view which is afterwards extended in the definition of regional strategies and in a set of ten thematic plans and eighteen pilot projects.

In particular, sustainability, the structural role of ecology and the effective enhancement of the different existing and potential ecosystems, permeate the whole Strategic Plan but are, in particular, the central elements of the Territorial and Landscape Plan, which includes the definition of a regional and local Green Infrastructure; of the Natural Environment Plan, which identifies the existing and potential plant communities and establishes the conditions for their adequate improvement and maintenance, and, finally, the Sustainable Development Plan, that analyzes the present flows of energy and resources and explores the territorial and urban models which would permit the reinforcement of internal metabolisms and the reduction of ecological footprints.

Keywords: sustainable planning, sustainable development, sustainable metabolisms, green infrastructure, management of natural areas, ecological footprint, ecological planning, public use of natural areas, productive use of natural areas, biodiversity.

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1 Introduction

The Calderona Mountain Range is a protected natural park [1, 2] located at the northern border of the Metropolitan Area of Valencia. Its mountainous landform and its deep valleys have historically housed a system of small villages and a deeply interwoven mosaic of traditional Mediterranean crops and forested areas. However, its closeness to the city of Valencia has created in the last decades a strong pressure for public use and for urbanisation, with an increasing constellation of mono-functional new housing states scattered across the whole territory. Likewise, traditional agriculture is receding whilst new irrigated monospecific crops and natural areas gain or recover new land.

It is precisely at this point where the Strategic Territorial Plan for the Calderona Mountain Range [3, 4] tries to define a new scenario based on the improvement and extension of natural ecosystems and on the creation of a more sustainable and harmonic relationship between the urban, agricultural and natural lands.

2 Analysis and diagnosis

2.1 Natural environment

The natural areas of the Calderona Mountain Range, include a wide variety of ecosystems and plant associations, ranging from water related communities located at the shores of small rivulets and creeks, to termomediterranean edapho-climatic communities covering wide extensions of uncultivated or non-urbanized land. The acidic quality of most of the soils and the strong contrast between the northern and southern sides of the mountains, increase even more the ecological potential of the site.

Fires and human intervention have reduced however the presence of the mature climax cork oak (*Quercus suber*) forest to the more internal areas of the mountain range, whilst other less developed stages of the ecological succession cover most of the natural land. These intermediate stages are formed basically by shrubs (*Cistus ssps, Quercus coccifera, Pistacia lentiscus, Rosmarinus officinalis, Ulex parviflorus*, etc.) which can be also accompanied by a tree layer of pines (*Pinus halepensis and pinus pinaster*), fig. 1.

Additionally, the analysis of the Calderona's natural environment included the identification and quantification of existing economic activities (cork harvesting, forestry, biomass production, hunting and apiculture); the evaluation of the existing fire prevention systems and, finally, a diagnosis of the levels and facilities for the public use of the natural park. All this information was collected in different tables and maps which showed an almost inexistent economic activity except for hunting, a lack of continuity and legibility in the network of tracks and a low level of implementation of the Fire Protection Plan [5]. The analysis also showed an increasing detachment and disaffection of local communities, which are somehow losing their personal and functional relationship with their natural sites.

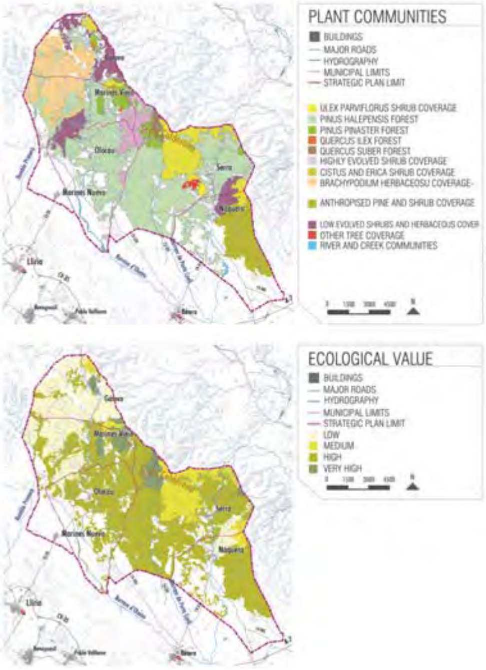

Figure 1: Existing plant communities (as per PATFOR [6]) and ecological value.

2.2 Landscape and land uses

The study of the different land uses and landscapes coexisting at the Calderona Mountain Range, shows a fast and intense transformation during the last decades. Somehow, the mosaic is changing, land specialisation is increasing and local communities try to redefine their relationship with a territory which has become protected and which seems to responds now to regional interests and demands.

The speed of those changes has made difficult their absorption in the landscape and the lack of functional relationship between neighbouring land uses promote a fragmented territory. All these aspects were analysed in a systematic way and were transferred to a set of maps or schemes showing the expected scenarios for the future and the current landscape quality of natural, agricultural, infrastructural and urban areas, fig. 2.

Figure 2: Landscape quality in natural and urban areas.

2.3 Sustainability

The harmonic integration of socioeconomic development and the preservation and improvement of natural and cultural heritage is one of the basic pillars of sustainable development. This principle was used in the whole Strategic Plan for the Calderona Mountain Range to analyze some variables like mobility, urban patterns or forestry but, at the same time, required the identification of some objective indicators to assess and develop new alternatives to the current ecological footprints and to the present use of water, energy, resources and residues.

In relation to water, the analysis showed that agriculture and urban-domestic use take the biggest shares in water consumption, fig. 3, presenting both of them a strong seasonality, that in the second case can be explained by the triplication of the population during the summer. Additionally, low density housing is clearly related to higher consumptions per residential unit. On the other end of the water cycle, sewage collection and treatment has improved considerably during the last decades but there are still some extensive housing states lacking sewage networks, what can become a serious environmental problem, especially when they are located over vulnerable aquifers.

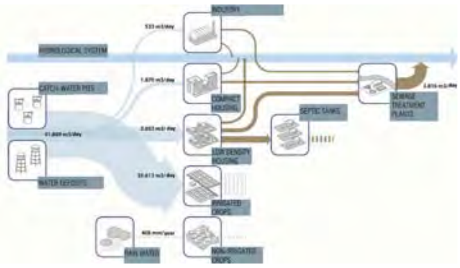

Figure 3: Water cycles. Estimated water consumption and sewage production in high season (summer).

In regards to energy consumption it can be said that this variable is being negatively affected by the predominant use of private transport and by the increasing presence of detached low density housing. This variable also presents a remarkable seasonal pattern and although production of renewable energies is still in an embryonic stage, some interesting projects have been developed to produce energy from biomass.

Finally and in relation to residues, the maintenance of natural and agricultural areas, together with the keeping of the many existing private gardens, produce a remarkable volume of biomass that can be enlarged by importing this material from neighbouring areas and that can be used for energy production. On the other hand, domestic waste can also be partially used in energy production but is also influenced by the strong seasonality of human presence and, although recollection and separation of domestic waste is properly developed, the summer peaks cause some logistic inefficiencies.

As displayed in table 1, all these factors were integrated in the calculation of the ecological footprint for different personal profiles. The results show how this variable is highly related with the degree of compactness and multi-functionality of the different types of urban fabrics and with the way of living that they induce in the people who live in them.

3 Objectives and strategies

3.1 Natural environment

The list of objectives included the integration of economic activities in forest management practices; diversification and improvement of public use facilities and activities; coordination of fire protection policies with forest management and agro-rural activities (low impact agriculture and extensive shepherding) and, finally, promotion of the highest and most bio diverse stages of ecological succession (mature forests), see fig. 4. All these objectives are partially included in the existing management plans of the Calderona Natural Park [1, 2] but have hardly been implemented.

Table 1: Ecological footprint for different human profiles.

	Carbon footprint	Food footprint	Housing footprint	Goods and services footprint	Total footprint per consumer	Required planets
Mean (Calderona area)	**9.85**	**15.35**	**4.31**	**8.83**	**38.33**	**2.44**
Person living in a compact town and working in a close industrial state	4.90	16.50	3.60	7.50	32.62	**2.08**
Housewife in compact town	5.70	14.90	3.60	7.50	31.75	**2.02**
Person living in a low density housing state and working in the city of Valencia	17.10	19.50	4.50	10.60	51.73	**3.29**
Part time farmer working also in the local service sector	5.70	16.50	6.10	12.70	40.92	**2.60**
Retired person living in a compact town	4.90	12.40	3.20	6.60	27.03	**1.72**
Retired person living in a low density housing state	15.20	17.00	6.50	9.10	47.73	**3.04**
Child living in a compact town	5.70	16.50	2.40	11.60	36.22	**2.31**
Child living in a low density housing state	17.40	19.50	7.40	12.00	56.24	**3.58**
University student living in a compact town	9.00	16.50	3.60	7.50	36.59	**2.33**
Temporary resident (in summer)	22.80	19.50	6.50	12.00	60.82	**3.87**
Mean (Spain)	**12.90**	**14.90**	**4.80**	**9.40**	**42.00**	**2.50**

Figure 4: Towards a multifunctional and sustainable use of natural areas.

3.2 Landscape and land uses

The definition of a regional green infrastructure is perceived as the main tool to manage and improve the present evolution of land uses and to put in relation the specific objectives for agricultural, natural, infrastructural and urban lands. This green infrastructure would include and connect strategic areas in the before mentioned lands and would also permit a global improvement in landscape quality. The objectives were all accompanied of a series of strategies for their implementation and are specially detailed for urban and infrastructural environments.

3.3 Sustainability

Objectives on sustainability included optimization of water consumption and sewage management; reduction of waste production and increase of recycling; reduction of energy consumption and promotion of renewable energies; enhancement of internal and multifunctional metabolisms, and, finally, the creation of some interactive systems to promote more sustainable ways of living. All these broad objectives were accompanied of specific strategies specially developed for the particular conditions of the Calderona Mountain Range.

4 Thematic plans

4.1 Natural environment plan

This Plan defines the conditions, agents and programs for the improvement and management of the natural areas of the Calderona Mountain Range.

Firstly, and in order to recover and reinforce the links of local communities with the, now protected, natural environment, the Plan explores and quantifies the economical activities which could be developed in those areas without affecting their environmental quality. As explained in the Plan [3], these activities would also have a small but socially important contribution in local economies and in local employment, playing at the same time a significant role in forest management and fire prevention.

Secondly, the Plan addresses the public use of natural areas by proposing a new zoning based in intensities of public use. This zoning would permit to organise the system of public tracks and would help to preserve the most valuable natural reserves, fig. 6.

Fire Prevention constitutes the third part of the Natural Environment Plan and, starting from the existing Fire Protection Plan [5], it explores how shepherding and extensive agriculture can become useful and culturally valuable actors on it.

Finally, the fourth part of the Plan deals with Forest Management. This subject is particularly crucial since, traditionally; there have been confronted positions on this issue: those in favour of more intense interventions (strong clearing and thinning) and those who support the spontaneous evolution of the forests. At this point the Strategic Plan for the Calderona Mountain Range advocates for differentiated policies and degrees of management depending on the fire risks, intensifying the clearings on vulnerable areas and in forest or agricultural fire breaks and keeping a relatively low level of maintenance in the natural matrix, fig. 5.

Figure 5: Degrees of intervention and management in different natural areas.

Figure 6: Proposed public use intensity map and conceptual structure for the network of natural tracks.

At a social level, the effects of these maintenance works on local economies and employments were both quantified and the participation of local administrations and outdoor related associations (hikers, climbers, hunters, etc.) was extended or reinforced.

4.2 Territorial and landscape plan

The Territorial and Landscape Plan was developed attending the principles of the European Landscape Convention and of the Valencian Planning System [7]. It considers a wide range of environmental, visual, cultural, and economic factors in order to optimise the location and intensity of each land use, guaranteeing at the same time the ecological and visual quality of the Calderona Mountain Range.

The Plan was structured in four main parts. The first one included the territorial and landscape characterization of the whole area (definition of landscape units as homogeneous entities with similar patterns and dynamics). In the second part, the quality and degree of visibility of the aforesaid landscape units and of their visual, environmental and cultural resources were estimated. Territorial and Landscape Objectives were formulated on the third part, preparing the floor for the fourth and last part which included the definition of a regional Green Infrastructure and a set of landscape programmes and regulations. Due to the fragmented character of the urban land, a more coherent and functional system of urban management areas was also defined in this last part.

As explained before, the proposed green infrastructure is a central element of the Territorial and Landscape Plan. Ecology has been an essential factor in its definition since it is expected to integrate, enhance and protect the wide diversity of existing ecosystems. This ecological function should not only be performed in natural or agricultural areas but also in the urban context, where the green infrastructure, by incorporating periurban and internal open spaces, is expected to create a capillary and highly accessible subsystem, fig. 7.

Some of the most significant ideas of the Territorial and Landscape Plan were further developed in four pilot projects. The first of them was aimed at facilitating a more adequate and diverse public use of the natural areas by redefining the network of tracks and routes at the Calderona Mountain Range. The second and third pilot projects were pre-designing two periurban parks in the villages of Naquera and Olocau, both of them were located in river areas and were taking advantage of the ecological potential of the sites and of their agricultural surroundings. Finally the fourth project was focused in the visual improvement of a poorly integrated road.

4.3 Sustainable development plan

The Sustainable Development Plan addresses two interrelated topics: socioeconomic development and sustainability. In relation to socioeconomic development, it gathers the determinations and proposals of the Agriculture, Forestry, Hunting, Tourist and Urban Plans, defining also the shared programs and structures which should facilitate their progressive implementation. The same applies to sustainability, where the Sustainable Development Plan incorporates the determinations of the before mentioned thematic plans with special attention to water, residues, energy, mobility, urban models and ways of living. In a second part, the Sustainable Development Plan drafts the following three programs that should permit their implementation: sustainable mobility, promotion of endogenous cycles (internal metabolisms) and monitoring of ecological footprints and sustainability levels. As in the other thematic Plans, a set of pilot projects exemplifying the application of the Plan were developed, dealing in this case with the following two topics: Promotion of public transport and Improvement of endogenous cycles for natural resources and labour, fig. 8.

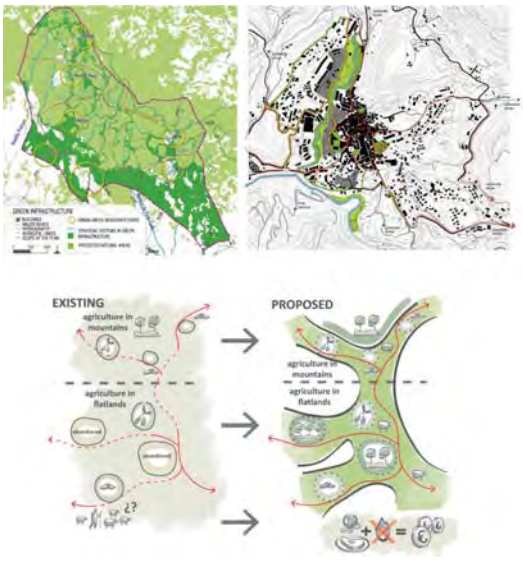

Figure 7: Regional and urban green infrastructures. Towards an agro-natural-urban integrated system.

5 Conclusions

Ecology and Sustainability can become structural and essential topics in Planning, guiding the evolution and transformation of both natural and anthropised areas. The Strategic Territorial Plan for the Calderona Mountain Range is guided by this principle and shows how ecology can become a proactive tool to improve the quality, biodiversity and sustainability of our cities, villages and rural areas. Likewise, the Strategic Plan assumes that sustainability should permeate al the layers of planning since only by creating sustainable pieces we can construct sustainable territories. In addition to this, the very same use of the concept of "metabolism" facilitates the required holistic point of view, whilst the introduction of indicators help us be more aware of how we, as individuals or collectives, can perform more sustainable ways of living.

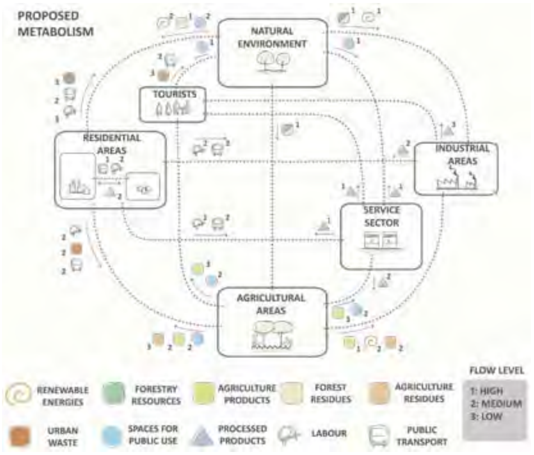

Figure 8: Improvement of regional sustainability. Towards endogenous metabolisms and cycles.

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The concepts of planning and design in sustainable stormwater management

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Abstract

Stormwater management requires general ideas and principles known as the "concept" to ensure the success of planning and design. In addition, the concept requires an understanding of the hydrology cycle as a basis of knowledge, which provides a mechanism to synthesize the knowledge of the hydrology cycle with the idea of planning and designing for stormwater management. Thus, this research aims to synthesize the concepts of stormwater management with that of the hydrology cycle as the environmental sustainability factor. Two objectives have been established: (i) to identify the concepts of planning and designing of stormwater management; and (ii) to analyse the relationship of the identified concepts with the hydrology cycle. In this qualitative research, three methods of data collection have been used: online journals, forum discussions and e-mail interviews. The collected data were analysed using five steps of descriptive comparative analysis. The results show eleven concepts: conservation of the watershed, compact urban form, retention of stormwater on site, treatment train, green network, harvesting and reuse of rainwater, redevelopment, streetscape ecosystem and restoration. The concepts are listed according to seven hydrology cycles – interception, infiltration, surface runoff, depression storage, evapotranspiration, groundwater flow and interflow. The hydrology cycle becomes the environmental sustainability factor for the identified concepts, as the goal of stormwater management is to replicate the process of the hydrology cycle to ensure the effectiveness of the concepts.
Keywords: stormwater management, concepts, principles, planning, design, sustainable, hydrology cycle, environment.

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1 Introduction

Stormwater is an excessive quantity of surface runoff. Stormwater happens during precipitation due to a decrement in the interception and infiltration rate of rainfall and due to an increment in the volume and flow rate of surface runoff. Consequently, a high and rapid volume of stormwater is discharged into rivers (low-lying area) in a short period of intense precipitation that causes overflowing and flooding of the nearby area (Chia Chong Wing [1]; Hassan [2]; Marsh [3]; Day and Dickinson [4]). In addition to flood issues, stormwater also causes river pollution and soil erosion, which damages the environmental habitat and public property (Department of Environment Malaysia [5]).

This severe environmental and social-economic damage happens because of major and abrupt alterations to the hydrology cycle. The pervious cover of nature is changed and deteriorates dramatically into a massive impervious cover of development. Vegetation cover is cleared and the landform is flattened and developed into buildings, roads, parking lots and pavements. The receiving water body, especially rivers, are changed – straightened, widened and structured into storm drainage (Marsh [3]; Day and Dickinson [4]; Department of Irrigation and Drainage Malaysia [6]; Miguez *et al.* [7]).

Specifically, according to Marsh [3], the runoff coefficient in urban areas can increase dramatically up to 90 to 100 per cent compared to the runoff coefficient in natural areas, which range from 10 to 20 per cent. The increase in the runoff coefficient is due to the loss of vegetation cover, soil composition and texture and landform slope, which function by controlling the infiltration and surface runoff of the hydrology cycle. The attributes of urban ecosystems with less vegetation cover to intercept the rainfall, less green areas, together with an increase in impaired soil texture and altered landform make it less permeable for the rainwater to infiltrate into the ground.

There are many stormwater management approaches to overcome the issues caused by stormwater, which cover stormwater quantity and quality aspects. Stormwater management is either a conventional conveyance approach like a storm drain or sustainable stormwater management, which focuses on a nature-based approach, such as Sustainable Urban Drainage Systems (SUDS), Low-Impact Development (LID) and Water Sensitive Urban Design (WSUD). All of the stormwater management manuals provide a wide range of guidelines, such as planning, design and technical construction.

This research intends to discuss the planning and design part of stormwater management. Specifically, the aim of this research is to synthesize the concepts of planning and design of stormwater management with the hydrology cycle as the environmental sustainability factor. Two objectives were established: (i) to identify the concepts of planning and design of stormwater management; and (ii) to analyse the relationship of the identified concepts with the hydrology cycle.

2 Concept of planning and design

The planning and design of the landscape is about connecting and synthesizing the knowledge of landscape ecosystems and design solutions for sustainable development and management. Lyle [8], in his definition on landscape design, emphasized the need to have scientific knowledge of natural ecosystems. In addition, Steiner [9] defined ecological planning as the use of biophysical and socio-cultural information to propose opportunities and constraints for decision-making in landscape development. Likewise, McHarg [10] described ecological planning as the understanding of biophysical and social processes in an ecosystem through the operation of laws and time. Furthermore, Lyle [8] proposed that the scientific knowledge of ecosystem design can be categorized into two. First, is knowledge of the landscape. It is important before planning and designing a landscape to know the biological process within the landscape. Second is the concept of design. In landscape design, the concept is crucial because it provides access to the mechanisms that join all the knowledge of the landscape ecosystem. The concept of planning and design offers a clear basis as an accepted reference according to which it appraises a means to manage a complex relation within a landscape (Kaplan [11]). Therefore, a concept of planning and design can be considered as a general idea or principle of solution for sustainable development and management.

Consequently, to identify the concept of planning and design for stormwater management, a hydrology cycle, together with its biophysical elements and processes, needs to be studied. This is crucial to ensure that the identified concept will contribute to the sustainability factor of planning and design of stormwater management that can replicate the natural hydrology cycle that has been lost due to improper planning and design.

3 Hydrology cycle as the environmental sustainability factor

Marsh [3] mentioned that in the hydrology cycle, the processes of the hydrology cycle are interrelated with other biophysical elements, such as topography, soils, vegetation and water bodies. In a natural landscape, the hydrology cycle is a continuous process of various forms of inflow and outflow of the hydrology cycle within the biophysical elements of a landscape (Ferguson [12]; Steiner [9]). It signifies the order of the movement of water in the landscape by diverse phases and forms. Table 1 shows the summary of the hydrology cycle, interrelated biophysical elements and the processes within a landscape. The scientific knowledge studied from this review was used as a sustainability factor for the identified concepts. Consequently, the hydrology cycle together with the biophysical elements and the processes were used as the basic concept for the planning and design of sustainable stormwater management in this research.

Table 1: Hydrology cycle, interrelated biophysical elements and the process (Marsh [3]; Steiner [9]; Ferguson [12]).

Hydrology Cycle	Biophysical Element Involved	Process
1. Interception	1. Vegetation (strata of trees, shrubs & groundcovers)	Interception and evapotranspiration.
2. Infiltration	1. Surface of landscape: 1.1. Soil (types, permeability and saturation) 1.2. Vegetation	Infiltration and absorption through permeability of soil and by root systems of vegetation.
3. Surface runoff	1. Topography and slope 2. Surface roughness: 2.1. Vegetation 2.2. Soil type 3. Water bodies (pond, lake, wetland and river)	Surface runoff flow into the lower area.
4. Depression storage	1. Topography (landscape depression) 2. Water bodies (pond, lake, wetland and river)	Collected within micro-topography and water bodies.
5. Evapo-transpiration	1. Vegetation 2. Water bodies (pond, lake, wetland and river)	Evapo-transpiration: retention of water and slow evaporation into the air.
6. Groundwater flow	1. Soil (types, permeability and saturation)	Infiltration and absorption. Slow discharge into streams through aquifer storage layer in the ground.
7. Interflow	1. Soil (types, permeability and saturation)	Infiltration and absorption. Slow discharge into streams through vadose storage layer in the ground.

4 Methodology

In this research, the qualitative approach was used as it is considered to be the best suited to the aim and objectives of the research. Three research methods were used. Firstly, 35 topics from the online journal at http://www.stormh2o.com that are related to the concept of planning and design of stormwater management were studied from the January 2007 to May 2012 issues. Secondly, a topic about the concept of planning and design of stormwater management was posted to a Google group forum discussion (http://groups.google.com/group/rainwater-in-context) through which four respondents replied and gave eight attached links to documents. In addition, twenty related topics in the forum discussion were

studied. Lastly, eight respondents answered the e-mail interview in which thirteen more documents were attached to the e-mail for reference. Furthermore, grounded theory was used as a strategy of inquiry to seek interaction among the collected data and to derive an understanding about the identified concepts (Charmaz [13]; Glaser and Strauss [14]; Creswell [15]). In analysing the collected data, five sequential steps of descriptive comparative analysis were used (Creswell [15]) (Figure 1).

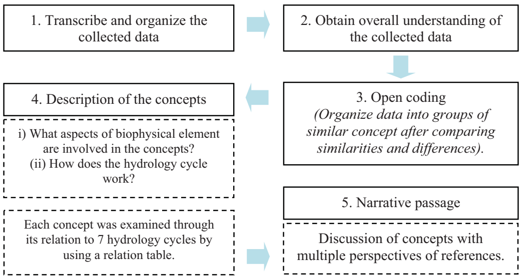

Figure 1: Five steps of descriptive comparative analysis (Creswell [15]).

5 Result and discussion

Eleven concepts of planning and design have been identified after the analysis process.

The first concept is the conservation of the watershed. The conservation of the watershed is considered as a main priority concept of planning and design by the Toronto and Region Conservation Authority [17]. The conservation of the watershed covers the conservation and protection of crucial water body ecosystems or hydrologic elements, such as stream buffers and wetlands to act as natural stormwater quality and quantity management. The conservation of the watershed relates to all hydrology cycles: interception, infiltration, surface runoff, depression storage, evapotranspiration, interflow and groundwater flow. The undisturbed biophysical elements of vegetation, topography, water bodies and soil can function at optimum level to filter the stormwater from nearby development, as mentioned by Richards [16].

The second concept is the harvesting and reuse of rainwater. Crabtree [18], Hager [19] and the Australian and New Zealand Environment and Conservation Council [20] stated that rainwater needs to be harvested and reused as a multi-purpose resource. The harvesting and reuse of rainwater concept relates to six hydrology cycles: interception, infiltration, surface runoff, depression storage, evapo-transpiration and groundwater flow. The interception refers to collecting

the rainwater from roofs and gutters, and channeling the rainwater into a rain barrel for later reuse. The infiltration, surface runoff, depression storage, evapotranspiration and groundwater flow refer to the reuse of harvested rainwater for watering the landscape or plants, especially during the dry season. The reuse of rainwater promotes inexpensive and sustainable significant water reuse when practiced by the community in long-term planning.

The third concept is the compact urban form. The compact urban form combines three planning and design ideas: (i) preservation of the natural environment, (ii) planning of the compact form or layout of a city, and (iii) planning for the high density of population and infrastructure (Aurbach [21]). The sustainability of the compact urban form can be achieved by planning a mixed-use development of commercial, institutional and residential, and a mixed-transit network (Nisenson [23]). Similarly, it can be achieved by designing multi-use green infrastructures or strategies, as highlighted by Dumont [22]. The idea behind a compact urban form is to restrict the development to a concentrated area within a watershed boundary in order to protect more pristine watershed areas. The compact urban form relates to all hydrology cycles: interception, infiltration, surface runoff, depression storage, evapotranspiration, interflow and groundwater flow. Through the compact urban form, the conserved watershed area can function at optimum level to manage the stormwater issue, as mentioned in the first concept. The conserved biophysical elements can filter and clean the stormwater and wastewater from nearby high density and compact areas.

The fourth concept is redevelopment. Redevelopment, also known as retrofit or infill development, is a concept to achieve compact urban form and high density. Stormwater management in the redevelopment concept focuses on multifunctional stormwater infrastructures or strategies within developed areas, as mentioned by EPA-NOAA Smart Growth Implementation Assistance for Coastal Communities for Sussex County, Delaware [24] and Ferguson [25]. Multifunctional refers to various benefits offered by a single stormwater infrastructure. For example, a wetland strategy offers various benefits to the wildlife ecosystem and also a recreational area for the community. The redevelopment concept relates to six hydrology cycles: interception, infiltration, surface runoff, depression storage, evapo-transpiration and groundwater flow. The interflow cycle is not related to redevelopment, because, according to Stephens and Dumont [26], interflow cannot function without a vadose storage layer of soil. In developed areas, the vadose storage layer is usually removed due to construction works, such as the insertion of underground pipes and digging of drainage. Moreover, Stephens and Dumont [26] stressed that once the vadose storage layer has been lost, its restoration is impossible. Since the redevelopment concept focuses on developed areas, it can only restore the interception, infiltration, surface runoff, depression storage, evapo-transpiration and groundwater flow cycles.

The fifth concept is retention of stormwater on site. Retaining on site means storing the retained stormwater and releasing the stormwater slowly over a period of time. The release process of the stormwater is to return the stormwater into the ground to recharge the underground water table; for instance, the use of the storage basin strategy (Marsh [3]). In addition, Hager [19] and the Construction Industry Research and Information Association (CIRIA) [27] indicated the design of subsurface storage, such as basins, ponds and a rain garden strategy to promote storage and infiltration of stormwater for better management. Moreover, the Australian and New Zealand Environment and Conservation Council [20] specified two levels of treatment to retain stormwater on site. The secondary level of treatment requires the use of strategies like filter strips, grass swale, extended detention (dry) basins, infiltration trenches and infiltration basins for the sedimentation and filtration process. The third level of treatment requires the use of pond and wetland strategies for the sedimentation, filtration and adsorption process. The retention of stormwater on site relates to seven hydrology cycles: interception, infiltration, surface runoff, depression storage, evapotranspiration, groundwater flow and interflow. According to Briglio [28] and Ferguson [29], the depression storage cycle happens when the stormwater is collected at the lowest depression of landform, while the evapotranspiration cycle happens through vegetation and water body ecosystems. The infiltration and groundwater flow cycle function through the root system of vegetation and soil (Ferguson [29]; Rutherford [30]; Low [31]). In addition, researchers have suggested that interception and surface runoff cycles also occur in stormwater retention on site. This is because of the use of vegetation as part of the biophysical elements in the concept: the foliage of vegetation will intercept some of the rainwater before the stormwater flows into the retention area. The surface runoff cycle occurs during the process of directing the stormwater into the retention area. Furthermore, researchers classified the interflow cycle based on two conditions: in natural landscapes and in developed landscapes (Briglio [28]). In natural landscapes, the interflow cycle can function as the vadose storage layer of soil is still conserved. Unlike in developed landscapes where the interflow cycle cannot function due to the absence of a vadose storage layer of soil (refer to Stephens and Dumont [26], as explained in the fourth concept).

The sixth concept is the treatment train. The treatment train is a modification of the train or landform to manage stormwater in the lowest areas and to protect the buildings and infrastructure by locating them in the highest areas. According to Low [31], the “treatment train is a method of integrating several strategies for various functions such as paving, channeling, storage and filtration that collectively manage the stormwater”. The treatment train concept can be classified into two areas: (i) upper-stream or highest point of the site, and (ii) downstream or lowest point of the site, as suggested by Broughton [32]. The classification is important in order to plan and design the strategies at site-scale level. In the upper-stream areas, source control strategies are crucial to reduce and treat the stormwater quantity and quality to reduce the impact in the downstream areas (Marsh [3]; Toronto and Region Conservation [17]; Broughton [32]). The treatment train relates to seven hydrology cycles: interception, infiltration, surface runoff, depression storage, evapotranspiration, interflow and groundwater flow, as it combines collective strategies (Low [31]). The infiltration, interflow and groundwater flow cycles function through the root

system of vegetation and soil. The surface runoff and depression storage cycles function through the movement of stormwater from the highest point of upper-stream into the lowest point of downstream. Lastly, the interception and evapotranspiration cycles function through vegetation and water body ecosystems. Furthermore, for the interflow cycle, researchers have classified it based on two situations: (i) natural landscape, and (ii) developed landscape (refer to Stephens and Dumont [26] and Briglio [28], as explained in the fourth and fifth concepts).

The seventh concept is the streetscape ecosystem. The streetscape ecosystem involves the integration of stormwater strategies with the street and its features, such as the median and traffic circles. Strategies like street planting and vegetative swale help to reduce the impervious cover (Toronto and Region Conservation [17]; Hager [19]; Australian and New Zealand Environment and Conservation Council [20]). Through the streetscape ecosystem, one of the extensive impervious covers can be used as a medium to manage stormwater. This is a good opportunity as the street is the main source of stormwater, and, to manage stormwater at the source, is very important. The stormwater from the street should be diverted from the drainage and directed into the landscaped curb, median and traffic circles where the vegetation can remediate the stormwater through the phytoremediation process. The streetscape ecosystem relates to six hydrology cycles: interception, infiltration, surface runoff, depression storage, evapo-transpiration and groundwater flow. The interception and evapotranspiration cycles happen through vegetation planted along the street and at the landscaped street features. The surface runoff and depression storage cycles happen by directing and storing the stormwater into the landscaped curb, median and traffic circles. The infiltration and groundwater flow cycles occur at the landscaped street features through the root system of vegetation and soil while the interflow cycle cannot take place because the streetscape is within a developed area (refer to Stephens and Dumont [26], as explained in the fourth concept).

The eight concept is restoration. Restoration concerns rehabilitating to a former condition: from a degraded condition to a healthy condition of biophysical elements of topography and slope, vegetation, soil and water bodies for the hydrology cycle to function. Marsh [3] and Hager [19] emphasized the strategy of soil, vegetation and topography restoration in order to restore the conveyance, storage, infiltration and treatment processes of the hydrology cycle. According to the Australian and New Zealand Environment and Conservation Council [20] and the Construction Industry Research and Information Association (CIRIA) [27], the conveyance process can be restored through filter strips and swale. The storage process can be restored through basins and ponds, while infiltration and treatment can be achieved through permeable and filter drains. Restoration relates to six hydrology cycles: interception, infiltration, surface runoff, depression storage, evapo-transpiration and groundwater flow. The interception and evapotranspiration cycles occur through restoration of the vegetation and water body ecosystems. The surface runoff and depression storage cycles occur through restoration of the topography and slope, and water

body ecosystems. Lastly, the infiltration and groundwater flow cycles occur through the root system of the vegetation and soil.

The last concept is the green network which is about the conservation and restoration of interconnected natural areas and retrofit green areas, especially the hydrology ecosystems. The green network is important in large-scale watershed planning to ensure the stormwater can be managed at the optimum level through all the processes of the hydrology cycle within the biophysical elements of the green network. The green network relates to all the hydrology cycles: interception, infiltration, surface runoff, depression storage, evapo-transpiration, interflow and groundwater flow. All the hydrology cycles can function because of the conservation of critical ecological areas, such as wetlands, riparian corridors and flood plains where all the biophysical elements are intact for optimum biological functions.

Lastly, the identified concepts are listed in relation to the order of priority (Table 2). The order of priority is based on the order of the highest relation of each concept with the hydrology cycle. In Table 2, the concept for number three is similar to number eight, and concept number four is similar to number nine. However, the concept has certain differences in the “presence of natural or undisturbed natural water body ecosystems” (green colour code) and “without the presence of natural or undisturbed natural water body ecosystems” (yellow colour code). The difference in the coding is significant enough to give a novel insight into the classification of the concepts. The reason being that the green colour code highlighted the significance to conserve the pristine biophysical elements for the hydrology cycle to function at the optimum level, whereas the yellow colour code showed the deficiency in the interflow cycle.

Table 2: Relationship of hydrology cycles with the concepts of planning and design of stormwater management.

Concept	**Hydrology cycle**	**Interception**	**Infiltration**	**Surface runoff**	**Depression storage**	**Evapo-transpiration**	**Interflow**	**Groundwater flow**
1. Conservation of watershed	**Relation**	🟦	🟦	🟦	🟦	🟦	🟦	🟦
2. Compact urban form		🟦	🟦	🟦	🟦	🟦	🟦	🟦
🟩 3. Retention of stormwater on site		🟦	🟦	🟦	🟦	🟦	🟦	🟦
🟩 4. Treatment train		🟦	🟦	🟦	🟦	🟦	🟦	🟦
5. Green network		🟦	🟦	🟦	🟦	🟦	🟦	🟦
6. Harvesting and reuse of rainwater		🟦	🟦	🟦	🟦	🟦		🟦
7. Redevelopment		🟦	🟦	🟦	🟦	🟦		🟦
🟨 8. Retention of stormwater on site		🟦	🟦	🟦	🟦	🟦		🟦
🟨 9. Treatment train		🟦	🟦	🟦	🟦	🟦		🟦
10. Streetscape ecosystem		🟦	🟦	🟦	🟦	🟦		🟦
11. Restoration		🟦	🟦	🟦	🟦	🟦		🟦
Legend:								
🟩 Similar concept to the yellow colour code but **with** the presence of natural/undisturbed biophysical elements – water body ecosystem								
🟨 Similar concept to the green colour code but **without** the presence of natural/undisturbed biophysical elements – water body ecosystem (retrofit, restored, man-made)								
🟦 The concepts have a relation with the hydrology cycle								
⬜ *White colour in the column of the hydrology cycle* The concept does not have any relation to the hydrology cycle								

6 Conclusion

In conclusion, to achieve sustainable stormwater management, a clear fundamental concept of planning and design must be outlined. The concept must be based on scientific knowledge in order to ensure the success of planning and design. In the context of stormwater management, the concept was outlined based on the hydrology cycle, the biophysical elements and the processes in order to replicate the hydrology cycle within landscape development. The researchers note that the priority order list of the concepts is important to identify which concept should be focused on, and to give a clear classification and information for the decision-making in respect of planning and design in sustainable stormwater management.

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Risk-oriented approach to long-term sustainability management for oil and gas companies in the course of implementation of investment projects

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Abstract

Under conditions of the economic and technology-related risks growing in the contemporary society, the availability of an efficient risk management system represents a crucial factor of business competitiveness and rate of return. This paper presents a proprietary approach to risk management for oil and gas companies in the implementation of investment projects. A rating model for investment project risk assessment considering the numerosity of factors is presented. A method for economic capital assessment based on the Merton–Vasicek model was developed which allows establishing the operating targets for long-term sustainability management for oil and gas companies under conditions of investment risk. Practical aspects of the risk assessment and management for oil and gas business are considered, as applied to a company playing in the sector. The results of the study may be used by the management of oil and gas companies, investors and analysts in the course of financial decision-making.

Keywords: long-term sustainability, oil and gas company, investment project, investment risks, probability of default, logit model, Merton–Vasicek method.

1 Introduction

Attraction of private investments in oil and gas companies is currently one of the priority lines of the sector development. The required amount of raised capital

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allows not only upgrading the existing technology but also setting up up-to-date objects in accordance with investment projects under implementation.

However, for potential investors, along with the yield and payback period, there is an undated question: how sustainable is this oil and gas company, what are its development outlooks, and what specific risks the investment project will run.

Therefore, we see an emerging complicated problem consisting not only in the study into latent risks run by the oil and gas company, but also in the analysis of the company's long-term financial sustainability in the realisation of multidirectional investment projects, taking into account the probability of default and volatility of mineral commodity markets.

The undertaken study resulted in the developed proprietary approach to the assessment of oil and gas company's economic capital, which allows the online identification of the most critical points in the implementation of respective investment projects and the development of corporate long-term financial sustainability management program.

2 Development of long-term sustainability for oil and gas companies

The current economic literature gives a variety of definitions for long-term sustainability of a company. Within the framework of this study, defining its principal development vector, the long-term financial sustainability of an oil and gas company should be deemed the business ability to ensure the continuity of performance, stability of revenue generation with continued capability of cost optimisation and high level of innovation activity considering sustainable competitive edges, unique market position and destabilising environmental exposure.

The basic factors affecting the development of long-term financial sustainability of and oil and gas companies were listed above. Nevertheless, the modern risk-oriented approach to the assessment of corporate sustainability defines a number of additional factors, such as: level of assumed risk within implementation of a specific investment project undertaken by an oil and gas company, related probability of the project default, as well as the company's ability to cover the default losses, i.e. the amount of economic capital (Domnikov *et al.* [1]).

2.1 The role of economic risk management in industrial development

The internal and external environment of the industrial company, are as a sources of opportunities for the realization of competitive advantages and as a sources of hazards for industrial development. Economic impacts from the implementation risks can be the following:

1. Direct losses associated with material damage inflicted company (losses of resources, fixed assets, intangible assets);
2. Deficiency the planned profit, cash flow due to the reduction of income, excess spending growth, loss of benefit, the use of investment alternatives.

Due to the complexity of the technological environment, economic and financial relations, the growing of uncertainty risk factors the main problem of risk management in industrial development take on special significance for long-term business planning and strategy implementation.

The variety of risks that track the development of industrial companies, includes the several economic risks. Quality of the risk-management defines:

1. The continuity of supply, which is the main condition for the regular industrial production;
2. The stability of production sales and operating cash flow of the business;
3. The efficiency of investment activity, adherence to which is achieved by the proper selection of investment projects and business portfolio of the company;
4. Business supporting of the necessary financial resources for current operations, capital programs, maintain technological level and modernization of production capacities.

In this regard, sustainable industrial development is impossible without the effective mechanism for the identification, evaluation and management of economic risks.

2.2 Specifics of investment risks run by oil and gas companies as an assessment factor for long-term financial sustainability

Within the framework of this study, twelve principal risks were considered including those of latent nature, which emerge during implementation of investment projects undertaken by oil and gas companies.

All specific risks are divided into two groups according to the level of impact on the oil and gas company: exogenous risks and endogenous risks (Domnikov *et al.* [2]). Below is given a brief characterisation of each of the groups.

The exogenous risks are independent of operations conducted by the oil and gas company and are beyond its control. In this study, the following risks are considered as such:

- Risk of "state attractiveness" characterised by the investment climate of a country where the company is operating (X_1);
- Risk of "regional attractiveness" characterised by the investment climate and developmental trends of a region where the company's investment project is being implemented (X_2);
- Mineral resource-related risk: global trends in the overall sector development considering the volatility of mineral commodity market (X_3);
- Government support-related risk: pursuit by a government in the country where the company is situated to make public investments, guarantee a certain level of return on private investments (X_4);
- Currency-related risk characterised by a potential losses for the company as a result of adverse changes in the foreign exchange rates (X_5).

The endogenous risks are the outcome of assessment and analysis into all spheres of operations and financial activities undertaken by the oil and gas company. The following risks are considered as such:

- "Operating" risk: general deterioration of company's financial standing as a result of inefficient operating activities (X_6);
- Investment project-related risk: risk of increase in the company's financial losses related to the implementation of investment projects (X_7);
- Investment risk: risk of general deterioration of company's financial standing as a result of inefficient miscellaneous investment activities (X_8);
- Underfunding risk: risk related to the investment project cost growth (X_9);
- Risk of contingent financial losses which are difficult to forecast and of a latent nature (X_{10});
- Environmental risk characterised by excessive industrial emissions to the environment (X_{11});
- Technology-related risk: plant and equipment renewal rate (X_{12}).

The practical assessment and analysis of each of the presented risks are given in Section 5 of this article.

3 Rating model for assessment of investment projects

General methodology for the assessment of long-term sustainability of investment projects based on the calculation of the company's economic capital was presented by the authors in a number of works (Domnikov *et al.* [1]). One of the components in this approach is a calculation of default probability for analysed investment projects using the logit model (Merton [3]). Specifics of the logit model are described in paragraph 3.1.

3.1 Specifics of the rating model for assessment of investment projects

Within the management of long-term financial sustainability for oil and gas companies, the assessment of emerging investment risks run by the projects offered for implementation is made by using a logit model. This involves a logistic transformation applied to the forecasting, based on the maximum likelihood (ML) method (Vasicek [4]).

General form of the logit model is given in eqn (1) (Vasicek [4]):

$$PD \quad = (y_i = 1) = \frac{1}{1+e^{-z}}, \tag{1}$$

where PD – the investment project default probability; $(y_i = 1)$ – the case where the investment projects becomes in default; $z = (b_0 + b_1 * X_{i1} + b_2 * X_{i2} + \cdots + b_n * X_{in})$; X_{ij} – the value of financial indicator *j* for investment project *i*; b_j – the estimated significance of factor *j*.

The basis for the logit model is data characterising the borrower's financial activity. As a rule, the logit model includes at least ten financial variables for analysis: equity to debt ratio, return on total assets, net earnings index, dummy variable characterising the sign of net earnings for the previous two years, etc. (Ohlson [5]).

Apart from the basic financial indicators, the logit model considers the combination of exogenous factors (investment climate in the country and region,

level of sector governmental support etc.), which play a key role in the process of financial decision-making by the investor.

The use of the logit model results in the ultimate ranking of investment projects according to the default probability.

3.2 Application of rating model to the assessment of investment projects undertaken by oil and gas companies

The model includes twelve risks described above; each of them has its own particular features within each of the investment projects of interest.

Given the difficulties in acquisition of statistical information on default probabilities for similar investment projects, this study made use of the expert assessment method. A questionnaire poll was conducted among heads of departments and divisional superintendents of an oil and gas company in Russia with respect to the assessment of presented risks according to the specified scale (Domnikov *et al.* [6]).

This assessment resulted in the specification of a logit model for the oil and gas company, applicable to each project *i*. The refined z parameter in eqn (1) will assume the following form, such as eqn (2):

$$z = \ 0.5578 + 1.0012 * X_{i1} + 0.8794 * X_{i2} + 0.1478 * X_{i3} + 0.9841 * X_{i4} + 0.5878 * X_{i5} + 0.6587 * X_{i6} + 1.0231 * X_{i7} + 0.1495 * X_{i8} + 1.0488 * X_{i9} + 0.8974 * X_{i10} + \ 0.2358 * X_{i11} + 0.9875 * X_{i12} \tag{2}$$

4 Basic components of capital risk model

The key parameters characterising an investment project for the purposes of assessing the economic capital are the following (Domnikov *et al.* [1], Gorby [7], Merton [3], Ohlson [5], Vasicek [4]):

PD – probability of default. A key indicator characterising the project risk level and reflecting the potential probability of the investment project default.

LGD – loss given default. Expected average relative losses to be incurred by the company in case of the investment project default. In case of default this portion of the investment project cost will be lost irrecoverably. The reason for introducing this indicator is that in the event of investment project default the project may be realised in full or in part by means of sale, insurance and option claims, etc.

EAD – exposure at default. This characterises an absolute value of the investment project and is determined by the project's full actual or forecast capital, current and other costs.

M – maturity. An average period during which the risk maintains its position. This is determined by the project investment phase duration. Prolonged investment phase will lead to growth of risks due to increased uncertainty of the implementation results. Shortened investment phase will lower the overall project risk.

The PD assessment model as a component of capital risk was described above. The economic capital is calculated considering the probability of investment project default.

The PD parameter is assessed in 4 steps:

1. Data pre-processing for modelling is made based on the implementation statistics for the company's investment projects over the durable period (at least 3 years). The key parameters for assessment may be the LGD for each defaulting project or the RR (recovery rate) characterising the percentage of the project cost, which was recovered as a cash flow following the project default.
2. Classification of investment projects by the criterion of LGD difference significance. Clustering of investment projects may be based on the criteria of scale, objectives, effect types, implementation periods, cash flow types, state of economy and other criteria. The final clustering shall be based on the criterion of significance of average differences in the sample, which may be estimated using the Student t-test, Fischer F-test, Kolmogorov-Smirnov test, Mann-Whitney U-test (Gmurman [8]).
3. Formulating the LGD distribution for each cluster. Based on the LGD statistical data the distribution for each classification group is formulated.
4. Estimation of LGD distribution form and determination of key parameters. At this step the distribution form is estimated and parameters for LGD modelling in each classification group are determined. The distribution form may be estimated using the chi square test, Anderson-Darling test, Kolmogorov-Smirnov test (Gmurman [8]).

From henceforth, when modelling the economic capital by Merton–Vasicek model the LGD numeric values will be used, however, for calculation of capital risk by simulation modelling method, LGD may be used as a random variable with parameters specified in Section 4.

The maturity characterises the penalty on the prolonged investment phase. Additional adjustment for the capital risk for the project duration more than 1 year is made using eqn (3) (Vasicek [4]):

$$M \quad = \frac{1+T \quad -2.5*b(PD)}{1-1.5*b(PD)}, \tag{3}$$

where M – the maturity, T – the investment project risk horizon, b(PD) = 0.00852 – 0.05489×ln(PD).

Shift and slope parameters for the maturity may be estimated by the company itself for different types of investment projects, based on the statistical data. Also, the model may be adjusted taking into account the investment project average duration (Gurtler and Heithecker [9]).

Also, the concentration factor for the company's investment projects may be considered a penalty, however, the concentration modelling is beyond this study.

5 Application of economic capital assessment model for an oil and gas company

Supposing that the investment program of an oil company includes 5 investment projects with the source parameters as given in Table 1.

Table 1: Key parameters of investment project under implementation.

№	Projects	Full cost, $ million	Project implementation period, years	Probability of default, %
1	Replacement of cold water pump	10	0.3	3.5
2	Upgrading of main oil pipeline	45	2	8.1
3	Oil storage construction	35	2	8.5
4	Upgrading of oil refining department at Refinery No 1	120	4	5.5
5	Upgrading of petrol station chain	30	2	5.4

Given the requirement to manage the long-term sustainability of oil and gas assets, determination of the financial sustainability strategic level, which is the long-run target, is the important stage of risk management. This level of financial sustainability may be determined using a target long-term credit rating the company is seeking to obtain. The company value and development strategy becomes an important factor in the risk assessment and management. Each credit rating may be assigned a certain level of PD, depending on the forecasting horizon. One of the matching options for credit rating and probability of default is given in Table 2 (Domnikov *et al.* [10], Khodorovsky *et al.* [11]).

Table 2: Correspondence between the probability of default and credit rating.

Rating	1-Y PD	3-Y PD	5-Y PD
AAA	0.008%	0.03%	0.1%
AA	0.04%	0.16%	0.28%
A	0.16%	0.4%	0.58%
BBB	0.3%	1.4%	3%
BB	1.15%	8.6%	15%
B	5.8%	15.4%	32.6%
CCC or lower	26.57%	45.5%	60%

The probability of default determines the level of confidence required to calculate the contingent losses and economic capital of an oil and gas company, which is calculated using eqn (4):

$$\gamma = 1 - PD, \tag{4}$$

where γ is the confidence level determining the probability of smash up non-occurrence; PD is the probability of default corresponding to the target credit rating.

Based on the LGD distributions, an estimate of statistically distinctive LGD basic parameters for each type of investment projects was obtained. The distribution is presented in Fig. 1 and Table 3.

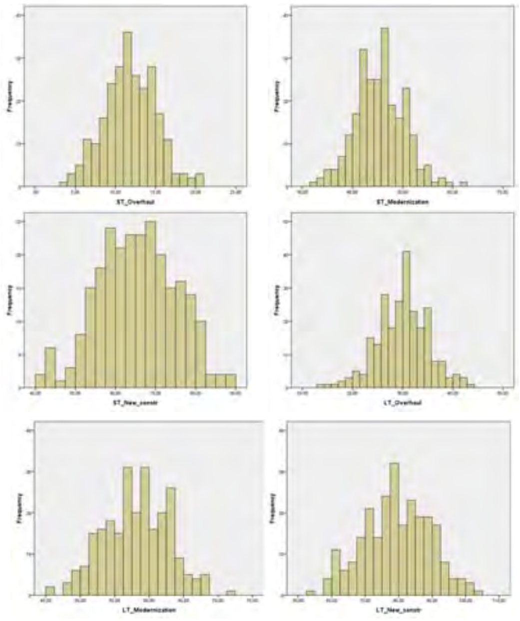

Figure 1: LGD distribution for main types of investment projects.

Table 3: LGD estimates for main types of investment projects.

Project duration/ Project type	Overhaul	Upgrading	New construction
Short-term	12%	45%	65%
Long-term	30%	58%	80%

The Merton–Vasicek model (Merton [3], Vasicek [4]) was used as a method for estimating the economic capital. The correlation coefficient between the project indicators and macro indicators, which allows separating the idiosyncratic risk from the systematic risk, is estimated individually for each of the project type. In this model the reliability parameter is specified at a level of 99.97% which corresponds to the target credit rating BBB. The company's economic capital is calculated using eqn (5) (Domnikov *et al.* [1]):

$$CaR = EAD * LGD * \left(N * \left(\frac{N^{-1}(PD) + \sqrt{R} * N^{-1}(\alpha)}{\sqrt{1-R}} \right) - PD \right), \tag{5}$$

where CaR – company's capital risk; N – standard normal distribution function; R – coefficient of correlation between the project (company) indicators and the overall state of economy; α – level of reliability.

The calculation of capital risk required to attain sustainability corresponding to *AAA, BBB, BB* ratings is presented in Table 4.

Table 4: Calculation of capital risk for different levels of financial sustainability.

Project	*EAD*	*T*	*PD*	*LGD*	*R*	CaR_{AAA}	CaR_{BBB}	CaR_{BB}
Replacement of cold water pump	10	0.3	0.035	0.12	0.1	0.19	0.15	0.03
Upgrading of main oil pipeline	45	2	0.081	0.58	0.25	12.11	10.26	3.43
Oil storage construction	35	2	0.085	0.65	0.2	9.97	8.46	3.31
Upgrading of oil refining department at Refinery No 1	120	4	0.055	0.58	0.55	28.77	25.82	0.15
Upgrading of petrol station chain	30	2	0.054	0.58	0.62	6.38	5.95	-0.06
Total:						57.41	50.64	6.85

The calculations have shown that the higher is the target corporate credit rating, the higher requirements to capital are set by the model. Thus, to match AAA credit rating, the capital required to cover the losses from the implementation of investment projects is $57.41 m, to match BBB rating, $50.64 m, and to match BB rating, $6.85 million (Peter [12]).

6 Conclusions

The business competitive position largely depends on its ability to perform in sustainable manner and to generate cash flows. In this aspect, the key issue is the risk management problem, the solution of which is a pre-requisite for ensuring the long-term sustainability of companies. This problem acquires a special significance under conditions of implementing the investment projects, which may either enhance the business efficiency and scale or lead the company to collapse. The capital management model which is widely used and commonly recognised in risk management is the basis for the approach offered by the authors to the risk management for oil and gas companies. A model for project default probability assessment was developed based on the rating system; a method is offered for estimation of capital risk key components, i.e. losses given default, exposure at default and maturity.

The methodological approach to the assessment of investment portfolio risks based on the Merton–Vasicek model proves effective and simple in application, however, a number of lines for modelling capital risk are promising. In particular, it is necessary to develop an approach to estimate the correlation between the investment projects and the overall state of economy, which implicates the formulation of a multi-factor indicator allowing the global trends and their impact on investment activity to be identified. Also, an important problem consists in the refining of EAD model, which considers the project cost distribution at defaulting. Solution of the said problems will allow ensuring the sustainable development of business under conditions of uncertainty and risk.

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Effects of the Brazilian biodiesel certification in the relationship between the biodiesel industry and small-scale farmers

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Abstract

The production of biodiesel in Brazil is encouraged by the government through the Fuel Stamp, a certification system linked to the National Plan for Production and Use of Biodiesel – PNPB – aimed at promoting economic and sustainable development. It focuses on social inclusion, also intending to reduce dependence on fossil fuels and emission of pollutants and diversify the energetic matrix through the use of different oil sources as raw material. Certification – and with it a number of tax benefits – are granted to industrial processors that are supplied with raw materials coming from small-scale farms. Thus, it facilitates the access of the family farms in this value chain. The objective of this work is to analyze the effects of this system of certification in the transactions between its main agents, farmers and processing industries. For this purpose, the work makes a revision of the studies that national public agencies have elaborated on regional cases and also scientific publications. Results show that this measure allowed the insertion of family farmers in the production chain and enabled the sustainable rural development. However, it presents gaps as the occurrence of failures in the fulfilment of contracts between family farmers and the industry. Moreover, in spite of being crop diversification, one of the objectives of the certification system, the preference of the industry for soy as raw material – because of technological reasons – is displacing traditional regional crops (for example palm and castor oil).
Keywords: biodiesel production, small-scale farms, Brazilian agriculture, Social Fuel Seal, rural development.

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1 Introduction

Biodiesel productive chain has a recent development in the world. In the case of Brazil, in spite of researches carried out over the last decades on this issue, it was only in 2004 that PNPB (National Program of Production and Use of Biodiesel) was officially launched by the government to consolidate the biodiesel market.

According to Milazzo *et al.* [1], in EU and the US sustainability and security of energy supply are the main concerns regarding biodiesel production, whereas in Brazil the socio-economic aspect is emphasized. The use of biodiesel as biocarburant energy indeed diminishes the dependence on fossil fuels and emissions of polluting gases. However, differently from the international tendency that puts focus on these environmental aims, biodiesel chain in Brazil divulges social inclusion as a fundamental pillar of its policy, in addition to the diversification of the energetic matrix using regional raw materials.

In order to encourage this social inclusion, a certification system was created – the Social Fuel Seal (SFS), which is granted by the Ministério do Desenvolvimento Agrário (MDA) [2] to the biodiesel producers who obtain raw material from family farmers. By way of a contract, biodiesel processors are committed to providing technical assistance to farmers, and they receive as a benefit tax reduction (which varies according to the type of raw material and the region where it is obtained) and allowance to participate in biodiesel auctions organized by ANP (Agência Nacional de Petróleo), where biodiesel is bought. In most ANP auctions (80%), the selling company needs to have the SFS. The formation of cooperatives among farmers is also stimulated to catalyse the transactions between them and industries, state Stattman and Mol [3].

An important issue regarding this chain in Brazil relates to natural advantages of this country, such as the territorial extension and favourable agro-climatic conditions for biomass production, according to Beneditti *et al.* [4]. However, despite these advantages Dos Santos *et al.* [5] warn that, if the government does not make the necessary interventions to diversify raw materials, the prevalence of soy, with higher yields and productive infrastructures controlled by large capital, will hinder the development of regional crops that may serve as raw material for biodiesel.

Within this context, the objective of this work is to analyse the effects of the Brazilian certification system in the transactions among its main agents, agricultural producers (and their cooperatives) versus processing industries. It is important to remark that the environmental aspects of biodiesel production exceed the scope of our study and will not be specifically tackled in this paper.

The remainder of this paper structures is as follows: in the following section, an overall picture of biodiesel production in Brazil is outlined. Section 3 tackles the main methodological aspects of this investigation. In Section 4, relationships among the main agents of the biodiesel chain are analysed in four case studies referred to different regions of Brazil. Discussion is carried out in Section 5, where positive and negative results will be assessed for each component of the chain: agriculture, manufacturing and distribution. Finally, we will present the conclusions of this study.

2 Background: current scenario of biodiesel in Brazil

As Pereira *et al.* [6] state, there are numerous plants distributed throughout Brazil that process oil from different crops such as soy, palm, castor, babassu, sunflower and peanuts. All these oils are suitable for the production of renewable fuel – raw materials representing about 75% of biodiesel production costs in Brazil, according to Conab [7]. The choice of the raw material is influenced by the potential of the different oilseeds for each geographic region and climate, states Khalil [8]. Palm oil and babassu palm are more appropriate for north region and rapeseed, sunflower and cotton are more favourable in the south. However, the total production of soybean oil-based largely prevails in Brazil (81.36% of total production), followed by the bovine fat (13.36%) and cottonseed oil (4.11%). The production of alternative crops is small and locally-based, as pointed out by Leonardi *et al.* [9].

Indeed, in spite of the efforts made to diversify the raw materials for biodiesel production, soybean large-scale monoculture production, with little demand for manpower (thanks to mechanization) and strong connection with commodity markets, is massively used as raw material despite its low oil content per hectare. Meanwhile, crops such as *jatropha curcas*, castor beans and palm, with a high oil content, do not experience any rapid expansion for biodiesel production. Soybean plantations already occupy 35% of the cultivated lands in Brazil, according to IBGE [10].

According to Conab [7], Brazil is the second largest soybean producer in the world, with a production of 81.3 million tons in the crop year 2012/2013. This production is led by the states of Mato Grosso, Paraná, Rio Grande do Sul and Goiás (29%, 20%, 15% and 11% of the national production respectively), and is expanding to the eastern states of Maranhão, Tocantins, Piauí and Bahia.

As for the socio-economic aspects of biofuel production, Dos Santos *et al.* [5] recall that the PNPB establishes a linkage between an energy policy and a social policy, by certifying the biodiesel producers that buy 10–30% of their feedstock from family farmers.

According to Stattman and Mol [3] the PNPB allowed the introduction of biodiesel in the Brazilian energy matrix which established biodiesel mandates, initially B2 (2% of biodiesel in diesel) to B5 (5% of biodiesel in diesel) to be reached in July 2010. Under legal provision, the required percentage of biodiesel mixed with diesel passed from 5% to 6% from Jul/2014, and 6% to 7% from Nov/2014. However, justified by the public interest, the National Energy Policy Council may at any time reduce it to 6%, states ANP [11].

Federal tax exemptions and incentives differentiate according to the utilized raw material, the size of the agricultural producer providing the raw material and the region of production. Steps are taken to stimulate biodiesel production and social inclusion mainly for family farmers in disadvantaged areas such as the semi-arid Northeast and Amazon. Thus, the percentage family farmer feedstock necessary for the industry to obtain the SFS is 15% in Center-West and North, 30% in North-East and Semi-Arid and 30% in South-East and South (year crop 2010/2011).

According to ANP [11] there are 58 plants of biodiesel authorized by ANP to operate, corresponding to an authorized total capacity of 21,163.5 m^3/day (see Figure 1).

Region	State Name	Plants	Capacity (m^3/d)
North	RO Rondônia	1	90,00
	TO Tocantins	2	441,00
		3	531,00
Northeast	BA Bahia	2	963,42
	CE Ceará	1	301,71
		3	1265,13
Center-West	GO Goiás	7	3481,00
	MS Mato G. do Sul	3	1030,00
	MT Mato Grosso	17	4873,25
		27	9384,25
Southeast	MG Minas Gerais	3	431,13
	RJ Rio de Janeiro	2	413,70
	SP São Paulo	6	1837,97
		11	2682,80
South	PR Paraná	4	1113,00
	RS Rio G. do Sul	9	5677,33
	SC Santa Catarina	1	510,00
		14	7300,33
Total		58	21163,51

Figure 1: Biodiesel plants authorized (m^3/d). Based on ANP (Dec/2014).

Finally, as regards to the economic impact of biodiesel production, it is important to note that it also stimulates the development of alcohol industry, consumed in the transesterification process for biofuel by the ethyl route, with the subsequent generation of employment and income, as highlighted by Pereira *et al.* [6].

3 Methodology

The information necessary for this work was obtained by way of an intensive review of the literature. Authors consulted national public agencies' reports and scientific publications that have elaborated on regional case studies, in order to determine the present situation of the investigated energetic sector.

Apart from scientific publications, consultations were made with competent organisms responsible for the biodiesel sector in Brazil such as MME, Ministry of Mines and Energy; EMBRAPA, Brazilian Farming and Livestock Research Agency; ANP, National Petroleum Agency; MDA, Ministry of Agriculture Development and CONAB, National Supply Company. International Symposiums that took place in Brazil were also used as reference, as well as journals with national impact.

Case studies will be analysed paying particular attention to the implications that the SFS is having for parties (small-farmers, cooperatives and industries), as well as the capacity of this certification to reduce uncertainty of transactions.

4 Relationships among the main agents of the biodiesel chain in different regions of Brazil

PNPB and the Social Fuel Seal have been widely known in several regions of Brazil and have had different effects in each case. For a better understanding, the analysis have been tackled separately for each region.

4.1 The southern region, state of Rio Grande do Sul

In the southern region, Dos Santos and Padula [12] analysed the way transactions occur in the biodiesel supply chain in Rio Grande do Sul. These authors state that before SFS was launched there was more opportunism in the relationships among actors, and family producers sometimes did not comply with their commitments with industries or cooperatives, commercialising the grain with another agent who offered a better price. This situation created uncertainties in the transactions and frequent changes of raw material suppliers.

With the implementation of SFS, industries are obliged to sign contracts assuring the grain value and technical assistance to family farmers. This fact made the transactions attached to the plants become more favourable to family producers, minimizing their intention to act in an opportunistic way. As a result, the variation of suppliers tend to diminish. The greater the confidence in the exchange relations among family farmers, the greater the frequency of transactions, what makes the chain structure more stable. The authors point out, however, that limitation of purchase in auctions with volumes and prices established by the government restrain the strategies of the industries and their profit possibilities.

Another empirical study by Silva *et al.* [13, 14], also focused in the southern region, analysed the impact of the SFS on the sustainable development from the industries' point of view. They found that a great motivation for these industries to insert in such market is the fact that PNPB guarantees the demand of biodiesel. The reason why industries choose SFS is a better participation in ANP auctions and the proximity to family farmers, since the Seal makes it possible to access to

a bigger market share. The main suppliers of the industries are cooperatives that mediate the relationship with the family farmers.

As for sustainable development, this addresses the socio-economic and, to a lesser extent, the environmental impact of this policy. The increase in the profits for the industry, as well as the creation of jobs and income for the region (450 jobs in Cachoeira do Sul, a municipality located in Rio Grande do Sul, and connection with over 1000 farmers directly) are highlighted. It was also noted that the SFS allows the approximation and faithfulness of farmers previously set aside by the system. As one environmental issue, the authors mention the provision of technical assistance to orientate farmers towards the correct application of the chemical products, avoid waste and soil erosion – what also has a social lecture.

It is worth noting, as an important factor discussed in this study, that according to processors biodiesel production in Brazil does not greatly interfere in the production of food, even considering that frontiers of soya cultivation are expanding. Moreover, the by-product of biodiesel production, specifically bran at low price, is alleged to revert to more food since it can be used for animal feeding. Other positive factor underlined in this study is the stimulation of areas that generally would be unproductive during winter time.

A negative statement made by the industries is that the farmer who cultivates other crops hardly stops producing them to produce soya. In sum, the Seal brings the industries bureaucratic changes seen as a barrier but, in general, it is considered as an opportunity for their insertion in the market. The investigated industries reported that only because of the SFS they would have the intention to participate in the biodiesel production market. Before that time they did not visualize competitive advantage, what was only possible because of all the incentives of the policy (tax benefits and guaranteed participation in auctions).

4.2 The south-eastern region, state of Minas Gerais

The empirical analysis performed in the south-eastern region by Leite *et al.* [15] compares different types of farmers in two regions: the semi-arid areas and the more humid region of the Brazilian Southeast, both in the state of Minas Gerais. Each farming system shows a distinct decision-making process and requires specific solutions.

In the more humid region, medium-large scale farms, there is an annual rotation of soya followed by grass seed; this cultivation is made by means of intensive use of inputs (machinery, agrochemicals) and farms differed mainly in size (49.1 ha to 116.7 ha).

In the case of semi-arid areas, small-medium size (2.4 ha to 46.4 ha), *diversity* is the most prominent characteristic of this production system. Farms are less intensive, combine cultivation with cattle production on grassland (larger farm area) or use a part of the land to produce maize and beans for self-consumption (smaller farms), and show low market orientation.

In both research areas, yields of sunflower and castor bean are relatively low. The provision of soil nutrients helps farmers to increase oil production and economic profits. The contracts included farmers' technical assistance with seeds – inputs provided by biodiesel producers.

In general, humid zone farms are more successful in obtaining information and credit and in delivering feedstock production, report Elbehri *et al.* [16]. In fact, farmers using soybean as raw material respond better to all terms of the policy of oil crop production and show higher gross margins than maize/beans farmers in semi-arid zones.

The potential of biodiesel crops for farmers in arid zones is lower than in humid zones, resulting in poor outcome in small-scale family farmers. These small-scale farmers were less affected by the biodiesel policy benefits, since the aggregate value associated with biodiesel oil crops was not sufficient to compete with traditional crops (i.e. beans). With fertilizer supply, sunflower crop could be a good alternative for these farmers.

Farmers and cooperatives indicate as an alternative to improve the viability of biodiesel production crushing the oil feedstock locally, through the deployment of small-scale oil extraction units, what could reduce current transportation distance by 75%.

4.3 The north-eastern region, state of Bahia

According to Stattman and Mol [3], the government noted complications with the implementation of the PNPB in this area due to the fact that biodiesel companies had little experience with technical assistance for family farmers.

Family farmers had small land areas, and they were only partly available for biodiesel feedstock production. Small producers also had little experience with biodiesel crops and seed provisions were not always appropriate or timely provided, resulting in low harvests, state Kilham *et al.* [17]. Contracts between family farmers and biodiesel industry were often ignored by farmers because they do not have business experience and preferred to produce other crops, what favoured local traders. In addition, a lack of commitment by industry as regards to payments and seed delivery is reported by Watanabe *et al.* [18]. Problems such as high logistical and transaction costs were recurrent.

From 2009, industries were allowed to buy biodiesel feedstock from agricultural cooperatives, and still receive the desired SFS if the cooperative has the legal permission emitted by the MDA. The number of cooperatives and farmers involved in biodiesel production have increased ever since because of the new market opportunities and the provision of technical assistance and seeds for farmers. Financial support for technical assistance and biodiesel contracts allowed the professionalization of cooperatives and more participation in the PNPB. As for the benefits for individual farmers, these authors mention the assistance for irrigation and for crops adapted to the agro-ecological conditions of the region. A local seed bank was also developed to improve productivity.

Cooperatives agree that medium-sized family farmers are better benefitted from the technical assistance and better adapt farming practices, because they have greater capacity to use new knowledge and change old production practices. The smallest farmers in remote areas produce what is essential to their subsistence and have less ability for structural changes, thus they benefit less from this policy, add Watanabe *et al.* [18]. In addition, they do not always understand the cooperative system. Distance and poor infrastructure complicate agricultural assistance in

remote areas. In general, these farmers choose not to join the PNPB or are not interested in becoming members of cooperatives. Some cooperatives report that farmers are not fully aware of the potential benefits of the policy for them.

There is uncertainty for cooperatives due to a significant dependence on the SFS for their establishment in the biodiesel market. Many cooperatives identify, as negative cases, industries that only use soy for biodiesel production and sell the other vegetable oils (castor and palm) to other industries, because they get higher market value for uses different to biodiesel production, as reported by César and Batalha [19]. In addition, some farmers do not want to stop negotiating with other potential buyers of their raw materials, breaking the contract assumed by SFS.

In sum, the PNPB states to have succeeded in stimulating agricultural modernization and innovation and thus the social inclusion of family farmers, but not all of them are equally benefitted from this policy. Cooperatives operate as instruments for the government to reach small farmers thus channeling technical advice, seeds, infrastructure and credit facilities to members. They created horizontal links between farmers and a vertical link between farmers and state/business organizations network, conclude Stattman and Mol [3].

4.4 The northern region, Amazon

In Brazil, palm crop is normally cultivated in the Amazon region, due to its good climate conditions for high oil palm productivity. Palm has a higher productivity than other oilseeds (3–6 tons of oil/ha by year), as well as more energetically efficient than other biodiesels and fossil fuels. According to César *et al.* [20] palm oil is not yet an important part of the biodiesel chain; in 2012, palm represented only 0.32% of this business. However, support policies such as easy credit and tax incentives reduce the cost of production and enable the competitiveness of this cultivation and regionalization of biodiesel production.

The intensive use of manpower, year-round production and good business opportunities are positive aspects of oil palm cultivation by family farmers. Moreover, this oilseed can be cultivated together with subsistence farming and intercropping with short cycle crops such as beans and corn. However, the production by family farmers is still experimental. Industries are only beginning to identify the family farmers in the northern region to participate in the production of palm. The strategy is to set processing plants in new nearby areas.

The SFS were signed with a small number of farmers to detect and correct failures before implementing it on a larger scale. Technical assistance is constant, which allows a better connection between industries and the small producers. According to these researchers, although there are groups of rural workers in the North of the country, cooperatives are still beginning to operate in this region.

As negative factors, the authors point out that the transportation infrastructure in palm cultivation regions is precarious. Industries often have to build and maintain roads. Difficulties related to register the family farmers interested in participating in PNPB are also reported, due to difficulties in accessing the regions where their properties are located.

The price of oil palm is currently high, what is considered another barrier in spite of its higher quality. These authors conclude that it is possible to expand its production to large scales if there is private and public participation to supply the food industry and the biodiesel chain.

For the time being, biodiesel production is less profitable than food industry considering oil palm, but biodiesel chain can also promote fuel supply in many isolated places of the northern region. According to these researchers, the use of oil palm appears to be a viable medium-term possibility, contributing to biodiesel chain and social inclusion of family farmers. The SFS quota for the North of the country is encouraging to engage processing industries.

5 Discussion

Table 1 summarises the main implications that, according to the analysed studies, the SFS has for participants (small-scale farmers, cooperatives and industries).

Table 1: Implications of SFS and biodiesel expansion.

Actor	
Small-scale farmers	- SFS is making possible the access to this chain for many small-farmers. - It is promoting farm diversification. - Farmers receive training and in some cases inputs (e.g. seeds) provided by industries. - Technical assistance orientates the producer towards the correct application of the chemical products avoiding waste and soil erosion. - Some participants face difficulties to stock their production in their small holdings. - Little experience with energy crops and difficulties to access appropriate seeds, resulting in low yields. - Subsistence farmers can hardly adopt the necessary changes to produce energy crops.
Cooperatives	- Strengthening and professionalization of cooperatives. - Cooperatives are investing in new facilities and equipment because of their relationships with industries. - However, investments make cooperatives very dependent on the maintenance of the SFS.
Industries	- Easier access to public credit and tax incentives. - Better conditions to participate in ANP auctions. However, they are restricted to public auctions and cannot resort to other potential buyers. - Contracts do not reduce industries' uncertainty, since sometimes farmers adopt opportunistic behaviour (in spite of the contracts, they sell to other buyers if they are offered a better price). This leads industries to look for new suppliers continually. The participation and mediation of cooperatives is reducing uncertainty. - There are several logistic and accessibility problems to access to farmers' production. In some cases industries have to construct roads and access to get raw material from some areas.

Source: Authors' elaboration

Besides the implications that SFS is having for participant farmers, the analysed studies also show that the system is side-lining other small farmers. In some cases, they are farmers located in remote areas with poor infrastructures, so that transportation costs are very high. In other cases, some small-farmers are reluctant to introduce some productive and managerial changes, particularly when they produce for self-consumption. Moreover, there are also farmers who prefer not to join cooperatives – which are channelling raw material from farmers to industries, so they keep out of this value chain.

From the point of view of regional crop diversification, authors point out that biodiesel production would not interfere with regional food production, which would prevent food insecurity implications. Nevertheless, the federal government's aim to promote energy crops diversity is not being realized due to infrastructure constraints and incipient technological development.

6 Conclusions

The consolidation of the biodiesel sector is still in process and depends on macro factors like government policies and micro questions like the input availability and production costs for each region and raw material. In spite of the PNPB and the SFS, important regional disparities persist regarding its performance (consolidation of cooperative structures, technological developments, diversity of raw material). Moreover, although SFS has allowed many small-farmers and cooperatives to participate and profit from this value chain, some uncertainties remain, particularly regarding the opportunistic behaviour of some farmers or the dependence of cooperatives on stable industries' demand.

On the other hand, according to WEF [21], government may impose additional costs and slow down the development of biodiesel sector due to excessive bureaucracy, overregulation and inability to provide appropriated services for the sector.

Issues related to sustainable development, with regard to the environment, should be analyzed more deeply, in order to achieve more tangible results.

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Energy strategies of industrial enterprises

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Abstract

In the context of a common external instability, uncertainty and unpredictable dynamics of energy prices, energy management is becoming one of the key focuses in industrial activities. Especially it concerns energy-intensive industry consumers using expensive and qualified energy sources as well as operating in a competitive market environment. The paper describes the types and sequence of formation of energy policy based on the principles of rational market behaviour. A comparative analysis of energy strategies of industrial enterprises is given. The structure of energy market capacity of the company and its relationship with the process of implementation of the chosen energy strategy is revealed. The examples of organizational and technical solutions in the energy strategies that promote energy efficiency and environmentally friendly production are given.
Keywords: energy strategy, energy costs, energy market, rational behaviour, market potential, organizational risks.

1 Introduction

All too often, energy sector reforms are conducted without due attention to energy consumers, although from the point of view of public interests it is the consumer who should be the focus of reform. Among the problems that arise because of this, we can identify the following: information asymmetries and poor understanding of energy market structure, bounded rationality of consumers, unfair terms in standard contracts drafted by suppliers, lack of legislation and weak public awareness, low quality of supply and different services, including ecological, dispute resolution procedures. In the period immediately following liberalization especially information asymmetries and cognitive errors could be widespread [1, 2]. It must be noted also that electricity (and partly gas) are very peculiar goods for which we should not expect that all industrial consumers are able to make rational and informed choices.

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Many corporate energy consumers are quite wary of current energy sector reforms and do not have a clear roadmap to adjust their behaviour to new circumstances. The following questions have to be answered:

- What are the implications of the reforms for the consumer?
- What will be the opportunities?
- What are the risks and threats?
- Is the consumer ready for operating in a competitive market environment?

Volatile energy prices have consistently increased the role of the energy factor in companies' economic performance. This is particularly relevant to energy intensive consumers that use energy derived from costly and renewable sources and operate in highly competitive markets.

2 Key approaches to energy cost management

There are two approaches to energy management which constitute an adequate response to growing energy prices [3]. The first one is to *reduce energy costs of a company to a minimum* considering more or less strict restrictions on the productivity of equipment, product quality, safety and the environmental impact of production processes. It has to be assumed that the consumer is unable to control energy prices or choose energy suppliers, so the desired result is mainly achieved through energy conservation and opting for cheaper energy sources when possible. In individual cases companies might adjust their range of products by discontinuing the ones with the highest energy inputs.

A peculiarity of this approach is that it weakens the link between energy management and operations management. As a result, the introduction of cutting-edge energy intensive technological processes and innovative products slows down, the availability of electric power per worker and electrification of production processes become stagnant. The approach, therefore, impedes the technological development of a company by keeping it at the achieved level of efficiency. This does not apply, however, to energy intensive facilities where electrification is at the maximum level. In this case, reducing costs is the only possible option.

The second approach is based on the principle of *optimization of energy costs* to meet the criteria of increasing the cost effectiveness of production and the company's competitiveness in relevant markets. In this case energy conservation and growing energy efficiency of production processes are combined with the introduction of new technologies and electrification, with energy saving measures and electrification not contradicting each other, but complementing and depending on one another. Although this concept might lead to higher energy costs than the first one, but technological development gets a new impetus to ensure the implementation of the company's strategic goals.

At the same time, execution of the more progressive and, of course, more effective concept of optimization of energy costs lies on the premise that the consumer is able to search for and freely choose between power supply options, energy prices, power suppliers and various supply services. As a result, a need appears to create *an energy strategy of an industrial enterprise* to be used as a tool for implementing the principle of "rational behaviour".

The management of manufacturing companies, therefore, starts to be guided by a completely new logic and methods when making managerial decisions. In the absence of any specific restrictions, such company can, for example, choose:

- whether to operate in a regulated or competitive electricity market;
- whether to buy electricity on the spot market or under a bilateral long-term contract;
- whether to enter the wholesale market or to sign a contract with a utility company on the retail market;
- whether to use the services of an independent utility company or a supplier of last resort;
- whether to deal with energy conservation issues on its own, or hire an energy service company;
- whether to buy electricity and heat from external suppliers or go off-grid;
- whether to use its privately generated electricity for the company purposes only, or to start selling it.

3 Rational behaviour of the energy consumer

Rational behaviour of the energy consumer can be defined as the desire to make the maximum use of advantages and opportunities offered by energy markets in order to cut energy costs, increase electrification of production facilities and develop one's own energy business while minimizing relevant threats and risks.

In this connection, a company should be guided by the following *principles of rational behaviour*.

Motivation for reducing (optimizing) energy costs. Different consumers will be inclined to take up a certain mode of behaviour in energy markets depending on *the strength of their motivation to take active steps*. Figure 1 shows two different kinds of behaviour: rational proactive (left) and passive ineffective (right). It has to be noted that positioning oneself in the market as a qualified consumer (who is an independent participant in the wholesale market), or as a customer of a utility is not necessarily a sign of the consumer's ineffective actions in the future (such positioning might be stipulated by technical characteristics of the consumer).

It is important to emphasize the impact of consumers' rational behaviour on boosting and maintaining competition in the production and sale of energy. By contrast, indifferent behaviour, if adopted en masse, can kill competition altogether.

Monitoring of one's energy market potential. Energy market potential describes technological, economic and organizational prerequisites for the consumer's ability to navigate a competitive market and manage market risks effectively. It is necessary to introduce energy market potential as a concept and a characteristic of an enterprise in order to determine:

- the market status of the consumer;
- motivation for reducing energy costs and engaging in energy business;
- the readiness of energy managers to be proactive in markets;
- priority market strategies (considering the results of an earlier analysis).

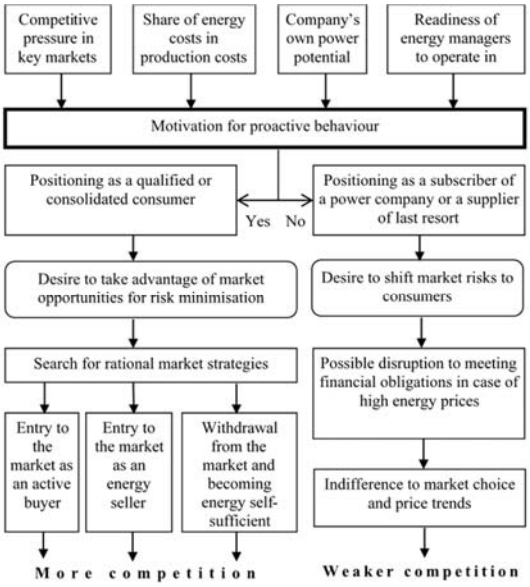

Figure 1: Alternative behaviours of industrial enterprises in electricity markets.

Table 1 presents elements of the potential, relevant indicators and areas of their application. Specifically, technological potential largely reflects the possibility of off-grid energy conservation, economic potential indicates the motivation factor; organizational potential shows the quality and preparedness of energy management in the company. The different types of energy potential call for different approaches to evaluating the characteristics.

Table 1: Structure of energy potential of an industrial enterprise.

Type of potential	Indicators and characteristics	Application
Technological	Connected load	Determines the consumer's status
	Energy intensity of production	Shows the importance of energy costs for core business
	Structure of energy consumption	Determines the choice of priority sources of energy
	Renewable energy potential	Assesses the possibility of energy self-sufficiency
	Adjustment options of energy consumption units	Indicates the expediency of switching to peak-load pricing
Economic	Intensity of competition in key markets	Assesses motivation for reducing energy costs
	Investment opportunities	Provides opportunity for off-the-grid power supply; prospects of developing energy business
	Financial performance	Determines the consumer's status
Organizational	Availability of automated metering devices	Determines the consumer's status
	Level of advancement in organizational structure of energy management Capacity for (low-cost) energy conservation	ssesses the readiness of energy management to operate in markets

It is possible to conclude that the higher the energy potential of a company, the bigger the room for active steps and the wider the choice of energy strategies and options of their combinations, while energy management becomes more flexible.

Flexible positioning in energy markets coupled with an active search for effective suppliers and bringing the company's energy management system into line with conditions in the competitive market. The principle implies that energy managers should possesses certain competencies to be able to operate successfully in electricity markets. Namely, they should be aware of:

- how electricity tariffs are constructed in the regulated and competitive sectors of the energy market;
- the basics of selecting an energy supplier;
- what services that are offered by energy service companies and utilities;
- how to organize cooperation with a vertically integrated company in a regulated market;
- modern methods of price risk management;
- technological and economic fundamentals of combined-cycle energy generation and ways of improving energy efficiency;
- the key types of advanced stand-alone power installations.

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4 Building energy strategies of the company

The main tool for implementing rational behaviour of the consumer in a certain sector of the market is his energy strategy. It defines a certain course of action that the company's energy management takes to take advantage of opportunities and offset threats and risks of the market.

Three basic strategies can be set out for different companies that reflect the above mentioned principles of rational behaviour in energy markets:

1) strategy of the buyer;
2) strategy of the seller;
3) combined strategy.

The strategies have a number of distinctive features.

Strategy of the buyer (Figure 2). This strategy can be referred to as a "price search strategy". It is suitable for companies that do not have power generating installations of their own and are not going to build any, or when available power generating units only meet part of their energy demand.

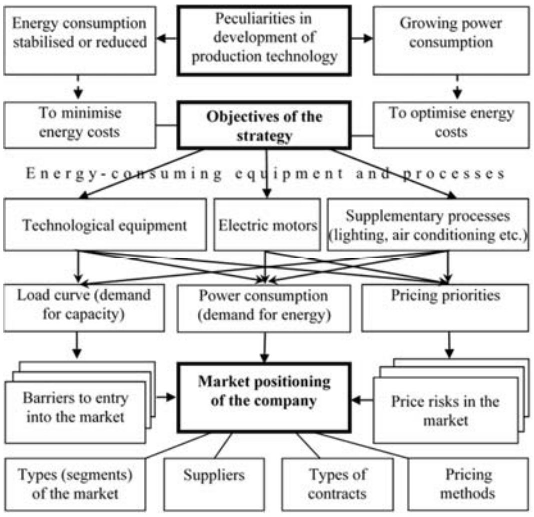

Figure 2: Building "price search" strategy of the buyer.

Technology used by some industrial enterprises results in the high energy intensity of production and the degree of production electrification that is close to limit values (for example, in electrometallurgy). In such a case, the strategic goal would be to "minimise energy costs" by improving energy efficiency and encouraging energy conservation as well as selecting a certain acceptable price of electricity considering the technical and commercial reliability of suppliers. At the same time, the desire to obtain the lowest price while having a margin for efficiency improvement in areas of production where electricity has no alternative is not only unproductive because it in fact blocks up investment in rationalizing energy use in such facilities, but also confuses the mindset of managers.

Other companies have technical and economic capabilities to use interchangeable energy sources and increase the level of production electrification when replacing high-quality fuels with electricity (for example, in some high temperature processes in machine building). Making use of these opportunities naturally leads to a higher share of energy in total production costs. On the other hand, the cumulative effect of electrification brings down other types of costs, increases equipment productivity and the quality of products. The overall economic effectiveness of production grows.

This case is matched by an objective of the strategy defined as "optimisation of energy costs". Here, the search of the best price is aimed at increasing the economic competitiveness of electricity by comparison with a substituted energy source (mainly natural gas). This means that the upper threshold of the electricity price band is determined by prices of natural gas. Consequently, it makes sense here to look for the lowest possible price of electricity.

As shown in Figure 2, demand for electricity by a manufacturing company is broken down into three blocks combining specific consumers: energy consuming equipment and processes. The reason is that the objectives of the buyer's strategy might differ not only with regard to different companies, but also depending on energy consuming processes within a specific company, with pricing priorities being different too. For example, cost optimisation as a strategic objective is consistent with technological consumption where there is room for electrification (for example, furnaces can be fueled by either gas or electricity). That is why it is desirable to obtain a permanently low price of electricity here. The objective of cost minimisation covers electric machinery and lighting as electricity is virtually the only source of energy for them, so higher energy tariffs encourage conservation. Additionally, consumers in the indicated blocks differ in power consumption modes and, sometimes, in their requirements for reliability of supply.

Therefore, the "block method" suggested in the buyer's strategy makes it possible to make more informed plans for capacity and power demand and put forth differentiated requirements for price thresholds and price risks. For example, an acceptable price risk when purchasing electricity for lighting can be higher than for technological purposes. Naturally, the implementation of the approach will necessitate installing submeters on each piece of equipment.

Arranging demand in blocks of processes envisages that they can simultaneously bid in different energy markets with different price offering mechanisms and price risks. For this reason, it is necessary to regularly monitor prices in all potential markets and accumulate strategic information for more effective risk management.

Strategy of the seller (Figure 3). The strategy can be dubbed "energy business". The following processes are engineered as part of the strategy:

- generation and sale of electricity (capacity) in wholesale and retail markets;
- generation and sale of heat (capacity) in local markets;
- provision of technology services in a wholesale electric power market (under a contract with the grid operator).

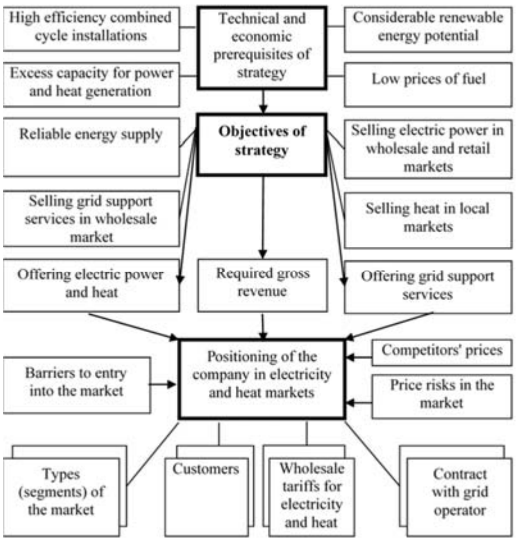

Figure 3: Building "energy business" strategy of the seller.

Running an energy business requires that the company have spare (excessive with regard to its own needs) generation capacity. The capacity can emerge as a result of reduction in its own energy consumption and subsequent changes in the output and product range. It can also emerge when industrial boilers are converted into steam turbine power plants and when factory steam turbine power plants are converted into gas turbine combined cycle plants. Both primary and backup installations can be used as commercial energy sources. Of course, only major corporations that have the necessary investment resources and access to cheap fossil fuel (e.g. big gas and oil producers) can afford to build heat and power plants with any significant capacity or buy assets of a major power plant for the purposes of energy business.

There are three main factors that define the competitiveness of an industrial heat and power plant in the heat and power market. First of all, it is the technological and economic characteristics of installations, steam turbine power and combined cycle units boasting the best ones. Secondly, it is the prices of fuel and the relative prices of electricity and natural gas. Taken together, these factors form the target revenue of the power plant. Thirdly, it is necessary to accurately determine wholesale tariff rates for electricity and heat, which will require effective price marketing arrangements and a method of allocation of the plant's indirect costs that is in line with the current market situation.

One has to bear in mind that the competitiveness of power plants varies seasonally: it is at the highest in the autumn and winter and is down in the summer when fossil fuelled electrical power generation decreases. It is, therefore, necessary to develop a mechanism of seasonal support for the company's energy business. Obviously, there are all sorts of solutions available.

As an ancillary business one should consider the potential of industrial heat and power plants to enter the market of technology (grid support) services (maintenance of grid reserve capacity, frequency regulation etc.). This market is organized by the grid operator, who also hires service providers.

Combined strategy (Figure 4). The strategy is called "consumer-regulator". Such a company buys electricity (capacity) in various markets, but also offers and provides frequency regulation services on the technology market. Two schemes can be employed as part of the strategy: with flexible power units and with back up peaking generators.

Flexible technological equipment should have the load shedding capability for peak demand times (up to a standstill) without any detrimental effect on the quality of products (for example, ferroalloy furnaces). During the nighttime the equipment should run in an accelerated mode. Demand for the regulatory resource of flexible technological equipment arises from the grid operator when, for example, it needs to restore balance of the grid or make up for a lack of peak demand capacity. In addition to receiving the asked price (later – a bid price set at auction) paid by the market operator for the services, the company can be exempt from a fee for grid reserve maintenance that is included in electricity tariff rates.

The standby peaking generator promptly goes online when the company's own costs of producing electricity fall below peak demand charges, and vice versa: when the company buys peak demand power if the prices are right, the generator is halted. This helps to manage through peak demand periods. Additionally, the generator can be included into the grid reserve capacity, which could enable the company to charge for this kind of service.

It has to be noted that any technology service available in the wholesale market is only paid for when it is solicited by the grid operator (provided there is an appropriate contract between the company and the market operator).

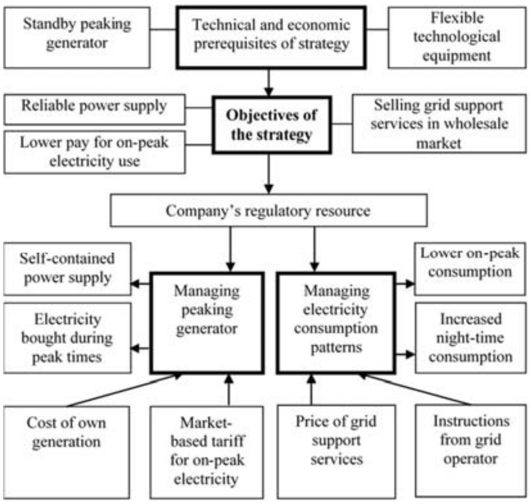

Figure 4: Building combined "consumer-regulator" strategy.

5 Conclusion

The following sequence of actions is suggested for building the above strategies:

- analyse technical and technological feature of production that predetermine the choice of a basic strategy;
- determine objectives, taking the technology factor into account;
- provide justification for the volume and structure of demand (supply) for energy sources and relevant services, including price priorities and restrictions;
- choose types (segments of markets), supplier (buyers), types of contracts and price-taking mechanisms.

We must emphasize that in terms of the consumers interests development of market relations in the power industry should ensure the stabilization and reduction of energy prices, increasing the quality and range of related services. Nevertheless, the basic value of the liberalized electricity market is the freedom of consumer choice.

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Sidoarjo mud: creating worth from waste

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Abstract

Sidoarjo mud (SM) is generated in considerable amounts from a volcano mud eruption caused by drilling from a gas exploration in the Porong area, Sidoarjo, East Java, Indonesia. The eruption of Sidoarjo mud has damaged the environment and destroyed a significant number of villages. Because of this, a study has been undertaken to convert this material from waste to valuable material in concrete construction. It is noted that Sidoarjo mud is perceived as a material that can be used as a partial cement replacement material called pozzolanic, and also as a source material for geopolymer concrete. Some studies revealed that the overall chemical composition of Sidoarjo mud is similar to Portland cement (OPC), and it is known that the content of Si, Al and Fe in SM is higher than in OPC. It is also known that the chemical composition Si, Al and Fe are the important elements in concrete especially for the properties development. In this study, it is evident that for conventional concrete, SM has clearly provided increased compressive strength and tensile strength at 10% replacement of cement weight by 26% and 9%, respectively.

Keywords: Sidoarjo mud, grain size, chemical composition, workability, compressive strength.

1 Introduction

Concrete is made from a properly proportioned mixture of hydraulic cement, water, fine and coarse aggregates and, sometimes, chemical or mineral admixture is added as an additive. Currently, the most common hydraulic cement used in construction material is Ordinary Portland Cement (OPC). Annually, the demand for concrete in the construction industry continuously increases, also causing the

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increase in demand for the use of Portland cement. It was estimated that OPC production increased from about from 1.5 billion tons in 1995 to 2.2 billion tons in 2010 [1].

The environmental issues associated with the production of OPC are well known. The quantity of the greenhouse gas, especially CO_2, released into the atmosphere due to the calcinations of limestone and combustion of fossil fuel during the manufacture of OPC was approximately one ton for every ton of OPC produced. In addition, the number of energy required to produce OPC is not renewable [2].

The increasing use of OPC persuades the researcher to consider how to reduce the use of OPC in concrete. These efforts include the utilization of supplementary cementing materials (SCMs) such as fly ash (FA), silica fume (SF), ground granulated blast furnace slag (GGBFS), rice-husk ash (RHA) and metakaolin, which can be used as a partial replacement to OPC [2].

2 Literature review

Recently, it was found that a new cementitious material called Sidoarjo mud (SM) is being produced abundantly in Indonesia. The material is a flood mud coming out from the earth bowels, which occurred in Sidoarjo, East Java, Indonesia [3]. Figure 1(a) and 1(b) show the SM eruption and impact to the surrounding area. The volume of mud is estimated to be about 100 thousand cubic meters per day, and the mudflow has brought tremendous impact to the surrounding community, especially the economic activity in East Java. The tragedy has also caused evacuation of villages, home/shelter destruction, agricultural and plantation area destruction, more than 15 factories flooded, causing the layoff of more than 1,873 people, educational and infrastructure facilities destruction, inhibition of toll roads between Malang and Surabaya that affect daily activity in Ngoro (Mojokerto) and Pasuruan regions which are the main industrial areas in East Java [4].


(a) (b)

Figure 1: The SM flood mud coming out from the earth bowels, in Sidoarjo, East Java, Indonesia. (a) The SM eruption; and (b) impact of SM to the surrounding area.

In addition, the SM is also harmful to public health. The content of heavy metals of 2.565 mg/liter Hg is alarming compared to the standard which is only 0.002 mg/liter Hg. It leads to respiratory tract infections, skin irritation and cancer. The phenol content can cause rupture of red blood cells (hemolytic), palpitations (cardiac arrhythmia), and renal impairment [5].

Numerous methods have been adopted to stop the SM flow such as dropping thousands of concrete balls into the mud volcano mouth [6], however, this method failed to stop the flow. Another method was to build containment 'basins' or 'ponds' by enclosing areas of land within earth walls, or levees [7]. It was known that this method did help to limit the damage, but it was not a sustainable solution because heavy rain caused the wall to collapse. Finally, it was decided to channel the mud to the Porong River and into the sea (Madura Strait), but the viscosity of the mud hampered the effort. Technical problems arose because the pump did not work well when mud siltation occurred in the pump [8].

Indonesia's environment ministry continues to seek alternatives to prevent the mud ending up in Madura Strait by collecting the mud on the beach and creating new mangrove wetlands or using the mud as a building material for road construction, or using it as a fertilizer mixture [5].

3 Experimental program

In this work, fresh SM was dried under the sun and placed in the oven at 100°C for 24 hours for further drying [9, 10]. This is important to eliminate the water content, so that smoke can be reduced when calcined. Then, the dry SM was placed in a furnace at a temperature of 500°C for five hours. After the calcination period, the mud was allowed to cool down gradually in the furnace until the temperature was similar to the outside or surrounding environment. The mud was then passed in a ball-mill machine for grinding for about two hours, and then sieved to obtain a particle size of less than 100 µm.

It is expected that the SM has a particle size similar to cement, so that it can act as a microstructure filler at the interfacial transition zone (ITZ). The mud characterization was performed using XRD analyses. Figures 2(a) and 2(b) show the solid SM and the ground SM, respectively.


(a) (b)

Figure 2: SM as supplementary cementing material. (a) Solid SM; and (b) grain size SM.

4 Results and discussion

The characterization of material was conducted to understand the material's chemical composition. It was found that the chemical composition of SM is similar to OPC while the particle size of SM is finer than OPC. It is evident that it can be a pozzolan as well as a filler.

Table 1 shows the chemical composition of SM and OPC. The SM is characterized with high silica, alumina and ferric, while OPC is characterized with high lime (calcium) and silica contents. It is evident that the elemental oxide of SM is quite similar to OPC and the sum of SiO_3, Al_2O_3 and Fe_2O_3 content is 76.5% which can be categorized as a class C of FA.

Table 1: Chemical composition of OPC, FA and SM.

Chemical	OPC	FA	SM
SiO_2	20.40	24.9	38.0
Fe_2O_3	4.64	32.3	26.2
Al_2O_3	2.84	10.3	12.3
CaO	67.70	20.9	7.46
Cl_2O	-	-	3.20
K_2O	-	2.8	4.77
SO_3	2.20	0.70	2.02
MgO	2.06	2.08	1.25
LOI	0.16	6.02	4.80

In terms of Cement Replacement Materials (CRMs) [9, 11], the SM had contributed to concrete properties such as compressive strength and tensile strength. It is shown from Figure 3 that cement replacement by SM is investigated up to 20% inclusion. In the short term, such as 1 day and 2 days, the compressive strength with 5% and 10% SM is significantly more than OPC but 15% and 20% SM is similar. The figure also shows that the increasing trend of compressive strength from 3 days to 28 days of 10% and 15% SM is similar with OPC In addition, at long term, after 28 days, the compressive strength of 5% SM is higher than 10% SM inclusion. It means that SM can improve the concrete properties in the long term.

It is also evident that increasing compressive strength from 5% to 20% SM follows a parabolic curve with peak compressive strength at 10% replacement of cement. Compressive strength after 15% SM is lower than OPC. It means that the optimum use of SM as cement replacement material in concrete is 10%, although after 28 days there is a possibility that compressive strength of 5% SM will be higher than 10% SM as shown in Figure 4.

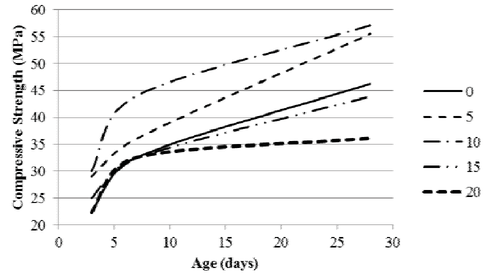

Figure 3: Compressive strength versus time.

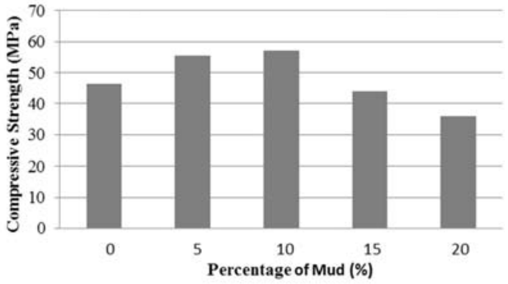

Figure 4: Compressive strength at 28 days.

Figure 5 shows that the tensile strengths of SM at 28 days with percentage of SM up to 20% replacement are higher than OPC, with the optimum splitting tensile strength at 10% replacement. However, splitting tensile strength of 20% SM is also higher than OPC.

SM porosity at 28 days it is shown in Figure 6. It is evident that porosities of SM with 5% and 10% replacement are lower than OPC, but for 15% and 20% SM it is found to be higher than OPC. It means that 5% and 10% SM have less pore in concrete, so that it gives higher compressive strength. On the other hand, 15% and 20% SM have more pore, and it gives lower compressive strength. It is generally accepted that the lower porosity will bring higher compressive strength in concrete.

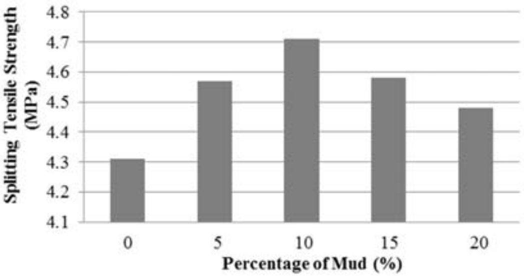

Figure 5: Tensile Strength at 28 days.

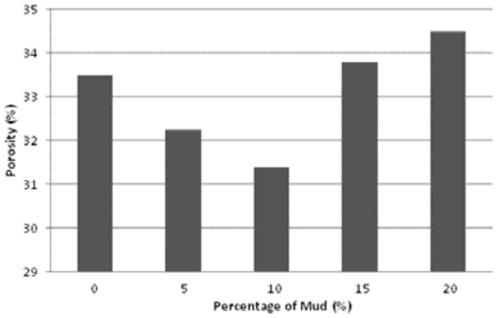

Figure 6: Porosity at 28 days.

5 Conclusion

The study to investigate the use of SM in concrete has been done to general properties of concrete and it is confirmed that treated SM from Porong, Sidoarjo, East Java, Indonesia, can be utilized in concrete as a cement replacement material. This material is available in abundance in Sidoarjo which, if not utilized, will have an adverse environmental impact.

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Section 6
Sustainable development studies

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Effect of sediment load reduction in tidal entrance channels

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Abstract

A matter of concern in water management is that the removal of suspended sediment accompanying the withdrawal of freshwater from a stream for commercial or recreational uses may induce long-term morphologic changes in the downstream estuary. To calculate the change in the cross-sectional area due to sediment load reduction in the estuarine entrance channel, the well-known method of Escoffier is used, and, separately, the adaptation time is estimated. The analysis is applied diagnostically to the Matanzas Inlet on the Atlantic Coast of Florida. It is a useful tool for a first-order estimation of the impact of withdrawal at tidal entrances where data for more accurate process-based modeling are scarce.

Keywords: Matanzas Inlet, method of Escoffier, sediment transport, tidal inlet, water management

1 Introduction

High water consumption usually requires water management agencies to consider long-term impacts of the withdrawal of freshwater from riverine streams. For example, the state of Florida's Minimum Flows and Levels statute mandates a scientific assessment of the likely downstream effects of reduction in the sediment load accompanying freshwater withdrawal (Neubauer *et al.* [1]). A significant reduction in high stream-sediment load may have measurable effects on the morphology of urbanized entrance channels where marine infrastructure can be dense. A method to calculate the cross-sectional area of entrance channels in sedimentary equilibrium was developed by Escoffier [2]. We will follow that

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approach to consider the likely effect of sediment load reduction on the cross-section, and calculate the time for adaptation from the initial to the final equilibrium cross-section. Lastly, we will diagnostically apply the method to Matanzas Inlet on the Atlantic Coast of Florida (Fig. 1).

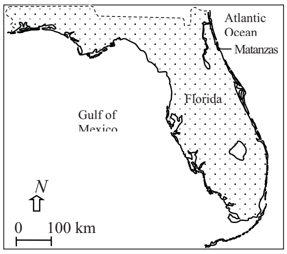

Figure 1: Map of Florida showing Matanzas Inlet on the Atlantic Coast.

2 Entrance cross-section

In general, the variation of area $A(x)$ of estuaries in sedimentary equilibrium can be approximated as

$$A(x) = A_0 e^{-\Xi x} \tag{1}$$

in which A_0 is the area at the seaward end, $x = 0$, of the estuarine entrance and Ξ defines the rate of convergence of A (Fig. 2). For entrances of short length x_L, we will assume that the mean depth is reasonably represented by $h_0 = A_0/B_0$, often the only available depth, with B_0 the width at the mouth. From Eq. (1) the mean area A_L is

$$A_L = \frac{A_0}{\Xi x_L}\left(1 - e^{-\Xi x_L}\right) \tag{2}$$

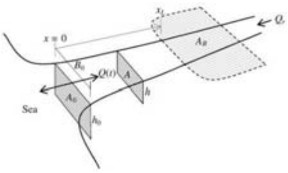

Figure 2: Estuary entrance definition, characteristic dimensions and parameters.

In general, h_0 increases with A_L and influences bed resistance (e.g. O'Brien and Dean [3]). This increase is evident in Fig. 3, which includes entrances from both, the Atlantic and the Gulf of Mexico, coasts of Florida. As A_L increases the width increases more readily than h_0, which is limited by the scouring ability of the tidal stream-power. "Small" and "large" entrances are notionally defined with respect to area and separated at A_L = 20 m². The dependence of h_0 on A_L is less sensitive at wide entrances than at narrow ones. Moveable-bed model data are included for completeness. The mean trends are given by

$$h_0 = pA_L^m \tag{3}$$

with p and m equal to 0.224 and 0.500 for small entrances, respectively, and 0.369 and 0.333 for large entrances. From Eq. (3)

$$\frac{dA_L}{A_L} = \frac{1}{m}\frac{dh_0}{h_0} \tag{4}$$

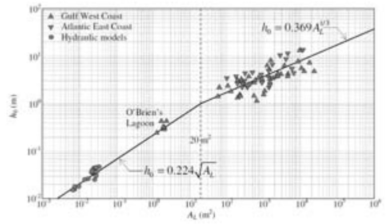

Figure 3: Dependence of h_0 with A_L at entrance channels in Florida based on data from Powell *et al.* [4]. O'Brien's Lagoon vanished during 1980s. Physical model data are from Bruun [5].

Thus, as m is smaller (= 1/3) at large entrances compared to small (= 1/2), area change (relative to original) at large entrances is more susceptible to depth change (relative to original) than at small entrances.

3 Sediment load

Following Powell *et al.* [4], we will relate the volumetric bed-material load Q_s to water discharge Q by the well-known Einstein-Brown formula for sand transport (e.g. Julien [6]) as applied to channels in sedimentary equilibrium. This formula can be expressed as

$$q_s = K\frac{q^6}{h^7}; \quad K = \frac{20gn^6}{9\nu\left(s-1\right)^2} \tag{5}$$

where at any distance x, $q_s = Q_s/B$ is the unit sediment load, $q = Q/B$ is the unit discharge, B is the channel width, h is the water depth, s is the particle specific

gravity, v is the kinematic viscosity of water and n is Manning's bed resistance coefficient representing energy loss distributed over the channel.

Estuaries that generally conform to Eq. (1) are considered to be in sedimentary equilibrium over a suitably long duration relative to tidal period T. At every x the tide-mean area $A(x)$ bears a fixed relationship with the mean tidal prism $P(x)$ raised to some power (close to unity) (O'Brien [7]). From Hughes [8] and Powell *et al.* [4] among others, this relationship based on Eq. (5) is

$$A = \Omega P^{6/7} \tag{6}$$

where

$$P = \frac{2UA}{C_k\sigma}; \quad \Omega = \left(K\frac{C_k^6\sigma^6}{\pi^6 p^2\alpha_s Q_s}\right)^{1/7} A^{4/21} \tag{7}$$

In Eq. (7), C_k (= 0.86) accounts for the effect of overtide, which increases the prism above its value obtained by assuming the discharge to be sinusoidal. The fraction α_s defines reduction of sediment load, and $\alpha_s Q_s$ is the load in transport. As α_s becomes smaller than 1, Ω increases and, for a given P, A increases as well. If we hypothetically consider the width to remain constant, sediment load reduction will erode the bed, i.e. increase the channel depth. This is evident from the dependence of q_s and q on h in Eq. (5). The rate of expansion of the cross-section by erosion will decrease gradually from maximum at the onset of adaptation to nil when the new equilibrium area is achieved.

Equation (6) sets the sediment transport requirement in the equilibrium estuary. To address its range of applicability, in Fig. 4 data are given from nine estuaries. Overall, given A in m² and P in m³, 0.0015 is a mean equilibrium value of Ω in the absence (α_s = 1) of load reduction. For individual channels the exponent tends to differ from 6/7. Equation (6) has been used extensively for entrance channels, with the actual value of the exponent ranging between about 0.95 to 1.05 depending on the coast, e.g. Atlantic or Gulf, and whether the channel is natural or modified by jetties or dredging (Powell *et al.* [4]).

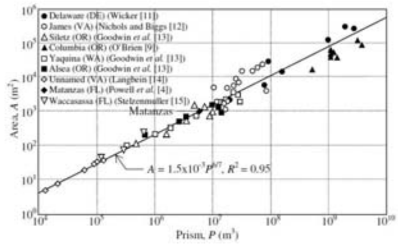

Figure 4: Cross-sectional area against mean tidal prism from nine U.S. estuaries, based on data compiled by Alkhalidi [16] and Powell *et al.* [4].

Equations (6) and (7) provide a means to estimate the unit sediment load q_s (average value over flood or ebb tide) along the estuary with known A and P. This is done in Table 1 for the Columbia River estuary (Oregon–Washington). Cross-section 1 at the Pacific Ocean entrance and cross-section 9 40 km upstream mark the lower reach of the estuary in which the sandy bed has a median grain diameter of 0.24 mm (O'Brien [9]). Noting that $s = \rho_s/\rho_w$, the relevant parameters are water density ρ_w = 1,010 kg m⁻³, sediment density ρ_s = 2,650 kg m⁻³, water kinematic viscosity 1.15x10-6 m² s⁻¹, nominal tidal period T = 44,712 s and Manning's n = 0.044 (Leopold *et al.* [10]). There is a general agreement between the measured and calculated unit loads, q_{sm} and q_{sc}, respectively. However, the error ε_r varies widely between -52.1% and 259%. The mean value of 29.6% is smaller and not unreasonably high, considering the interfering effects of tidal asymmetry, river discharge and the approximate method used to derive the loads (O'Brien [9]).

Table 1: Unit discharges and loads along the Columbia River estuary, Oregon/Washington.

Cross-section No.	h (m)	A (m²)	P (m³)	q_{sm} (m² s⁻¹)	q_{sc} (m² s⁻¹)	ε_r (%)
1	14	4.70x10⁴	1.04x10⁹	2.36x10⁻³	1.37x10⁻³	-40.4
2	12	4.00x10⁴	1.38x10⁹	1.18x10⁻²	2.30x10⁻²	100
3	9	4.00x10⁴	1.07x10⁹	3.82x10⁻³	6.67x10⁻³	78.6
4	8	4.90x10⁴	1.09x10⁹	5.18x10⁻³	2.48x10⁻³	-50.9
5	17	1.20x10⁵	3.12x10⁹	5.99x10⁻³	2.98x10⁻³	-49.1
6	7	5.60x10⁴	1.20x10⁹	1.43x10⁻³	2.26x10⁻³	61.7
7	10	9.50x10⁴	3.64x10⁹	1.48x10⁻²	5.18x10⁻²	259
8	6	6.40x10⁴	1.07x10⁹	1.27x10⁻³	5.96x10⁻⁴	-52.1
9	10	1.70x10⁴	4.94x10⁸	1.69x10⁻²	9.86x10⁻³	-40.2

Data source: O'Brien [9].

4 Equilibrium area

The equilibrium cross-sectional area A_{Le} of the entrance channel can be identified from the Escoffier diagram sketched in Fig. 5. It is defined by two relationships between area A_L and maximum (flood or ebb) current velocity (amplitude) U_m. The hydraulic curve H is determined by the tide at the mouth, channel length, depth, width and flow resistance, as well as the flood water storage capacity of the embayment of surface area A_B upstream of the short channel. The sedimentary curve S obtained from Eq. (6) can have a slightly negative or positive slope depending on the actual exponent in Eq. (6). Curve $S(\alpha_s$=1) characterizes the equilibrium of the channel in the absence of load reduction. The intersection of $S(\alpha_s$=1) with H, at point a, defines pre-load-reduction value of A_{Le}. The respective velocity is U_{ma}. The second intersection at a' represents a channel at the threshold of instability in the sense that in the event of a sudden deposition of sediment the area and the current velocity will decrease, while flow resistance will increase. This in turn will encourage further deposition, area reduction and velocity

reduction. Eventually this "downward spiraling" process will reduce the flow to the point at which the sand from the river or the littoral zone will effectively close the mouth. In the present case, since the pre-load-reduction channel is in stable equilibrium, we will not consider the condition at a' further.

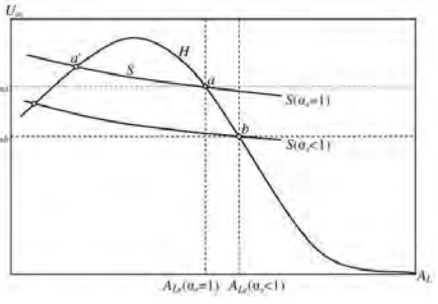

Figure 5: Escoffier diagram showing area-velocity relationships for short tidal channels.

We will consider large channels, with m = 1/3 in Eq. (3), for which the H-curve is obtained from a conveniently linearized relationship between the hydraulic head-loss due to bed resistance and the current velocity, i.e. linearized Darcy head-loss equation (e.g. Bruun [5]). The selected solution for the H-curve is one among several similar inlet hydraulics solutions obtained by solving the depth-integrated unsteady flow-continuity and momentum equations for short open channels (Bruun [5]). The solution assumes that the channel has no length, i.e. x_L is a notional length that determines inertia of the mass of water in the channel and bed resistance to water movement. The tidally oscillating discharge $Q(t)$, where t is time, depends on surface area A_B. This area is considered to rise and falls in unison, i.e. the surface is horizontal at all times as seawater enters as flood flow and leaves together with freshwater as ebb flow. The freshwater discharge $Q_r << Q_m$, where the latter is the maximum tidal discharge during ebb (or flood) flow. Inasmuch as over the length of a typical estuary, tidal motion is in the form of a wave, i.e. its rise and fall are not in-phase, A_B is an effective area consistent with in-phase water level oscillation.

The solution for the peak tidal velocity $U_m = Q_m/A_0$ is given by

$$U_m = \frac{\sqrt{2}k_0 A_L^{13/9}}{k_4}\sqrt{\sqrt{\left(1-\frac{k_1}{A_L}\right)^4 + \left(\frac{k_4}{A_L^{22/9}}\right)^2} - \left(1-\frac{k_1}{A_L}\right)^2} \tag{8}$$

where

$$k_0 = a_0 A_B \sigma;\; k_1 = \frac{x_L\, A_B \sigma^2}{g};\; k_2 = \frac{a_0 A_B}{2x_L};\; k_3 = \frac{2g x_L n^2}{p^{4/3}};\; k_4 = \frac{16}{3\pi} k_1 k_2 k_3 \qquad (9)$$

Application of Eqs (6) and (8) to real systems has been extensively explored and described elsewhere (e.g. Bruun [5]). For given tidal amplitude a_0, U_m is sensitive to A_B and channel length x_L, which together determine the relative roles of head-loss and inertia of the oscillating water mass in the channel.

The *S*-curve is obtained from Eqs (6) and (7). The area A_{Le} is the equilibrium value at which the *H* and *S* curves intersect, i.e. the area which simultaneously satisfies the two equations. It is readily obtained by solving Eqs (6) – (9) after setting $A_L = A_{Le}$. The solution, implicit in A_{Le}, is

$$A_{Le} = \left\{ k_5 A_{Le}^{16} \left(\sqrt{\sqrt{\left(1-\frac{k_1}{A_{Le}}\right)^4 + \left(\frac{k_4}{A_{Le}^{22/9}}\right)^2} - \left(1-\frac{k_1}{A_{Le}}\right)^2} \right)^6 \right\}^{1/7} \frac{1}{(\alpha_s Q_s)^{1/7}} \qquad (10)$$

where

$$k_5 = \frac{2^9 K}{\pi^6 p^2} \left(\frac{k_0}{k_4}\right)^6 \qquad (11)$$

Equation (10) is solved iteratively for A_{Le}.

5 Effect of load reduction at Matanzas Inlet

Matanzas Inlet, the entrance of Matanzas River estuary (Fig. 6), is subject to semi-diurnal tide with meso-tidal amplitude a_0 = 0.75 m. In the approximately 3 km long entrance channel, freshwater discharge Q_r is negligible compared to a tidal mean discharge of 626 m^3 s^{-1} (Powell *et al.* [4]). The channel is short compared to the tidal wave length where *g* is the acceleration due to gravity and σ = 2π/*T* is the tidal angular frequency. Taking *T* = 44,712 s and h_0 = 2.6 m (Powell *et al.* [4]), x_L is only 1.3% of the tidal wave length.

Referring to Fig. 5, as soon as sediment load is reduced, the point of intersection of the $S(\alpha_s{=}1)$-curve with the *H*-curve at *a* denotes a hypothetical condition because the flow area cannot change instantaneously. In reality, adaptation of the area from $A_{Le}(\alpha_s{=}1)$ to $A_{Le}(\alpha_s{<}1)$ takes place only after a suitably long time as the interaction between flow and sediment transport gradually leads to a new equilibrium.

The dependence of A_{Le} on α_s can be illustrated for Matanzas Inlet. We will take the year 1976 when the estuary had been undisturbed by a significant storm over the previous 12 years since Hurricane Dora in 1964. The relevant values are: x_L = 3,000 m, A_B = 3.5x10^6 m^2, *p* = 0.369, *n* = 0.0285, *s* = 2.65 and *v* = 10^{-6} m^2 s^{-1} (Powell *et al.* [4]; Bruun [5]). The sediment load Q_s = 1.8x10^{-4} m^3 s^{-1} is obtained by calibration of Eq. (10) with respect to the 1976 channel cross-section area of 820 m^2. We will consider the load reduction fraction αs to range from 1 (no reduction) to 0.25.

Figure 6: Matanzas Inlet, Florida (Google image).

In Fig. 7, for α_s = 1, 0.75, 0.50 and 0.25 the *H*-curve and the four *S*-curves intersect at A_{Le} = 820, 864, 928 and 1,047 m^2, respectively. In Fig. 8 the plot of Eq. (10) shows that, consistent with Fig. 5, A_{Le} decreases with increasing load reduction. The pre-load reduction tidal prism *P* = 6.2x10^6 m^3 obtained from Eq. (7), with $A_L = A_{Le}$, is close to 5.2x10^6 m^3 at about the time of load reduction (Powell *et al.* [4]).

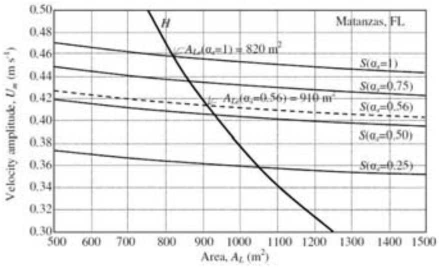

Figure 7: Effect of sediment load reduction on the equilibrium area of Matanzas Inlet.

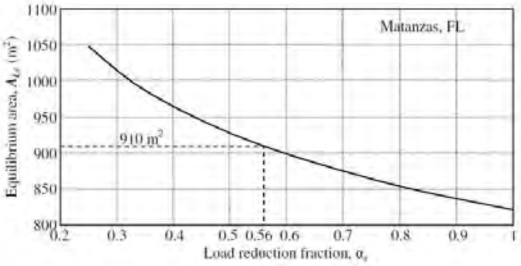

Figure 8: Variation of equilibrium area of the channel with load reduction fraction at Matanzas Inlet.

In 1976/77 a land breach between the estuary and the ICWW (Fig. 6) reportedly due to Hurricane Dora in 1964 was repaired (Hayter and Mehta [17]). This action is believed to have decreased sand movement in the entrance channel. A manifestation of load reduction was that, by 1995, a reasonably long (19 yr) duration for the entrance to achieve new equilibrium, A_{Le} increased to 910 m^2, i.e. by 11%. This increase corresponds to a calculated volumetric discharge of 1x10^{-4} m^3 s^{-1}, i.e. α_s = 0.00010/0.00018 = 0.56 (or 56% of the pre-load-reduction value) as the 19-year mean.

6 Adaptation time

As the method of Escoffier concerns equilibria only, for an estimation of the adaptation time relevant to load reduction we use a modified form of the approach of O'Connor *et al.* [18] developed for the effect of altering the tidal range on the estuary cross-section. Letting *N* denote years, the rate of expansion of area A_L due to bed erosion at the onset of load reduction (*N* = 0) is conveniently taken as

$$\left(\frac{dA_L}{dN}\right)_{N=0} = M(q_s - \alpha_s q_s) = Mq_s(1-\alpha_s) \qquad (12)$$

where *M* is the erosion rate constant (e.g. Julien 2010). The expansion, at first rapid, gradually wanes until A_L approaches a new equilibrium value A_{eF} (corresponding to point b in Fig. 5). This can be expressed as

$$A_L = (A_{eF} - A_{eI})(1 - e^{-K_3 N}) + A_{eI} \qquad (13)$$

where subscript I denotes pre-load-reduction equilibrium. The time-constant K_3 is obtained from Eqs (12) and (13) as

$$K_3 = \frac{Mq_s(1-\alpha_s)}{A_{eF} - A_{eI}} \qquad (14)$$

If after N_F years the area reaches a value (1-ε)A_{eF}, which is close to A_{eF} (using ε = 0.05, a conveniently small fraction amounting to A_L reaching 95% of A_{eF}), we get

$$\frac{A_L}{A_{eI}} = \left(\frac{A_{eF}}{A_{eI}} - 1\right)\left[1 - e^{-\left\{\frac{1}{N_F}\ln\left[\left(\frac{A_{eF}}{A_{eI}}-1\right)/\left(\frac{A_{eF}}{A_{eI}}\varepsilon\right)\right]\right\}N}\right] + 1 \qquad (15)$$

in which the term within the curly brackets is K_3. Finally,

$$N_F = \frac{A_{eI}\left(\hat{A}_{eF} - 1\right)}{Mq_s(1-\alpha_s)} \ln\left(\frac{\hat{A}_{eF} - 1}{\hat{A}_{eF}\varepsilon}\right) \qquad (16)$$

where, $\hat{A}_{eF} = A_{eF} / A_{eI}$ is used merely for compactness of the equation.

At Matanzas, A_{eI} = 820 m^2, h_0 = 2.8 m, A_{eF} = 910 m^2, α_s = 0.56 and $q_s = Q_{sh0}/A_{eI}$ = 6.14x10^{-7} m^2 s^{-1}. Choosing *M* = 1.24 as calibration value yields N_F = 6x10^8 s, i.e. 19 years (1976–1995). In general, *M* depends on the grain size, bed features and channel geometry. Identification of this dependence for Matanzas requires three-dimensional numerical modeling of sandy bed erosion in the channel.

7 Concluding comments

The analytic method provides a first-order estimate of the impact of reduction in sediment load (due to upstream freshwater withdrawal) on the cross-section of the tidal entrance channel. The degree of area expansion relative to the original and the time it takes to expand are both important in defining the protocol for water uptake, e.g. by pumping. The method is illustrated by application to Matanzas Inlet. Although in general numerical modeling is a powerful tool to assess quantitative effects of load reduction, the described approach is especially useful for preliminary estimations of impacts at tidal entrances for which the morphodynamic database is limited.

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Sustainable development of the Russian Arctic regions

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Abstract

The paper describes a model of six econometric equations, which is used for the analysis of development sustainability of Chukotka autonomous district – one of the Russian Arctic regions. The paper analyzes the following spheres of human activities within the region: the social sphere, the industrial sphere and the environmental sphere. Each sphere is evaluated with indicators. The theoretical views of various researchers on sustainable development are analyzed and the definition of sustainable development of the spheres of human activity in the arctic region is given. Under sustainable development of the arctic region one should understand such dynamics of the development indicators of various spheres of human activity in the region that show growth of the human development potential. The human development potential can be estimated with the human development index (HDI). The paper includes methodological principles of creation of the model of six econometric equations for the analysis of development sustainability of the region. Each equation is an ADL-model, because the ADL-model allows for estimation of dependencies of different indicators of human activity on the current and past time series of other indicators. The endogenous and exogenous variables of the model were chosen. The algorithm of model parameters calculating is being discussed. The coefficients of the six econometric equations are calculated on the data of Chukotka autonomous district. The analysis of the results is presented. The methodological principles of model creation and the solving results can be used while working out the sustainable development strategy for municipality, or single arctic region, or even all the Russian arctic regions.

Keywords: sustainable development, econometric equations model, ADL-model, Arctic region.

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1 Introduction

The object of analysis of the article is Chukotka autonomous district. This territory belongs to the regions of the Far North, which includes the whole Chukotka peninsula, the part of mainland and several islands (Wrangell island, Ion and Ratmanov islands and others).

The Chukotka territory is rich in water resources. There are more than 8000 rivers more than 10km long. The majority of the rivers are mountainous. The rivers are primarily fed by snow and rainwater, with long periods of freezing (7–8 months) with intensive floods and uneven river flow. Some rivers are freezing up to the bottom with forming of ice barriers. Break-up of the rivers is often accompanied with congestions due to later break-up in the lower course.

The majority of the lakes are of thermo-karstic origin, only some of the lakes are situated in the mountainous part of the district. The lakes near the Arctic ocean are of lagoon origin, so they are with salt water. The majority of the lakes are with running water, some of the low-lying lakes become swampy.

There are 44 groundwater origins found, 19 of them are used.

The vast amounts of mineral resources can be found in the region. They are crude oil, natural gas, coal, gold, tin, wolfram, mercury, copper and uranium. In the sea sediments of the East Chukotka coastal area one can find single diamonds [1].

The population of the district is 50,555 people (2014, Rosstat). Population density is 0.07 pers./sq. km. (2014). The urban population is 67.47% (2014).

Industry. The industrial development began in the late 1930s. It was extraction of hard and brown coal, that is up to now is used in the region.

In 1940s the construction of tin extracting industry and uranium mine was initiated. The uranium mine was functioning up to 1953.

A new stage in the industrial development of the region began since the late 1950s, when new gold, tin and wolfram deposits were discovered. There were created mining and processing facilities. Many settlements of workers around the deposits were created. In 1970s the mercury deposit was discovered. Gold mining in the district was developing and reached its highest point in 1974 (more than 36 tn. were mined). In the next years the mining volumes decreased due to depleting. Up to 1990 gold mining was about 15–19 tn. per year.

Later on, the economic crisis of the post-soviet period influenced the mining industry of the region. Massive loss of jobs in the mining sector led to mass outflow of people from the region. Exploration works were almost frozen and tin and wolfram extraction was totally suspended. The gold mining was performed by only small groups of workers with the total mining volume of less than 5 tn. per year. All the workers' settlements were liquidated.

Since the year 2000 foreign investors showed their interest in the main gold and silver mines of the region. Mining was renewed, new settlements of workers were created. The alluvial mining volumes decreased however, while the gold ore mining went sharply up. In 2008 for the first time since the last 20 years the production volume exceeded 20 tn. It became possible because of commissioning of a new gold mine. During all the industrial mining period of Chukotka autonomous district it was produced over 900 tn. of gold, 200 tsd. tn. of tin and 90 tsd. tn. of wolfram oxide. An extremely prominent is copper deposit, which is one of the largest in the world. However, lack of transport infrastructure and enormous investments needed inhibit the development of the deposit.

Other industries of the region besides of mining are developed poorly. These are small fish processing firms and producers of construction materials, which are concentrated primarily on the intraregional needs.

Agriculture. Despite of unfavorable climate conditions the agricultural segment is developing. However it could never satisfy the local needs in the full scope.

The main agricultural development direction is reindeer farming. The Chukotka pack of reindeers is one of the largest in the world. In 1970 the number of reindeers was about 587 tsd. livestock (25% of the world total). In the early 2000 it was a reduction of over 5 times. Besides of meat and skin the important medical raw material such as antlers is prepared.

Another important agricultural segment is hunting. Hunting of wild reindeers provides local population with diet meat. There is also hunting for moose, wolves, wolverines, bears, American minks, sables, Arctic foxes, muskrats, hares and ermines. The most prominent type of fowl is partridge [2].

Sea hunting and fishing is traditional among the population of the coastal settlements. One hunts walrus, seals, ringed seals, bearded seals. Fishing is primarily salmon. In some settlements one can find some fur farming.

In many Chukotka settlements population is engaged with greenhouse farming. In central and western parts of the district, in the non-freezing zones, an open-air cultivation of potatoes, cabbage and reddish takes place.

For hay gathering the meadows of the drained thermo-karst lakes are used.

Transport system. Chukotka district can be distinguished for its poor transport system; this is stipulated by low population density as well as severe climate conditions (winter lasts up to 9 months). So, road building becomes very costly and technically difficult. Today roads with pavement exist only in cities and the nearby settlements. The rest of the territory has the so called winter roads with no pavement. This roads are made of tamped snow, so they can be used only during winter time. For transportation one uses all-terrain vehicles, snowmobiles and trucks with enhanced off-road mobility.

There are no railway roads in the district. In some places one can find only narrow-gauge railway roads that serve local industrial purposes.

The main types of transport for long distances are by sea and by air. Every city has an airport. Despite of geographical proximity to Alaska there are no regular transport connections by sea or by air with it.

Maritime traffic can be also difficult during the freeze-up or ice break-up periods.

There are 5 seaports of the Northern Sea Route functioning in the region [3].

2 Theoretical background of sustainable development

The development program of Chukotka autonomous district assumes creation of the development model of the human activity spheres in the arctic region. Further the created model is to be used for analysis of development sustainability. The model creation demands for analysis of the human activity spheres in Chukotka autonomous district and for historical analysis of sustainable development researching. While understanding sustainable development as a process we inevitably touch upon the question of an equilibrium, because during the development process all socio-economic systems pass from one equilibrium state to another.

The analysis of scientific research in the sphere of sustainable development shows that research during many years was based on different theoretical and methodological approaches to the problem of equilibrium of socio-economic systems. The existence of sustainable development trajectory was justified in the fundamental research works of classical economists such as Leontief, Solow, Stiglitz, Hartwick, Barbier, Gylfason, Daly, Kvaerner, Markandya, Rennings, Hubert, Anders *et al.* [4–9].

Regional factors of economic growth and sustainable development as well as approaches to modeling of sustainable development were developed in the works of the following economists: Blam, Granberg, Goubaidoullina, Gourman, Dnilov-Danilyan, Doumova, Kleiner, Lossev, Seliverstov, Tatarkin *et al.* [10–12]. As a general methodology of sustainable development of regional socio-economic system a theory of economic dynamics can be taken. This theory was developed in the research works of Kondratiev, Schumpeter, Harrod, Kudland, Prescott, Menshikov, Klimenko, Yakovets. A synergetic paradigm of regional socio-economic development is based on conclusions presented in the works of Prigozhin, Stengers, Wag. The concept of transition from “spatial economics” to “time economics” as a condition of innovative production was developed in the works of Bekov, Yu. Mamedov, Inshakov, Ossipov.

The complex assessment of the regional sustainable development includes 3 aspects: industrial development of the territory, development of the social sphere, environmental condition of the territory. Every aspect is assessed with a system of indicators. The industrial development is evaluated with the indicators: – a share of GRP of the region in the total sum of all GRPs; – a share of regional export in the total Russian export; – a shipped volume of regional production. The development of the social sphere is assessed with the indicators: – level of income of the population and development level of the social infrastructure. Environmental conditions are characterized by harmful emissions to the atmosphere. The sustainable development of the territory within the region means balanced development of all the spheres in the region, i.e. the state where positive changes in one sphere do not incur neither negative dynamics of the indicators of the other spheres nor negative dynamics of the composite human development index of the region.

The author meaning of the category “sustainable regional development” is introduced. It is viewed as a managed process of development within the three 3 spheres of human activity in the region. The balanced development of the spheres is being controlled in order to increase the human development potential. The human development potential is evaluated with the human development index.

3 The methodology of model creation

The methodological principles of model creation are determined by the choice of system of related econometric equations that serve to describe the development process within the 3 spheres of human activity of Chukotka autonomous district. The main basics of model creation are described below.

Selection of exogenous and endogenous variables. Comprehensive analysis made up the choice of the following endogenous variables: y_t^1 – the share of Chukotka gross regional product(GRP) in the total sum of Russian GRPs; y_t^2 – the share of regional export in the total Russian export; y_t^3 – the level of income of Chukotka population; y_t^4 – harmful emissions from stationary sources within the region to the atmosphere; y_t^5 – the share of shipped production of the region in the total shipped production of the Russian Federation; y_t^6 – the level of development of the infrastructural industries of the region.

It is assumed that every endogenous variable depends on the same endogenous variable taken with some lag as well as on other variables presented as time series. The distributed lag method enables research of dependencies of that kind [13, 14].

We assume that y_t^1 depends on y_{t-1}^1 and on the previous values of the indicators: the level of income of Chukotka population (y_{t-j}^3), payments for import of technologies and technical services (x_{t-i}^1), level of labor productivity (x_{t-i}^2), number of doctor calls (x_{t-i}^3).

We assume that y_t^2 depends on y_{t-1}^2 and on the previous values of the indicators: the share of shipped production of the region in the total shipped production of the Russian Federation (y_t^5), growth rate of labor productivity (x_{t-i}^5), the development level of manufacturing (x_{t-i}^6).

We assume that y_t^3 depends on y_{t-1}^3 and on the previous values of the indicators: the share of Chukotka GRP in the total sum of Russian GRPs (y_t^1), harmful emissions from stationary sources within the region to the atmosphere (y_t^4), growth rate of labor productivity (x_{t-i}^5), population growth (x_t^7).

We assume that y_t^4 depends on y_{t-i}^4 and on the previous values of the indicators: the share of shipped production of the region in the total shipped production of the Russian Federation (y_t^5), energy consumption (x_t^8), the number of families living in the region (x_t^9).

We assume that y_t^5 depends on y_{t-1}^5 and on the previous values of the indicators: the level of income of regional population (y_{t-j}^3), labor productivity (x_t^2), spending for technological innovations (x_t^4).

We assume that y_t^6 depends on y_{t-1}^6 and on the previous values of the indicators: the share of Chukotka GRP in the total sum of Russian GRPs (y_t^1), the level of income of the regional population (y_t^3), the growth rate of labor productivity (x_t^5), the development level of manufacturing (x_{t-i}^6), population growth (x_t^7).

For carrying out of analysis under these assumptions the ADL-model was chosen. The model enables the assess dependencies of the values on current and previous time series of other indicators [15].

The selection of the lags for the variables in time series, which show strong correlation with the indicator of the last period, i.e. checking for autocorrelation of the indicators in all the time series. The lags with strong correlation with the indicator for the last period are selected. The significance of the autocorrelation coefficients is tested with the Q-statistics (Ljung–Box test) [16].

Checking of endogenous and exogenous parameters for multicollinearity, composing of the correlation matrix, consideration of the pairs of variables with correlation coefficient over 0.8, selection of one variable for the further analysis.

Analysis of time series for stationarity with the DF-test (Dickey–Fuller test).

Presentation of the system of equations in the structural view.

The structural form of the model makes visible the influence of any exogenous variable on the endogenous variable.

The identification of the system of equations. The procedure of testing of the structural form of the model for the necessary and sufficient conditions of identifiability [16–18].

The necessary condition of identifiability: comparison of *M-m* with *k-1* (where *M* is the number of pre-identified variables of the model; *m* is the number of pre-identified variables in the equation; *K* is the number of endogenous variables of the model; and *k* is the number of endogenous variables in the equation).

The sufficient condition of the identification for an equation is fulfilled if the rank of the sub matrix (that is composed only of the coefficients of the variables that are not presented in the equation) equals the number of endogenous variables minus one.

If the sufficient condition of the identification is fulfilled for every equation of the system then all the equations are super-identified (there are no un-identified equations in the system). This means that the whole model is also super-identified and, hence, the two stage least squares method is to be applied for determining the parameters of the equations.

If the structural form of the system of simultaneous equations is identified, then the indirect OLS method should be applied for determining the parameters of the equations. The OLS algorithm is realized in 3 steps: 1) on the basis of the structural form of the system of simultaneous equations the reduced form is constructed where the parameters are expressed with the structural coefficients; 2) the coefficients of every equation are assessed with the OLS method; 3) on the basis of the assessments of the coefficients in the system of simultaneous equations the structural coefficients are determined with the equations in the reduced form.

The transformation of the structural model to the model in the reduced form.

Transformation means a set of iterations resulting in no y_t^i left in the right side of the equations.

The assessment of the parameters of the structural system: the adequacy assessment (accuracy) of the equations in the reduced form of the model is carried out with F-statistic; determining of the coefficients of the reduced form of the model with the OLS-method.

The first step of the model assessment is assessment of the adequacy (accuracy) of the equations. The mathematical equation is checked for adequacy with the empirical data. This means also checking for sufficiency of the included independent indicators that influence the resulting variable. The check for adequacy of the regression equation is generally performed with the F-statistic.

The second step is determining of the coefficients of the structural form of the model. With the help of the reduced form for all super-identified equations the theoretical values of the endogenous variables in the left side of the equation are determined by putting the initial values of the exogenous variables to the right side of the obtained system of equations. So we get the table of theoretical values of the endogenous variables.

Further, putting the obtained theoretical values of the endogenous variables instead of actual values and using the simple OLS method we determine the equation coefficients for the structural form of all the super-identified equations.

4 Descriptive statistics

The time series of endogenous and exogenous variables are formed with data obtained from regional subsidiaries of the Federal Statistics committee of the Russian Federation
http://www.fedstat.ru/indicator/data.do;
http://www.gks.ru/bgd/regl/b13_14p/IssWWW.exe/Stg/d1/04-02.htm;
http://www.gks.ru/bgd/regl/b13_14p/IssWWW.exe/Stg/d2/13-01.htm;
http://www.gks.ru/bgd/regl/b13_14p/IssWWW.exe/Stg/d3/21-16.htm;
http://www.gks.ru/bgd/regl/b14_11/IssWWW.exe/Stg/d02/26-03.htm;

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http://www.gks.ru/free_doc/new_site/perepis2010/croc/perepis_itogi1612.htm;
http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/enterprise/industrial/.

5 The results of the research – the model of economic development of Chukotka autonomous district

As a result of complying with the principles of creation of sustainable development model we obtained the model of economic development of Chukotka autonomous district in the type of initial structural model (1) of 6 equations. Later on after analysis of the initial data the model can be transformed to the model in the reduced form:

$$\left\{\begin{array}{l} y_t^1 = a_0 + a_1 y_{t-1}^1 + ...a_i y_{t-i}^1 ... + b_1 y_{t-1}^3 ... + c_1 x_{t-i}^1 + c_2 x_{t-i}^2 + c_3 x_{t-i}^3 \\ y_t^2 = a_0 + a_1 y_{t-1}^2 + ... + a_i y_{t-i}^2 ... + b_1 y_{t-1}^5 ... + c_1 x_{t-i}^4 + c_2 x_{t-i}^5 + c_3 x_{t-i}^6 \\ y_t^3 = a_0 + a_1 y_{t-1}^3 + ... + a_i y_{t-i}^3 ... + b_1 y_{t-1}^1 ... + b_2 y_{t-1}^4 ... + c_2 x_{t-i}^5 + c_3 x_{t-i}^7 \\ y_t^4 = a_0 + a_1 y_{t-1}^4 + ... + a_i y_{t-i}^4 ... + b_1 y_{t-1}^5 ... + b_2 x_{t-i}^8 + b_3 x_{t-i}^9 \\ y_t^5 = a_0 + a_1 y_{t-1}^5 + ... + a_i y_{t-i}^5 ... + b_1 y_{t-1}^3 ... + b_2 x_{t-i}^2 + b_3 x_{t-i}^4 \\ y_t^6 = a_0 + a_1 y_{t-1}^6 + ... + a_i y_{t-i}^6 ... + b_1 y_{t-1}^1 ... + b_2 y_{t-1}^3 ... + c_1 x_{t-i}^5 + d_1 x_{t-i}^6 \end{array}\right\} \qquad (1)$$

The assessment of the autocorrelation of the endogenous variables for selection of the lags in the time series has shown that the highest coefficients are observed only for variables y_{t-1}^4 and y_{t-1}^5. The coefficients are 0.69298 and 0.75823 respectively. That means that the variables of harmful emissions from stationary sources within the region to the atmosphere and the share of shipped production of the region in the total shipped production of the Russian Federation are included in the model with the lag *t-1*.

As a result of the multicollinearity test of the endogenous and exogenous variables the exogenous variables with correlation lower than 0.6 were excluded from the model. The analysis has shown, that four endogenous variables (y_t^3, y_t^4, y_t^5, y_t^6) have a relatively high correlation (the maximum coefficient equals 0.61734) with endogenous variables with the lag *t-1* (y_{t-1}^1, y_{t-1}^5, y_{t-1}^3, y_{t-1}^1). The variables with the lag *t-1* are included into the model.

While analyzing of time series for stationarity the Dickey–Fuller test was performed with the Eview software for every time series. The analysis of one of the indicators – the share of the GRP in the sum of the Russian GRPs – is presented below in the table 1.

The t-statistic of the coefficient equals -0.467572, this value is lower than critical level of t-statistic for 5% significance level (and even lower than 1% critical level) for the researched model. The critical level of t-statistics is -1.605603. It means that with 1% level of significance the time series is stationary.

Table 1: The results of the Dickey–Fuller test for stationarity of the time series. The share of the GRP in the sum of the Russian GRPs.

		t-Statistic	Prob.*
Augmented Dickey–Fuller test statistic		-0.467572	0.4966
Test critical values:	1% level	-2.717511	
	5% level	-1.964418	
	10% level	-1.605603	

The check for identifiability conditions shows that the necessary and sufficient conditions of identifiability are fulfilled. The structured form of the system of simultaneous equations is precisely identified, i.e. for determining the equations parameters the indirect OLS-method should be applied.

For finding the coefficients of the regression equations the SPSS Statistics 2.0 software was used.

After the analysis of the initial data, selection of the data that corresponds to the model creation principles and determining of the regression coefficients for the system of equations, the structural form of the model is the following (2):

$$\left\{\begin{array}{l} y_t^1 = -0,299 + 0,00000649 x_{t-1}^1 - 0,000001942 x_{t-1}^3 \\ y_t^2 = 0,800 + 0,777 x_{t-1}^5 - 0,805 x_{t-1}^6 \\ y_t^3 = 645,007 + 1204,669 y_{t-1}^1 - 557,569 x_{t-1}^5 \\ y_t^4 = 0,347 + 521,722 y_{t-1}^4 - 3,405 x_{t-1}^8 + 0,191 x_{t-1}^9 \\ y_t^5 = -2,690 + 22,49 y_{t-1}^5 + 0,088 y_{t-1}^3 \\ y_t^6 = 0,877 + 5,03 x_{t-1}^6 + 0,31 y_{t-1}^1 \end{array}\right\} \qquad (2)$$

Transformation of the system of equations (2) with the substitution method made it possible to get the reduced form of the model. The number of equations in the reduced form is equal to the number of endogenous variables of the model. Each equation of the reduced form expresses an endogenous variable with all the pre-defined variables of the model. The right side of each equation consists only of the pre-defined variables and residues and the left side is only one of the endogenous variables. That means that the whole system is a system of independent equations.

So we obtain the system of independent equations in the reduced form (3):

$$\left\{\begin{array}{l} y_t^1 = -0,299 + 0,00000649 x_{t-1}^1 - 0,000001942 x_{t-1}^3 \\ y_t^2 = 0,800 + 0,777 x_{t-1}^5 - 0,805 x_{t-1}^6 \\ y_t^3 = 645,007 + 360,196 y_{t-1}^1 + 0,008 x_{t-1}^1 - 0,002 x_{t-1}^3 - 557,569 x_{t-1}^5 \\ y_t^4 = 0,347 + 521,722 y_{t-1}^4 - 3,405 x_{t-1}^8 + 0,191 x_{t-1}^9 \\ y_t^5 = 54,071 + 22,49 y_{t-1}^5 - 31,697 x_{t-1}^1 - 0,00176 x_{t-1}^3 - 49,066 x_{t-1}^5 \\ y_t^6 = 0,784 + 0,00000201 x_{t-1}^1 - 0,0000006 x_{t-1}^3 + 5,03 x_{t-1}^6 \end{array}\right\} \qquad (3)$$

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6 Conclusion

The described model consists of six econometric equations and includes six endogenous variables. The variables such as the share of the GRP in the sum of the Russian GRPs; the share of regional export in the total Russian export; the level of income of the population; the level of development of the infrastructural industries of the region are influenced only by exogenous variables with the lag *t-1*. The variables such as harmful emissions from stationary sources within the region to the atmosphere; the share of shipped production of the region in the total shipped production of the Russian Federation are influenced by exogenous variables with the lag t-1 and by the similar endogenous variables with the same lag.

The presented model is the core of the sustainable regional development concept. This development is a managed process of development of the three sectors of human activities. The balanced development of the spheres is controlled in order to increase the human development potential. The following order is meant: the growth and forecast for the industrial, social and ecological spheres are estimated according to the indicators of the model. The manageability of the development process within these three spheres of human activity depends on control of the balanced development of the spheres and on the analysis of the human development index dynamics.

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Relationship between community pride and participation needs in sustainable tourism development of Fishing Village: a case study of Samut Sakhon Province, Thailand

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Abstract

This article investigates the relationship between community pride and participation needs in the sustainable tourism development of ‘Fishing Village’ in Samut Sakhon Province, Thailand. Pearson correlation was used to determine the relationship between these variables. In-depth interviews were also used to gather detailed data. The findings reveal that community pride regarding emotional bonding with other members and resource awareness have a strong relationship to the participation needs excluding willingness to sacrifice personal time. To conclude this research, this fishing village has the potential for sustainable tourism development as awareness of community pride connected to participation is the vital sign indicating an approach of sustainability. Thus, the sustainable development plan should indicate this community strength and encourage the knowledge in aspects of mutual needs for the willingness of working for the community. The paper ends with suggestions for future research.

Keywords: community pride, community participation, Fishing Village, Thailand.

1 Introduction

As a result of the acknowledgement of sustainable development from the publication of the Brundtland Report, Our Common Future by the World Commission on Environment and Development (WCED) in 1987, this concept has been integrated in many areas including tourism [1]. Consequently, sustainable tourism has been widely used in alternative forms such as ecotourism, responsible

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tourism and community-based tourism [2] as it is suggested as the appropriate approach for a long-term vision [1], by minimising the negative impact of tourism while maximising the benefit to locals [3] together with environmental and cultural conservation [4]. When engaging the principles of sustainable tourism community is an essential part, not merely to be considered as just a resource of the destination [5], but also in the need to engage in collaborative participation including the decision making process, in order to share the benefits and improve quality of life [6], although in some cases participation has been limited, proving difficult when facing obstacles and apathy [7]. Nevertheless, a number of studies such as [8–10] state that community pride is one of the key factors in encouraging the participation of a community.

In Thailand, sustainable development was initially underlined in the Eighth National Economic and Social Development Plan (NESDP) which started by emphasising on benefiting local people through community empowerment through training and skills development along with sustainable development [11]. Consequently, the concept has been adapted to tourism and numerous local areas have applied policies of sustainability by the community itself or at a larger level such as the local government or Sub-district Administrative Organisation (SAO). In this case, the Fishing Village of Samut Sakhon Province, Thailand has recently received an increase in popularity from domestic tourists as the location provides a unique glimpse of the traditional way of life of local fishermen and their families, offers coastal scenery along with Bryde whale sightseeing, has strong local wisdom and pride within the fishing community, and a united conservation in facing challenges such as coastal erosion [12]. To handle this increased influx of tourists and environmental degradation, Pantainorasingh SAO, a local government sector that takes charge of Fishing Village, initially drafted a tourism development plan concerning sustainability. Nevertheless, before making any tourism plan or implementing it, it has been suggested that a community assessment which includes their assets and needs is essential [13]. These needs, especially the need for participation in controlling and decision making, are key principles of sustainable tourism development [14]. Hence, this research aims to explore the participation needs in tourism management for the residents of Fishing Village. Moreover, as previously mentioned community pride will reinforce community participation, other objectives include the investigation of the connection between the fishing village’s community pride and the participation needs required for effective tourism development, both an essential part of the community assessment. Suggestions are provided within this paper for a sustainable tourism development plan.

2 Objectives

- To explore Fishing Village’s community participations needs for sustainable tourism development.
- To examine the relationship between the community pride and participation needs of Fishing Village.

3 Literature review

Sustainable tourism development refers to the environmental, economic and socio-cultural aspects of tourism development and an equitable balance established between these three dimensions to guarantee its long-term sustainability [4]. Numerous studies such as [13–15] refer to the principles and objectives of sustainable tourism development. They primarily focus on improving the quality of life for local people, along with protecting both the natural and built environment, whilst also offering a quality experience for visitors. There are also a number of principles relevant to sustainability; for example, resource accountability, stakeholder involvement, carrying capacity, women and minority empowerment [14]. However, since this paper aims to underline community participation based on community pride, the review will focus on the linkage of community participation with sustainable development.

In referring to community participation, Arnstein's review of participation degree [16] has been widely claimed. The review indicated three degrees of participation; non-participation, partial participation and degree of citizen power, in which to succeed to full citizen power, residents' empowerment of decision making is needed. While the decision making process is considered as the most crucial action of citizen participation [14], other processes include, implementation, benefit sharing and evaluation [17]. The significance of community participation towards sustainable tourism development covers local perspectives which are voiced, expressed in the design or planning and decision making, to be able to improve plans, decisions and service delivery; cohesive encouragement by sharing common goals and an opportunity for seeking collectively to assess problems and plan solutions together [8]. In other words, it is a sign of empowerment meaning locals are likely to share control and the benefits of the advantages of sustainability that is community well-being [6].

Such well-being not only provides the benefits of economic empowerment; for example, cash flow in community, employment opportunities and local ownership [14], but other perspectives linking to community pride are also vital as it crucially drives residents' involvement [10]. Community pride refers to the positive feelings of attachment and the emotional bond residents feel about their community and their feelings of satisfaction within the community [18]. Similar to the concepts of 'place attachment' [19] and 'sense of community' [20] which also refer to an affective bond between people and places that impact residents engagement within the community [9], and these will encourage community-level interaction in which residents would like to participate in activities. These take the forms such as participating in a community improvement project or working with other members of the community to try to solve local problems [21]. It is further explained that the concept interlinks with the 'psychology' of community empowerment that residents uphold self-esteem, to realise their own uniqueness and value their culture and natural resources as well as traditional knowledge [6]. Nonetheless, the level of community pride or attachment is possibly influenced by other determinants such as length of residence [9], satisfaction in local social ambience e.g. community spirit, friendliness and quality of local [22] and local social networks [23]. The high degree of community attachment can be perceived in the positive way that locals want to participate either to conserve their location's identity or willingly work to improve the well-being of residents [24]. In contrast, it is also seen as a negative impact of tourism due to concern over changes and problems that may dilute or divide their affective community [25], which could possibly lead to a negative or resentful attitude of residents towards tourism [26]. It also should be noted that even though residents have certain needs for participation in community; some obstacles lie outside these requirements for community involvement such as unsteady planning from local government [24], lack of financial resources, elite domination and corruption [7].

Following this overview of the literature, the researcher made the decision of choosing Fishing Village of Samut Sakhon Province as a case study due to the ongoing tourism plan draft. It has been known for its intellectual tourism which engages educational visitors wanting to experience the fishing community's way of life [27]. The location is also famous for its local wisdom towards the making of a unique shrimp paste, called 'Kapi' in Thai and also for local participation in coastal erosion prevention [12] through which community pride and attachment is reflected. Furthermore, it has received increased popularity from the bike tour route from Bangkok, in which Fishing Village is one of the featured tourism stops. Others come to indulge appetites for fresh seafood close to Bangkok, another significant reason for the rise in the number of visitors is the opportunity for spotting Bryde whales. Therefore, this study may be of benefit to planners in understanding local needs in participation including potentials and weaknesses regarding community pride in order to improve the tourism development plan in the future. The specific hypotheses in this research include (1) community participation needs in sustainable tourism development are acknowledged by residents in Fishing Village and (2) the community pride of residents has a relationship with participation needs.

4 Methodologies

This research had two stages; stage one was questionnaires and stage two was in-depth interviews. The questionnaires developed by the researcher were employed with 306 samples from residents to achieve the objective of the study regarding community pride and the requirements for local participation. The content of the questionnaires was investigated for validity by three experts in tourism and was represented in the index of item objectives congruence (IOC) equivalent as 0.78. Pre-testing of the research questionnaire was carried out by 30 respondents in the Khanom District, another community tourism destination in Thailand and the reliability of questionnaires was found by using Cronbach's Alpha Coefficient at 0.81. To obtain further detailed information regarding community pride and resident participation, in-depth interviews were also conducted with two of the local administrators and a leader of community.

Opinions from the questionnaires was recorded using a Likert scale. Then data was processed by a statistical programmed software which indicated frequency, percentage, mean and standard deviation. Pearson correlation (two-tailed) was used to interpret the data in this section. Following this phase, data analysis from interpreted questionnaires and the in-depth interviews was categorised into the two themes of the research objectives, community participation needs and the relationship between community pride and participation need.

5 Findings

306 questionnaires were completed by residents from various professions (Fishermen, agriculturists, merchandisers, local administrators, housewives and retired people) who have lived in the fishing village for over 10 years. It was revealed that the gender ratio of participants was 67.6% male (207 of samples) to 32.4% female (99 of samples) with an age range from 20–50 years old and over. Over half of the respondents, 58.17% (178 of samples) acknowledged the sustainable tourism development but were unsure of a certain or definitive meaning, while 30.07% (92 of samples) knew and were able to explain the meaning. The rest of respondents, 11.76% (36 of samples), had no idea about the concept. Their opinions regarding participation needs are presented in Table 1, whist the opinions relevant to community pride as well as the correlation with participation needs are represented in Table 2. This data was grouped with the data from the in-depth interviews with local administrators and the community leader and the results are discussed using the three following themes.

Table 1: Fishing Village community participation's needs in sustainable tourism development.

Items	Components of participation needs	$\overline{X}$	SD
1	Needs in planning	4.06	.54
2	Needs in decision making	3.97	.62
3	Needs in partaking with activities	4.32	.68
4	Needs in evaluation	3.85	.65
5	Needs in benefits sharing	4.09	.56
6	Overall needs in participation	**4.06**	**.41**

5.1 Community participation needs in a sustainable tourism development

It was revealed by the interviews that the fishing village has initiated a community awareness of fishery life style conservation under the community leader, Mr Somchai Subsripaiboon. The residents have been involved with activities in the community based on the strong relationship they have along with shared co-operative funds. The local administrators indicated that the local quality of life is improving with navigational sign post construction and infrastructure upscaling as well as tourism promotion. They also referred to the positive relationship between the local government and the community, such as resident involvement with projects organised by local administrators. Decision making within the community exists with regard to fishing and living matters but is not yet concern with tourism. In response to sustainable tourism development, according to Table 1, the results indicated that respondents were likely to agree concerning the participation needs in each item which is represented as an overall average in item 6 ($\overline{X}$ = 4.06, SD =.41). The item respondents agreed the most concerning item was item 3, needs in partaking with activities ($\overline{X}$ =4.32, SD =.68). Item 5, needs in benefit sharing and item 1, needs in planning, followed respectively ($\overline{X}$ =4.09, SD =.56 and $\overline{X}$ = 4.06, SD =.54). Item 2, needs in decision making, which is the most critical part in participation came in the fourth place ($\overline{X}$ =3.97, SD =.62), and the last was item 4, needs in evaluation ($\overline{X}$ =3.85, SD =.65). When referring to the Standard Deviation (SD) as a measure of dispersion of each item, it is representational of the low dissemination of data resulting in the agreement towards a similar single direction. The community leader stated via interviews that residents in the community would also like to participate in a sustainable tourism development, however there is the problem that no such plan currently exists.

Table 2: The relationship between community pride and community participation needs.

Items	Topics relevant to community pride	$\overline{X}$	SD	r
	Place attachment			
1	Positive feelings towards community	4.24	.65	.014
2	Emotional bonding with other community members	4.15	.65	.302*
3	Place attachment raising to others	4.21	.68	-0.23
	Values and resources awareness			
4	Community resources awareness i.e. natural resources, culture, and local wisdom	4.35	.48	.498*
5	Readiness to prevent loss and conserve community resources from outsiders	4.26	.66	0.74
6	Participation in activities regarding resources protection and conservation	4.26	.61	.222*
	Willingness of involvement with community			
7	Willingness to sacrifice your personal time to work for community	3.38	.69	.109
8	Involvement with community work when others need your help	3.44	.55	-0.89
9	Convincing other members to work for community	3.44	.50	.133*

*$p<0.05$

5.2 Relationship between community pride and community participation needs

Considering community pride, data from the interviews indicated that locals were proud of their fishing lifestyle. Apart from the continued existence of the fishing village with its high basement-styled wooden houses, to sustain the fishing trade and traditional way of life, locals continue their wisdom and customs through the making of local shrimp paste 'Kapi'. This was represented and has been considered as the main career for housewives under the female leader, Mrs Chailai Ributr. While the other leader, Mr Somchai would demonstrate fishing every weekend to young locals in order to acknowledge the values, traditions and skills as well as create an opportunity for an optional job in the future. The community leader emphasised the closeness of the neighbourhood as a collective influence for participation in community. This was also reported by the questionnaires analysed in Table 2, residents agreed to having community pride in their locality and a resource awareness to similar levels, the item respondents agreed to the most was item 4, community resource awareness ($\bar{X}$ =4.35, SD= .48).

This is continually demonstrated in the previous table as the item grouping concerning values and resource awareness; participation in activities regarding resource protection and conservation and community resource awareness, show the strongest levels of community agreement. Following that order to a slightly lesser scale is the item grouping connected to place attachment; positive feelings towards community, place attachment raising to others and emotional bonding with other community members. In contrast, respondents agreed the least to questions under the willingness of involvement with community section, which contained willingness to sacrifice personal time to work for community ($\bar{X}$ =3.38, SD =.69), involvement with community work when other needs ($\bar{X}$ =3.44, SD =.55) and convincing other members to work for community ($\bar{X}$ =3.44, SD =.50). Similar to Table 1, each item revealed a low Standard Deviation (SD), hence the agreement of respondents seem to be in accordance with each other. After investigation of the results of the relationship between community pride topics to participation needs by the indicated correlation (r) with a statistical significance at 0.05, it was revealed that 4 out of 9 items unearthed emotional bonding with other community members (r = .302*), community resource awareness (r = .498*), participation in activities regarding resources protection and conservation (r = .222*) and convincing other members to work for community (r = .133*). Matched with the data from the questionnaires, it was also revealed from the interviews that residents put more effort towards resource degradation prevention. With the village being located near the coast, where coastal erosion was occurring, there were collaborative actions from locals to protect their community by helping each other construct bamboo barriers to reduce the impact of the strong waves that have been eroding the seashore and destroying residential areas. Furthermore, due to the loss of mangrove areas around the village caused by natural disaster as well as coastal erosion, the local government; Puntainorasingh SAO also took the

action of planting mangrove forests and asked local students to join in, in order to raise community value awareness.

5.3 Critiques towards sustainable tourism development in Fishing Village

Regarding the interviews, questions relevant to the obstacles of sustainable tourism development were asked and informed the research of two main issues. The first one was the lack of participation by the new generation, as the circumstances have changed for the well educated new generation, the majority of which have at least graduated from secondary school. They tend to work in other careers that generate more income. Moreover, it was stated by parents that they would prefer their children to work in other careers than being fishermen although they remain proud of their lives and community. It was further explained that this was also due to the unstable nature of the income derived from fishing and the associated risks with ventures out into deeper waters. Consequently, it is foreseeable that the lack of new generation participation may impact the community severely in the future and any plans for sustainable tourism development. The second aspect was the limited knowledge of sustainable tourism, based on interviews, it was revealed that a number of locals perceived tourism as an income influx involving mass tourists. When referring to tourism, locals were likely to make links to the quantity of tourists rather than considering the quality of different tourist types. Such apparent lack of awareness and knowledge of low impact tourism planning to tradition, environment and way of life, may have a detrimental effect on the locals concept of sustainable tourism development and their eagerness to participate in it.

6 Discussion and conclusion

The results of this research indicated a match with the hypotheses. Firstly, it has been revealed that the community would like to participate in sustainable tourism development. Based on Arnstein's model, residents hold a degree of citizen power as they are empowered by independent decision making which is representative of the type of crucial action needed for citizen participation [6]. In this regard, as a sustainable tourism development plan has been drafted, this community participation from the village can be the essential part that encourages sustainability. Nevertheless, by reviewing the results it can be seen that although the level of overall need for participation in tourism was high ($\bar{X}$ = 4.06, SD =.41), the decision making needs which were the essential part was not the topic in which the respondents agreed the most ($\bar{X}$ = 3.97, SD = .62). This may imply that they may have limited knowledge and a lack of information regarding sustainable tourism development, respondents may also feel unsure of decision making and details relevant towards this. Hence, local administrators should encourage resident awareness towards all aspects of sustainability in tourism particularly those that have links to local decision making.

Secondly, community pride has been shown to be significant in this research, being perceived in various aspects. First, the fishing way of life, by which most of the residents in the location earn their living, the location is hence aptly called 'Fishing Village' with the constructions of high basement-styled wooden houses and it welcomes many visitors that travel there to experience the villages unique identity amidst its traditional architecture and customs. Next, it is the traditional knowledge of making local Kapi, not only in regards to local wisdom but it also represents a type of sustainability, reinforcing further aspects such as the empowerment of women [14]; with housewives that are able to obtain an income from their skills, craft and produce. Finally, the natural resource awareness, they are proud of their location which is comprised of fisher lifestyle households, the coast and is the location of Bryde whales. They also acknowledge the problems caused by coastal erosion to the extent that they launched a collaborative action for erosion prevention. Other key elements include the passing on of skills and traditional knowledge to the next generation, with local children learning the local fishery lifestyle at the weekends giving them pride in their community. As community pride refers to the positive feelings of attachment and emotional bonds residents feel about their community and their feelings of satisfaction within the community [28], such is the case revealed in this research. According to the results, aspects of community pride in values, resources awareness and emotional bonding with other members were essential pillars relevant to community participation needs. These feelings of bonding to others also drove participation in activities regarding natural resources protection and conservation by convincing individuals to work together for the sake of the community. In this case, not only does it represent the closeness between locals, it might also outline the significant roles of the community leaders reinforcing local involvement. Nevertheless, some of the viewed aspects of willingness of involvement and place attachment limited relationship to participation needs. Regarding willingness of involvement, it may be limited in this area due to the fishing way of life which involves sailing out for a living. Hence, it is difficult for any fishermen who needs to be out of village to work, from days to weeks, to involve themselves or commit to community activities. While there were other items that respondents highly agreed on which are; the place attachment in the aspect of positive feeling towards community, pride awareness raising and readiness to protect and conserve community resources from outsiders, they may be less significant when compared to other statistical significant factors driving locals involvement such as emotional bonding to other members, values and resource awareness.

To conclude the study, the fishing village of Pantainorasingh SAO, Samut Sakhon Province has potential for development as a sustainable tourism destination as it revealed full citizen power involvement based on community pride. Hence, the local administrators should encourage and sustain this pride by having on ongoing project of activities raising pride awareness. Some critiques were found such as the limited knowledge of sustainable tourism development as well as the possibility of the local generation not inheriting and keeping the traditional customs and ways of living. The local administrators should further reinforce all aspects of sustainability to residents, especially the components of

participation; planning, involvement, evaluation, benefit sharing including decision making, a vital component in community empowerment. The welcoming and encouragement of quality and appropriate tourist types is also needed. With sustainable tourism in a small-scale area it is essential to cultivate a small-scale approach and create local awareness for the promotion of the quality of tourist rather than the quantity. Moreover, given the boating lifestyle of local fishermen, the tourism plan and activities would do well to focus on training local women, the majority of which are housewives, and may potentially be able to hold other jobs and key positions within the village. It is important that the next generation gets involved with aspects of tourism destination. Apart from learning local fishing, coastal erosion prevention, residents may also train and encourage young members of the community to act as local guides or representatives to further raise pride and emotional bonding.

7 Suggestion for future researches

This research only focused on the relationship of community pride to community participation needs. As sustainability is comprised of a variety of factors, including collaboration between government, stakeholders and locals, future research may study other aspects reinforcing sustainability in order to contribute a more complete sustainable tourism development plan for this location. Moreover, the various characteristics of respondents may be analysed in the future in order to find out their internal factor driving participation needs.

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Section 7
Energy issues

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Risks of systemic transformation in energy companies

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Abstract

Among the various risks (financial, technological, environmental, market) that accompany the energy production systemic (strategic) risks are the most complex and difficult in terms of valuation, allocation of control object and determining the consequences. The key feature to manage those risks is the almost complete absence of statistical data on the impact and consequences of organizational innovations. It should be understood that each organizational decision, especially in the energy companies, is largely unique and can lead to transformation of the whole management system in power companies and even in the energy market. The paper contains a model of strategic risk management, based on the priority results setting. Original organizational risk assessment methodology was formed as well as mechanisms of suppression of their sources were established. Testing of methods is carried out for the key energy production result that is "reliability of electricity supply".

Keywords: risks, power companies, organizational innovations, risk-related area, reliability of energy supply.

1 Introduction

Depending on the approach to managing risks, all structural changes in power companies may be divided into three groups.

The first one contains "risk-free" decisions. They usually are local changes, connected with, e.g. automation of certain managerial processes, minor streamlining of managerial structures etc. Job cuts caused by such measures and a decrease in corresponding expenses can be easily defined by the "count-up" method [1].

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Solutions falling into the second group are aimed at certain economic and social results. However, their initial assessment demands a probabilistic approach. These changes are normally of "behavioral type", they are concerned with those elements of the management system where their effect depends directly on the adequate reaction of employees, which is more or less unpredictable. It might be an upgrade to the mechanism of motivation which is carried out with the aim of reducing personnel turnover and increasing performance. In this case, the risk of the structural decision is accounted for through the mean value of corresponding final results counted by the machinery of expert assessments.

The third group consists of radical structural changes of a systemic type, aiming to bring the management of the power company to a crucially new quality level. These are deep radical changes in ideology and technology of management affecting the fundamentals of corporate philosophy and involving reengineering all key business processes in the company. It should be realized that carrying out such complex changes contains factors which, under unfavourable circumstances, are able to cause serious deformations in the management system of the company, a sharp decline in its performance and even financial crisis [2]. To prevent and localize such threats (risk events), it is necessary to know the kinds of risks, their sources, type of possible threats and their symptoms (indicators). So managing risks in such reforms has considerable methodological peculiarities which are contemplated further in the article.

2 Research methodology

The peculiarity of managing structural risks lies in the almost complete absence of statistics for the performance and consequences of structural innovations in power companies. It should be considered, too, that every structural decision is largely unique at its core. So one has to use prior and indirect expert assessments based on analyses of data like the following:

- financial and economic conditions of the company at the beginning of changes;
- the level of personnel readiness to accept deep structural changes;
- the readiness of managers at different levels to conducting change;
- the level of detail in specific projects and programs of change;
- the degree of top management awareness of the authorities' intention to carry out local reforms in the electric power sector, changes in legislation etc.

To analyze structural risks and risk management in power companies, their classification has been developed. It is shown in the table 1. The following *classification features* were identified.

Level of risk. It is necessary to divide structural risks by this criterion for making decisions related to a particular direction of transformations and their radical character. If the risk is deemed to be negligible, it does not have to be taken into account. If the risk is unacceptable, the decision should probably be discarded. At intermediate values, relevant risk minimization measures should be taken.

Table 1: Classification of risks of structural innovations in an electric grid company.

Classification criterion	Type of risk	Comments
Scope (radicality) of changes	Local	Connected with changes in specific elements of management system
	Systemic	Connected with cardinal reformation of the whole management system
Level of risk (expert estimates)	Negligible	Close to zero
	Low	Less than 30%
	Intermediate	From 30 to 60%
	High	From 60 to 80%
	Unacceptable	More than 80%
Sources (factors) of risk	Personnel	Personnel unprepared for change
	Operational	The concept is not justified and there are mistakes in carrying out innovations
	Regulatory	Unstable government policy in reforms and regulation of natural monopolies.
Final results of the company performance	Technological	Decrease in reliability of energy supply, higher deterioration of equipment
	Economic	Growth of production expenses and decrease in labour performance
	Commercial (financial)	Cut in volumes of realization and profit, change in the cost of the company
Position of the company	External	Is conditioned by frequent and rough disturbance in the environment
	Internal	Is conditioned by the degree of preparedness of the company to reforms
Controllability	Controllable	Can be accounted for and minimized
	Uncontrollable	Can be accounted for, but cannot be minimized
Field of changes	Profile	Connected with changes on the main sphere of activity
	Diversification	Connected with creating additional businesses
Results of change	Main	Likelihood of losses of the expected results of changes
	Related	Likelihood of getting undesirable results of changes
Risk events	Primary	Decrease in management performance
	Secondary	Deterioration in final results of the company

Position of the company. "External" and "internal" risks are substantially different in the power of their sources as well as in the ability of the company to influence their level. In particular, the unstable macro and micro environment in which the company functions makes one pay special attention to "external" risks.

Controllability. We regard "internal" risks as fully controllable and due to be minimised. As regards "external risks", the situation is not univocal. A certain part of them is seen as not managed by the company. But the other part can be influenced indirectly to some degree using a range of different methods. In any case, one has to constantly monitor the environment and track down controllable and uncontrollable components of "external" risks.

Sources of risks. This classification is important because it grasps the whole process of managing changes in a power company, from concept formulation and personnel training to tracking and analyzing the consequences of "systemic fluctuations" at the level of the state economic policy and in the sphere of regulating natural monopolies. The latter is especially important to the reform and integration of grid companies into the market.

Field of changes. This classification is also directly related to a grid company that seeks to diversify its business and enter ancillary services markets. Naturally, approaches to organizational risk management in the sphere of regulated business activity (distribution of electricity) and unregulated business will have significant differences.

Results of changes. Here the following point is important: associated risk can turn out to be much more important than the main risk, if its source is powerful. For instance, the lack of personnel training for changes, serious blunders in conceptual provisions for the reforms, operational mistakes during their implementation can cause dangerous destructive effects on the personnel of the power company, a sharp decline in the management's innovation activity and even make the company unmanageable.

Final results of the company performance. Eventually all structural changes must contribute to an increase in innovation activity, production efficiency and competitive ability of the company in a market system. The dynamics of corresponding final results show the success of the carried out reforms and act as a basis for adjustment of all reengineering decisions in the company.

Scope (radicality) of changes. This classification is needed to distinguish methodological approaches to the management of different kinds of risks. As was shown above, local risks are common to those groups of structural decisions which are aimed at getting specific predetermined results. Systemic risks are typical of radical changes in management and they need a specific "heuristic" approach which is suggested in this work.

Risk events. Here risks are divided according to consequent risk events of two types: connected with deformations in management system (level 1) and a decline in final results of the company performance (level 2). The primary risks are, therefore, personnel, operational and regulatory ones, and the secondary risks are technological, economical and commercial. The given classification is used for developing a model of the risk environment (see below).

The suggested classification makes it possible to define the structure of organizational risk and identify approaches to assessment and minimization of its specific types.

We also introduce the notion "risk environment", which means a specific environment where processes of structural innovation of the strategic type are carried out [1]. The figure 1 shows structural elements of the model of risk environment developed on the basis of the given classification of structural risks. Solid lines show the main connections, dotted lines – additional ones. According to this model, the risk environment includes (in downward direction):

- sources of primary risks;
- primary risks;
- risk events of the first level (caused by failures and deformations in the management system);
- secondary risks;
- risk events of the second level (connected with deterioration of the company performance).

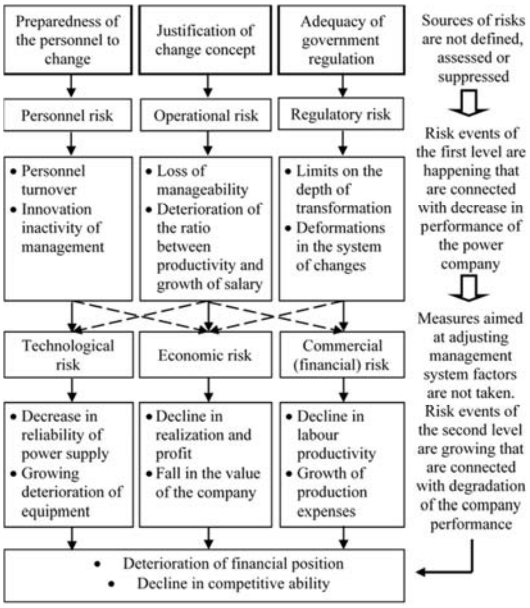

Figure 1: Model of structure of risk environment.

As one can see from the model, the risk events of the first level in case of their occurrence turn into the sources of secondary risks and may with some degree of probability initiate a decrease in the final results of the company.

The right side of the figure depicts a negative scenario of actualization of risk events in case risk assessment is ignored and a lack of risk management.

On the basis of the model of risk environment a method of structural risk assessment is created and a relevant mechanism for suppressing it is formed.

The risk of structural decision (innovation) of a radical type (in our classification it is a systemic risk) should be understood as a probabilistic threat of deterioration of the results of the company. Using the classification of risks and the model of risk environment, the following method of defining a systemic risk can be offered (1):

$$R_j = N_i \cdot P_i \cdot P_{ji} \qquad (1)$$

where R_i – risk of deterioration of the final result *j* of the power company (or occurrence of *j* type event); N_i – power of the risk source of *i* type event, preceding *j* type event and acting as its factor (*j*-type event is related to a decrease in efficiency of management system in the power company); P_i – probability of decrease of event *i*; P_{ji} – probability of fulfillment of the event *j* under the influence of actualized event *i*.

3 Testing the methodology

We will demonstrate the application of the suggested method on one simplest example. Let us choose the reliability of electricity supply as the final result of the power company performance. Thus, risk event *j* actualizes – "decrease in reliability of electricity supply". It is seen from the scheme in the figure that this event is connected with technological risk. Event *i* is increasing personnel turnover, that is, this event triggers event *j*. Moreover, turnover is seen as a result of blunders in the management system. Turnover is mediated by personnel risk, the source of personnel risk is insufficient preparedness of staff for changes.

The power of the source of risk can be estimated expertly on a 100-point scale, shown in percentage points. Given the method of defining personnel preparedness and the corresponding scale for our example, the power of the source of personnel risk will be

$$N_i = 100 - L \qquad (2)$$

where N_i is the power of risk source, L – level of personnel preparedness, %.

It is worth noting that in formula (1) the product of power of risk source multiplied by the probability of the *i*-event (i.e. personnel turnover) gives us the estimate of the personnel risk, and the whole formula shows technological risk (related to the decrease in reliability).

Probabilities P_i and P_{ji} are the most difficult ones to estimate. In this respect, experts can get help from some "rough" targets, following out of the logic of processes happening in the risk environment of structural innovations. In particular, it is possible to follow the three simple rules below.

1. Both factors (P_i and P_{ji}) increase as the power of risk source grows.

2. If L < 50%, than $P_i > 0.5$ (if the level of preparedness is less than 50%, the probability of staff turnover is more than 0.5).
3. $P_{ji} > P_i$ (probability of a decrease in reliability of electricity supply due to personnel turnover is higher than probability of an increase in personnel turnover due to personnel unpreparedness for change).

Let us suggest that for our example we got the following estimates: L=30%, P_i=0.7, P_{ji}=0.8. Then the technological (secondary) risk of a decrease in supply reliability during the fulfillment of this structural innovation according to (1) and (2) will be: P_j=(100-30)*0.7*0.8=39.2/40%.

At that personnel (primary) risk is 49%=[(100-30)*0.7].

According to the given classification (see table 1) a 40% risk is intermediate and cannot be ignored. Consequently, it is necessary to take measures to neutralize (suppress) the corresponding source of risk.

Similarly, the assessment of the remaining kinds of secondary risks is carried out: economic and commercial (financial). We would like to highlight that risks must first be analyzed individually for different final results. As it is shown in the figure 1, every risk has its own corresponding results. Then mean average values for the three risk estimates are calculated considering the index of relative importance of these results for the power company. It is only after that decisions on dealing with the sources of corresponding primary risks are made.

For example, the following values of primary risks have been received: technological – 40%, economic – 25%, commercial – 5%. This implies that main efforts should be concentrated on suppressing the source of personnel risk. The source of operational risk does not have to be handled directly, but it is necessary to control the state of the company's management system during the transformation to detect and localize the risk events of the first level on time (see figure.). As for regulatory risk (supreme as compared to commercial), it can be ignored altogether.

4 Economic risk reduction in the course of interaction between energy companies and consumer

Industrial development makes interaction between power companies and consumers closer and more intense. Consequently, companies face greater risks. The energy company finds it most difficult to manage systemic risks, whereas for industrial consumers the biggest challenge is economic (market risks).

The risks faced by consumers in a competitive electricity market are the following:

- price fluctuations in a spot market. These are mainly caused by changes in the supply and demand for electricity, with falling prices being undesirable for sellers and rising – for buyers;
- non-execution of a contract (in terms of prices and amount of electricity to be delivered) in a contract market;
- rejection by the market operator of a price bid in the process of competitive capacity outtake;

- a lack of match between the consumed amount electricity and planned consumption.

Unfavourable electricity price fluctuations are particularly disruptive because they hurt the financial performance of the company and make energy cost reduction planning less reliable.

The following market risk reduction methods could be recommended to consumers operating in a competitive market.

Technological solutions. The key trend is to ensure the flexibility of power supply by making use of one's own power generating units and (or) shutting down a part of equipment during high-price periods (peak hours).

Organizational solutions. These suggest establishing industrial and regional alliances of manufacturing companies that would facilitate their effective operation in the competitive energy market. Such associations could set up their own energy trading companies or sign contracts with existing ones for, among other things, managing expertly all types of market risks. It is advisable to set up energy trading departments within individual companies during a reorganization of energy management to operate effectively in the new environment.

Direct contracting. A bilateral contract is an agreement between a buyer and a seller to supply electricity at prices that are fixed for a specified period of time. However, bilateral contracts, especially those stipulating physical delivery of electricity, are sometimes fraught with problems such as the risk of non-execution of contractual obligations, the difficulty of establishing a mutually acceptable price and of finding effective suppliers. The latter tend to sign direct contracts only with the most lucrative clients – major energy consuming companies. This circumstance makes financial contracts (in combination with buying electricity on a spot market) more preferable in many cases.

Financial (commodity market) instruments for risk management. Standardised futures and options contracts for electricity that are traded in commodity markets as well as their numerous combinations are considered to be one of the most efficient price risk management tools. The risk of contract breach is mitigated, too, because the commodity market with its highly effective financial assurance mechanism acts as an intermediary between the buyer and the seller of futures.

Supplier diversification. It is advisable, when possible, to buy required amounts of electricity (capacity) in portions from various sectors of the market (spot, contract and regulated markets) and from various suppliers (including generators and retailers). The combined risk is, therefore, distributed across a large number of contracts (suppliers).

5 Conclusion

1. The ultimate risk control concept for strategic structural changes is based on a number of provisions:
   - risk management has to be organized as a continuous process including three stages: preparation, implementation of changes, final stage;

- the results of preliminary risk assessment provide grounds for deciding on the reasonability, forms and methods of handling specific kinds of risks;
- in the course of transformations, monitoring of the main factors of the company management system is carried out in order to detect symptoms of risk events of the first level (personnel turnover, loss of controllability, blunders in the system of incentives, regulatory deformations etc.) and to make necessary adjustments. This is caused by the instability of risk sources and their ability to come to life with the time after being suppressed;
- at the end of the first stage, complex control of all results is carried out and a decision is made whether to move on to the second stage.

2. Training for personnel, especially managers at all levels, to prepare them the upcoming change should be considered the most universal and effective way of minimizing structural risks. It is also necessary to substantiate the concept of changes and its implementation programme very carefully.

   We recommend starting transformations with less risky steps, acting on the principle of the lying cone or pyramid. It makes it possible to warm up the team of innovation managers well, gradually complicating tasks and accumulating decision-making experience. In the course of implementation of the programme it is necessary to watch out for interim results of the innovation in order to make adjustments to the innovation process in advance, without allowing serious blunders or failures to happen.
3. At the same time, monitoring of the environment should be carried out with an emphasis on the behavior of consumers, competitors and especially authorities. In this regard, the best way to minimize risks is to maintain constant and reliable contact with these subjects. It is helpful to organize regular collection of information on the results of changes with similar ultimate goals that were implemented in other power companies. If the information on failures becomes available, then changes should be put on hold with a comprehensive analysis of the colleagues' failures. It should be remembered that abandoning a decision that is "too risky" or postponing it is another reliable way to minimize risk.

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Assessing the environmental impacts of 2nd generation (lignocellulosic) feedstock under the energy–climate reference scenario using LUISA modelling platform in EU-28

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Abstract

In this study a comprehensive analysis of the environmental impacts of 2nd generation (lignocellulosic) feedstock using LUISA (Land Use Integrated Sustainability Assessment) spatial modelling platform has been performed under the Energy–Climate reference scenario in EU-28 from 2010 up to 2050. The definition of this reference scenario and its implementation in LUISA is described in this paper, emphasizing the role of the renewable energy directive in the promotion of renewable energies under sustainability criteria for the biomass production, including energy crops. These sustainability criteria attempt to minimize the potential negative impacts on environment, social and economic aspects. Accordingly, site selection is a crucial step, taking into account the ecological requirements of herbaceous and woody lignocellulosic crops for energy purpose. Geographical areas characterised by high suitability levels for the cultivation of energy crops were identified and mapped. A possible solution to land competition conflict is the use of degraded and potentially contaminated lands for growing energy lignocellulosic crops in those areas. The main output from LUISA over the allocation of energy crops are displayed and analysed in detail.
Keywords: energy crops, modelling, allocation, European Union, sustainability.

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1 Introduction

The work presented in this report is an application of the Land Use Integrated Sustainability Assessment platform (LUISA) based on the Energy Climate Package under a Reference Scenario defined as specified in the Energy Trends to 2030 [1], as well as the Roadmap itself [2].

The Climate and Energy legislative package adopted in December 2008 established different measures to mitigate climate change and promote renewable energy [3]. This package is designed to achieve the EU's overall environmental target by 2020: 20% reduction in greenhouse gas emissions from 1990 levels, 20% share of renewable energy in the EU's total energy consumption and a 20% improvement in EU's energy efficiency. An important role in this context plays the Renewable Energy Directive (RED) aim at promoting the use of renewable sources for the energy and transport sectors (2009/28/EC) [4].

In this study energy crops are hereinafter regarded as non-food, lignocellulosic crops, belonging to the so-called category of 2nd generation feedstock. They have been considered as perennial energy crops that are grown specifically for their fuel value [5]. Broadly speaking, lignocellulosic crops generally fall into two categories: herbaceous and woody crops (Short rotation coppice) [5–8]. In the LUISA configuration, the herbaceous lignocellulosic crops considered are: Miscanthus (Miscanthus spp.), Switchgrass (Panicum virgatum), Reed canary (Phalaris arundinacea), Giant reed (Arundo donax) and Cardoom (Cynara cardunculus). In the case of woody lignocellulosic, the tree crops considered are: Willow (Salix spp.), Poplar (Populus spp.) and Eucaliptus (Eucaliptus spp.).

According to the RED, sustainability criteria to minimize the potential negative impacts on environmental (biodiversity, soil, climate change, water, air quality and resource use), social (land competition and labour conditions) and economic aspects (bioenergy costs) must be taken into account for the production of biomass for energy uses. Most of the criteria listed in the RED were included in the modelling configuration of LUISA, and specifically: restriction on protected areas and with high biodiversity value, restriction on land with high carbon stock (forest, wetlands and peatlands), preference of using superplus lands (degraded and abandoned lands), maximum slope limits for cultivation, on sites susceptible to soil erosion only perennial crops can be grown, adapt management practices (crop choice and yields) to local biophysical conditions, among others [5].

2 An overview of LUISA modelling platform

2.1 Structure, applications and policies in LUISA

LUISA is a dynamic, spatial modelling platform based on biophysical and socio–economic drivers. The platform has been developed to assess land use impacts of European policies by providing a vision of possible futures and quantitative comparisons between policy options. LUISA simulates future land use changes; land functions related to the resulting land use patterns are then inferred and described by means of spatially explicit indicators [9].

LUISA has been employed in a number of different policy assessments projects, which the scope and goals of those projects varies substantially. It reveals the breadth of topics where land-use impacts are relevant as well as the flexibility of the LUISA platform. Some of these applications are: impacts of policy alternatives for coastal zone management, impact of the green measures of CAP (Common Agricultural Policy), water blueprint project, impacts of shale gas development in Europe, resource efficiency in Europe, assessing the direct and indirect land-use impacts of the Cohesion Policy, assessment of ecosystem services among others.

LUISA is structured in three main modules (figure 1): the ‘demand module’, the ‘land use allocation module’ and ‘the indicator module’ [10, 11]. The demand module receives direct input from several external macroeconomic models: EUROPOP for population [12], GEM-E3 [13] for industry and commerce, CAPRI [14], for agricultural commodities (production of food, feed and energy crops), and GLOBIOM/G4M [15] for forestry. The allocation module spatially distributes the regional land use demands to 100m pixel resolution considering biophysical characteristics, neighbourhood factors, the competition for land and policy-based restrictions. The main final output of the allocation module is a time series of yearly land use map, from 2007 to for the EU28. The indicator module addresses the impact of the policy measures implemented upstream according to the goal of the analysis The assessment under the reference scenario presented in this document refers mainly to the impact of the EU policies on energy production from 2nd generation feedstock (energy crops) at regional level.

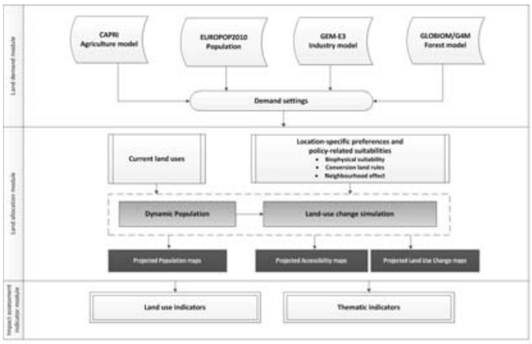


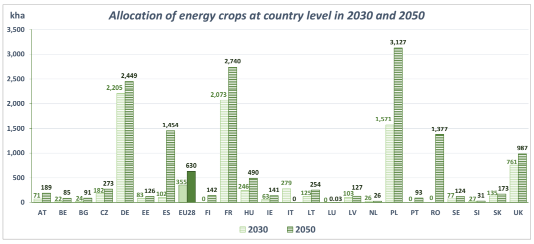
Figure 1: Modular structure of LUISA and the main models and dataset included.

3 Energy crops allocation and exploitation of soil fertile land from LUISA

In this section, the simulated allocation of energy crops is analysed in detail in three different fashions: share of energy crops over the total land available for their cultivation; total acreage of planted energy crops; and quantity of energy crops cultivated on different classes of fertile land. Results are aggregated at three geographical levels: country, region (NUTS2) and province (NUTS3).

3.1 Energy crop allocation at European and regional scale

According to the LUISA’s simulation results, energy crops in EU28 occupy 8,532 and 15,126 kha in 2030 and 2050 respectively. It represents over 3.1% and 5.9% of Europe’s total available land area, respectively. As figure 2 shows, the EU average is 355 kha and 630 kha in 2030 and 2050, respectively. This translates in an increase of 77% between 2030 and 2050, but with a significant variability between Member States. Poland, France, Germany, Spain, Romania and the United Kingdom are the countries that contribute the most, in terms of acreage, to the production of energy crops, accounting all together for 80% of the European acreage. In the final year of the simulation (2050), the availability of energy crops reaches up to more than 3,000 kha (Poland), whereas the tiniest presence is below 100 kha (Luxembourg, Bulgaria, Belgium, Slovenia, the Netherlands and Portugal). It must be noted that, according to the CAPRI model projections, energy crops are not forecasted to be introduced in Denmark, Greece, Croatia, Malta and Cyprus.



	AT	BE	BG	CZ	DE	EE	ES	EU28	FI	FR	HU	IE	IT	LT	LU	LV	NL	PL	PT	RO	SE	SI	SK	UK
2030	71	22	24	182	2,205	83	102	355	0	2,073	246	63	279	125	0	103	26	1,571	0	0	77	27	135	761
2050	189	85	91	273	2,449	126	1,454	630	142	2,740	490	141	0	254	0.03	127	26	3,127	93	1,377	124	31	173	987

Figure 2: Amount of land, expressed in thousands of hectares, occupied by energy crops on available land, at county level, for the years 2030 and 2050 in EU 28. Country values are represented by striped background; solid background indicates the European average.

As shown in figure 3, the allocation of energy crops is globally projected to increase in Europe. The European average is approximately 2.8% and 4.2% in

2030 and 2050, respectively. In only few regions the share of allocated energy crops over the available land exceeds 10%. One example is the region of Cheshire in the United Kingdom, which reaches 14.6% and 17.7% in 2030 and 2050 respectively. Despite the fact that the number of regions above 10% share is higher in 2050, most of these regions belongs to Poland; other can be found in the United Kingdom and Germany.

Figure 3: Share of allocated of energy crops on available land, at NUTS2 level for the year 2050 in EU-28.

Local differences regarding the allocation patterns of energy crops at NUTS3 level are mainly due to the total amount of available land within each province (figure 4). On the other hand, energy crops are encouraged to occupy areas with unfavourable biophysical characteristics, such as degraded and contaminated lands (see section 3.3). In 2020 and 2030, Germany shows the highest number of provinces with energy crops production above 50% on available land. These same German provinces keep a stable share of allocated energy crops in 2040 and 2050. Some provinces in Poland and the United Kingdom show a similar behaviour. On the contrary, minimum production of energy crops is mostly located in Sweden, Finland, Slovenia, Bulgaria, Latvia, Estonia, Austria and Portugal, where the share of allocated energy crops does not reach 1% in any province.

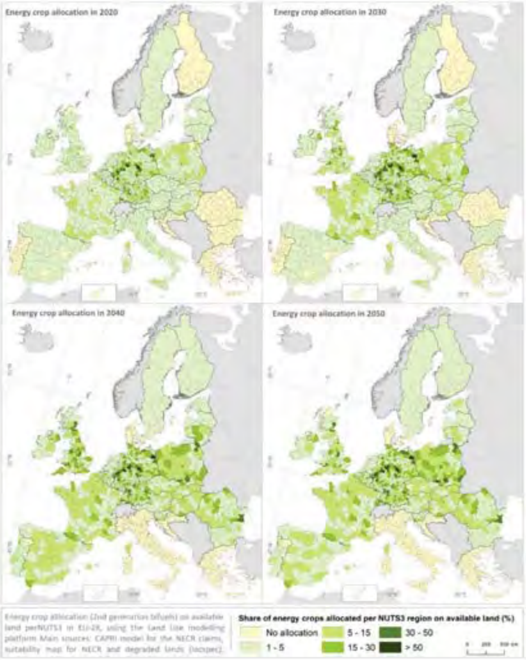


Figure 4: Share of the allocated energy crops on available land, per NUTS3 region, for the years 2020, 2030, 2040 and 2050.

The absolute amount of cultivated energy crops offer a different picture, if compared to the shares described in the first part of this section. The land occupied by energy crops is expressed in ha, for the years 2030 and 2050. In 2030, France is by far the European country that counts the vastest surface dedicated to energy crop production, reaching more than 182,000 ha in the Pays de la Loire, followed by Poland with 176,000 ha allocated in the Mazowieckie region, and Germany with approximately 158,000 ha cultivated in the Brandenburg region. Many of remaining countries show a quite homogeneous pattern at NUTS2 level, with most of their regions falling into the first group of the ranking, up to 25,000 ha. In 2050 (figure 5), the highest amount of land allocated to energy crops can be found not only in Poland, Germany and France, but also in Romania and Spain.

Figure 5: Total availability of energy crops, expressed in hectares, at NUTS2 level, in 2050.

3.2 Allocation of energy crops according to biophysical suitability levels

In this section, allocated energy crops are classified according to the local biophysical conditions where these crops might be grown referred to as 'suitability levels' (very low, low, moderate, high and very high). The higher the suitability, the higher the potential productivity level (yield), thus reducing the need of additional inputs potentially harmful to the environment. Figure 6 reports how many hectares of energy crops have been successfully allocated in the most suitable areas in EU, providing an overview at regional scale for the years 2030 and 2050. In 2050, energy crops are predominantly allocated on very high and high suitability levels in the central and south part of France, north of Spain, Portugal, few regions in Bulgaria and Hungary. In entire countries like The Netherlands, Belgium, Luxembourg and Ireland, and numerous regions in United Kingdom, Spain, Bulgaria, Romania and Germany, energy crops are mainly

allocated on moderately suitable land. Allocation on low and very low levels is mainly predominant in regions of the central and eastern part of Europe, and in Finland and Sweden. In 2050, the allocation of energy crops on moderate, high and very high suitability levels (35.5%, 10.3% and 2.6% respectively) increases to 48% (6,982 kha in total) with respect to 2030.

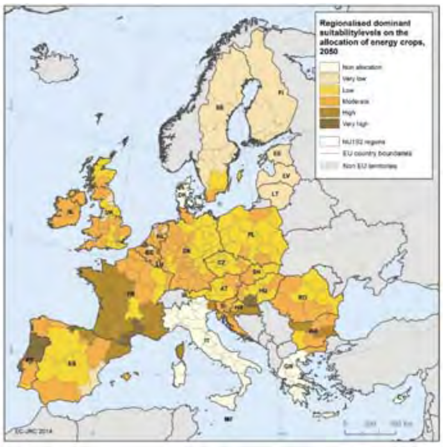


Figure 6: Suitability level on which the majority of energy crops, at NUTS2 level, are allocated in the year 2050.

In order to fulfil the sustainability criteria introduced by the RED and to avoid competition with other conventional agricultural crops, a possible solution is the use of degraded, low productivity lands and potentially contaminated lands for growing energy crops, as discussed in the following section.

3.3 Use of degraded and contaminated lands for energy crops allocation

Within the scope of the present article, *degraded lands* are referred to as lands with a decrease on current and/or future capacity of the soil to support human life [5]. EU-specific policies applied to 2^{nd} generation lignocellulosic feedstock must be considered in order to convert different land uses to energy production purposes. As food production needs good quality soils, the reclamation of degraded and contaminated lands can offer additional positive implications to planting energy

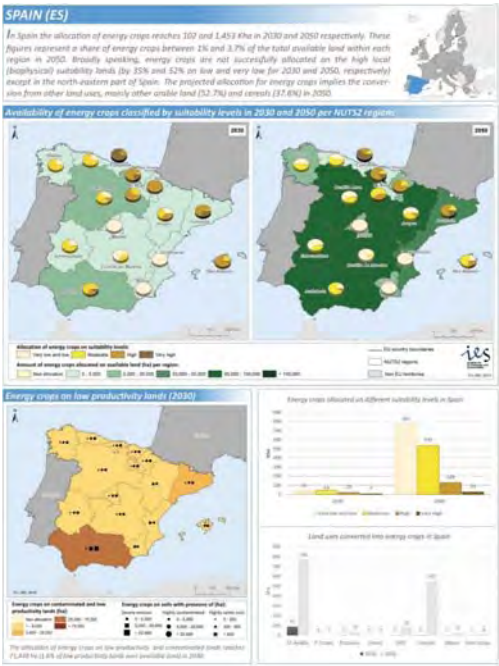
crops in those areas. Soil salinity, severe erosion areas and contaminated lands have been selected as unfavourable agriculture soil conditions [16–20]. In fact, some of the selected lignocellulosic species have particular ecological properties that allow them to be grown in such affected/degraded soils. The amount of land allocated for each category of unfavourable agriculture soil conditions is aggregated at NUTS2 level. In 2030, the share of energy crops allocated on degraded and contaminated lands varies strongly across NUTS2 regions of the Member States. High proportions of energy crops allocated on degraded land can be mostly found in some parts of Italy, Spain, France, Belgium and the United Kingdom, reaching more than 45% in 2030. In 2050, the overall picture for Europe is similar to 2030; main differences can be found in Portugal, .which shows high shares and previously had no allocated energy crops; and Italy, whereby energy crops are no longer present in 2050.

3.4 Assessment at regional level of the energy crop allocation

Further development at regional level (NUTS2) are there presented for each Member State, exemplified by Spain (figure 7). Analysing the results, it is possible to group Member States under two main profiles:

Countries in which the availability of energy crops is considerably high and the exploitation of low productivity lands might be high or low. France, Germany, United Kingdom and Poland, with high production and high use of degraded and contaminated lands, belong to this first profile. In these countries, 15% of low productivity lands are used by energy crops on available land. In the particular cases of Spain and Romania, the figures show worst results: the allocation on degraded lands is about 1.6% and below one percentage point, respectively. In addition, Germany, United Kingdom and Poland allocate energy crops on low, very low and moderate biophysical suitability levels, which means that more inputs might be needed for the production. On the contrary, France, Spain and Romania have a better distribution among the moderate, high and very high suitability levels. The projected allocation of energy crops implies the conversion from other land uses, and for these high producer countries, mainly other arable land and cereals suffer the higher losses.

Countries in which the availability of energy crops is moderate or considerably low, and the usage of low productivity lands might be high or low. In the first case, with moderate production and high use of degraded and contaminated lands, Austria is the only country with a high reconversion of low productivity lands, nearly 8%. Other countries, such as Bulgaria, Czech Republic, Estonia, Finland, Hungary, Lithuania, Latvia, Luxembourg, Portugal and Sweden, are moderate and low producers respectively, and low user of degraded and contaminated lands (below 1%). In the particular case of Belgium, Ireland, Italy, The Netherlands, Slovakia and Slovenia, the figures show better results: the allocation on low productivity land is 3% on average. With the exception of Bulgaria, Hungary, Italy, Portugal, and Slovenia, where energy crops have a better spreading among the moderate, high and very high suitability levels, the remaining countries allocated energy crops on low, very low and moderate biophysical suitability levels.


SPAIN (ES)

In Spain the allocation of energy crops reaches 102 and 1,453 Kha in 2030 and 2050 respectively. These figures represent a share of energy crops between 1% and 3.7% of the total available land within each region in 2050. Broadly speaking, energy crops are not successfully allocated on the high local (biophysical) suitability lands (by 35% and 52% on low and very low for 2030 and 2050, respectively) except in the north-eastern part of Spain. The projected allocation for energy crops implies the conversion from other land uses, mainly other arable land (52.7%) and cereals (37.6%) in 2050.

Figure 7: Example of a factsheet for France, reporting the allocation of energy crops per suitability levels and on low productivity land, 2030 and 2050.

4 Conclusions

LUISA (Land Use Integrated Sustainability Assessment) modelling platform allows for simulating the allocation of different land uses simultaneously, taking into account all the relevant policy constraints and incentives that have a direct impact on the spatial distribution of such uses. At the same time LUISA allocation mechanism are based on spatial explicit suitability criteria, mainly related to biophysical characteristics, neighbourhood effects and conversion rules between the simulated land uses.

In the current modelling exercise, and in compliance with the CAPRI model specifications, energy crops are referred to as non-food, lignocellulosic crops, belonging to the so-called category of 2nd generation feedstock for energy production. Energy crops have been analysed with respect to the level of soil quality (suitability) where they have been allocated. Overall, it can be stated that growing energy crops on high biophysically suitable land results in a reduction of water consumption, inputs use, such as fertilizers and pesticides, thus minimising the associated negative environmental impacts. Moreover, the reclamation of degraded and contaminated lands to planting energy crops can offer additional positive implications with the main purpose to avoid land competition with other conventional agricultural crops. Soil salinity, severe erosion areas and contaminated lands have been selected as unfavourable agriculture soil conditions.

According to LUISA´s simulation results, energy crops in EU28 occupy 8,532 and 15,126 kha in 2030 and 2050 respectively It represents over 3.1% and 5.9% of Europe's total available land area, respectively. Poland, France, Germany, Spain, Romania and United Kingdom are the countries that contribute the most to the production of energy crops. Concerning the simulations of energy crops allocated on unfavourable agricultural soil conditions (high salinity areas, severe erosion, highly contaminated areas by heavy metals) can be mostly found in some parts of Italy, Spain, France, Belgium and the United Kingdom.

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Section 8
Sustainable indicators, monitoring and assessment

Developing and identifying sustainability indicators in the Singapore context

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Abstract

Singapore's geographical setting, being a highly industrialized city-state, with limited natural resources have placed it in a unique position to deal with key issues in its commitment to sustainable development. Evolving sustainability science and assessment tools that underpin sustainability efforts are instrumental in guiding decisions and policies in the drive towards achieving sustainable development. Practical sustainability methods or indicators are viewed as imperative to determine the successful implementation and outcome of sustainable strategies and policies.

We propose the preliminary development of sustainability indicators for four main important subjects for Singapore: i) carbon footprint; ii) energy; iii) water; and iv) waste management and landfill. For carbon footprint, a preliminary model was introduced to estimate the greenhouse gas (e.g. CO_2) emissions considering the manufacture of resources to (value-added) products. Limitations and potential performances of "clean energy" will be discussed, as well as, water supply and demand. In the fourth indicator development, the limited land area of Singapore (718.3 km^2) and its total dependence on an offshore landfill for the disposal of MSW (municipal solid wastes) is investigated.

Keywords: sustainable indicators, carbon footprint, energy, water, landfill.

1 Introduction

As the rise in population, resource depletion and climate change continue to become global concerns, many cities around the world have developed sustainable

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development plans. Singapore's geographical setting, being a highly industrialized city-state, with limited natural resources have placed it in a unique position to deal with key issues in its commitment to sustainable development [1]. Evolving sustainability science and assessment tools that underpin sustainability efforts are instrumental in guiding decisions and policies in the drive towards achieving sustainable development [2]. Practical sustainability indicators are viewed as imperative to determine the successful implementation of sustainable strategies and policies. Different indicators have been developed to serve various needs, and are carefully selected based on specific elements deemed important to a country [3]. This work describes the development of sustainability indicators for four main important issues in Singapore.

2 Carbon footprint

A few methods have been proposed to generate national carbon footprints (CF). Schulz [4] illustrated the challenges in CO_2 accounting for the city-state of Singapore as vibrant economic system. Hertwich and Peters [5] performed national CF analysis using a combined multi-regional statistical model considering input-output factors, consumption trends, and other variables. While life cycle assessment (LCA) is inarguably the most systematic and accurate way to derive product carbon footprints [6], such thorough assessment is time consuming to be performed on a national scale. Here, we propose a systematic, yet simplified, method to estimate the nation's CF for the manufacturing sector, which can help in gauging CO_2 in target reduction policies [7].

2.1 Carbon footprint of manufactured products

In this section, we consider Singapore's global strategic position as a manufacturing hub, and propose a model to generate the carbon footprint (CF) considering the inflow of resources that are processed into (value-added) products. As an easy and quick analysis, the following equation is proposed:

$$\text{Total CF}_{(\text{manufacture})}/\text{year} = \{ [\text{CF}_{(\boldsymbol{P})}] - [\Sigma[(\text{CF}_{(\boldsymbol{r})}) \text{ x } af\,]_i] \} \text{ x } \boldsymbol{P}_{\text{year}} \qquad (1)$$

where CF$_{\boldsymbol{P}}$: total life cycle CO_2 of value-added Product **P**, including resource extraction, processing, and final manufacture (in kg/tonne P); $\boldsymbol{P}_{\text{year}}$: total production of ***P*** in a year (in tonne per year or tpy); CF$_{\boldsymbol{r}}$: CO_2 from extraction and processing of main resources (in kg CO_2/tonne $\boldsymbol{r}_i$) to make ***P****; i*: 1, 2, 3…..(number of main resources ***r***) to make ***P*** and af_i (*allocation factor*): CO_2 fraction from CF$_P$ assigned according to the conversion/transformation (according to mass) of $\boldsymbol{r}_i$ to ***P***.

The overall method is illustrated in Fig. 1.

Equation 1 is applicable to a wide range of manufactured products to generate the CF of value-added goods, especially where:

- the process of dealing with – or lack of – massive amounts of data (statistical information) can be eliminated

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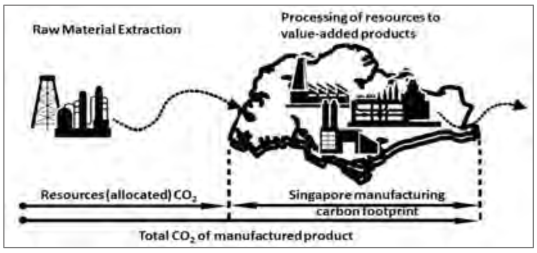

Figure 1: Life cycle approach for estimating carbon footprint.

- a life cycle approach is required
- quick and easy calculations are needed based on data obtained from widely available LCA databases (e.g. [8]).

2.2 CO_2 adjustment factor for Singapore

In order to adjust the total CF to the case of manufactured products in Singapore, an "*emission adjustment factor*" or "*ef*" is introduced. The amount of "*ef*" is estimated according to the type of fuel mixed for combustion or electrical energy required in the manufacture/processing of ***P***. Therefore:

$$\text{Total CF}_{(\text{national\_manufacture})}/\text{year} = \text{Equation (1)} \times [(\chi)ef_{(\text{fuel})} + (1\text{-}\chi)ef_{(\text{elec})}] \qquad (2)$$

where χ = amount of process energy supplied by fuel combustion (in-situ) and $ef_{(\text{fuel})} = \frac{\text{kg CO}_2 \text{ per MJ energy use (home country)}}{\text{total kg CO}_2 \text{ per MJ energy (reference country)}}$

$$ef_{(\text{elec})} = \frac{\text{kg CO}_2 \text{ /MWh (home country's fuel mix for electricity generation)}}{\text{total kg CO}_2\text{/MWh (reference country's fuel mix for electricity generation)}}$$

A few CO_2 emission examples, based on a country's specific fuel mixes for electricity generation, are: 390 kg CO_2/MWh for Singapore (fuel mix of 95% natural gas, 1% oil, 4% waste-to-energy), 457 kg CO_2/MWh for China [9] and 715 kg CO_2/MWh for US [10]. The aggregated European electricity mix is reported as 462 kg CO_2/MWh [11]. By default, $ef_{(\text{fuel})}$ = 1 in the case where there is lack of information.

2.3 CF example: resources to petrochemicals

The manufacture of polypropylene (PP) is taken as an example. The APME European average data [12], for PP production on a cradle to gate basis, is taken as representative to obtain CF$_P$ of polypropylene. Emissions of CO_2 due to crude oil and natural gas extraction can be sourced from same database [12] (Table 1).

Table 1: Data for polypropylene (PP) manufactured from raw materials.

<table>
<tr><th colspan="3">Life cycle data of CF$_P$</th></tr>
<tr><td colspan="2">Total CO_2 emissions from life cycle of resources to 1 tonne PP (main input: r_1 = 940 kg crude oil; r_2 = 586 kg natural gas; 0.44 MWh electricity)</td><td>CF$_P$ = 1852 kg CO_2 per tonne</td></tr>
<tr><th colspan="3">Life cycle data of resources (r_i)</th></tr>
<tr><td rowspan="2">CF_{r_1} = 560 kg CO_2 per tonne crude oil
CF_{r_2} = 138 kg CO_2 per tonne natural gas</td><td colspan="2">Allocation factor</td></tr>
<tr><td>$af_1 = \frac{940}{1000}$</td><td>$af_2 = \frac{586}{1000}$</td></tr>
</table>

The annual PP produced in Singapore was reported to be 370,000 tpa [13]; hence the total CF of Singapore for PP can be deduced by equation (1): Total CF$_{(\text{manufacture})}$/year = {[1852] – [(0.94 × 560) + (0.586 × 138)]} (kg/tonne) × 370,000 tpy = 461 million kg CO_2/year. With $ef_{(\text{elec})} = \frac{390}{462}$ and $\chi = 0$; CF$_{(\text{national\_manufacture})}$ is adjusted to ~ 389 million kg CO_2/year for the manufacture of polypropylene. By similar calculations steps (via equations 1 and 2), the total CF for the manufacturing of polyethylene, xylenes and benzene are: 657, 366, and 325 million kg CO_2/year respectively.

3 Energy

With lack of fossil resources, Singapore imports natural gas and oil from other countries [1]. One of the policies aimed at increasing energy security for the country is in diversifying energy sources. Here, we focus on the potential of solar energy, with the target of 5% of energy delivered by solar by 2020 [14], which is a total ~ 2.5 TWh. equation (3) presents the potential energy delivered by solar:

$$\text{SI}\left(\frac{\text{MWh}}{\text{m}^2}\right) \times \text{area(m}^2) \times \text{E(\%)} \times \text{PR(\%)}](\text{MWh/year}) \qquad (3)$$

where SI (Solar insolation): Amount of solar energy received per square meter; for Singapore, $(\frac{\text{MWh}}{\text{m}^2})$/year = recorded as 1,627.9 $(\frac{\text{MWh}}{\text{m}^2})$/year [15]. Area: Potential area available for installation. E(%): Efficiency of solar panel, i.e. ratio of solar cell output to the incident energy in the form of sunlight (recommended range of 16% to 20% according to crystalline and concentrated photovoltaic or PV) [16]. PR (%): Performance ratio, i.e. portion of energy available for export to electrical grid after losses (e.g. thermal or conduction losses).

The available areas for solar panel installations are on building rooftops. The possible usable areas for solar installation in future are reported to be 27–47 km^2 [16]. However, a moderate 10–30 km^2 was applied, along with PR = 67% to 77% [17], to generate the potential TWh/year. The results are shown in Fig. 2.

With E = 16% and PR = 67%, around 5 TWh is readily achievable if an area of 10 km^2 is dedicated to solar installation. A potential 20 TWh/year can be realized if a total area of 30 km^2 is installed with PV. Another issue is the costs of solar. Fig. 3 illustrates the efficiency (%) of solar vs. costs/m^2 according to thin film solar technology, crystalline or concentrating photovoltaics (in 2008), as reported

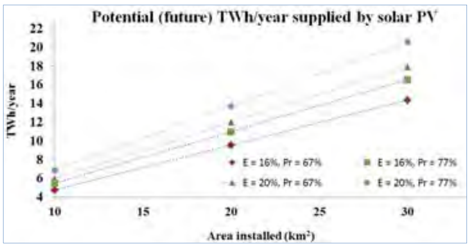

Figure 2: Potential energy from solar according to various scenarios.

by Doshi *et al.* [18]. As an additional sustainability dimension for solar indicator, costs can be factored in according to the types of technology employed to give:

$$\frac{\text{Equation (3)}}{\left[\frac{\text{Costs of solar tech}}{\text{m}^2}\right] \times \text{area}(\text{m}^2)} \tag{4}$$

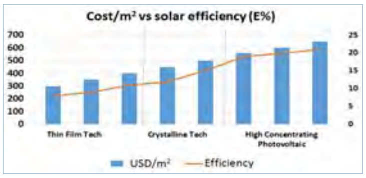

Figure 3: Costs/m² vs efficiency of solar.

4 Water

With a land area of 718.3 km², it is essential for Singapore to maximize the use of water catchment areas resourcefully [1]. The small city-state currently uses two-thirds of the main island for local water catchment. Plans are on-going to increase this capacity to 90% by the employment of variable salinity water treatment by 2060 [19]. In the aim to reduce the reliance of water imports (which is 40% of demand [20]) and be self-sufficient, investments into water reclamation (known as NEWater) and desalination are also underway. Currently NEWater and desalination systems provide 30% [1] and 25% of total water demand respectively [21].

Several indexes have been developed to measure water sustainability, each with slight variations based on different needs and scales, with Watershed

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Sustainability Index (WSI) [22] and Water Provision Resilience (WPR) [23] being the most relevant to Singapore. Such indexes (Table 2) attempt to describe the multi-faceted state of the studied water system.

Table 2: Water indicators: issues considered.

Watershed Sustainability Index (WSI)	Water Provision Resilience (WPR)
• Hydrology • Policy • Quality of Environment and Life	• Supply • Finances • Infrastructure • Water Quality • Provisions • Governance

As Singapore is known to provide safe potable water to its population, indicator developments would aim towards self-reliance (reduced water imports), described by the Self-sufficiency index introduced as equation (5) [24]. The index takes into account the economic and social aspects of sustainability:

$$\text{Self-sufficiency Index} = \frac{\text{Total water supply - Imported water}}{\text{Total water demand}} \tag{5}$$

4.1 Targets and indicator recommendations

The supply of water in year 2014, and planned future projections, for years 2016 and 2060, are compiled in Table 3 from various reports [1, 19–21, 25, 26].

Table 3: Present and future water capacities.

Capacity (Mm^3/day)	2014	2016	2060
Imported water	1.14	1.14	0
Catchment water	0.68	0.68	0.95*
NEWater	0.54	0.77	1.75*
Desalination	0.45	0.45	0.80*

*Based on demand of 3.18 Mm^3/day in 2060 [27].

In order to assist in water supply planning and monitoring, three water sustainability indicators are proposed for Singapore:

$$\text{Long-term Sufficiency} = \frac{\text{Local capacity } (\frac{\text{Mm}^3}{\text{year}})}{\text{Local water demand } (\frac{\text{Mm}^3}{\text{year}})} \tag{6}$$

$$\text{Water Resilience} = \frac{\text{Local unused capacity (NEWater + Desalination)}(\frac{\text{Mm}^3}{\text{year}})}{\text{Amount of imported water + Variability of local catchment water}(\frac{\text{Mm}^3}{\text{year}})} \tag{7}$$

$$\text{Catchment Efficiency} = \frac{\text{Catchment water production } (\frac{\text{Mm}^3}{\text{year}})}{\text{Catchment Area} \times \text{Rainfall} \times \text{Surface Run-off Coefficient } (\frac{\text{Mm}^3}{\text{year}})} \tag{8}$$

While equation (6) measures the self-reliance of the country's ability to supply water without the input (import) of external sources; equation (7) introduces a buffer against non-controlling sources. It also attempts to capture any forms of risks associated with the continuation of imported water supply and fluctuations in local catchment water production which can be affected by weather. A variability of catchment water of 0.23 Mm^3/day was estimated. Equation (8) encapsulates the productive use of land areas dedicated for water catchment systems. Plans are currently underway to obtain 90% area coverage for water catchment [19]. With a high portion of space purposed for water catchment, it is important to measure its overall efficiency. For the Catchment Efficiency sustainability index, a value closer to 1 is desired.

4.2 Present and projected indicator values

With a demand of 1.82 Mm^3/day in 2014 [19], Long-term sufficiency in 2014 is calculated (via equation (6)) as 0.92. And the current combined production output and spare capacity of NEWater and desalination plants is calculated out to be 1.09 Mm^3/day and 0.58 Mm^3/day respectively. Hence, Resilience is 0.61. In 2016, Singapore's 5th NEWater plant is expected to be operational, supplying 0.23 Mm^3/day of water [26]. By interpolation, the expected demand in 2016 is estimated as 1.88 Mm^3/day. This will result in a combined water production output, as well as, spare capacities of 1.13 Mm^3/day and 0.77 Mm^3/day coming from NEWater and desalination plants respectively, leading to an increased Long-term Sufficiency and Water Resilience of 1.01 and 0.79 respectively.

Singapore has plans to increase NEWater and desalination capacities up to 55% and 25% of future demands by 2060 [19]. Supposing a long-term sufficiency target of 1.10 by 2061 is achievable (with a safety-uncertainty factor of 10% applied to account for variability in weather and coastal conditions), the potential catchment water capacity will reach 0.96 Mm^3/day – a 40% increase of the current 0.68 Mm^3/day capacity. Water Resilience would then be 0.98.

Table 4 summarizes the indicator values in 2014, predicted values in 2016 due to the opening of a new NEWater plant, and suggested values for 2060.

Table 4: Indicator values.

Indicator/Year	2014	2016	2060
Long-term sufficiency (equation (6))	0.92	1.01	1.10
Water resilience (equation (7))	0.61	0.79	0.98

Catchment efficiency is not projected due to unavailable data

5 Waste, recycling and landfill

In this section, the limited land area of Singapore and its total dependence on an offshore landfill for the disposal of municipal solid wastes (MSW) is investigated. Semakau landfill covers 350 hectares and has a capacity of 63 million m³. It is split into two phases. The capacity of Phase One is 11.4 m³ and is projected to be full around 2015 [28]. The development of Phase 2 of Semakau landfill began in 2014 and is estimated to be completed by the first quarter of 2015. When completed, it is projected that the new landfill cell is capable of meeting the waste disposal requirements of Singapore up to 2035 or beyond. In order to prolong the lifespan of the landfill, only inert waste materials and incinerated by-products (bottom ash and fly ash) are sent to Semakau landfill. Therefore, the total waste occupying the landfill, and the corresponding lifespan of the landfill are related to the space taken up yearly by the waste volumes determined by the densities of inert wastes (ρ_{inert}) and ash (ρ_{ash}) after incineration (Fig. 4).

Figure 4: Overview of wastes sent to Semakau landfill.

5.1 Waste statistics and trends

Based on statistics [29], it can be observed that the total waste generated, total waste incinerated and total waste recycled all increase almost linearly during the past years, albeit at different rates. Therefore, the following equation was modeled to determine the rate of landfill volume occupied each year:

$$\text{Vol}_{\text{landfill}} = \Sigma_{1999}^{\text{target year}} \left[\frac{\text{Mass}_{\text{inc}} \times \phi_{\text{waste-to-ash}}}{\rho_{\text{ash}}} + \frac{\text{MSW}_{\text{total}} \text{ - Mass}_{\text{inc}} \text{ - MSW}_{\text{rec}}}{\rho_{\text{inert}}}\right] \tag{9}$$

where $\text{Vol}_{\text{landfill}}$: accumulated volume of total wastes which go to landfill (vol), which is set at < 63 million m³ (Semakau fixed capacity); $\text{MSW}_{\text{total}}$: MSW generated (million tpy) = 0.362 × (year – 2006) + 5.154; MSW_{inc}: waste incinerated (million tpy) = 0.074 × (year – 2006) + 2.293; MSW_{rec}: waste recycled (million tpy) = 0.284 × (year – 2006) + 2.697 until year 2020; $\Phi_{\text{waste-to-ash}}$: mass ratio between waste-to-ash after incineration (%); ρ_{inert}: density of inert solid wastes, ca. ~ 1.5 to 2.0 tonne/m³ [30, 31]; ρ_{ash}: density of ash, reported (average value) as 1.5 tonne/m³ [32].

5.2 Projected waste volume and Semakau landfill's lifespan

An estimated 75% is made for mass reduction rate ($\Phi_{\text{waste-to-ash}}$) by incineration. Based on the estimation through linear regression, in year 2020, the recycling rate ($\frac{\text{MSW}_{\text{rec}}}{\text{MSW}_{\text{total}}}$) would reach 61%. As a conservative assumption, we assume that after 2020, the recycling rate would not increase beyond 61%. Based on these parameters, equation (9) projected that by 2015, $Vol_{landfill}$ would reach 8.43 million m^3 of waste. This amount approximately matches Semakau's Phase One capacity. The graphical results – displayed in Fig. 5 – from equation (9) shows that total $Vol_{landfill}$ equaling to 61.06 million m^3 would be reached in year 2049, which is still within the landfill's total designed capacity of 63 million m^3.

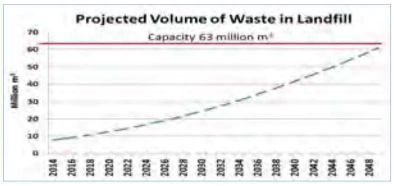

Figure 5: Projected total waste occupying landfill.

6 Summary

A summary of the indicators presented, uncertainties and national targets are compiled in Table 5.

Table 5: Summary of sustainability indicators.

Topics	Sustainability indicators/ measurements	Uncertainties/risks	National targets
CO_2	Simplified carbon footprint estimation tool for manufacturing sector	Data availability and reliability; future clean schemes on "clean" technology	Reduction of ~ 650 ktonne $CO_{2\text{-eq}}$ by 2020 for manufacturing sector
Energy	• Potential energy delivered by solar (TWh/year) • Potential energy vs costs × area installed	Weather, technological advancement, costs, area for installation	5% of energy delivered by solar by 2020 (2.5 TWh/ year)
Water	Indicators suggested: • Long-term sufficiency • Resilience • Catchment efficiency	Weather-related risks, land area for catchment, possible rise in demand	Capacity targets for 2060: Catchment water = 0.95* NEWater = 1.75* Desalination = 0.80* *All in Mm^3/day
Waste, landfill	Trend of waste sent to landfill relating recycling rate and waste densities	Uncertainty in population growth; MSW per capita	Capacity set at < 63 million m^3; Lifespan ≥ year 2045

Sustainability indicators or assessment tools play a crucial role in informing and guiding national policies [1, 2]. Methods to estimate national carbon footprint have been discussed in literature [4–6], with the need for substantial levels of data.

A simplified life cycle method focusing on resources-to-manufactured products was proposed to eliminate the amount of input-output coefficients required. With advanced PV solar technologies that can provide efficiencies of 20% or more, the nation's policy for solar energy (2.5 TWh/year by 2020) [14] can be made possible along with an installed area of ≥ 10 km^2 [16]. The development of three water indicators considered Singapore's water supply and demand mix, as well as, the ongoing efforts to secure the nation's water demands till 2060 [19, 20, 25]. However, the dynamic nature of water supply considering risks and weather-related factors were omitted. The final indicator (equation 9) provides some answers to the lifespan of Singapore's only offshore landfill [28]. Supposing recycling rates can be maintained at ≥ 61% in 2020 onwards, Semakau landfill will reach its full capacity around year 2049.

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Sustainability in practice: integrated assessment to support policy and decision-making processes

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Abstract

Sustainability has been recognized, when facing multifaceted decision and policy making processes, as a discipline that broadens the scope under which issues are taken into account. This is considered important given the complex and interrelated challenges faced by societies nowadays. However, it has been found in literature that the sustainable approach still has several obstacles to tackle, from the weakening of its discourse to the lack of real influence and low consensus on its meaning and practice. To reinforce the operational side of sustainability, several methodologies have been designed and implemented over the years with two main shortcomings: an inability to assess sustainability issues as a whole and more specifically, a lack of practical steps that can be included on a day-to-day basis. Integrated assessment emerges as a possible way to summarize the complexity of studying issues from a broader perspective but it is applied in different ways with diverse outcomes that require careful examination. These outcomes are compared by analyzing four integrated assessment tools: life cycle assessment, cost-benefit analysis, stakeholder analysis and multiple scale integrated analysis of societal and ecosystem metabolism. The aim is to observe and determine the degree to which they contribute to the consolidation of the sustainable approach and how they support decision-making processes. It is intended that this exercise help build a diverse yet deep common base for further conversation that will facilitate the process of searching and selecting alternatives to drive socio-ecological systems towards a more sustainable future.

Keywords: sustainable approach, consolidation of sustainability, integrated assessment, policy making, decision-making.

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1 Introduction

Narrowly described as covering present needs without compromising those of the future [1], sustainability has become an important pillar when facing development issues. The present twofold scenario with climate change and scarcity on the environmental side and, conflicts related to inequalities and economic crisis on the socioeconomic one, makes it even more imperative that we consider equity between and within generations in order to achieve more sustainable cycles of human progress [2]. As awareness of resource scarcity grows, tools and methods for determining the best way to use them are needed.

However, there is no *one* or *best* way but several ones with different implications and consequences making the task much more complex. Success is not achieved by simply incorporating a sustainable approach into processes where many different interests and goals are at work. Missing still are the practical steps to actually address real issues. Searching for means to integrate sustainability into the processes that lead to real-world actions is necessary so that sustainable principles can drive actions that will result in more consistent decisions, policies and a more balanced development.

1.1 Measuring sustainability

Long has been discussed how measurement methodologies contribute to sustainability [3]. Some consider *measuring the immeasurable* as a way to market natural and social goods and services so that they can be traded like any other product [4, 5], while others see that sustainability needs to be evaluated in order to simplify its complexity and generate more accurate assessments [6, 8].

While both considerations have pros and cons, sustainability as a discipline still needs to reinforce its operational side. There is a lack of consensus on its definition and practice, showing contradictions between its conceptual and normative conception. The interdisciplinary and diverse conceptualization of sustainability contrasts with its more reductionist practice related to predictive statistics [9]. This contrast has a dual effect: on one hand it gives a broader spectrum for sustainability to be applied in different fields [10, 11]; while on the other, makes it harder to get reliable, provable results and therefore receive consideration as a scientific approach [12, 13].

Methods that are used to assess sustainability issues have different outputs which are the result of different ways of understanding and applying sustainable parameters and principles. Thus, the challenge of dealing with diverse, non-quantifiable and even incomparable variables should be taken into account when evaluating socio-ecological systems [12].

1.2 Aims and objectives

The present article analyses four tools to identify how they enable the integrated assessment of sustainability and how they influence decision-making processes.

After beginning with an introduction to sustainability measure, followed by the aims and objectives of the paper, section two briefly presents the implemented overall methodology, the selected approach and its justification. Section three overviews the integrated assessment of sustainability and its role in policy design and decision making processes by reviewing four commonly used tools in order to identify how they work and what are the needs and possible pathways to help in the consolidation of the sustainable approach. Section four discusses the results which are then followed up by some conclusions.

2 Methodology

Integrated assessment has emerged as a way to account for goods and services usually overlooked by the conventional conception of value. It also considers important aspects of sustainability such as ecological and social justice [6, 14] and adds them to the search for efficiency. This approach is based on the value of biodiversity and the other factors that provide services needed for human kind within an ecosystem [15], observing that the real sources of wealth are the biosphere and the social dynamics that occur within it. Therefore, even if they are outside the market, these are the real sources of value [16].

There is a great difficulty in managing something without valuing it first [17]. Before this, as stated by Meadows "*we measure what we value, but we also get to value what we measure*" [18]. Sustainability assessment can help make people conscious of values invisible to market-oriented economics, considering more than just profit when making daily life decisions that can dictate the pace at which a society develops. It also strengthens social capital, reduces the degree of dependence on the exterior and helps to cope with external forces such as climate change, top-bottom policies or economic crisis [19].

3 Integrated assessment, policy design and decision-making processes

The actual state of sustainability assessment is characterized by the existence of several tools and methods carried out by different users with diverse backgrounds and purposes. There are as many sets of sustainability indicators as organisms and research groups that develop and implement those sets [13], showing the low level of commonality that is rooted in the lack of consensus on the very concept of sustainability [20, 21].

It should be noted that integrated assessment methods are the function of the adopted vision of sustainability and this determines the kind of policies and actions derived from these methods. Therefore, the degree to which these exercises actually contribute to sustainability depends on the goals and agendas of researchers and their vision of sustainability.

3.1 Policy and decision-making

While making decisions, policy makers try to undertake complex issues related to sustainability with certain standards. Meanwhile, governments must negotiate with different actors that have different perceptions of a problem. Along the process, the challenge is to find a balance between getting enough support from the parties involved and achieving goals [22].

Decision theory gives three different ways of making decisions according the level of definition and understanding of the process: structured, semi-structured and unstructured [23]. The majority of environmental and social policy decision-making processes tend to be unstructured and interrelated. However, they are treated separately by researchers as can be inferred by the methods they implement, in contrast with the broadly accepted socio-ecological system [24]. These are the reasons for studying how integrated assessment can enhance and facilitate decision-making processes, which in turn contributes to catalyze efforts towards sustainability.

3.2 Methods

Selected tools, as seen in Figure 1, are in accordance with the three main dimensions of sustainability. Hence it is possible to compare the way in which they actually contribute to the consolidation of sustainability as a whole and to each one of its branches. The focus here is directed on how integrated assessment provides useful information and enhances decision-making and policy design processes as an indicator for strengthening the sustainable approach.

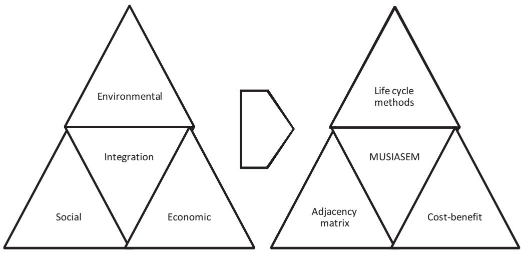

Figure 1: Selected integrated assessment tools.

With many possible options, selected methods may not be the most representative in some aspects, but regarding the objectives of the present paper they were considered as suitable because they allow both quantitative and qualitative analysis. Some have an explicit integrated perspective while others can be implemented in ways that provide a more holistic view.

3.2.1 Life cycle methodologies

Over the last 20 years, life cycle methods have become part of the most popular environmental assessment tools for evaluating and describing environmental effects caused by products, processes or activities [25]. Life cycle assessment (LCA) is the basic tool among them and it is defined as the analysis of the processes of extraction, use, recovery, emissions and waste generation of a product or service [26]. There are other life cycle methods that complement this scope such as: social life cycle assessment, which includes effects on poverty levels; life cycle costing, accounts the monetary costs or benefits to a defined stakeholder; and life cycle sustainability assessment (LCSA), that analyses the extent to which the life cycle of a product affects the meeting of needs for both present and future generations.

Interest is placed on how life cycle methods can be used to assess sustainability while aiming for simplicity. LCSA is the most adequate method for it focuses on whether a product is sustainable or not in terms of how its life cycle affects the environment, the levels of poverty among current generations and stock changes for future ones [27]. Helps to visualize what the production and consumption model that prevails globally involves. However, it has a high data requirement and has low incidence in policy developing for the difficulty to communicate its results. It is a business-oriented method that focuses on the ecological sphere still lacking a full incorporation of sustainability [28].

3.2.2 Cost-benefit analysis

Among the most commonly used economic evaluation tools, the cost-benefit analysis (CBA) focuses on assessing whether a program, policy or a specific investment is financially viable. Therefore, it is useful for determining if benefits can outweigh costs and expresses both the negative as well as the positive effects a certain action can produce in monetary terms [22].

CBA consists of the identification and economic valuation of current and future costs and benefits of a project; determining the rate of discount; time horizon fixation; developing one or more methods to bring the costs and benefits to present values; and estimating the relationship between the costs and benefits [29, 30]. It uses mechanisms such as grants and subsidies accounting or shadow prices to correct market errors [31]. Usually such studies are used in project evaluation and are typically expressed in terms of the willingness to pay for a specific good or service (consumer preferences).

The major strength of CBA is that it enables the evaluation of different outcomes by translating them into monetary units. Therefore, tangible and intangible, direct and indirect costs and benefits can be assessed in one single analysis. Here is where the integrated character of this instrument is shown.

However, this same strength has been considered the weakest point of CBA. The reason is that by adopting a unidirectional approach with a single criterion assuming all things involved as commensurable, it is impossible to accurately reflect the complexity of interrelated systems, such as socio-ecological systems [32]. The difficulty of measuring and monetizing some aspects can lead to its disregard.

3.2.3 Stakeholder analysis

Stakeholder analysis enables the identification of the group or network existing regarding a specific issue, to face multiple interests and goals when making

decisions or developing policies. It has evolved from its political economy and business management background to include fields such as decision theory, multiple criteria analysis and social participatory approaches [33].

This method helps to understand how a system works while assessing how changes can affect the system. The latter is achieved by the identification of key actors, their interests and perspectives at different levels aiming to understand interactions within development and environmental issues.

One of the methods in stakeholder analysis is the matrix of asymmetric adjacency. It consists on the identification of main social actors within the analyzed socio-ecological system and is based on the perspective provided by the stakeholder according to the intensity and nature of the interaction with other actors. Reflects the nature of relationships between actors represented by assigned values that show the degree of interaction, whether it is positive or negative, etc. Also, ranges are established in terms of the intensity of the interaction between actors and the particular system in the studied area, identifying groups whose decisions and actions directly affect the local ecosystem and that in turn, are affected by how the ecosystem is managed [34].

Stakeholder analysis works as a practical methodology to identify solutions and design policies; it offers a holistic view, can be applied to different subjects and consumes relatively low quantities of time and resources. However, it has some limitations in providing practical answers and does not ensure a strong participation of involved actors [22].

3.2.4 Multiple scale integrated analysis of societal and ecosystem metabolism (MuSIASEM)

The MuSIASEM method arises from the concern of information transfer between levels when facing multiple scales and dimensions in complex interrelated issues, where usual quantitative tools are found to fail. It responds to the question of how to assess complexity by adopting a holistic metabolism approach of the socioeconomic and ecological systems [35].

The metabolism of energy and material flows is analyzed following the semantic criterion of fund and flow elements. Fund elements show the characteristics of the system and are to be sustained; flow elements refer to the functions of the system and interact with the studied context.

The strength of MuSIASEM is its integrated nature. It also provides qualitative and quantitative information about the functioning of a system.

Some weaknesses are also to be found. The social dimension is not fully addressed focusing on labor force and household consumption and there is no explicit incorporation of a participatory approach. Second, its descriptive nature makes it difficult to enhance sustainability related decision making and policy design processes. Third and last, it is found to be highly time consuming. It should be stated that these limitations have been partially addressed in a poverty analysis study case [36] and more explicitly by Serrano-Tovar and Giampietro [37] where they propose a multiple source assessment in a rural environment, with a bottom-up approach gathering local data from farmers and a top-down using national statistics.

4 Discussion of the results

The previous analysis has shown that integrated assessment can contribute in different ways to sustainability and give different inputs that can be helpful for decision makers. In this section, results are observed in terms of how the selected methods enhance sustainability and decision making processes.

The selected methods were ranked following the sustainability weak or strong categories (see Table 1) that have been broadly implemented among consulted literature [8, 34, 38, 40]. Weak sustainability methods take into account terms and values that follow a standardized view of sustainability due to its translation into monetary terms [4, 40, 41]. Strong sustainability methods are those who adopt a broader scope that approaches to an interdisciplinary and systemic view of nature, society and also the economy [8, 34, 38, 39].

Table 1: Analysis of selected methods in terms of their contribution to consolidate sustainability.

Method	**Main consulted authors**	**Approach / Case**	**Contribution to sustainability**	**Input for decision making processes**
Life cycle methods	Jones, Rose and Tull 2011 Jørgensen, Herrman & Bjørn 2013 Klöpffer 1997 Shields et al. 2011	Environmental engineering & assessment; Policy making.	Medium.- business oriented; main focus on the environmental dimension; lack of consensus regarding relation to sustainability.	Visualization of production-consumption model; internalization of associated costs; difficulty to communicate results.
Cost-benefit	Cordero et al. 2006 Falconí & Burbano 2004 Munda, 1995 Runhaar, Dieperink & Driessen, 2006	Ecological Economics; Watershed case study.	Weak.- centered on monetary values; commensurability issues.	Useful and clear results; better if complemented to broaden the scope.
Stakeholder analysis	Grimble & Wellard 1997 Rescia et al. 2008 Runhaar, Dieperink & Driessen, 2006	Socio-ecological system; Decision making; Rural landscape case study.	Strong.- captures traditional, cultural, economic and natural values.	Practical method; enables identification of solutions; offers a holistic view.
MuSIASEM	Giampietro, Mayumi & Ramos-Martin 2009 Madrid, Cabello & Giampietro 2013 Serrano-Tovar & Giampietro 2014	Socio-ecological system; Complexity; social metabolism.	Strong.- provides an integrated scope; includes quantitative and qualitative information; adaptive capacity.	Descriptive method; provides robust information; holistic view on how the system is functioning.

Table 1 classifies the four selected methods and main consulted authors, the kind of approach or application of the assessment, followed by the assessed grade of contribution to the consolidation of sustainability and the input for decision making processes that the instrument provides.

Life cycle methodologies are among the environmental engineering assessment instruments. They are considered to have a medium grade of contribution to sustainability due to their business orientation and focus on environmental impacts. Many other factors than the supply chain are involved [28], however this is partially addressed by LCSA. As for their input to decision making, these methods have relatively low incidence due to the difficulty in communicating their results. Even so, it is a recognized framework for studying the impacts of productive systems on the environment. [28].

CBA is an economic instrument with an ecological economics approach. It is considered to have a weak contribution to sustainability mostly because of the implication of commensurability, implying that environmental or social services and goods can be substituted just like market ones. Notwithstanding its clear results when facing decision making processes, if benefits exceed costs, losses can be easily compensated by other means such as economic payments [31, 42, 43]. CBA is still an important part of integrated assessment due to the ease of communication (everyone understands "money talk") and inputs for scenario building [44]. Researchers state that sustainability-related issues must be assessed by hybridizing different knowledge areas and values [9, 45].

Stakeholder analysis accounts for the socio-ecological system approach and is strongly related to decision making processes. It has a strong contribution to the sustainable approach because it ponders diverse values such as traditional, cultural and natural ones. It also accounts for economic values, but enables the determination of common values and goals [22, 46]. Social learning tools can be incorporated for more solid outcomes [47, 48].

MuSIASEM has a complex socio-ecological system approach. Its integrated scope provides a strong contribution to sustainability analysis. It includes both quantitative and qualitative data and its adaptive nature gives flexibility to the methodology which in turn suits the nature of sustainability [35, 37, 49]. As for the inputs for decision making, they seem more blurry due to its descriptive character and the much needed experts throughout the analysis. Nevertheless it is important to account that this analytic tool provides an almost exhaustive view of the way a system functions [50].

5 Conclusions

More than focusing on a general consensus as normally understood, what is here acknowledged is that efforts must be directed to broaden the scope under which sustainability is implemented. The idea is not to create a *best-way* to analyze and respond to sustainability related issues, but to build a diverse yet deep network that acts as a common base for further development.

Integrated assessment has been largely implemented as shown in the literature for analyzing sustainability. Each application has a specific knowledge background that determines the kind of approach and the degree of importance given to sustainability. They also generate different inputs for decision making that can be more or less useful for enhancing these processes by communicating results and providing robust information for stakeholders to allow for.

Especially when related with complex issues that involve multiple scales and dimensions, integrated assessment is key to help decision makers find alternatives. In this sense, examples that are found to have a greater contribution to the sustainable approach provide a broader scope to analyze these alternatives in a systemic way so as to make better informed decisions. Although this can have an impact on the complexity of the decision making processes, it is worth the trade-off in order to be able to achieve more sustainable solutions.

The integration of the sustainable approach is still weak among the reviewed assessment tools. This is shown in the fact that environmental issues dominate over the more intangible social and institutional issues. Efforts are already being made towards this matter as shown by the social life cycle assessment, life cycle sustainability assessment and the execution of cost-benefit analysis as a complimentary device. However, stakeholder analysis and MuSIASEM are the examples that incorporate sustainability in a broader sense among the studied integrated assessment tools and if combined their performance could be even more useful for decision-makers.

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Section 9
Ecosystem restoration

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Choice of revegetation techniques for degraded areas using environmental damage assessment in the Amazon Forest, Brazil

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Abstract

The success in environmental recovery process is highly dependent on the knowledge of the characteristics of the new environment formed. Knowledge about historical degradation, activities developed, aspects and negative environmental impacts of human activity, allied with the characteristics of the new environment formed, allows the definition of effective strategies to the environmental recovery process. In this sense there is a necessity to develop more effective techniques and proposals for environmental recovery in degraded areas especially those that are located in regions with high environmental relevance, and explored by activities which promote a high degree of change in the environmental components. This paper presents a methodology for recovery of mined areas, using the assessment of environmental damage to define the recovery strategies. The work was developed in the Amazon ecosystem in a region explored by Cassiterite mining. The environmental damage was assessed in terms of the physical and biotic environment components, listed from the environmental aspects and impacts of historical exploration. Physical and chemical analyzes of degraded substrates were used to support zoning processes and to select the recovery activities. The methodology allowed identifying different degraded conditions in substrates, and determining the most affected environmental components. It was possible to define appropriate actions to recover the location, consolidating a methodology to manage degraded areas by mining and other activities with similar levels of environment alteration.
Keywords: Amazon forest, mining, recovery, soil.

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1 Introduction

The expansion of the human population requires the conversion of natural systems to other uses, even though these are crucial sources of environmental services and are important to the survival of humanity. As an example the process of occupation of the Amazon biome can be mentioned, with the accelerated process of environment degradation and deforestation, or the mineral exploration, and unordered timber.

Accordingly, several studies have been published warning of the environmental risks that may arise from removing large portions of the Amazon primary forest. Its importance to global climate balance, global water and energy cycles show the importance of adopting actions for its preservation [1–3]. The recognition of natural areas as being important to maintain quality of life, has been a growing concern in nations, society, businesses and government agencies to environmental issues. Nowadays, the commitment in relation to environmental preservation has intensified. Thus, according to the negative responses of nature to its intensive use, there is a growing awareness that human actions on the environment must be minimized, seeking to combine the development and sustainability.

In this context the long history of mineral exploration in Brazil must be highlighted. Since the colonial period the activity has been carried out intensively. Currently Brazil is one of the greatest exploitation countries of mineral resources in the western world [4].

The world reserves of Cassiterite resources was approximately 5.6 Mt (million tons) in 2008, distributed as follows: 1st – China (30.4%), 2nd – Indonesia (14.3%), 3rd – Peru (12.7%), 4th – Brazil (9.4%), 5th – Malaysia (8.4%), 6th – Bolivia (8.0%), 7th – Russia (5.4%) and 8th – Australia (2.7%) [4]. It shows the significant role that Brazil has in the international trade of Cassiterite.

Therefore a vital component in the exploration of mineral resources in Brazil is the recovery and/or restoration of degraded areas. Especially in surface mining cases, an activity which has major impacts on soil and landscape. This consists in a complex task that requires different techniques and strategies, being closely related to the level of degradation of the environment, and the defined future use for the area [5].

A broad spectrum of recovery methods has emerged from the demands for projects of recovery [6]. When the given area is surrounded by large forest remnants the forest restoration has a great chance of success, even if in the beginning there were only one or a few species, because local diversity will be guaranteed by the dispersion of seeds from the adjacent forest areas.

However in cases where the area is isolated with great mischaracterization of relief, and removal of surface soil layers, it is necessary to adopt the topographic reconstruction and rebuild the soil layers, until it is possible to provide the minimum necessary conditions for the development of vegetation and the ecosystem that will inhabit the region. In other situations the environmental damage may not allow such a development, and therefore it may be necessary to assign another use to the site.

In this sense it is crucial to understand the historical process of degradation, the history of developed activities, aspects and negative environmental impacts of human activity, and in addition to the characteristics of the new environment formed, implement effective activities for environment recovery. Thus, this work presents a methodology to recover degraded areas explored by Cassiterite mining activity, on floor tilling substrate, based on the assessment of environmental damage, developed in Amazonian ecosystem.

2 Materials and methods

2.1 Characterization of the study area

The study area is located in the National Forest of Jamari, administered by the Brazilian Institute of Environment and Renewable Mineral Resources – IBAMA, located 90 km from the city of Porto Velho (RO), in the municipality of Itapuã d'Oeste, with an approximate area of 225,000 ha, of which 90% of the total area is covered by open rainforest [7].

The climate is equatorial hot and humid, with average temperatures of 24°C and an annual rainfall of 2,550 mm. The rain season occurs between December and March. The relative humidity is around 80% to 85% with a defined dry season between July and August.

Since the early 1960s, the Amazon region has been explored for the extraction of Cassiterite, these activities have created degraded areas whose environmental recovery has been performed.

The activities of recovery degraded areas by mining in the Jamari National Forest began in the 1990s, but given the ineffectiveness of the initial activities in 2000, strategies based on environmental damage assessment have been developed to obtain success in the recovery process.

2.2 Environmental damage assessment

To assess the environmental damage we used an adaptation of the methodology used in environmental impact assessment using the evaluation matrix proposed by [8].

The environmental damage was assessed in terms of physical and biotic components of the environment, listed from the identified environmental aspects and impacts in the historical exploration of the site.

The environmental characterization was performed based on four criteria: (1) Magnitude: which refers to the dimension of the environmental damage, presenting as small (Sm), Medium (Med), and Large (L); (2) Temporality: assessing the duration of the damage. The damage may cease with the completion of the activity, characterized as temporary (T), or continue for a long time, considered permanent (Per); (3) Reversibility: indicates whether the damage is irreversible (Irr) or can return to the original state, considered to be reversible (Rev); (4) Comprehensiveness: is related to the area of influence of environmental damage, considered punctual (Pnt) or, if the surrounding areas are affected, regional (Reg).

The classification of environmental severity was performed to determine the influence of the environmental damage on the environmental quality. It was assigned a numerical scale to weigh the environmental damage (Table 1), and, subsequently, the environmental damage was scored using a predetermined numerical range, with values assigned according to their characteristics and their respective weights (Table 2).

Table 1: Criteria used for weighting the severity of environmental damage.

Value	Classification
1	Damage sufficiently severe, with consequences often corrected naturally in the short term.
2	Damage bit severe, with the possibility of natural recovery in the short to medium term.
3	Damage moderately severe, with consequences corrected in the medium term, deserving greater attention by area managers.
4	Severe damage, with serious consequences in the affected region and necessity of intervention by area managers.
5	Damage very severe, requiring urgent treatment action by area managers.

Table 2: Values assigned to Magnitude, Temporality, Reversibility and Comprehensiveness of environmental damage and weighting values.

Characteristic	Weight	Attributed values		
Magnitude	5	Sm = 1	Med = 3	L = 5
Temporality	3	T = 2		Per = 4
Reversibility	5	Rev = 1		Irr = 2
Comprehensiveness	2	Pnt = 1		Reg = 3

The level of significance of the environmental damage was determined according to the intervals presented in Table 3. The significance level is associated with the importance of giving environmental damage, indicating the need to prioritize those with a higher level of significance in the decision-making process.

Table 3: Numerical scale of significance used to classify the environmental damage.

Numerical scale	Level of significance
Smaller than 30	Little significant damage. No need for mitigation measures with possibility of natural restoration of the affected area.
31 to 40	Significant damage with fewer consequences. Need for measures to control, monitor, and mitigate the damage, implemented in the medium or long term.
Greater than 41	Damage very significant. Requires immediate intervention.

2.3 Data processing and analysis

The analysis of degraded soil substrate particle size was conducted through the pipette method. The soil substrate density was determined using the volumetric ring, and volumetric density of particles by the method of volumetric flask, with composite samples collected from 5 to 35 cm.

Chemical analyses were conducted in order to evaluate the conditions of the soil substrate to support the vegetation development. The pH ($CaCl_2$), organic matter content, available phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and extracted aluminum (Al), cation exchange capacity (T), and base saturation (V %) were determined.

Field and laboratory data were organized, digitized and included in the relational database of Microsoft Access. Photographic records were also attached. The results of the environmental damage in the field and office were confronted and any discrepancies were corrected.

From the results, we have established a methodological recovery proposal for each environmental damage situation encountered.

3 Results and discussion

3.1 Environmental zoning of mining areas

The different activities and processes involved in Cassiterite mining result in substrates with characteristics that arise from the type and composition of the matrix rock, degradation processes, shape and duration of exposure to remaining material.

Due to a very wide variety of situations, the classification of the material to be recovered was made necessary to establish the required recovery approaches and the correct interpretation to the results obtained by environmental damage assessment. Figure 1 shows the zoning proposition established.

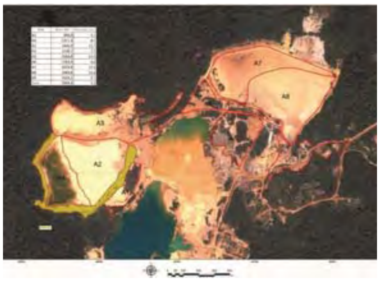

Figure 1: Environmental zoning in the mining area.

A7, A8 – pit mine: The armhole opening for exploiting Cassiterite requires exposure of the slopes and the construction of berms. The steepness of the slopes and width, traditionally, is determined according to the characteristics of the material, the process of pit opening, the need for access roads, and the volume of ore to be exploited. In turn, this volume depends on the purity of the ore and the economic aspects of the process (market value of Cassiterite, stripping ratio/ore extraction costs, discharge of water in processing, etc.). To the extent that the pit deepens, it requires greater exposure of slopes and larger area of berms.

Tailings deposition area – dry and wet: In areas of open pit, ore removal without the return of sterile or even the surface horizons (pit filling) leads to a remnant substrate formed by a heterogeneous mass of material. These areas are filled with sediment, drained or partially drained, with variable grain size, subject to flooding, causing problems in sustaining the physical terrain, making the mechanization difficult or impossible. The characteristics of this substrate depend on physical and geochemical properties of the rock that gave rise to the waste, but usually they are very poor and devoid of organic matter, and greatly hinder plant growth.

A2, A3 – reject dry: The dry reject is near to the dam of the tailings containment. It presents larger particle size, mainly sand, little or no soil structure, low or very low natural fertility and the mechanization is sometimes difficult, because the material is very loose. They also have excessive drainage capacity which makes the material with low water retention capacity.

A1, A4, A5, A6, A9 – reject wet: Represents the farthest dam containment of tailings, usually near watercourses. Its particle size is very thin with predominance of clay. Due to its proximity to watercourses it may remain flooded part of the year; a prior study of the drainage is necessary for the recovery process. Trafficking machinery is very difficult because of the constant presence of excess moisture.

3.2 Assessment of environmental damage in mining area floor

Table 4 shows the matrix used to assess the environmental damage in areas localized in floor tilling substrate. Damages with greater significance are linked to the physical environment. In biotic environments the most significant damages are linked to changes in forest structure and removal of native forest.

The results are consistent with the history of exploration, since the mining process produces profound changes in the landscape, with the removal of topsoil, and alteration of surface water drainage, resulting in significant damage in the physical environment.

According to [9] alternatives applied to the recovery of degraded areas can be distinguished according to the field of scientific knowledge which they are based: revegetation, geotechnology and remediation. These alternatives have the goal of physical, chemistry, and biological environment stability.

In this context, considering the analysis of environmental damage, it was decided to primarily implement the topographic reconstruction of the area and subsequently the revegetation.

3.3 Surveying techniques for topographic reconstruction

The topographic reconstruction is understood as the realization of simple earthworks, redesigning existing irregular topographic surfaces in newly mined areas. The activity is performed with the aid of machinery and equipment of the mine.

Even with the possibility to shape the relief, the new surfaces obtained were significantly different from the original ones.

The topographic reconstruction of degraded surfaces comprises the initial stage of the technical support for the recovery of degraded areas; either with the objective of re-establishing the vegetation or other form of use to the degraded site. In this field, the studies are still incomplete, because geological forms associated to the landscape are not able to be redone with human action.

Operations to topographic reconstruction and preparation of surfaces that were considered basic in the process of environmental recovery, and their respective sub operations are shown in Table 5.

Knowing the operations to be performed, the planning was starting for the execution of the work, setting the time and the resources needed.

3.4 Techniques for revegetation in degraded areas

For the construction of a new ecological system it was understood to be the revegetation of the degraded site. The success of vegetation reconstitution is highly dependent on the reconstitution of the soil, from the degraded substrate. For this purpose the operations listed below were employed.

Composting: In mined areas, soil organic matter and nutrients are low or nonexistent. The application and incorporation of some type of organic matter (litter, organic compounds, etc.) on the substrate surface proved to be very influential in the acceleration of the process of forest restoration. The compost was prepared with two kinds of organic materials (sawdust and manure), easily found in areas adjacent to the National Forest of Jamari.

Table 4: Results of environmental damage assessment in floor tilling substrate.

		ATTRIBUTES/WEIGHTS					
Environment	**Environmental damage**	**Magnitude**	**Temporality**	**Reversibility**	**Comprehensiveness**	**Significance (weighted sum)**	**Recovery technique**
Physical	Reduction of infiltration/ increase of superficial runoff	2*5	4*3	2*5	3*2	**38**	**Topographic reconstruction**
	Loss of soil	3*5	2*3	1*5	3*2	**32**	
	Loss of soil horizons	3*5	4*3	1*5	3*2	**38**	
	Amendment of the water quality	1*5	2*3	1*5	1*2	**18**	
	Generation of waste water	2*5	2*3	2*5	3*2	**32**	
	Silting of watercourses	3*5	4*3	1*5	3*2	**38**	
	Changes in air quality	3*5	4*3	1*5	3*2	**38**	
	Generation of solid waste	2*5	2*3	1*5	3*2	**27**	
	Noise generation	1*5	2*3	1*5	1*2	**18**	
Biotic	Removal of vegetation	2*5	4*3	1*5	3*2	**33**	**Local revegetation**
	Loss of biodiversity	1*5	4*3	1*5	3*2	**28**	
	Alteration of terrestrial habitats	1*5	4*3	2*5	1*2	**29**	
	Loss of terrestrial species	1*5	4*3	1*5	3*2	**28**	
	Mortality of terrestrial fauna	1*5	4*3	1*5	3*2	**28**	
	Disturbance of fauna	1*5	2*3	1*5	3*2	**22**	
	Loss of terrestrial habitat	1*5	4*3	1*5	3*2	**28**	
	Reduction in species density	3*5	4*3	1*5	3*2	**38**	
	Loss of aquatic species	1*5	4*3	1*5	3*2	**28**	
	Loss of aquatic habitat	1*5	4*3	2*5	1*2	**29**	

Table 5: Indicated operations to topographic reconstruction.

Topographic reconstruction	Surface preparation
Bulging or smoothing: Bulge consists of parts of very uneven terrain that may compromise the surface preparation for planting or replanting	*Plowing:* Operation of cutting, elevation, inversion and pre-breakdown of the soil/substrate
Terracing: Construction of retaining structures for the runoff of rain in the area through terraces	*Disking:* Operation of desegregation and levelling of the soil/substrate
Slope reconstruction: Process of smoothing the form of abrupt cuts aimed at the planting or replanting process	*Scarification:* Disruption of compacted layers of subsurface soil/substrate
Removal: Removal of soil material or substrate for subsequent use in the planting or replanting process	*Subsoiling:* Practice of disruption of the compacted layers at a depth of 40 cm
Transportation: Translocation of the substrate at a short considerable distance	*Rotary tillage:* Operation of tillage/ substrate using rotary hoes
Compression: The process consists of compressing the substrates in order to improve the stability for further planting	*Furrowing:* Practice of making furrows in the soil/substrate
Creation of drainage channels: Opening channels to help control local erosion	*Pitting process:* Drilling holes along the ground surface/substrate
Leveling: Promote systematization of the area through a pre-established level	*Capping of the soil:* Assume a given area on a substrate of interest aimed at planting

Green manuring: Green manure is an ancient agricultural practice, which aims to improve the productive capacity of the soil by adding organic material not decomposed, constituting of plants, exclusively grown for this purpose. These plants may or may not be produced in situ and can be used before completing their growth cycle, or even after. From numerous tests in the greenhouse and in the field, four legume species were selected, they showed good growth and adequate dry matter production in these degraded systems: *Crotalaria juncea* (sunn hemp), *Canavalia ensiformis* (jack bean), *Cajanus cajam* (faba bean), and *Aterrima mucuna* (velvet bean). They are sown in the form of a cocktail party, forming a true “green carpet” surface.

Use of “top soil”: The loss of organic matter is a major problem for the recovery of degraded areas in Brazil. The storage and reuse of fertile soil layer (“topsoil”) produces excellent results, but most mining companies consider this to be a costly and difficult technique, because this layer is very vulnerable in tropical soils or steep slopes of some soils in many mines.

Chemical fertilizer and liming: Chemical fertilizers are required for the restoration of degraded soils; a quantity of application must be defined in terms of fertility analysis, and must be performed annually in the first years of management.

Revegetation with native species: The recovery activities aim to allow the succession process in the site that is being worked on, ensuring that all the fundamental factors occur that possibility could or provide the ecosystem successions. Among the critical factors for the development of ecosystem succession in degraded areas is the availability of species, which until recently was seen as just planting seedlings of different species on site.

4 Conclusions

The methodology used for assessing environmental damage allowed the definition of the different substrates and recovery actions to be applied on site. The methodology used can be applied to manage areas degraded by mining and other activities with similar levels of damage to the environment components.

The restoration of degraded soils by surface mining depends on a large number of factors, such as texture and structure of soil, slope, length of slope, volume of rainfall in the area, vegetation cover, type and extent of the degree of erosion reached. The technique to be adopted depends on the changing level of human activity in the observed factors.

However, the use of just one technique, such as topographic reconstruction, for example, may not be sufficient to recover the landscape or the environmental quality. The techniques presented have singular objectives, acting in specific components of the environment, at different levels of damage. To recover the soil and the landscape composition, it is necessary to reconstitute the ecosystem characteristics, allowing the succession process to obtain more complex ecosystems. The biological, chemical and physical characteristics from the environment must be re-established in order to provide the degraded site the self-recover capacity as the activities of recovery cease.

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Economics of ecosystem restoration: using derived demand to promote sustainable ecosystems

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Abstract

Land managers face a complex set of choices when developing restoration and management strategies to promote resilient landscapes. Restoring landscapes is costly; making full restoration beyond the means of most land management agencies. This necessitates difficult choices and a careful consideration of which areas of the landscapes to restore and how intensively they should be restored to achieve the greatest net benefit. We define the problem in the context of derived demand where optimal restoration is derived from the value to the ecosystem or landscape. The derived demand framework enables us to closely integrate economics with ecological principles of restoration and resiliency to arrive at cost effective solutions. We develop the economic framework for identifying and selecting the most advantageous sites to restore given a fixed restoration budget. This framework informs and guides budget allocations across market and non-market goods and services to optimally restore the natural capital. The theoretical development is demonstrated with a case study showing the value added achieved from introducing a restoration management effort (fuel treatment) at Sequoia and King's Canyon National Park in the United States.

Keywords: restoration, economics, natural capital, environmental capital, return on investment.

1 Introduction

Public land management agencies embraced ecosystem management in the 1990s, resulting in a broad set of complex ecosystem values to consider. With no pragmatically viable economic methodology for relating changes in the value of ecosystem services to management alternatives, the "Committee of Scientists" [1]

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proposed to use and measure a particular ecosystem's departure from a baseline or reference condition as a foundational concept. Management effort involving restoration would be required to bring the ecosystem back to the "baseline condition". Hardy *et al.* [2] and Hann and Bunnell [3] introduced "condition class" (CC) to measure the departure of the current ecosystem condition from a reference condition. For managerial purposes, CCs are typically constructed to define three to five distinct conditions. Customarily, CC 1 meets the most desirable ecological standard ("excellent condition"), while higher numbered CCs are increasingly less desirable. Further, the classification scheme is often specific to each eco-type or natural community.

The overall purpose of assigning CCs across a landscape is to identify areas that would have a high priority for restoration treatments. In a specific managerial example for managing National Forest in Florida, [4] five CCs were identified to provide the foundation for: 1. prioritizing treatments, 2. for balancing restoration with maintenance treatments (where maintenance treatments are used to keep an ecosystem in a desirable condition) and, 3. to increase management efficiency. While this is a specific example, it is representative of land management decision-making processes that depend solely on biophysical metrics. While physical metrics are crucial to meeting managerial objectives, they omit the economic content essential to guide cost-effective allocations of scarce resources. Implicitly assuming that lands in poor condition such as CC 5, would be restored to a more desirable condition, fails to address the important reality that restoration choices depend as much on values and costs as they do on CC. Assume two areas where one is predominantly ponderosa pine and the other is primarily sequoia and both are classified as CC 5. If funds are available to only restore one of them, then CC provides no guidance as to how to allocate management resources.

In its most basic form, ecological restoration represents re-investment in the natural capital that provides a flow of benefits (i.e. nature's services over time). The question that should guide the investment process is, "Where and how can investments be made to provide the greatest return in a world of scarce resources reflected by limited budgets?" This question and the stated purposes of restoration (above) cannot be adequately addressed without integrating sound economic analysis with the biophysical information.

2 Integration of economics and ecological restoration

A sound economic approach to investing in restoration (natural capital) requires information on the physical condition of the capital asset as well as the cost and value of restoration. Valuation often proves to be the most problematic information to reliably obtain. Many of the benefits of restoration are characterized as non-market services where pricing information is not readily available. Hence, economists have often relied on stated preference approaches to obtain such values. In stated preference approaches, questions are asked of a set of potential respondents, under controlled conditions, to generate value estimates. Many traditional approaches to stated preference have been criticized as being unreliable or as too costly to obtain. For example, Gregory and Slovic [5] indicate the difficulties of using traditional stated preference methods to determine the value of environmental goods and services with multi-dimensional characteristics. When an ecosystem experiences a broad range of deviations from its desired state across a spatial scale, a multi-attribute elicitation of service trade-offs are needed to determine if marginal adjustments to ecosystem structure can provide social value added. Schultz *et al.* [6] argue that stated preference methods must be coupled with accepted indicators of ecological condition to determine the marginal value of an additional unit of improvement in that condition.

A key issue with the use of stated preference approaches is the recognition that the problem requires answering the question concerning the value of managerial action that will improve a complex ecosystem. The value of the managerial action and the condition of a complex ecosystem are both beyond the understanding of the general public making traditional stated preference approaches of questionable relevance. Instead, posing the question to knowledgeable officials tasked with the daily management of the ecosystem is more likely to produce an informed response. This also requires recognizing that the demand (value) for managerial action is derived from the value of the ecosystem. With this consideration a derived demand approach is addressed.

The MARS stated preference valuation method was designed to addresses the above concerns in a restoration context (Rideout *et al.*, [7]). Through a structured elicitation of preferences, decision makers provide estimates of marginal restoration value. A familiar environmental asset is defined as the numeraire asset to provide a reference to enhance the ability of officials to make comparisons of relative value. It also establishes a non-monetized currency that facilitates the elicitation process. Marginal rates of substitution (MRS) (the value of restoring one natural asset class relative to another asset class) are obtained for all relevant assets on the study site. Classic utility theory provides the foundation such that we can express utility (benefit) as a function of the set of the natural assets: $U(A_1, A_2, \ldots A_n)$. Each asset could exist on any hectare over the planning unit. Here, $U(A_1)$ denotes the benefit of restoring one hectare of asset 1. The rates of substitution between assets are defined by the slope of the utility function with respect to other assets at the forest's "baseline" endowment of human, cultural, and natural assets that may be improved with restoration effort.

$$MRS_n = -\frac{\partial U/\partial A_1}{\partial U/\partial A_n} \tag{1}$$

The rates of substitution defined by (1) denote the marginal value of treating a hectare of any particular asset. The value added (VA) from treating any hectare i with asset n is defined by (1). This is performed pragmatically by using the principles and techniques of the "MARS" valuation system discussed in the case study below.

For a hectare (or cell) containing N restorable assets, we sum the improvement value across each asset as shown in (2). Here, we use the example of environmental capital that depreciates in value naturally with time (T). This implies that the value added from a current restoration effort depends upon the amount of time since the previous restoration effort assuming the previous restoration was fully effective. This example could be modified to reflect asset

degradation for other reasons such as industrial activity or recreational use. With this example, the value added (VA) from restoration is dependent on the time since last treatment (T).

$$VA_i = \sum_{n=1}^{N} MRS_n\,(T_i) \tag{2}$$

For a depreciating asset with respect to time $\frac{\partial MRS_n}{\partial T} < 0$, and this derivative denotes the natural rate of depreciation. Such depreciation can occur in natural systems where man has excluded or limited a natural process such as fire. A natural fire-dependent system will typically decay with time unless treated, for example by a restorative fuel treatment as in the case study discussed below. The value added from the treatment would depend upon the particular asset and the time since it was last treated, $VA(T)$. Most treatment schemes involve natural assets, For example, if a hectare of land were treated to improve song-bird habitat and long-leaf pine, then the value of the improvement is additive across those two assets (n) as shown in (2).

The potential to add value across the entire landscape is shown in (3) where value added is summed across all cells (hectares) I^0.

$$TVA = \sum_{1}^{I^0} VA_i \tag{3}$$

To maximize the net benefit of a fixed restoration budget "B^o" across many natural assets and hectares, we select the hectares on the landscape (I) that provide the greatest net restoration value added without exceeding the budget. This can be expressed as:

$$MAX = TVA(I) + \lambda[B^o - C(I))] \tag{4}$$

where the cost of restoration is denoted by C(I). The first-order conditions for selecting hectares to treat is denoted as:

$$\frac{dTVA}{dI} = \lambda\left(\frac{dC}{dI}\right) \tag{5}$$

Equation (5) states that the hectares selected for treatment generate a benefit greater than or equal to the budget-constrained (λ) marginal cost of treatment. Lambda denotes the marginal value of increasing (decreasing) the restoration budget by one unit of currency in which B^o is expressed. A more pragmatic and equivalent interpretation is to treat cells from highest to lowest net value added until the budget is expended.

3 Restoring the desired landscape condition

To demonstrate the application of the above economic concepts into the decision-making process we provide an example using a study site where restoration management planning is critically engaged with a spectrum of human and ecosystem values. We quantify and show the effects of alternative planning strategies on the improvement of the desired management condition. While the restoration management effort used here is fuel treatment a similar approach could

be used with an alternate restoration management effort (non-fire) to support other specific restoration management analysis.

3.1 Study site - Sequoia and Kings Canyon National Park

Sequoia and Kings Canyon National Parks (SKNP) is located in the western Sierra Nevada mountain range in California and consists of about 360 thousand hectares. The park contains; sequoia groves, vast tracts of montane forest, subalpine woodlands, oak woodlands and chaparral. Years of fire exclusion have degraded the natural condition such that it can benefit from fuel treatment restoration efforts [8].

3.2 Assessing the current condition

We begin by using equation (3) to assess the baseline condition of the study site. The strategic spatial management and planning system STARFire [10] facilitates these computations. Consistent with the restoration literature, the baseline assessment represents the current condition of the landscape relative to a desired (fire) management condition. The baseline assessment requires three core data sets. The first reflects the spatial fire behaviour characteristics of the study area and the second is used to estimate the value change of the restoration effort (fire effects) and associated treatment costs. The third considers fire history information to inform time since last fire and estimates of ignition density which in turn, inform burn probability.

Fire behaviour was estimated using the public domain software FlamMap5 from FIRE.org (a fire behaviour analysis program that computes potential fire behaviour characteristics over an entire landscape using constant weather and fuel moisture conditions). The resulting spread rate (m/min), fire intensity (BTU/ft^2), maximum spread direction (degrees), and flame length (m) calculations were provided to STARFire. The data used to run FlamMap were downloaded from LANDFIRE (an interagency vegetation, fire and fuel characteristics mapping program).

The MARS (Marginal Attribute Rate of Substitution) [7] valuation system was used to estimate the relative marginal value (RMV) of fire effects for restoration efforts. Using a structured elicitation process, SKNP resource professionals identified the resources (human and natural) whose values were positively or negatively affected by fire. Next, the fire-induced value changes of resources at different intensities/severities were explicitly quantified. The return interval for cover types whose RMV is sensitive to time since last fire/treatment was established. Resources assessed included: protection of property, cultural resources (Giant Sequoias) and forest cover species (including Foxtail Pine, Ponderosa Pine, Sequoia Groves, Red Fir, Lodgepole Pine, Foothill Chaparral and Montane Chaparral). Figure 1 shows the spatial arrangement of these resources.

Fuel treatment cost can vary depending on scale, cover type, ecosystem condition (maintenance vs. restoration) and broad fuel type (grass like, tree like and shrub like). Treatment costs reflecting these combinations were obtained from SKNP and supplied to the analysis.

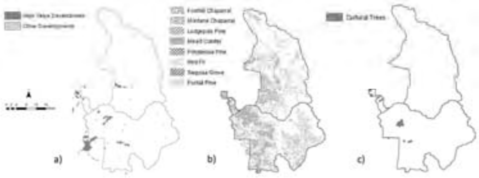

Figure 1: Spatial location of selected fire management resources. (a) shows human development, (b) vegetation cover types, (c) shows cultural resources.

Spatial layers representing fire history, ignition locations and fire perimeters were obtained from SKNP and were used to supply estimates of ignition density and support burn probability calculations. A 'time since last fire' raster was generated from the fire perimeter polygons and used to support the MARS evaluation.

With these three core datasets in place, STARFire analyzed the landscape to identify the potential to add value through fuel treatments. Fuel treatments can add value by restoring the ecosystem (fully or partially) to a more desired condition, but can also add value by improving burn conditions (lower intensity) or reducing the burn probability in locations that have the potential to harm life and/or property. This potential is recorded for each raster cell on the landscape.

3.3 Well-informed decision making

By applying equation (5) we were able to address the question from section 1 above: "Where and how can investments be made to provide the greatest return?" Using the potential valued added for each raster cell, cost was introduced to identify the raster cells that produce the highest return on investment (ROI). By expanding the budget, the number of treatable cells increased and a set of well-informed management alternatives were generated as in Figure 2 below.

Figure 2: Each panel shows recommended treatment alternatives arrived at by maximizing ROI. Moving right across the panels shows increased treatment budgets.

3.4 Quantifying the management effort on the landscape

To simulate the effects of the fuel treatment management effort, the three core data sets for each management alternative were updated to reflect the physical effectiveness of the treatment. The fire history data set was updated to reflect the treatment perimeters (the resulting changes to fire intensity and time since last fire influences the post treatment $RMV's$ used in STARFire). Post treatment fire behavior data was generated in FlamMap5 by updating the fire modeling landscape. STARFire was used to reprocess the landscape and define the post treatment condition.

The difference between the expected value of the pre and post treatment landscapes approximates the value added by a particular fuel treatment application on the landscape. This was calculated for each management alternative and is expressed as a net benefit (return-cost).

4 Results

Results of the case study analysis show that increases in the investment or budget level, when applied to the sites producing the greatest return on investment, generated increasing valued added at a diminishing rate as shown in Figure 3. Note that if the currency used is the same for cost and for return, the shape of the curve will be unaffected. From observing Figure 3, a budget allocation located on the x-axis can be demonstrated to produce the return shown on the y-axis so long as the treatment is selected in a manner that produces the greatest return on investment.

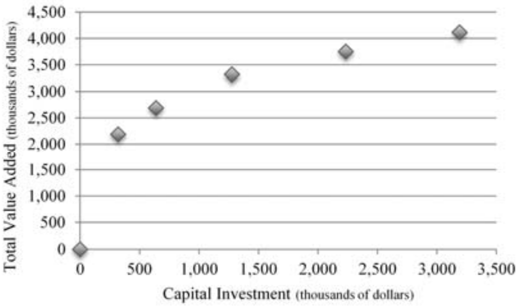

Figure 3: Total value added (thousands of dollars) over capital investment (thousands of dollars) showing diminishing returns.

5 Conclusions

One of the global challenges facing many natural landscapes is the restoration of natural capital to a desired condition. Scarce resources reflected in fixed budgets results in complex land management choices including; the prioritization of restoration treatments, choosing between new restoration efforts and the maintenance of existing treatments, and the ability to increase management efficiency. In a first-level analysis, biophysical information is inadequate to guide or resolve choices. Likewise, economically naive systems that search for spatial patterns while applying scoring systems are similarly handicapped. However, when biophysical information is integrated with marginal values and costs well-informed cost-effective decisions can be achieved. When the biophysical information is properly integrated with marginal analysis; including marginal values and costs, land managers can select the treatment locations producing the greatest return on investment for their restoration effort, as shown in the case study, they can optimally allocate the limited budget to produce the greatest program benefit. Two key considerations bridge the integration: 1. recognizing that the value of restoration effort is derived from the value added to the landscape through treatment and 2. using a marginal value system such as MARS. In a second-level analysis, a sound demonstration of cost-effective decision-making and resource allocation promotes compelling arguments for enhancing restoration budget allocations.

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Section 10
Policies

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Environmental impact assessment of the employment of methane-run buses: a case study analysis for Padua, Italy

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Abstract

This paper analyzes the impact of new fuel technologies in connection with emission standards on public transport emissions as a basis for traffic planner's decision making in Padua (Italy) in the period of time before construction works for the introduction of a tram network was planned. After analyzing the public and private transport system in the most critical urban environment of Padua, first, an engineering model is constructed to technically calculate the environmental impact of methane-run buses (Euro IV) in comparison to buses running on other types of fuel. Afterwards, similar results are obtained by using (pseudo) data in reduced form relations. Finally, the quantification of transport externalities is discussed, whereby different methods of environmental valuation are pointed out with special emphasis on health issues. The results of this study will be used as a basis for future comparative research assessing the social and environmental impact of public policy measures that have been implemented.

Keywords: transport externalities, public transport policies, pseudo data approach, particulate matters, European emission standards.

1 Introduction

The worsening of quality of life and the more and more frequent appearance of diseases due to air pollution, specifically particulate matters, even in mid-size cities requires a detailed evaluation of the ecological and economic impacts of public transport systems. Such systems are indeed an important aspect of public policy as they enjoy superior predictability in comparison to private transport, and they can affect private transport internally in terms of substitutability. Moreover,

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the realization of more sustainable transport calls for the development of a more efficient public transport system as well as the adoption of new technologies for public vehicles with low environmental impact. The first option aims at the reduction of private car traffic by ensuring a good level of accessibility, service and comfort, mainly in urban areas surrounding the city centers, in which private traffic is often limited by municipality regulations. This situation is particularly critical in some mid-size Italian cities where the inadequacy of the road system around the urban area concentrates traffic along very few arterials. The second option proposes the introduction of innovative transport solutions which assure very low emissions and reduced noise and vibrations with acceptable investment and operating costs. First of all, a more intensive substitution with greener fuels (biodiesel, methane, LPG, etc.) can be applied to buses propelled only by an internal combustion engine (ICE), therefore enabling reduced emissions with limited rise in costs. Otherwise the use of hybrid and pure electric vehicles can be considered. In particular, the pure electric vehicles (ZEV) supplied by an external overhead wire (tramway, trolley-bus, intermediate rubber tired systems with guided running mode) or by on-board batteries can fulfill the zero emission targets. However, the former require a high transport demand to cover the considerable investment and operating expenditure, and they are often critical to integrate into the urban environment; the latter have limitations related to the present status of commercial batteries, as regards both the operating range and the passenger capacity. The utilization of ZEV buses supplied by fuel cells (FCs) seems to be a very promising solution as regards both the operating range and the efficiency, if the FCs are supported with on-board energy storage devices; however, at present the costs of such technology and of the hydrogen supply infrastructure seem to be still too high and the long-term reliability of the FCs is difficult to predict. In Padua a tram network has been in service for a few years providing a connection between the center with certain outlying areas. The tram operation has led to an appreciable improvement in accessibility and a reduction of private cars circulating in the downtown area and its surroundings. However, its extension to other urban areas planned at the time of its construction is still under discussion, because of the high infrastructural impact and expenditures. In particular, there is one residential area near the Padua center (Chiesanuova) showing critical emission levels harming the health of inhabitants, where the tramline will not be implemented; consequently, alternative solutions for improving the efficiency of public transport in this area have to be considered, in particular to improve air quality for residents. Contrary to other residential areas of Padua, Chiesanuova is characterized by high traffic densities and a well-developed public transport system of bus lines, provided with vehicles ranging from Euro II to Euro IV emission standards. In this context, the paper attempts to show the degree of environmental and potential social improvements in Chiesanuova by replacing all gasoline and diesel-run buses (Euro II, III) by methane run buses (Euro IV).

In the introductory section, the transport situation of the north Italian city of Padua in 2006 with particular reference to the residential area of Chiesanuova is investigated. First, the estimations of the regional environmental agency (ARPAV [1]) regarding the traffic densities and the specific emissions are examined.

Afterwards, starting from the data provided by municipality of Padua and by the main public transportation company Azienda Padova Servizi (APS [2]), the relevant traffic emissions caused by public transport are evaluated by using the software program COPERT III [3], analyzing different transport scenarios. The generated data are integrated in a pseudo data approach, i.e., using engineering representations, regressions map out a reduced form between technical variables and emissions (Griffin [4, 5]), allowing for a comparison of results obtained by the technical model and that of the pseudo data approach. Moreover, results are used to made reference to the possible evaluation of the social costs based on the study conducted by the WHO [6], discussing aspects of monetary quantification of transport externalities associated with other local studies.

2 Background information

In recent years, the city of Padua was repeatedly interested in pollution problems, mainly because the level of particulate matters (PM) exceeded the health limits several days every week (WHO [6]). The introduction of the new public transport system Metrotram in March 2007 propelled by electric motors, has led to a considerable improvement of the transport service in the urban context, substantially confirming the preliminary evaluations developed by Andriollo *et al.* [7]. However, some areas not immediately supplied by this service require a more detailed evaluation of the transport modes and of the public transportation capacity in terms of both the replacement of private cars and the improvement of the environmental conditions by introducing less pollutant vehicles. From this point of view Chiesanuova is a very critical zone, located to the west of the Padua city center: even if it is a well-served area in terms of public transport; it is characterized by high traffic densities. For instance, the number of vehicles measured by sensors placed in the roadway is about 200,000. Furthermore, in comparison to other areas near the Padua center, the traffic includes different types of vehicles, such as urban buses, motorcycles, private cars, as well as heavy commercial vehicles (HCV) and light commercial vehicles (LCV) (Environmental Agency of Veneto (ARPAV) [1]). Although passenger car traffic predominates (85% of the average number of vehicles for each category ARPAV [1]), in the investigated area the public transport system covers a non-negligible part of the operating vehicles. In this context, substitutability between public and private transport plays a crucial role. As displayed by Table 1, the number of private cars decreases in streets characterized by high densities of urban buses. On the other hand, the number of motorcycles is positively correlated with the number of urban buses, presumably due to the traffic rules (as, e.g. one-way streets which are bidirectional for buses). Further analysis focuses on the street sections mainly characterized by public transport: Figure 1 illustrates the three street sections investigated in Chiesanuova, denoted by A; B; C the main data on which are reported in Table 2. Section A (located outside of the historical center) consists of two different bus routes, number 10 and 6; sections B and C (inside and close to the historical center); where the bus routes number 10, 5, 6, 9 and number 5, 6, 9 are situated, respectively. The total number of the regularly scheduled urban public transit bus types was counted on the basis of the APS [2] timetable and the roadmap.

Table 1: Pairwise correlation matrix analyzing the measurements (number of vehicles).

	HCVs	LCVs	Motorcycles	Passenger cars	Urban buses
HCVs	1	–.35	–.51	.99	–.62
LCVs	–.35	1	.89	–.4	.66
Motorcycles	–.51	.89	1	–.55	.79
Passenger cars	.99	–.40	–.55	1	–.70
Urban buses	–.62	.669	.79	–.67	1

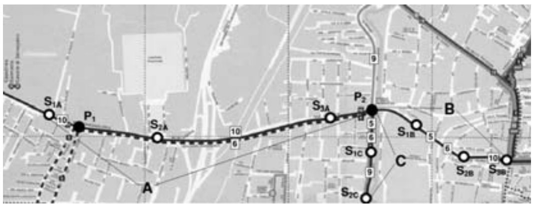

Figure 1: Bus routes in the area of Chiesanuova (street sections A, B, C); number 5, 6, 9, 10; bus stops: S_{1A}, S_{3A}, S_{1B}, S_{3B}, S_{1C}, S_{2C}; cross points: P_1, P_2..

Table 2: Data of the examined street sections.

Section	Route subdivision	Bus route	Bus/day(*)
A	S1A-S2A: 1.3 km S2A-S3A: 2.5 km S3A-P2: 0.35 km	10	185
	P1-S2A: 1 km S2A-S3A: 2.5 km S3A-P2: 0.35 km	6	57
B	P2-S1B: 0.35 km S1B-S2B: 0.4 km S2B-S3B: 0.3 km	5-6-10	79-114-185
C	P2-S1C: 0.4 km S1C-S2C: 0.3 km	5-6-9	79-57-118

(*): Both directions

In order to evaluate the influence on bus operation due to the presence of different types of vehicles, a statistical analysis is carried out using data on emission levels published by the ARPAV [1], a pairwise correlation matrix for six street sections within Chiesanuova (see Table 1). In the pairwise correlation matrix, each cell represents the correlation coefficient denoted by r and calculated over all the available data, which measures the degree of linear relationship between the two variables involved. The results reported in Table 1 show that the number of urban buses is highly correlated with all types of vehicles, primarily with the number of motorcycles and private cars.

As displayed by Figure 2, section A shows a relevant increase in the total number of vehicles with a corresponding decrease in the average vehicle speed in 2005. Interestingly, the average speed in 2005 is remarkably lower than that in 2002, even if the increase in traffic densities is minor; this indicates that, in addition to the number of vehicles, other factors also matter (e.g. road conditions, as the overpass in section A, impact on medium speed (Data concerning the number of vehicles are gained by the Municipality of Padua)).

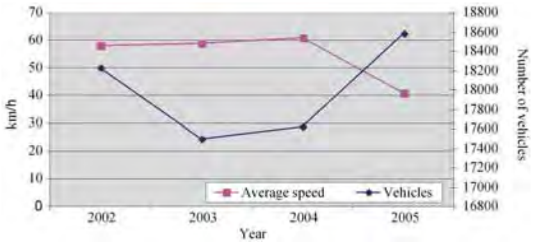

Figure 2: Daily number of vehicles and average speed in section A (2002–2005).

The lowest emission levels can be observed in streets characterized by "flowing traffic" in Padua to be considered by traffic planners when deciding on public transport policies in Chiesanuova (see, also Amrusch [8]). This shows that under constant road conditions in Chiesanuova, however, public policy will have to focus on improvements in public bus transport in this area, as no alternative infrastructural solutions (e.g. the amplification of the tram network) are planned. This analysis (displayed by Table 1 and Figure 2) seem to accentuate the importance of public bus transport in Chiesanuova also due to the possibility of substitution of private for public transport in future, as the decrease in the average speed along with the increase in air pollution is primarily attributed to the increase in private car use.

3 Data analysis and emission estimation

On the basis of European emission standards, the fleet of buses maintained by the APS [2] (Figure 3(a)) is composed by environmentally friendly models (e.g. methane-run buses meeting the EURO IV emission standards) and buses equipped with EURO III, II and I standard engines – running on dual-fuel or diesel. Other than on Sundays – when only ecological bus types are used – during the week bus types are randomly chosen for different bus routes in Padua, whereas during peak traffic hours all types of vehicles are used. As a consequence, the investigation focuses on emissions produced by public transport during the week.

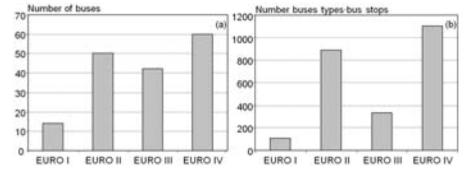

Figure 3: (a) Classification of the main part of the APS [2] fleet based on emission standards; (b) total number of buses per day in Chiesanuova, subdivided according to their emission standards.

By using the software program COPERT III [3], emission factors are calculated for all daily operating types of buses. The calculation of emissions requires a prior detailed classification of all types of buses operating in the street sections A, B and C regarding emission classification standards as well as the estimation of the average speeds of buses with respect to the distances between two subsequent bus stops as further input data. To consider the lengths of each bus route along with the quantity of buses daily operating on a route the number of buses is multiplied by the number of distances between any two corresponding bus stops and cross points (see Figure 1 and Table 2), obtaining the value of 2368 observations related to the weights of bus models and emission standards used in Chiesanuova.

As the rolling stock of bus models used by the APS [2] was larger than the number of daily employed buses in 2006, all buses (exclusively the bus line 10 merely running on methane (Euro IV)) were first weighted according to the emission standards classification (EURO I (9%), II (73%) , III (18%)) and then buses (Euro I, II, III, IV) were weighted according to bus models maintained by the APS (e.g. differing in length, kilowatts, cubic capacity and engine power) within emission standard classifications.

Thereby, buses such as, minibuses or "extra-urban" buses, which were not used at all in section A, B and C, in 2006, were a priori excluded. Figure 3(b) shows that buses running on methane (Euro IV) were predominantly used in street sections A, B and C, whereby the vertical axis represents the number of buses with respect to the number of the corresponding bus stops.

On the other hand, in our sample around 48% are diesel-run and 46% are methane-run, whereas the remaining percentage is dual-fuel run.

As bus speed varies according to the bus stop distance and road characteristics (traffic rules, traffic densities etc.), particulate matters are calculated for all daily bus runs (see Table 2) between two bus stops, considering that buses are bidirectional. Since traffic emissions also vary according to the speed of buses, by using the software program COPERT III [3], (hot stabilized) CO and PM_{10} emission factors per bus, e_{pm}, expressed in g/km (see Table 3), are estimated with respect to all daily-travelling urban bus types and operating distances between two bus stops, denoted by d, on the predetermined bus routes, whereby the estimation reflects the measured medium speed (the medium travel time as well as the average speed between two subsequent bus stops are measured during the peak traffic hours in the afternoon on the 12th of June 2006).

Table 3: Emission factors *e* (PM_{10} expressed in g/km) with respect to streets sections A, B, C, bus stops and average speed (along with the number of buses in parentheses).

Street section A	Bus line 6 Euro I	Bus line 6 Euro II	Bus line 6 Euro III	Bus line 10 Euro IV
average speed S_{1A}–S_{2A} or P_2–S_{2A}	25km/h (N=5)	25km/h (N=42)	25km/h (N=10)	25km/h (N=185)
PM_{10} in g/km	.4780	.2944	.2059	.0390
average speed S_{2A}–S_{3A}	15km/h (N=5)	15km/h (N=42)	15km (N=10)	15km/h (N=185)
PM_{10} in g/km	.6963	.4285	.30	.0568
average speed S_{3A}-P_2	28km/h (N=5)	28km/h (N=42)	28km/h (N=10)	28km/h (N=185)
PM_{10} in g/km	.4398	.2707	.1895	.0359
Street section B	Bus lines 5-6 Euro I	Bus lines 5-6 Euro II	Bus lines 5-6 Euro III	Bus line 10 Euro IV
average speed P_2–S_{1B}	35km/h (N=10+7)	35km/h (N=83+58)	35km/h (N=21+14)	35km/h (N=185)
PM_{10} in g/km	.3732	.230	.1608	.0304
average speed S_{1B}–S_{2B}	30km/h (N=10+7)	30km/h (N=83+58)	30km/h (N=21+14)	30km/h (N=185)
PM_{10} in g/km	.4180	.2573	.1801	.0341
average speed S_{2B}-S_{3B}	20km/h (N=10+7)	20km/h (N=83+58)	20km/h (N=21+14)	20km/h (N=185)
PM_{10} in g/km	.5634	.3467	.2427	.0459
Bus routes 9, 6, 5	Bus lines 5-6-9 Euro I	Bus lines 5-6-9 Euro II	Bus lines 5-6-9 Euro III	
average speed P_2-S_{1C}	18km/h (N=5+7+11)	18km/h (N=42+58+86)	18km/h (N=10+14+21)	
PM_{10} in g/km	.6088	.3747	.2623	
average speed S_{1C}–S_{2C}	18km/h (N=5+7+11)	18km/h (N=42+58+86)	18km/h (N=10+14+21)	
PM_{10} in g/km	.6088	.3747	.2623	

Calculating the total daily PM_{10} emissions by

$$e_{PM} = \sum_{1}^{n_{bus}} PM \cdot d \tag{1}$$

in street section A, the value e_{PM} = 121 g is estimated, whereas in section B and C the quantities of particulate matters amount to e_{PM} = 62 g and e_{PM} = 67 g per day, respectively (Eq. (1)). Considering that the number of total daily runs per distance between any two bus stops in section A, B and C add up to 726, 1134 and 508, respectively, and that the investigated street sections A, B and C, are 4.15 km, 1.05 km and 0.7 km in length, respectively, PM_{10} come to 29 g/km in section A, 59 g/km in section B and 96 g/km in section C.

The lowest value in section A may be attributed to the fact that, in this section, the largest percentage of methane-run buses (76%) circulate – 185 methane-run buses daily contribute to a total of 24 g of PM_{10} – whereas 57 diesel- (21%) and dual-fuel-run buses (3%) produce about 39 g of PM_{10}, respectively. In section B the proportion of buses running on methane amounts to 49%, whereas in section C only diesel and dual-fuel-run buses circulate.

4 Environmental impact of public transport policies

4.1 Environmental quantification of the employment of methane-run buses in Chiesanuova

Technically, substituting all diesel- and dual-fuel-run buses for methane buses under the same traffic conditions in sections A, B, C, total daily particulate matter emissions produced by public transport would be reduced by 72 g, 48 g and 58 g, respectively (see Figure 4). In other words, the use of exclusively methane-run-buses in Chiesanuova would decrease emission factors by about 0.02 g/km in section A, 0.06 g/km in section B and 0.07 g/km in section C.

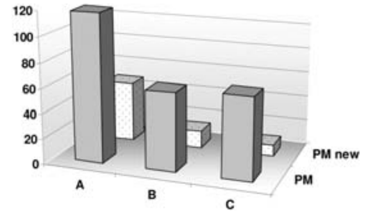

Figure 4: Particulate matters reduction after switching to methane-run buses.

Contrarily, replacing all existing methane-run buses by buses of Euro I; II and III emission standards (according to the above-mentioned weights) we can

separate out the effect of methane-run buses in Chiesanuova in 2006: methane-run buses reduce emissions by 61% in section A, B and C.

More precisely, in section A, methane-run buses decrease particulate matters by 34%, whereas in section B the decrease is 58%.

Alternatively, one can use the technical model to generate (pseudo) data (instead or as a substitute for direct measurements), and to use this data as the basis for statistical analysis in order to obtain reduced form relations; this method was pioneered by Griffin [4, 5].

The choice of functional form is based on theoretical considerations (the linear relationship between relevant variables, such as emissions and medium speed).

Using the method of Ordinary Least Squares, the regression for the whole sample (section A, B, C (N = 2368)) is given in Table 4 (1–3 and 7) along with the absolute t-statistics in parentheses explaining the variation of bus attributes and environmental characteristics in g/km particulate matters. Since buses are considered aggregations of attributes (as cylinder, power, etc.), regression based on pseudo data relates the particulate matters (PM) (2) or carbon monoxide (CO) (1) as well as concentrations of $PM_{2.5}$ (C2.5) (7) emitted by a bus, to its attributes. However, as emission standards are related to bus attributes, the variation in emissions is mainly explained by emission standards. The dummy variable Euro 4 takes on the value 1 for methane-run buses and zero otherwise, while the dummy variable Euro123 describes Euro I, Euro II and Euro III, which take on the values 1, 2 and 3, respectively.

Table 4: Regression analyses.

Coeff. & C	A, B, C (1)	A, B. C (2)	A, B, C (3)	A (4)	B (5)	C (6)	A, B, C (7)
C	2.16 (310.9)	.44 (56.5)	4.47 (903.7)	.46 (23.6)	.447 (38.5)	–.17 (15.15)	–8.058 (620.6)
Methane-run	1.27 (194.0)	–2.82 (391.2)	–.14 (28.0)	–2.77 (145.4)	–2.871 (295.1)		–1.973 (309.9)
M_kmh	–.03 (278.4)	–.03 (199.3)		–.03 (164.1)	–.032 (126.9)		–.033 (66.1)
Euro123	–.31 (104.4)	–.40 (129.5)	–.02 (11.1)	–.40 (46.9)	–.405 (97.9)	–.40 (79.87)	
KW			.00018 (3.1)				
Weight			.00016 (4.7)				
R^2	.99	.99	.73	.99	.99	.97	.98
Adj. R^2	.99	.99	.73	.99	.99	.97	.98
F-statistic	271612	257550	1575	102895	101384	19655	49684
Incl. obs.	2368	2368	2368	726	1134	508	2368
Dep. var.	log(CO)	log(PM)	log(DB)	log(PM)	log(PM)	log(PM)	log(C2.5)

Including only highly significant coefficients, regressions (2, 4, 5) display the strong impact of methane-run buses on the emitted particulate matters (PM) in g/km in Chiesanuova (section A, B, C) as well as A and B, showing a 282%, 277% and 287% particulate matters reduction. Regression (7) explains a 197% decrease

in $PM_{2.5}$ concentrations due to methane-bus operations. It should be mentioned that other functional form specifications (e.g. lin-lin) also give similar results, which extremely overvalue the technical results. As expected, the medium speed (medium km/h) is negatively correlated with all emissions in all regressions: if the bus speed increases by 1 km/h, emissions decrease by about 3%. It is to be considered that, although in section A the highest percentage of methane-run buses operate, in section A, the measured speed is lower than that in section B (presumably due to an overpass), increasing overall emission levels in section A. (Technically, the optimal speed, with respect to the level of particulate matters and fuel consumptions, of methane buses is considerably over 130 km/h, exceeding the speed limits on highways – which also is not feasible due to the bus stop distance, security issues and legal speed limits or traffic conditions related to private transport). Interestingly, upgrading the bus in terms of European emission standards reduces emissions by about 40% in section C (6), where no methane buses at all circulate – similar to sections B (5) and A (4).

Considering that the market price for methane was also lower than that of diesel in 2006, the utilization of methane-run buses allows substantial cost savings relevant for economic and efficiency considerations (APS [2]). Regression (3) provides evidence that the noise level (given in decibel) of a bus is negatively correlated with methane-run buses with possible impacts on health costs.

4.2 Social and economic impacts of the employment of methane-run buses in Chiesanuova

The monetary quantification of transport emissions could be done by environmental valuation methods (such as the hedonic pricing model or the contingent valuation method (CV)) aiming at measuring individual preferences. Contrary to the CV method based on the concept of stated preference, using the hedonic method (formalized by Rosen [9] and Freeman [10]) in the context of air pollution) the individual willingness-to-pay is revealed by choices in the market [11]. A study conducted by the WHO [6] shows that Padua is among the Italian cities risking higher mortality and morbidity rates due to the concentration of particulates with 202 work loss days (WLD) per 10-μg/m^3 increment in $PM_{2.5}$ concentration per year (city-specific impact functions were derived per 1000 people 15–64 years of age in the general population) per 1000 people per year.

An approximation of social health costs of PM in Chiesanuova based on WHO [6], for substituting gasoline- for methane-run buses (up to 20 meters in distance from roads), is calculated by using a basic dispersion curve formula, evaluating the maximum concentration in μg/m^3 of the X pollutant as:

$$X = 0.325 \exp(-0.3\ d^{0.5}) * (N/T) * EF \tag{2}$$

with d distance from roadside in meters, T time period assessed (1–24 hours), N number of vehicles in the period T and EF emission factor in g/km. Eq. (2) is applied by, e.g., Ministry of the Environment of Manatū Mō Te Taiao [12].

For N/T = 1/18 (assessing the concentration per run between two bus stops per bus within 18 hours, since for 6 hours during the night a negligibly small number of buses operates), the PM_{10} concentrations (in μg/m^3) are obtained for the total number of buses per bus stop distance travelled (commensurate with the weighted averages for Euro I, II and III calculated above), European emission standards classification and medium speed. Summarizing all PM concentration ratios in μg/m^3, public transport emits a daily concentration of 2 μg/m^3 of PM_{10} (or μg/m^3 1.5 of $PM_{2.5}$ [13]) within a distance of 20 meters from the roadside in sections A, B and C. The substitution of diesel- and dual-fuel-run for methane-run buses reduces the overall PM_{10} concentration to .47μg/m^3 PM_{10} (or 0.3265 μg/m^3 of $PM_{2.5}$, by applying the same conversion factor of 0.7 used by WHO [6]: $0.7 * PM_{10} = PM_{2.5}$). A 76% reduction in emission concentrations is substantial. Seeing that WHO [6] shows that in Padua an increase in 10 μg/m^3 of PM corresponds to 202 work loss days per 1000 people per year, in the residential areas near the street sections A, B and C, 31 work loss days are saved per 1000 people per year. For future research a detailed comparison of social costs attributed to private transport and public transport could be undertaken – in particular with respect to possible substitution effects of private for public transport. Moreover, in addition to the benefits for social welfare, the potential long-term cost savings for transportation companies, as APS [2], due to efficiency improvements using methane-run buses instead of more conventional fuel technologies could be evaluated.

5 Conclusion

Based on current public policy debates related to the public urban transport system in Padua, this paper first shows technically the impact of urban buses differing in emission standards and types of fuel, in particular methane-run buses, on particulate matters in a critical urban environment using generated data. Afterwards, a pseudo-data approach is applied to quantify the environmental impact of the exclusive introduction of methane-run buses, allowing for a detailed comparison of these two approaches. Finally, based on studies of economic and social quantification of traffic emissions with special emphasis on Padua, the social and health consequences of the exclusive use of methane-run buses in Chiesanuova are monetarily quantified and analyzed.

Empirical results show that higher European emission standards – in particular the use of methane-run buses – substantially reduce particulate matters in Chiesanuova, which is of particular importance, as in this area no tram construction is planned as a matter of public policy. The substantial air quality improvement as a consequence of use of methane-run buses also improves social welfare in monetary terms.

Of additional interest for traffic planners is the fact that the medium speed has a negative impact on emissions (as investigated in the introductory section), emphasizing the importance of keeping traffic flowing. Seeing that, in addition to the employment of methane-run buses in Chiesanuova, vehicle reduction (see introductory part) should be promoted (especially with respect to private transport). As traffic conditions also influence medium speed, the improvement of infrastructural road conditions in combination with vehicle reduction should be promoted for a constant medium velocity, thus improving air quality relevant for human health and other economic reasons as well as natural harmony in Chiesanuova.

Acknowledgements

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Critical analysis of the Brazilian national standard for concrete permeable pavement

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Abstract

The use of permeable pavement in Brazil has increased significantly in recent years, after being considered and encouraged in town Urban Drainage Masterplans and legislation. Unfortunately pathologies and poor performance are often observed. As part of sustainable urban drainage systems (SUDs) the main goal with a permeable pavement is to reduce the volume and also to increase the quality of stormwater runoff, but incorrect design and construction and/or lack of proper maintenance could lead to not meeting these goals. It then becomes necessary to develop the standards of the design, construction and maintenance of permeable pavements. In the paper the yet to be published Brazilian national standard for concrete permeable pavement is analyzed.

Keywords: permeable pavement, standardization, standard, SUDs, sustainable drainage.

1 Introduction

Following a worldwide trend, sustainable urban drainage systems (SUDs) strategies have been encouraged in Brazil in the last few years. These strategies are considered in most of the town regulations and Urban Drainage Masterplans. One of the most important is the use of permeable pavements. In most cases, however, a lack of knowledge is still observed in all the application steps, from design to evaluation. This entails a serious risk of improper working or, at least, a significant reduction of efficiency of this kind of stormwater control solutions. The development of a national standard comes to fulfill this gap.

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The main goals of this standard is not only to be used as an official reference at the legal level, but also to provide a guideline to designers, developers and public administrations. The standard covers terms and definitions, concrete surface course types, cross section types, requirements, construction, maintenance, test method for evaluation and a recommendation guideline for design.

Although the attendance of its recommendations is voluntary, in case of developments involving public agencies it becomes mandatory. So, a national standard has more strength than simple guidelines and is usually more effective in stimulating the growth of good practices on the field.

2 Permeable pavement standards

Some standards of permeable pavements in other countries were considered for reference. In the European Committee for Standardization (CEN) there aren't specific standards for permeable pavements. The British Standard Institution (BSI) however is available, the "BS 7533-13:2009. Pavements constructed with clay, natural stone or concrete pavers. Guide for the design of permeable pavements constructed with concrete paving blocks and flags, natural stone slabs and setts and clay pavers" (BSI [1]) which was used as reference for ABNT [2]. Besides the mechanical and hydraulic design criteria, the standard gives requirements for all pavement layers considering only the permeable interlocking concrete pavements.

On ASTM International (ASTM) there is a test method to measure the surface infiltration for permeable pavement that was used as reference on ABNT [2] and also standards that refer particularly to pervious concrete:

- ASTM C1688/C1688M-14a Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete
- ASTM C1754/C1754M-12 Standard Test Method for Density and Void Content of Hardened Pervious Concrete
- ASTM C1747/C1747M-13 Standard Test Method for Determining Potential Resistance to Degradation of Pervious Concrete by Impact and Abrasion
- ASTM C1701/C1701M-09 Standard Test Method for Infiltration Rate of In Place Pervious Concrete

The American Concrete Institute (ACI) also brings specific documents for pervious concrete:

- 522.1-13 Specification for Pervious Concrete Pavement
- 522R-10 Report on Pervious Concrete (Reapproved 2011)
- 522.1M-13 Metric Specification for Pervious Concrete Pavement

As seen above, normally it is preferred to have different standards that cover specifics requirements and test methods, rather than general standards referring to all issues of permeable pavements.

3 Terms and definitions

On terms and definitions the most important item is the definition of the pavement itself: a common mistake regarding permeable pavement is to apply a permeable surface over an impermeable/conventional structure. As it is possible to observe in Pagotto *et al.* [3] (Table 1), installing a pervious surface over a conventional base has no effect on runoff coefficient reduction, basically the main goal of permeable pavements.

Table 1: Comparison among wearing course applied on highway (Pagotto *et al.* [3]).

	Conventional (1995–1996)	Porous Asphalt* (1997–1998)
Number of rain events	125	162
Total depth of rainwater (mm)	698	796
Total duration of events with runoff (h)	646	774
Flow volume (m^3/ha)	5840	7825
Total duration of flow (h)	1108	1457
Mean of runoff coefficient	0.84	0.98
Mean of response time (h:min)	1:15	2:30

*maintaining the same conventional structure

In ABNT [2], pavement is defined as a structure that is able at the same time to resist and support vehicular loads and shear stresses and to improve surface course features regarding safety and comfort. The permeable pavement must comply with these requirements, while at the same time allowing the reduction of surface water impoundment and flow through infiltration and temporary storage. In respect of simple draining layers, permeable pavements should be able to also reduce runoff and to provide hydrograph attenuation. Hence the definition makes essential the presence of a permeable base to be considered a permeable pavement.

4 Surface course types

On concrete permeable pavement the surface course can be divided in two main types: modulated and monolithic. It is important to make such division since they will behave differently, although the requirements for infiltration must remain the same. The modulated can be interlocking concrete pavement or concrete slabs. Permeable interlocking concrete pavement allows water infiltration through enlarged joints or open spaces of solid units or through pervious concrete units. Concrete slabs provide water infiltration though the porous on the pervious concrete and are recommended for pedestrian traffic only. The monolithic type is made with pervious concrete cast in place.

5 Type of cross section

Permeable pavement can present three main types of cross section regarding infiltration: full, partial or no infiltration depending on subgrade features and contamination risk. On full infiltration all water goes to the subgrade, on partial

infiltration, part of the water goes to the subgrade and part through drainage pipes and on no infiltration all the water infiltrates through drainage pipes (Figure 1).

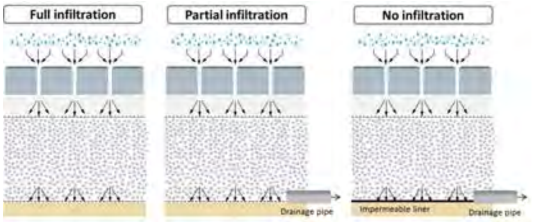

Figure 1: Type of cross section according to water infiltration (ABCP collection).

The ABNT [2] brings a reference attachment to help choose the infiltration type mention in section 0, although the designer is free to use the methodology that is considered the most suitable.

6 Requirements

6.1 General

Design should follow mechanical and hydraulic requirements and take in consideration the location and use of the site. ABNT [2] brings a few items that must be addressed on the design:

- implementation, type of use and interferences on pavement;
- load types and magnitude;
- subgrade load support;
- subgrade infiltration rate;
- soil behavior on saturated conditions when using total or partial infiltration;
- water table level, which is recommend to be at least 0.60 m below the pavement’s structure;
- contribution area cannot exceed five times the pavement area;
- minimum slope of 0.5% and maximum slope of 5%, for the contribution area maximum slope of 20%;
- when using precast concrete on surface course minimum mechanical resistance; bulk density when adopting pervious concrete cast in place;
- transversal and longitudinal joints detailing when using pervious concrete cast in place;
- water table contamination risk assessment.

Since designers in Brazil are not completely familiar with permeable pavement this item can be used as an initial reference without demanding a particular design method, which should be the choice of the designer. However the ABNT [2] also brings a suggestion of design method describe in section 10.

6.2 Materials for base and subbase

The conventional materials used on pavements are normally not suitable on permeable pavement, where the base/subbase should function as a reservoir allowing water infiltration and retention. To guarantee that the ABNT [2] recommends a void content of at least 32% and less than 2% of material finer than the 0.075 mm sieve (Table 2). It also recommends a grading size that would comprise those requirements (Table 3).

Table 2: Requirements for granular materials for base/subbase, bedding layers and joint material.

Feature	Method	Requirement
“Los Angeles” abrasion	ABNT NBR NM 51	< 40
Void content	ABNT NBR NM 45	≥ 32%
California bearing ratio (CBR) for base/subbase	ABNT NBR 9895	≥ 80%
Passing material on 0.075 mm sieve	ABNT NBR NM 46	≤ 2%
Bedding layer maximum aggregate size	ABNT NBR 7212	9.5 mm
Joint material maximum aggregate size	ABNT NBR 7212	≤ 1/3 of the smallest joint or open space width

Table 3: Grading size distribution for base/subbase.

Sieve size	Cumulative percent retained in mass (%)	
	Subbase	Base
75 mm	0	-
63 mm	0 a 10	-
50 mm	30 a 65	-
37.5 mm	85 a 100	0
25 mm	90 a 100	0 a 5
19 mm	95 a 100	0 a 35
12.5 mm	-	40 a 75
4.75 mm	-	90 a 100
2.36 mm	-	95 a 100

6.3 Bedding layer and jointing material

Permeable interlocking concrete pavement requires a bedding layer that serves as a smooth surface to the paving units and material to fill the joints, when it is the case. On regular interlocking concrete pavement sand is normally used but in permeable pavement a material with low fines content should be used that could allow fast water infiltration. The ABNT [2] recommends a grading size distribution according Table 4. It is also mentioned that the bedding layer should be uniform and constant and its length should be referred in project, being recommended between 20 mm and 60 mm before compaction with ± 5 mm variation. The jointing material should fill the spaces until 5 mm below the surface. The use of sand or stone dust is a common mistake that could block the water infiltration compromising the pavement performance from start.

Table 4: Grading size distribution recommendation for bedding layers and joint material.

Sieve size	Cumulative percent retained in mass (%)
12.5 mm	0
9.5 mm	0 a 15
4.75 mm	70 a 90
2.36 mm	90 a 100
1.16 mm	95 a 100

6.4 Surface course

6.4.1 Mechanical requirements

Table 5 mentions the mechanical resistance requirements for the surface course. On paving units of solid concrete the requirements are the same as for the conventional non permeable pavement according to ABNT NBR 9781. On paving units with pervious concrete the requirement is lower than the conventional one, maintaining the same test method. Due to the porous content, the results on mechanical resistance on pervious concrete present a high variance and thus it would be advised to adopt another feature as a control requirement. On pervious concrete cast in place it is advised to use density while on pervious concrete paving units could also use density or abrasion as there is a test method describe on the ABNT NBR 9781. Particularly in the case of the paving unit, adopting a lower resistance could bring confusion with the conventional concrete by bringing the misleading perception that the pervious concrete requires less strength.

The paving units or slabs, when delivered in less than 28 days, should present at least 80% of the resistance specified in the project. The pervious concrete cast in place should comprise with the ABNT NBR 7212 – *Execução de concreto dosado em central – Procedimento* and present the strength gain curve.

Table 5: Mechanical resistance and minimum height for surface courses on permeable pavement.

Surface course type	Load type	Minimum height (mm)	Mechanical strength (MPa)	Test method
Paving units (solid concrete)	Pedestrian	60.0	≥ 35.0	ABNT NBR 9781
	Light traffic	80.0		
Paving units (pervious concrete)	Pedestrian	60.0	≥ 20.0	
	Light traffic	80.0		
Concrete slab	Pedestrian	60.0	≥ 2.0	ABNT NBR 15805
	Light traffic	80.0		
Pervious concrete cast in place	Pedestrian	60.0	≥ 1.0	ABNT NBR 12142
	Light traffic	100.0	≥ 2.0	

The pervious concrete cast in place should have the density measure on field (fresh concrete) according ABNT NBR 9823 – *Concreto fresco – Determinação da massa específica, do rendimento e do teor de ar pelo método gravimétrico* and on hardened concrete according ABNT NBR 9778 – *Argamassa e concreto endurecidos – Determinação da absorção de água, índice de vazios e massa específica* and should present density above 1600 kg/m^3. Later the mechanical resistance is obtained by correlation with density.

6.4.2 Visual and dimensional inspection on paving units or slabs

The paving units or slabs should present uniform aspect, regular edges, right angles, free of shavings, defects, delamination or flaking. The minimum height should comprise Table 5 and be multiple of 20 mm with ± 3mm of tolerance.

6.4.3 Sampling

A pavement lot correspond to 2500 m^2 of pavement area and each lot should be test according Table 6. A specimen should be add for each 300 m^2 of pavement until the 10.000 m^2 limit.

Table 6: Minimum sampling on field.

Type of surface	Feature	Minimum specimens for 2500 m^2 lot	
		Number of specimens	Counterproof
Paving units or slabs	Visual inspection	6	6
	Dimensional avaliation	6	6
	Mechanical resistance	6	6
Pervious concrete cast in place	Fresh concrete density	One for each15 m^3	
	Hardened concrete density	3	3
Both	Infiltration rate	3	3

6.4.4 Hydraulic requirements

For all surface types adopted the ABNT [2] specifies a minimum infiltration rate higher than 10^{-3} m/s. A constant head permeameter can be used to verify this requirement in case of pervious concrete while enlarged joints or open space paving units can be verify according to Equation 1, which normally corresponds between 7% and 15% of the total area, as seen in Figure 2.

Figure 2: Area verification for enlarged joints or open space paving units.

The total percolation area should be obtained according equation (1):

$$A_{percolation} = \frac{external\ area-(internal\ area+spacer\ area)}{external\ area}. \qquad (1)$$

7 Construction

The ABNT [2] does not bring specific guidelines on construction and only mentions that the chosen method should be in accordance with the surface course type and that the same procedure could be adopted as in the conventional pavement as long as it doesn't conflict with the requirements already mentioned. It was not the scope of the standard to provide detailed guidelines on construction but permeable pavement could require a few different methods from the conventional pavement that if not followed could damage the performance of the pavement.

8 Maintenance and cleaning

Maintenance is advised when the pavements present a runoff coefficient lower than 10^{-5} m/s measured with the single ring method, described in section 9. Maintenance consists of the following steps: sweeping, water jet, suction debris and replacement of grouting material, if applicable. After these procedures the runoff coefficient must be at least 80% of the minimum permeability coefficient, if not other maintenance actions should be implemented according to the surface type.

ABNT [2] points out that any repair should use the same material as in the existing pavement, and it is forbidden to use any material that highlights the repair

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or damages the pavement behavior. Often a repair in permeable pavement is made using conventional materials, normally because of lack of information of the user.

9 Hydrological evaluation

One of the main goals on ABNT [2] was to present a simple method of hydraulic evaluation in order to confirm the performance of the pavement. The ABNT [2] mention laboratory evaluation considering only the surface course and in place measure for the finish pavement (Table 7).

Table 7: Infiltration rate requirements.

Surface course	Test method		Infiltration rate (m/s)
	Laboratory	In place	
Paving unit (enlarged joints or open spaces)	Single ring method	Single ring method	>10^{-3} m/s
Pervious concrete paving unit	Constant head permeameter ABNT NBR 13292		
Pervious concrete slab			
Pervious concrete cast in place			

In the laboratory, the measurement is made using a constant head permeameter and the test method described in the soil standard ABNT NBR 13292 – *Solo – Determinação do coeficiente de permeabilidade de solos granulares à carga constante – Metodo de ensaio*.

For in place measurement, the ABNT [2] brings as an attachment the single ring test method using as reference the ASTM [7]. This test method was initially proposed by Bean *et al.* [6] by adjusting a soil test method for permeable pavements. The method has been reviewed by Smith *et al.* [8] and Li *et al.* [9], who also analyzed the test method by the National Center for Asphalt Technology (NCAT). They both attested to the effectiveness of the ASTM [7] test method. The test method was successfully applied on field tests by Borst [10], Marchioni and Silva [5] and Jabur [11], confirming its simple operation and accurate results. It consists of pouring a pre-defined volume of water into a 30 cm cylinder maintaining a defined head measuring the time from when the water touches the pavement to full infiltration. The infiltration rate is then determined using an adaptation on Darcy's Law (Marchioni and Silva [5]).

The pavement acceptance relies on in place measurement, while the laboratory methods for surface course using pervious concrete are used only for preliminary acceptance.

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10 Base and subbase hydrological design

As an informative attachment the ABNT [2] brings a recommendation for the hydraulic design of the base and subbase based on BSI [1] and Smith [12]. The first step is defined by the infiltration type according to Table 8.

Table 8: Infiltration type according to local features.

Local conditions		Total infiltration	Partial infiltration	No infiltration
Subgrade infiltration rate k (m/s)	>10^{-3}			
	10^{-3} a 10^{-5}	x		
	10^{-5} a 10^{-7}	x	x	
Maximum water table level at least 1 m below the base		x	x	
Contaminants presence		x	x	

The base depth is obtained according to the methodology mentioned in Smith [12] using equation (2). This depth refers only to the reservoir capacity of the base and does not exclude a mechanical design.

$$dp = \frac{\Delta Q_c R + P - f T_e}{V_r} \qquad (2)$$

where: dp = depth of crushed stone base (m); ΔQc = increased runoff from contributing area per given design storm (m); Ac = contributing area (m²); Ap = pavement surface area (m²); R = contribution area and surface area ratio (Ac/Ap); P = design storm rainfall depth (m); f = soil infiltration rate (m/h); Te = effective filling time of the base, typically 2 hours (h); Vr = void ratio of the base crushed stone.

The infiltration rate (f) can be obtained according the test methods on *ABNT NBR 13292:1995 Solo – Determinação do coeficiente de permeabilidade de solos granulares à carga constante – Metodo de ensaio* and *ABNT NBR 14545:2000 Solo – Determinação do coeficiente de permeabilidade de solos argilosos a carga variável*. The design storm rainfall depth (P) should be obtained with data from local IDF (Intensity–duration–frequency) equation data considering a return period of minimum 10 years and 1 h duration.

11 Conclusion

The ABNT [2] will be published in 2015 and is expected to reach the interest stakeholders being municipalities, developers and contractors helping to guarantee acceptance performance on permeable pavement and reduction on pathologies. As is common in standards the text doesn't go further on details but provides the most important requirements for an acceptable performance of the pavement. However, it is still necessary for the development of specific guidelines for each type of surface course and cross section respecting the requirements mention on ABNT [2].

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Section 11
Waste management

New technology for the recycling of aromatic amine waste products and salts of heavy metals into a multi-purpose non-toxic product

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Abstract

New technology for the repurposing of toxic industrial waste into non-toxic, multi-purpose products is elaborated. The use of novel compounds for flotation separated potash ores, and as a mixture component for the neutralisation and lithification of domestic and industrial wastes and bottom sediments, are presented.

Keywords: toxic waste disposal, amino-complex compound, disposal of waste, flotation ore separation, bottom sediments, ecology.

1 Introduction

One of the major problems presented to natural and technical sciences by modern production methods is the creation of new technologies for the disposal of toxic industrial waste into multi-purpose, non-toxic products that meet certain technical requirements.

It is widely known that toxic industrial wastes pose a major environmental hazard. For example, the waste products of aromatic amines in Russia as a whole can be considered as a large-tonnage issue. Typically, semisolid aromatic amine waste products – in particular, diphenylamine – are taken to a landfill with periodic combustion taking place there. Liquid wastes from the manufacture of aniline and its derivatives as well as viscous waste monoethylaniline are discharged into slag collection points following acid waste treatment. At the same time, toxic amines evaporating from the waste pollute the atmosphere as well as, penetrating through the soil into groundwater, contaminating the water. Volley emissions of toxic

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water into open water cannot be excluded. The entire complex of harmful chemical substances released into the air and water basins from industrial emissions has an adverse effect on the soil fauna. During the combustion of resinous wastes in the production of aromatic amines and derivatives thereof, a wide range of organic compounds is formed in the air, the most carcinogenic of which are dioxins, toxic to the cells of living organisms. Vast areas of once fertile land are effectively turning into deserts due to salinisation and poisoning with pesticides.

With the aim of restoring natural resources, conservation and rehabilitation, it is necessary to create eco-friendly sustainable technologies for the utilisation of toxic industrial waste in multi-purpose non-toxic products.

2 Principal problems of waste management in Russia

2.1 Russia and the global waste management context

Russia produces more than 5 billion tonnes of waste annually. Of this, only 7–8% is recycled, and the rest – over 90% – of the waste is disposed of at unauthorised dumps and landfill sites [1]. These data are published in the July 2014 report by the Chairman of the Russian Public Chamber Commission on Ecology and Environmental Protection. The volume of accumulated waste in Russia has reached an unimaginable 90 billion tonnes. These wastes are disposed of in landfills occupying an area of 4 million hectares (slightly smaller than the area of the Netherlands), as well as in unauthorised dumps. Each year to these areas is added a further 400 thousand hectares of waste at unauthorised dumps. Figure 1 presents Federal Service for the Supervision of Natural Resources (Rosprirodnadzor) data on the dynamics of increasing waste in Russia [1].

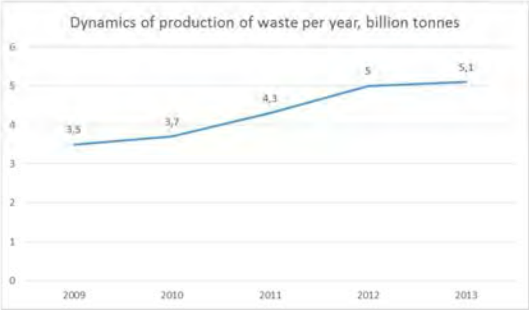

Figure 1: Dynamics of annual production of waste.

From the perspective of inhabitants of Sweden, Russian behaviour, having failed to develop a proper environmental business model is unsustainable. The Swedes are world leaders in the re-utilisation of waste products. Furthermore, not satisfied with recycling their own waste products, the Swedes even import them from the United Kingdom, Norway and Ireland, boosting their earnings by providing recycling services. More than 98.5% of the waste produced in Sweden is reprocessed. The remaining 1.5% consists of materials that cannot be recycled in an environmentally friendly way (e.g. ceramics, asbestos, phosphorus). Only these wastes need to be disposed of. In Sweden, there are 31 recycling plants in operation and 57 organisations for the collection and sorting of waste. In Russia, the industry sector also seems impressively well-supported, with the data in Figure 1 showing a large amount of waste materials. According to the Russian Ministry of Natural Resources and Environment, in 2013 there were 40 waste incineration plants and 53 waste sorting complexes in operation [1]. However, the environmental and economic benefits from its activities in Russia are incomparably lower than in Sweden. Despite the organisational activity, a thriving recycling business environment is yet to materialise. It should be noted that the processing of waste by incineration is the lowest level of utilisation.

With the development of new technologies for waste disposal in Russia, the situation gets much more complicated. There are Russian developments; however, only a significant part reaches the stage of industrial implementation. There is still close to zero interest in recycling as a business. According to the Head of the Department of Water and Energy and Renewable Energy Research at the Institute of Energy Strategy (IES), there are two basic technologies for processing waste into electricity and heat. These consist of the processing of organic waste into biogas in special landfills, and incineration [2]. The first technology remains to be mastered in Russia. The second is faced by great difficulties, since it requires the separate collection of the various wastes (glass, metal, food waste, etc.). While the Swedish model for waste disposal works successfully, thanks to a well-functioning system of collecting already separated waste materials, in Russia, a culture of separating wastes for collection is virtually non-existent. There are separate experiments being set into motion at the instigation of the municipalities. For example, a project to separate waste collection launched in Moscow by the company “Sphera Ekologii” a few years ago more or less came to nothing. In May 2013, the authorities equipped a few points for separate waste collection in the Petrograd district of St. Petersburg. It was assumed that, if successful, such facilities would appear in other areas. However, after six months the experiment was wound up. The Deputy Chairman of the city’s Environmental Committee reported the complete failure of the initiative, due to the fact that residents of the area apparently found it more convenient to simply throw away their garbage.

This may explain the significant difference between the Russian and Swedish approaches towards recycling. In Sweden, burial in landfills is the most expensive method of waste disposal. The authorities deliberately keep prices high to increase the cost-effectiveness of alternative means of recycling, which are more environmentally friendly, technologically advanced and, of course, expensive. Given these circumstances, the sorting and organisation of separate waste

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collection has become a profitable venture. Industrial companies do not carry the waste to landfills, but delivers it at zero cost to waste processing plants. There are also economic benefits to households. Having taken the decision to move to separate waste collection and concluded the relevant contract with the municipality, domestic residents enjoy significant discounts when paying for utility services [1].

2.2 The status of waste management in Russia

The Chairman of the Public Chamber Commission on Ecology and the Environment believes that “the main problem is the lack of a Russian market for waste management services. Much rests on the passing of relevant legislation. If the State should undertake the planned introduction of separation of waste, starting with various industrial enterprises, this would lead to a change in the mentality of the population in the long term”. In Russia, unlike in Sweden, landfill is the cheapest way to dispose of waste. Low rates of landfill sites for the processing of solid domestic waste results in investment in alternative methods of waste processing being seen as meaningless and environmentally unjustified. There is nothing cheaper than burying waste in the ground: current rates vary from 200 to 600 rubles per cubic metre [1]. These are the approximate prices for landfill paid by organisations involved in the disposal of household wastes. The so-called “trash taxi” has become Russia’s most competitive and vibrant segment (incidentally, the licensing of such services has already been abrogated for three years); meanwhile, in other segments of the industry there is a developmental hiatus. Alternative processing methods are generally developed only through the efforts of local administrative authorities, grants and subsidies. Depending on the type of material, the recycling of one tonne of waste in our country is approximately 4–8 times more expensive than landfilling it. This would suggest the necessity to take a decision to raise tariffs for waste disposal by at least 4–5 times [1]. In 2013, the Ministry of Natural Resources and Environment submitted a draft of a comprehensive strategy for the treatment of solid waste until 2030, in which the emphasis was on a shift in priorities from landfill to recycling. The proposed innovations should primarily relate to the recycling of the energy component of household waste.

There should be a set of measures aimed at the gradual introduction of separate waste collection and incineration at waste incineration plants. In terms of new methods, the construction of landfills, capable of producing energy from landfill gas, has been mooted. However, the launch of market-based mechanisms is not presupposed. Apparently, there are serious concerns that this will give more of an impetus to illegal dumping than to the development of the industry. Their occurrence and spread can now only be controlled with great difficulty. According to the head of the organisation “Greenpeace Russia”, compared to 16 thousand legal landfills in Russia at the present time, there are about 30 thousand unauthorised sites [1].

Consequently, in order to preserve and restore natural resources, it is urgently required to develop new technologies for the utilisation of toxic industrial waste in multiple applications.

3 New technology to improve the efficiency, safety, environmental utilisation and efficient disposal of toxic industrial waste

3.1 Synthesis of non-toxic amino-complex compounds from toxic industrial waste

We propose a new technology to be used in recycling facilities for processing resinous wastes arising from the production of aromatic amines and their derivatives, as well as wastes from metallurgical industries such as chlorides and sulphates of copper, zinc, iron and other metals [3].

Instead of incineration or storage of wastes, we propose to utilise them for the synthesis of non-toxic, multi-purpose amino-complex compounds (ACC) [4].

The use of waste products for the synthesis of amino-complex compounds at chemical enterprises and in titanium production has the following advantages.

- Simultaneous one-step neutralisation of unused by-products from the production of ferrous metallurgy and aromatic amines.
- No secondary contamination of the environment.
- The feasibility of a combining process without solvent, catalyst or heating, as well as eliminating the synthesis of amino-complex compounds in commercial products.
- The simplicity of the apparatus for the synthesis of amino-complex compounds.
- The simplicity of the process (instability in the structures of wastes from the production of aromatic amines does not require a modification of the process parameters and does not lead to a deterioration in the quality of the resulting product).

ACC is a crystalline powder with granular inclusions of different colours depending on the cation; its melting point is not less than 120°C.

ACC is stable in the air, does not become clumped during storage and may be contained without any special precautions for long periods of time.

The novelty of the developed industrial technology of extraction of ACC from toxic waste is protected by patents of the Russian Federation [5].

As an example, several methods of ACC production are introduced below.

Copper-aniline complex compound (CACC) $CuSO_4$•2An can be synthesised on an industrial scale; the straightforward technology of its derivation is as follows. Aniline is added to a 1.64% aqueous copper sulphate solution at room temperature and stirred; the molar ratio of copper sulphate to aniline is 1.5:2.0. A crystalline green deposit is precipitated as a consequence of the reaction. The resulting product is separated on a porous filter (such as a Büchner funnel) and dried in the open air. Wastes from chemical enterprises can be used for the manufacture of CACC. The resulting amino-complex compound is non-toxic (conclusion of the Leningrad Research Institute of Labour Hygiene and Occupational Diseases).

Copper-aniline complex compound $CuCl_2$•2An can be synthesised on an industrial scale with waste products from the Kemerovo aniline plant according to the following procedure. To a 1.0–3.4% aqueous aniline solution at room temperature is added the copper chloride and mixed at a molar ratio of copper chloride and aniline (1.3–1.7) : (1.7–2.0). A black fine crystalline product is formed, which is separated on a porous filter and dried in air.

The zinc-aniline complex compound $ZnCl_2$•2An can be synthesised from the waste products of chemical plants. At ambient temperature, an 80–90% aqueous solution of $ZnCl_2$ and aniline is mixed at a molar ratio of zinc chloride to aniline of (1.6–1.8) : (1.8–2.1). A white fine crystalline product is formed, which is separated on a porous filter and dried in air.

The iron-aniline complex compound (ACC) $FeCl_2$•2An can be synthesised from waste products from the Berezniki chemical plant (residues following distillation of aniline) and Berezniki Titanium-Magnesium Works (solid titanium chloride production). Mixing the distillation residue following distillation of aniline and chlorides from solid titanium production is performed based on a molar ratio between $FeCl_2$ and aniline of (1.7–2.0) : (1.5–1.7). The combination of components is carried out in a mixing tank. Upon completion of loading of the components they are stirred for 10–15 min. After stirring, the amino-complex compound forms in a cryptocrystalline state, which is removed and analysed for free amines. The product obtained should not contain free amines. The amino-complex compound is transported and stored in plastic bags.

To provide a rationale for the legality of the introduction of new technology in connection with the utilisation of industrial toxic waste, a synthesis of ACC from pure products and the study of their physical and chemical properties had already been carried out.

A comparison of the results of ACC research by IR spectroscopy, X-ray, magnetic chemistry and electron paramagnetic resonance permitted their structure to be determined. The data obtained on the geometric structure of the investigated ACC were used to determine the type of hybrid orbitals of Co, Ni, Cu and Zn for the purpose of calculating the overlap integrals of the "metal-nitrogen" bonds. In addition to data on the geometric structure of the complexes, the results of quantum chemical calculations were also used [6, 7]. A calculation of the overlap integrals between the hybrid orbitals of the metal and nitrogen was performed using the wave functions. The correlation analysis method demonstrated the sensitivity frequency of antisymmetric stretching vibrations of NH coordinated amines to the substitution position in the aromatic ring, the nature of the cation, anion salts and the presence of the naphthyl cycle [8].

3.2 Use of amino-complex compounds in the economy

Due to the diversity of their properties, amino-complex compounds are used in many areas of the economy. Some of these properties may be listed as follows.

3.2.1 Amino-complex compounds – mixing components for the neutralisation and lithification of domestic and industrial waste and bottom sediments

Amino-complex compounds can be used as a component for mixtures used to neutralise and lithify domestic industrial wastes and bottom sediments [9]. The invention relates to the production of artificial mineral mixtures intended for the disposal and lithification of liquid, viscous-plastic and solid domestic and industrial wastes and bottom sediments, sludges, etc., containing toxic compounds (salts of heavy metals, polycyclic aromatic hydrocarbons, petroleum products, synthetic surfactants, radionuclides, etc.). The technical result is an improvement in the mechanical quality of the obtained material.

The proposed compound has significant advantages over the following known compounds.

A commonly used mixture for sludge disposal and lithification of domestic and industrial effluents, containing the subsidiary filter substance of limestone or different slags and quicklime with CaO content – 82% in the amount of 60–80 wt.%. Pellets produced from the resulting interaction of the compound with slurries can be used in the cupola furnace charges or as a filler in the manufacture of concrete products. In addition, the resulting product can be stored in slag heaps as artificial ground. The disadvantages of this technology are the complexity of the sludge transformation mixture, the high cost of high quality lime used in very large quantities (60–80% by weight), the need for belt filters and renewal of filter-specific adjuvant composition [8].

The mixture is also known for the neutralisation and lithification of sludges, as well as domestic and industrial wastes and bottom sediments, including fly ash, aluminosilicate wastes, lime, Portland cement and fine aggregates. The mixture ensures detoxification of sludges and wastes and their conversion into environmentally friendly soil, suitable for compact storage or for use in construction as a local material. This technological solution should be taken as a prototype of the present invention. The disadvantage of the established mixture is the fact that aluminium silicate solids have the property of high tack in the presence of moisture, making the process of mixing and compacting the mixture extremely difficult. Furthermore, the materials resulting from waste sludge and lithification have poor mechanical properties, in particular low strength and elasticity, which limits their use in construction [8].

The present invention provides a solution for the creation of a mixture for neutralisation and lithification of domestic and industrial wastes, as well as bottom sediments, which would have reduced tack, easily stirred with neutralised waste or sludges and well compacted, thus solving the problem of increasing the mechanical properties of the resulting material.

Per the present invention, this objective is attained due to the fact that the mixture for neutralisation and lithification of domestic and industrial wastes, as well as bottom sediments, including aluminosilicate solids, lime and Portland cement, additionally introduced aniline complex compounds of copper and/or iron and polypropylene fibre. Through the implementation of the distinguishing features of the invention, the mixture acquires important new properties.

Aniline complex compounds of copper and/or iron permit film polymerisation of water molecules around the particles of hydrophilic aluminosilicate solids thereby virtually eliminating tack in the mixture. The resulting mixture is blended well with the detoxified substrate, increasing the uniformity of the resulting material and its compressibility.

Polypropylene fibre (fibrin) presents itself in a dispersed microfibrillar phase, which, when mixed with other ingredients adheres to a synthesised aluminosilicate binder; this interaction is responsible for the microstructure and homogenisation of the dispersion medium forming material.

Formula of invention: The mixture for neutralisation and lithification of domestic and industrial wastes, as well as bottom sediments, including aluminosilicate solids, lime and Portland cement, additionally introduced aniline complex compounds of copper and/or iron and polypropylene fibre with the following relationship of components, %:
Aluminosilicate solids 60–80;
Lime 5–15;
Portland cement 10–20;
Aniline complex compounds of copper and/or iron 1–3;
Polypropylene fibre 2–3.

3.2.2 The use of amino-complex compounds for flotation desliming of potash ores

Aniline complexes may find application in the flotation desliming of potash ores, consisting in treatment of the crushed ore with sludge reagent-collectors and flotation of the clay-carbonate and silicate slurries. Aniline complexes increase the efficiency of extraction and effectiveness of flotation of sludges, as well as reducing the cost of reagent-collectors.

The greatest difficulties in the flotation of potash ores arise from the presence of these clay-carbonate impurities which adsorb considerable quantities of reagent-collector onto themselves, thereby worsening the process of abietic flotation and raise the price of technology due to increased consumption of expensive and scarce reagent-collectors. In terms of collecting agents, clay-carbonate slurries during flotation of potash ores use a combination of polyacrylamide and block copolymer of ethylene oxide and propylene on the basis of fatty acids. For the flotation of sludges a combination of polyacrylamide ethoxylated compounds is used, for example, alcohol oxy-leaded "oksanol-O-18". A disadvantage of this method is the necessary use of the expensive and scarce flotation reagent – polyacrylamide [8].

A widely used flotation clay-carbonate sludge from abietic collecting agents consists of a combination of polyacrylamide and ethoxylated fatty acids (EFA). This method consists in the fact that the bulk flotation slurry is carried out in the presence of collectors with the following expenditures: polyacrylamide (PAA) 15–20 and EFA 30–40 g/t of ore. The disadvantages of this method are the low efficiency of the flotation sludges, low recovery of sludges, as well as the high cost and scarcity of polyacrylamide. The content of the sludge in the feed of the abietic flotation is reduced to 2% [8].

In order to improve the extraction efficiency and effective flotation of clay carbonate and silicate slurries as well as reducing the cost of collecting agents, crushed ore may be treated with ethoxylated fatty acids (EFA) and aniline complex compounds in a ratio of 4:1 (40 and 10 g/t of ore, respectively) [10].

Aniline complex compounds have the ability to hydrophobise the surface of clay particles and to increase their flotation activity, which leads to increased recovery in foam products of sludges during flotation. In addition, aniline complexes permit a complete elimination of the use of expensive and scarce polyacrylamide. As aniline complex compounds are obtained from chemical production wastes, they are cheap reagents.

The proposed method of flotation desliming tested in the Galurgiya Research and Development Institute laboratory of sylvite Starobin deposit with the content (wt.%): KCl 31.3 and insoluble residue 3.0. The ground ore particle size of -0.5+0 mm air-conditioned 2 min with sludge reagent-collectors: ethoxylated fatty acids, aniline complexes of zinc chloride ($ZnCl_2$2•An) or copper sulphate ($CuSO_4$2•An) at a dilution suspension of F:T = 2. Boot sequence: aniline complex, then EFA.

Aniline complexes applied as solutions of acids: $ZnCl_2$2•An – 18% solution in 2N HCl; $CuSO_4$2•An – 3.47% solution in 2N H_2SO_4.

Treated slurry was subjected to flotation reagents in the mechanical flotation machine slurry F at T = 3 for 3 minutes. For comparison, experiments were carried with the processing of a suspension in the traditional manner: polyacrylamide and ethoxylated fatty acids (15 and 40 g/t of ore, respectively).

The results of sludge flotation with proposed reagents in the prior art method are shown in Table 1. As a result of the sludge flotation according to the method proposed, it is possible to increase the efficiency of sludge flotation by 13–15% and the extraction of impurities at 13% in the foam product, resulting in a reduction in the slime content of insoluble residue in the chamber product – the feed of subsequent abietic flotation is reduced from 2.05 to 1.42% compared to the conventional method. Analogously tested aniline complexes of zinc and copper present themselves as aniline complexes of iron.

Table 1: The use of amino complex compounds and sludge reagent-collectors.

Experiment	Reagent consumption, g per tonne of ore					Extraction of insoluble residue in the foam sludge product, %	Contents of insoluble residue in the chamber product, %	Effectiveness of sludge flotation, %	Comment
	EFA	PAA	Aniline complexes		Ratio of EFA/complex				
			$ZnCl_2$*2An	$CuSO_4$*2An					
1	40	15	-	-	-	36.00	2.05	33.70	Known method
2	40	-	10	-	4:1	51.95	1.42	46.60	Proposed method
3	40	-	-	10	4:1	52.65	1.19	48.50	Proposed method

Thus, the main advantage of the proposed method consists in improving sludge flotation and the application of a new sludge reagent-collector – aniline complexes derived from chemical production wastes instead of expensive and scarce polyacrylamide.

4 Conclusions

A new technology for the utilisation of toxic industrial wastes into non-toxic amino-complex compounds is achieved by means a simple and cost-effective synthesis. Amino-complex compounds maintain their properties during prolonged storage without special precautions packing and storage.

Analysis of an experimental batch amino-complex compound showed that it lacked free aniline. It can be assumed that in practice amino-complex compounds do not require special measures that differ from the general rules in order to comply with safety regulations. Working with amino-complex compounds does not cause danger in hot weather, since they only decompose at temperatures higher than 120°C. Thus, working with amino-complex compounds is harmless.

Studies of the chemical and physico-chemical properties of the amino-complex compounds are not just theoretically interesting but are also of great practical importance, since they are widely used in practice. In particular, they are of interest for the management of some industrial processes, such as flotation desliming of potash ores; partial dehydration of colloidal gels of amphoteric hydroxides and clay minerals; the use of argillaceous rocks as raw materials for the ceramic industry. Using amino-complex compounds synthesised from toxic industrial wastes provides a clear ecological benefit.

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Physicochemical effects of long-term deposition of sewage sludge on Brazilian Oxisol

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Abstract

The aim of this work was to evaluate the effect of doses of sewage sludge (SS) when applied for sixteen consecutive years to the Brazilian Oxisols Typic Haplothox (sandy) and Typic Eutrorthox (clayey), on the chemical characteristics of soil fertility. The experiment was carried out in a field at Jaboticabal, SP, Brazil, using experimental design in randomized blocks with 4 treatments and 5 replications. Sewage sludge was applied on soil surface and incorporated at the 0–10 cm depth with a light harrow. Sixty days after SS application, soil samples were collected at the depth 0–20 cm (10 simple samples per plot, which were mixed to obtain a composite sample). The treatments were T1 = no SS and mineral fertilization based on soil chemical analysis, T2 = 5 t ha^{-1} SS, T3 = 10 t ha^{-1} SS, T4 = 20 t ha^{-1} SS, dry weight basis. Except for K in the Typic Eutrothox, the amendment of the soils did not affect soil fertility that was considered as middle fertility, and also did not affect maize grain production. The lack of effect of SS on soil fertility and plant production is attributed to the water deficit in the period between the SS incorporation and the soil sampling. The doses 10 t ha^{-1} SS increased K in the Typic Eutrorthox, probably due to K extraction from the soil organic matter. In all the treatments, the bases saturation was below the recommended for maize, that is 70%. Maize fertilized with 5 t ha^{-1} sewage sludge, dry weight basis, plus K, produced the same that the mineral fertilization.

Keywords: biosolid, soil fertility, maize, pollution.

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1 Introduction

Sewage sludge (SS) is a solid residue obtained in the wastewater treatment [1]. It is a heterogeneous material whose composition varies according to the origin of the sewer, i.e. from domestic or industrial areas, the period of the year and the social condition of the population [2].

The volume of sewage produced, expressed in liters per habitant per day, is affected by several factors such as climate, population size and economic situation, degree of industrialization of the area, measurement of water service, availability and cost of treated water etc. [3].

The growth of urban areas has caused social, economic and environmental problems as the generation of residues whose disposition has not been made adequately. The domestic residues are actually one of the great environmental problems, including SS. It has been estimated that 50% of the cost of treating wastewater is due to the disposition of the residue, which varies according to the disposition option [4].

The SS composition is closely related to the sociocultural status of the population since the chemical characteristics of the wastewater depend on factors such as consumption pattern, basic sanitation, industrial development, wastewater treatment process and quality of the SS produced [5, 6].

Application of SS in the soil may affect both the chemical composition related to soil fertility as well as those that cause a negative impact on soil, as the increase in trace elements concentration, phosphorus fixation and loss of nitrogen through ammonia volatilization. It may also contaminate surface and ground waters with nitrate, phosphate, trace elements and other possible pollutants.

The Brazilian SS production in 2011 was about 150–220 thousand tons per year, and that production is increasing with the increase in the sewer collection [7], which may cause a severe environmental problem if viable social, economic and environmental disposition methods for the residue are not developed [8].

The application of 67.5 t ha^{-1} SS in six successive years (2.5 t ha^{-1} during three years and 30 t ha^{-1} during the other three years) caused a grain production of 8.6 t ha^{-1} against 5.6 t ha^{-1} when chemical fertilization was used [9]. This positive effect of SS on maize grain production was also observed by other authors [8].

2 Methodology

The aim of this work was to evaluate chemical properties of two Brazilian Oxisols amended with rates of SS after sixteen annual applications of the residue.

The experiment was carried out under field conditions at Jaboticabal, São Paulo State, Brazil (21°15’22” SE 48°15’18” W) in two types of soils, a Typic Haplorthox (TH, sandy), and a Typic Eutrorthox (TE, clayey).

This experiment was started in 1996 and this work presents the data collected in the season year 2012/2013.

The experimental design was randomized blocks with four treatments (rates of SS) with five replications using plots with 60 m^2 (6 x 10 m).

In the season year 2012/2013 the treatments were 0 (control with no SS and mineral fertilization based on soil chemical analysis), 5, 10 and 20 t ha^{-1} SS, dry weight basis. Sewage sludge was supplied by the Wastewater Treatment Station operated by SABESP (Companhia de Saneamento Básico do Estado de São Paulo S.A) situated in Monte Alto, São Paulo State, Brazil.

The authors proceeded to the preparation of the area, through the application of herbicide. The application of SS to the soil was taken in November 2012, the start of the rainy period. The SS applied to the plots was distributed manually and incorporated into 10 cm depth with a light harrow. The soil was furrowed (90 cm between furrows), the mineral fertilizers were disposed into the furrows and maize (transgenic hybrid resistant to pests) was sowed.

The mineral fertilization in the treatments is shown in table 1.

Table 1: Mineral fertilization applied to the treatments.

Fertilizer	Treatments (t ha^{-1})			
	Control	5	10	20
	Sowing (kg ha^{-1})			
N	30	--	--	--
P_2O_5	50	--	--	--
K_2O	50	36	22	--
	40 days after sowing (kg ha^{-1})			
N	140	--	--	--
P_2O_5	--	--	--	--
K_2O	40	40	40	40

N = ammonium sulfate (18% N), P_2O_5 = simple superphosphate (18% P_2O_5) e K = potassium chloride (60% K_2O).

Sixty days after sowing, soil samples were collected at 0–20 cm depth. In each plot 10 simple samples were collected, which were mixed to form the composite sample representing the plot. Soil samples were air dried, sieved to 2 mm and analyzed for soil chemical properties (pH in $CaCl_2$ 0.05 mol L^{-1}, organic matter, phosphorus extracted by resin, potassium, calcium and magnesium extracted by KCl, H+Al) as described in Raij *et al.* [10]. Sum of bases, cation change capacity (CEC) and bases saturation (V %) were calculated with the data of K, Ca, H+Al.

To evaluate grain yield, cobs were collected from plants in the center line of each plot after 128 days after sowing. The cobs were husked, left to air and shade to complete the drying and thrashed. Grains were dried in a stove with forced air circulation at 60–70°C. Grain yield was expressed with 13% moisture [11].

The data were submitted to statistical analysis by the Tukey test at 5% probability (in the figures, letters followed by the same letter are not different in the test). We also made a group analysis for the comparison of the two experimental areas.

3 Results and discussion

The pH of the two soils ranged from 4.4. to 4.8 and was not affected by the treatments. In the rate 10 t ha^{-1} SS the pH of the soil TE was higher than the pH of the soil TH, fig. 1. The soil pH evaluation is very important for the knowledge of trace elements solubility and mobility in the soil profile. When pH increases, OH groups from the organic matter, Al and Fe oxides are ionized causing an increase in negative charges, increasing the soil adsorption capacity [12].

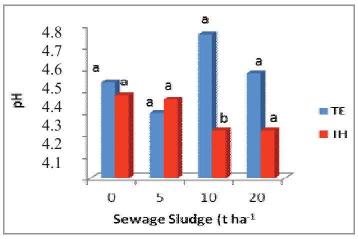

Figure 1: Values of pH in soils Typic Eutrorthox (TE) and Typic Haplorthox (TH) treated with rates of sewage sludge for sixteen consecutive years.

The concentration of organic matter was in the range of 25.8–26.4 g dm^{-3} in the soil TE and 18.4–21.8 g dm^{-3} in the soil TH and was not affected by the treatments, as shown in tables 2 and 3. This difference between the soils was expected since TE is clayey (clay = 61%), and TH is sandy (clay = 22%). When comparing the concentration of organic matter in the two soils, it was higher in TE for all the rates of SS, fig. 2. Some authors have observed that it is possible to increase soil organic matter for a long period of time, only for high doses of SS [13].

Phosphorus extracted by resin ranged from 45.2 to 67.8 mg dm^{-3} in the soil TE and from 41.8 to 79.8 mg dm^{-3} in the soil TH and no effect was detected for rates of SS sludge or for the soil type, tables 2 and 3, fig. 3. In an experiment with sewage sludge [9], an increase in soil P was observed, and it was concluded that the residue is an important source of P to soils.

Soil K was affected by the treatments only in the soil TE and in the rate 10 t ha^{-1}, which differed from the control, tables 2 and 3. Differences between soils were observed in all treatments, fig. 4. In the control, the soil TH presented more K than the soil TE, but in the treatments with SS, K concentration was higher in the soil TE. Fig. 5 shows a closely relation between soil K and organic matter in the soil TE.

Table 2: Chemical characteristics of a Typic Eutrorthox (TE) treated with rates of sewage sludge for sixteen consecutive years.

Treatments	P	OM	pH	K	Ca	Mg	H+Al	SB	CEC	V
	mg dm^{-3}	g dm^{-3}		----------	----------	---------- mmol$_c$ dm^{-3}	----------	----------	----------	%
0 t ha^{-1}	45.2 a	25.8 a	4.5 a	3.9 b	16.2 a	5.2 a	43.6 a	25.3 a	68.9 a	37.1 a
5 t ha^{-1}	61.6 a	26.2 a	4.4 a	5.1 ab	16.4 a	5.2 a	52.8 a	26.7 a	79.5 a	34.0 a
10 t ha^{-1}	67.0 a	26.4 a	4.8 a	5.7 a	19.0 a	6.2 a	43.2 a	30.9 a	74.1 a	41.6 a
20 t ha^{-1}	67.8 a	26.0 a	4.6 a	4.4 ab	19.0 a	5.8 a	45.2 a	29.2 a	74.4 a	40.1 a

OM = organic matter, CEC = cation exchange capacity, SB = sum of bases, V = basis saturation.
Means followed by the same letters are not different by the Tukey test at 5%.

Table 3: Chemical characteristics of a Typic Haplorthox (TH) treated with rates of sewage sludge for sixteen consecutive years.

Treatments	P	OM	pH	K	Ca	Mg	H+Al	SB	CTC	V
	mg dm^{-3}	g dm^{-3}		----------	----------	---------- mmol$_c$ dm^{-3}	----------	----------	----------	%
0 t ha^{-1}	41.8 a	18.4 a	4.5 a	5.8 a	9.2 a	2.2 a	31.4 a	17.2 a	48.6 a	36.0 a
5 t ha^{-1}	63.2 a	19.6 a	4.5 a	3.7 a	11.6 a	3.2 a	37.0 a	18.5 a	55.5 a	34.9 a
10 t ha^{-1}	79.6 a	21.6 a	4.3 a	3.6 a	12.6 a	3.0 a	38.4 a	19.2 a	57.6 a	33.6 a
20 t ha^{-1}	79.8 a	21.8 a	4.3 a	3.0 a	11.0 a	2.4 a	40.6 a	16.4 a	57.0 a	28.6 a

OM = organic matter, CEC = cation exchange capacity, SB = sum of bases, V = basis saturation.
Means followed by the same letters are not different by the Tukey test at 5%.

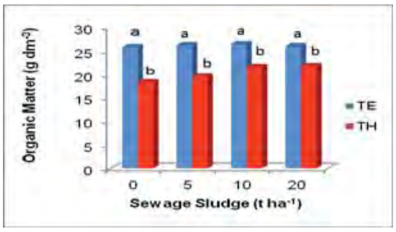

Figure 2: Values of organic matter in Typic Eutrorthox (TE) and Typic Haplorthox (TH) treated with rates of sewage sludge for sixteen consecutive years.

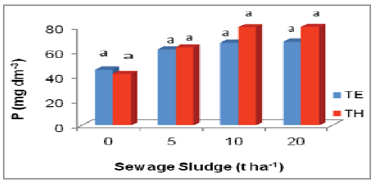

Figure 3: Values of phosphorus in Typic Eutrorthox (TE) and Typic Haplorthox (TH) treated with rates of sewage sludge for sixteen consecutive years.

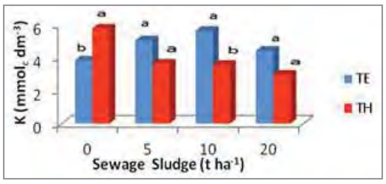

Figure 4: Values of potassium in Typic Eutrorthox (TE) and Typic Haplorthox (TH) treated with rates of sewage sludge for sixteen consecutive years.

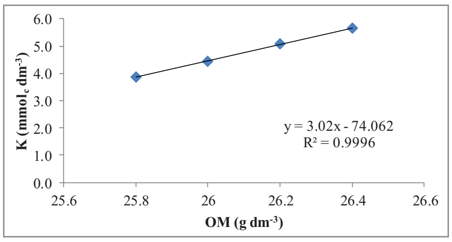

Figure 5: Relation between potassium and organic matter in the soil Typic Eutrorthox (TE) treated with rates of sewage sludge for sixteen consecutive years.

Depending on the processing of the wastewater treatment in the WTS, the content of K in SS may be very low, because this element is very soluble and stays in the water fraction during the processing, and so it is removed from the SS [14].

Calcium concentration in soil has no difference between the treatments in both the soils, tables 2 and 3. It ranged from 16.2 to 19.0 mmol$_c$ dm^{-3} in the TE and from 9.2 to 11.0 mmol$_c$ dm^{-3} in the TH, values considered high in terms of soil fertility [15]. In all the treatments, Ca concentration was higher in the soil TE, fig. 6. Some authors have observed an increase of Ca concentration in soil by using SS, but they used a residue treated with lime [16–18].

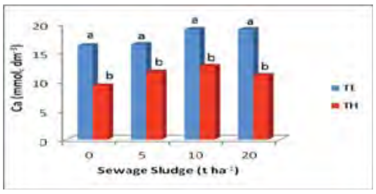

Figure 6: Values of calcium in Typic Eutrorthox (TE) and Typic Haplorthox (TH) treated with rates of sewage sludge for sixteen consecutive years.

The values obtained for magnesium also were not affected by the treatments in the two soils, tables 2 and 3. Soil Mg concentration ranged from 5.2 to 5.8 mmol$_c$ dm^{-3} in the soil TE and from 2.2 to 3.2 mmol$_c$ dm^{-3} in the soil TH, fig. 7. According to [4], studies have shown that the addition of SS increases the concentration of Mg in the leaves of sugarcane, maize and sorghum.

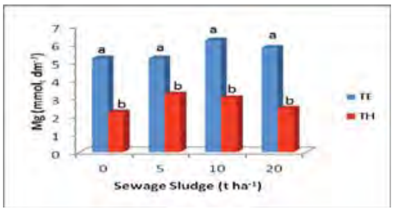

Figure 7: Values of magnesium in Typic Eutrorthox (TE) and Typic Haplorthox (TH) treated with rates of sewage sludge for sixteen consecutive years.

The data obtained for potential acidity (H+Al), sum of bases and bases saturation were also not affected by the treatments, tables 2 and 3. Considering the attribute H+Al, in the rate 5 t ha^{-1} SS it was higher in the soil TE compared to the soil TH, fig. 8. For the sum of bases in all the treatments the values were higher in the soil TE, fig. 9, while in the case of bases saturation only in the rate 20 t ha^{-1} SS were the values in the soil TE higher, fig. 11. The bases saturation (V %) was lower than 70%, and is considered the ideal value for maize crop and this may negatively influence the grain production.

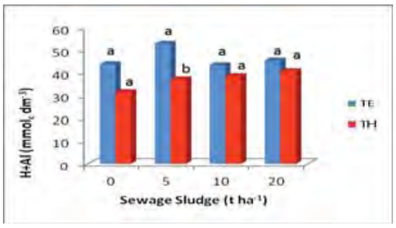

Figure 8: Potential acidity (H+Al) in Typic Eutrorthox (TE) and Typic Haplorthox (TH) treated with rates of sewage sludge for sixteen consecutive years.

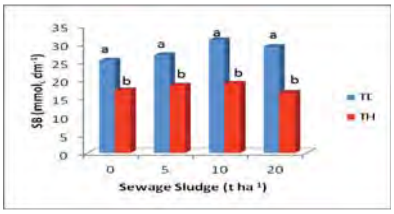

Figure 9: Sum of bases (SB) in Typic Eutrorthox (TE) and Typic Haplorthox (TH) treated with rates of sewage sludge for sixteen consecutive years.

The cation exchange capacity (CEC), estimated by the sum of K, Ca, Mg and H+Al, was not affected by the treatments and ranged from 68.9 to 79.4 mmol$_c$ dm^{-3} in soil TE and from 48.6 to 57.0 mmol$_c$ dm^{-3} in the soil TH, as shown in tables 2 and 3. In all the treatments the CEC was higher in the soil TE as compared to the soil TH, fig. 10.

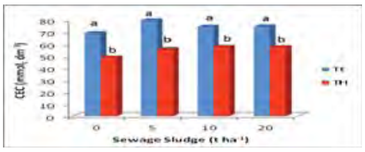

Figure 10: Values of cation exchange capacity (CEC) in Typic Eutrorthox (TE) and Typic Haplorthox (TH) treated with rates of sewage sludge for sixteen consecutive years.

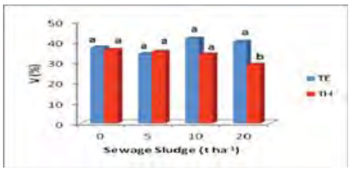

Figure 11: Base sauration (V) in Typic Eutrorthox (TE) and Typic Haplorthox (TH) treated with rates of sewage sludge for sixteen consecutive years.

The maize grain yield was not significantly different between the soils and the treatments, fig. 12. For both the soils, a rate of 5 t ha^{-1} SS, dry weight basis, plus K produced the same as the mineral fertilization.

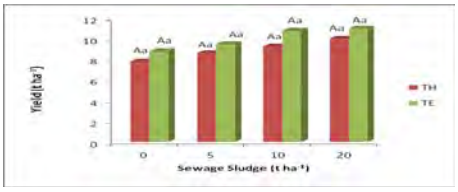

Figure 12: Corn yield in Typic Eutrorthox (TE) and Typic Haplorthox (TH) treated with rates of sewage sludge for sixteen consecutive years.

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4 Conclusion

Amending the soils Typic Eutrorthox and Typic Haplorthox with 10 t ha^{-1} SS in the sixteen consecutive years increased soil potassium concentration. The other soil characteristics evaluated (pH, organic matter, K, Ca, Mg, potential acidity, CEC, bases saturation and sum of bases) were not affected by SS amendment.

The amount of K correlated linearly and positively with the organic matter concentration in the soil Typic Eutrorthox.

Maize grain yield was not affected in the sixteenth year of sewage sludge application in rates of 5, 10 and 20 t ha^{-1}, dry weight basis.

The soil Typic Eutrorthox tended to present better chemical properties than the soil Typic Haplorthox.

After sixteen years of annual application of rates of sewage sludge the bases saturation is below the recommended for maize cropping (70%).

Maize fertilized with 5 t ha^{-1} sewage sludge, dry weight basis, plus K, produced the same as that of mineral fertilization.

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附件三、其他會議相關資料

Thirdly, I will show how we can use this foundation to scaling up, from primary producers to primary consumers, to second consumers, and so on in ecological networks. This approach opens a new view to re-examine species diversity-stability-productivity relationships in ecological systems.

Fourthly, I will exam the emergence of scaling properties and self-organizations in ecological systems, such as species-area curve, self-thinning law, etc. My talk will also include applications of this framework to study ecotone phase transitions, biological invasion, scaling from genomes to ecosystems, and global change biology.

Based on my own study and near 35 years working experience in the field, I have been so much inspired by Professor Ilya Prigogine's works and his thoughts. I met him in person only once, in 1992 Chaos Conference at Texas A&M University, College Station, USA; I showed him that how I used his theory: nonlinear Markov non-equilibrium thermodynamic stability theory to study ecological phase transitions and predict the tree-grass dynamics of savanna in southern Texas landscapes. I believe that his work and view will continue to inspire new generation of ecologists to study not only fundamental issues of ecology but also to very applied ecological problems in conservation biology, biological invasion, restoration ecology, ecological monitoring and assessment, global change, and sustainable development.

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SPECIAL PRIGOGINE AWARD LECTURE

Towards an energetically and thermodynamically-sounded approach to ecological complexity, modeling and sustainability

B. Larry Li
Professor and Director,
Ecological Complexity and Modeling Laboratory,
University of California

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Towards an energetically and thermodynamically-sounded approach to ecological complexity, modeling and sustainability

B. Larry Li
Professor and Director
Ecological Complexity and Modeling Laboratory,
University of California

Life is based on cycling of matter and consumption of energy. The spatial and temporal scales of these processes transcend from the micro-world, where living cells meet their energetic demand with nutrients diffusing through the cell wall, to the planetary scale, where continental vegetation cover and oceanic biota profoundly impact the global cycles of life essentials like water and carbon. On the basis of a holistic systems view and Prigogine and Haken's theories, my research has been focusing on addressing the following key questions: How do biological and ecological systems self-organize? What are the origins and mechanisms of emergence of scaling from individual to landscape levels (especially on emergence of dynamic scaling)? And what are the physical bases of non-equilibrium biological and ecological systems? I use mathematical, statistical, and computational modeling approaches as a way of exploring and answering these questions. These modeling approaches help identify general principles and basic mechanisms governing emerging properties of biological and ecological systems at multiple temporal and spatial scales based on energetic, thermodynamic and information considerations and allow us to have better understanding and modeling of ecological complexity, services and sustainability.

One of my earliest English paper entitled "Pansystems analysis: a new approach to ecosystem modelling" was published in Ecological Modelling in 1986 as part of 1984 ISEM Conference special issue edited by Professor Sven Jorgensen. In that paper, I proposed a new pansystems approach to study complex and strongly interacting dynamic processes in ecological system, i.e. the social-economic-natural complex ecosystems, and a rough framework of ecological complexity - modeling complex or large-scale ecosystems. This work, to large extent, reflected in part of my earlier views to apply Prigogine's far-from equilibrium thoughts to ecological systems.

In this lecture, I will start with re-examination of the classic logistic equation in population ecology, from the energy conservation law. We found that there exists a conservation of energy relationship comprising the terms of available resource and population density, jointly interpreted here as total available vital energy in a confined environment. We showed that this relationship determines a density-dependent functional form of relative population growth rate and consequently the parametric equations are in the form depending upon the population density, resource concentration, and time. Thus, the derived form of relative population growth rate is essentially a feedback type, i.e., updating parametric values for the corresponding population density. This resource dynamics-based feedback approach has been implemented for formulating variable carrying capacity in a confined environment. Particularly, at a constant resource replenishment rate, a density-dependent population growth equation similar to the classic logistic equation is derived, while one of the regulating factors of the underlying resource dynamics is that the resource consumption rate is directly proportional to the resource concentration.

Secondly, I will talk about energetic and thermodynamic foundation of ecological systems. A fundamental but unanswered biological question asks how much energy, on average, Earth's different life forms spend per unit mass per unit time to remain alive. Here, using the largest database to date, for 3,006 species that includes most of the range of biological diversity on the planet—from bacteria to elephants, and algae to sapling trees—we show that metabolism displays a striking degree of homeostasis across all of life. We demonstrate that, despite the enormous biochemical, physiological, and ecological differences between the surveyed species that vary over 1020-fold in body mass, mean metabolic rates of major taxonomic groups displayed at physiological rest converge on a narrow range from 0.3 to 9 W kg^{-1}. This 30-fold variation among life's disparate forms represents a remarkably small range compared with the 4,000- to 65,000-fold difference between the mean metabolic rates of the smallest and largest organisms that would be observed if life as a whole conformed to universal quarter power or third-power allometric scaling laws. The observed broad convergence on a narrow range of basal metabolic rates suggests that organismal designs that fit in this physiological window have been favored by natural selection across all of life's major kingdoms, and that this range might therefore be considered as optimal for living matter as a whole.

DELEGATE LIST

10th International Conference on
Ecosystems and Sustainable
Development

ECOSUD 2015

3 - 5 June, 2015

València, Spain

Organised by:
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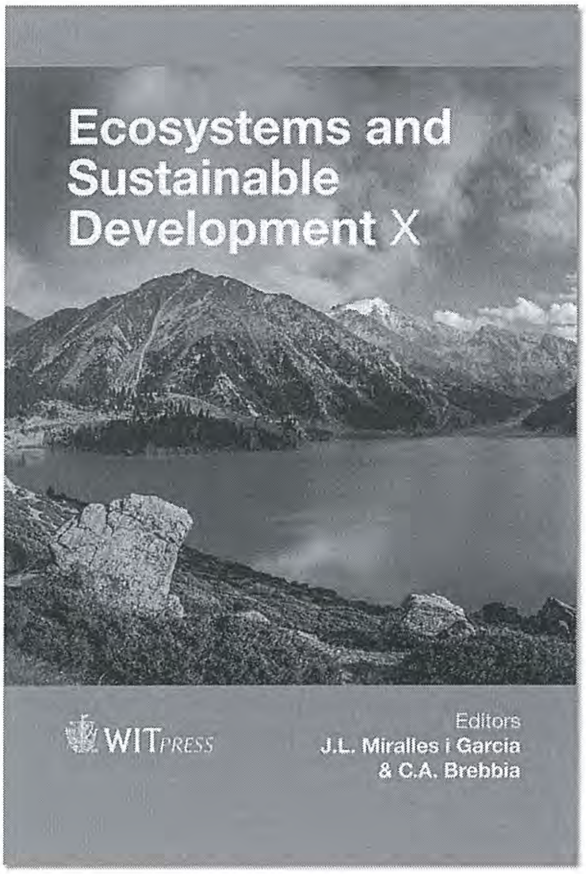
*Edited By: **J.L. Miralles i Garcia**, Universitat Politecnica de Valencia, Spain and **C.A. Brebbia**, Wessex Institute of Technology, UK*

The Tenth International Conference on Ecosystems and Sustainable Development is the latest in a well established series that originated from the work of the late Nobel laureate, Ilya Prigogine, who challenged us to develop the science of “”ecodynamics,”” integrating thermodynamics, ecology and economics. The papers presented at the conference, contained in this book, cover not only new research from all over the world related to ecological problems, but also new ideas and emerging concepts resulting from interdisciplinary efforts of scientists, engineers and economists.



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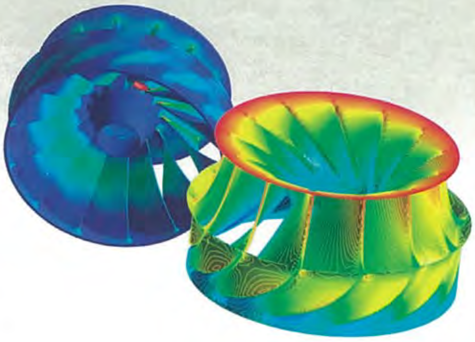
Located in the beautiful New Forest National Park on the south coast of England, Wessex Institute is a unique organisation serving the international scientific and industrial communities.

The overall aim of the Wessex Institute is to develop a series of knowledge transfer mechanisms, particularly directed towards the exchange of information between academics and professional users within industry.

This is achieved through a range of activities organised by a dedicated team of staff both within the Institute and its associate companies. A large network of prestigious contacts and links have been established with many organisations throughout the world.



Academic Research

The academic activities of Wessex Institute are centred on its New Forest campus at Ashurst Lodge. They consist of a series of post-graduate programmes, many of which are held in collaboration with other academic institutions around the world. These programmes of the Wessex Institute are supported by a variety of research and industrial organisations.

The academic success of the Institute can be measured by the substantial number of researchers who are in positions of responsibility in outstanding academic institutions and industry. Many have become full professors at some of the best UK universities including Imperial College, Nottingham and Brunel, whilst others are now professors in universities within their country of origin. These are major achievements for an independent research institution.

Wessex Institute is proud to retain strong links with its alumni, who actively collaborate with the activities of the institute. This interaction is another way in which WIT promotes the interchange of information.

Core Activities

Specialist Research within the areas of Computational Modelling, Damage Mechanics, Environmental Fluid Mechanics, Information Technology and Industrial Research.

It comprises research at post-graduate level as well as focusing on industrial requirements.

International Conference Programme that is constantly evolving in both size and scope. This has brought international renown to the Institute.

Publishing: WIT Press is the publishing arm of the Institute, which produces numerous scientific books, monographs, journals and edited works as well as the proceedings from the Institute's conference programme. This includes publication in digital as well as paper format.

Software: The software arm of the Institute continues to develop and maintain the Boundary Element Analysis System, which was originated by the Director of the Wessex Institute.

Services: The organisation provides support to industry in areas such as aerospace, offshore, naval and automotive, as well as specialised fields such as biomedicine, electromagnetics and fracture mechanics. Advanced consulting work for industry is one of the diverse ways of serving industry.

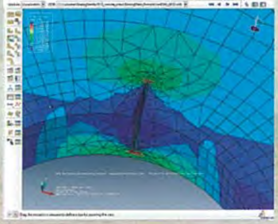
Major Research Activities

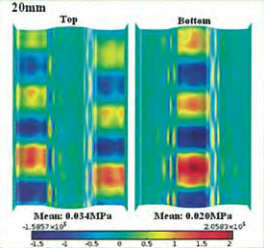
Research in Damage Mechanics relates to the development of computational tools based on the boundary element techniques for stress analysis problems.

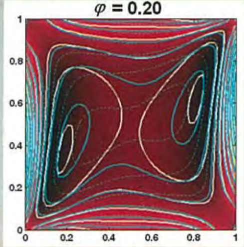
Work on Fluid Flow is dedicated to the modelling of environmental and fluid dynamics phenomena involving applications of high performance computing to the solution of problems in science and engineering.

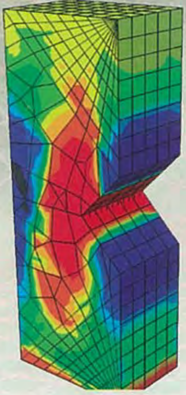
Industrial Research concentrates on solving problems of importance to industry and demonstrates the significance that Wessex Institute attaches to producing practical results.

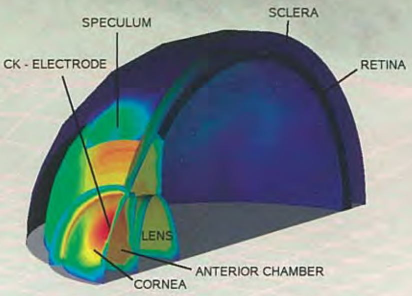
Advanced Modelling Techniques have been developed for the simulation of electrical – including cathodic protection systems – and electromagnetic problems. Applications include offshore studies, pipelines, biomedical, electromagnetic effects in the human body, acoustics and many others, mostly using Boundary Elements.

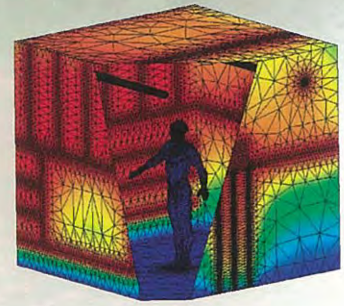












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WIT Press not only provides an essential contribution to the smooth running of the Institute's meetings by publishing their proceedings but also produces a substantial number of specialised monographs, and edited works as well as journals.

WIT Press publishes books and Journals in digital as well as paper format.

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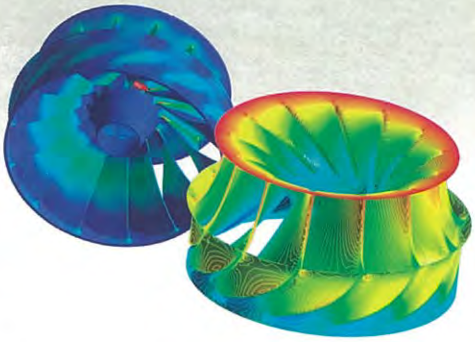

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Prof Carlos Brebbia

Wessex Institute is the brainchild of Professor Carlos Brebbia, who created WIT after a long and distinguished academic career.

Carlos was born in Argentina where he completed his first engineering degree. He spent two stimulating years after graduation as part of a small team setting up an Institute of Applied Mechanics. Following this, he registered at Southampton University in England for a higher degree, arranging to carry out his research partly at MIT. This experience, which he found most rewarding, set up the basis for his long and close association with the USA.

After obtaining his PhD at Southampton he worked for the Central Electricity Research Laboratories in the UK, a leading research establishment at the time. He left the Laboratories to take an academic position at Southampton University where he rose from Lecturer to Senior Lecturer and Reader. During his time at Southampton he took leave to become Visiting Professor at many other Universities, including an academic year at Princeton.

After having been appointed Full Professor of Engineering at the University of California, Irvine, he decided to return to the UK to set up Wessex Institute.

Carlos is renowned throughout the world as the originator of the Boundary Element Method, a technique that continues to generate important research work at Wessex Institute. He has written numerous scientific papers and is the author or editor of many books.

His current interests are in the field of strategic planning and research management and looking after all the activities at Ashurst Lodge to ensure that Wessex Institute and its associated companies continue to grow and develop in the right direction.

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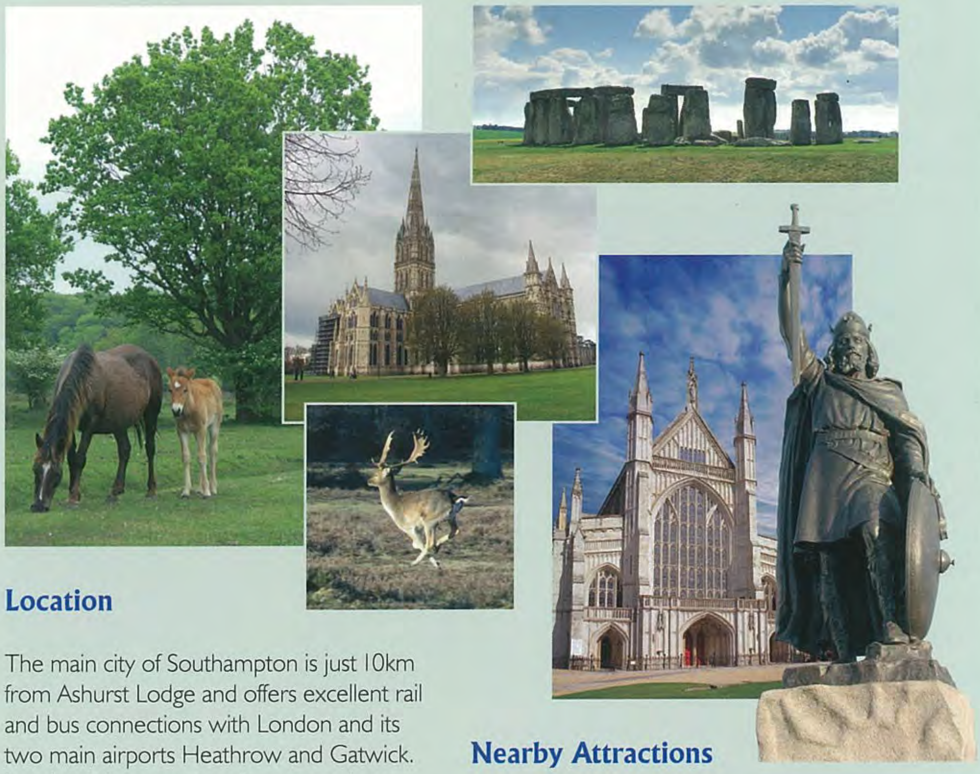

Accommodation and Facilities

The New Forest Campus offers excellent accommodation facilities for both its researchers and visitors. A series of individual rooms and purpose built cottages are available.

Residents may use the indoor swimming pool and all-weather tennis courts as well as other facilities on the campus.

Location

The main city of Southampton is just 10km from Ashurst Lodge and offers excellent rail and bus connections with London and its two main airports Heathrow and Gatwick. London is just over one hour away by rail from Southampton, with Eurostar connections to Paris and Brussels.

Ashurst Lodge itself is a short distance from a local train station (Ashurst New Forest) with rail services to Southampton and London.

The New Forest has two regional airports on its periphery – Southampton to the East and Bournemouth to the West – both within easy reach of Ashurst Lodge, offering many flights to different locations within Europe.

Nearby Attractions

Nearby Lyndhurst caters for day-to-day needs and has good pubs and restaurants. It is also the home of the New Forest Museum. Southampton has an excellent shopping centre, including a large mall and department stores as well as cinemas, theatres and museums.

Several major historic cities and sites are also within easy reach, such as Winchester, Salisbury and Stonehenge.

The New Forest itself has numerous places to visit and is the perfect location for enjoying walking, horse riding, cycling, sailing and fine landscapes. For more information on the New Forest see C. A. Brebbia's book "The New Forest – A personal view" WIT Press, Southampton. Available online at: *www.witpress.com*

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