出國報告 (出國類別：出席國際會議)

第73屆國際執行委員會會議暨
第24屆國際灌溉排水研討大會

服務機關：經濟部水利署水利規劃試驗所、經濟部水利署中區水資源局
姓名職稱：陳春宏所長、張庭華局長
派赴國家/地區：澳洲阿得雷德
出國期間：111年10月3日至111年10月10日
報告日期：112年1月

出國報告審核表

出國報告名稱：第 73 屆國際執行委員會議暨第 24 屆國際灌溉排水研討大會		
出國人姓名 （2 人以上，以 1 人為代表）	職稱	服務單位
陳春宏	所長	經濟部水利署水利規劃試驗所
出國類別	□考察 □進修 □研究 □實習 □視察 □訪問 ■開會 □談判 □其他＿＿＿＿＿＿＿＿ (出國類別請依預算書之計畫預算類別填列)	
出國期間：111 年 10 月 3 日至 111 年 10 月 10 日	報告繳交日期： 112 年 1 月 3 日	

出國人員自我檢核	計畫主辦機關審核	審　核　項　目
■	■	1.依限繳交出國報告
■	■	2.格式完整（本文必須具備「目的」、「過程」、「心得及建議事項」）
■	■	3.無抄襲相關資料
■	■	4.內容充實完備
■	■	5.建議具參考價值
■	■	6.送本機關參考或研辦
□	□	7.送上級機關參考
□	□	8.退回補正，原因：
□	□	（1）不符原核定出國計畫
□	□	（2）以外文撰寫或僅以所蒐集外文資料為內容
□	□	（3）內容空洞簡略或未涵蓋規定要項
□	□	（4）抄襲相關資料之全部或部分內容
□	□	（5）引用相關資料未註明資料來源
□	□	（6）電子檔案未依格式辦理
■	■	9.本報告除上傳至公務出國報告資訊網外，將採行之公開發表：
■	■	（1）辦理本機關出國報告座談會（說明會），與同仁進行知識分享。
□	□	（2）於本機關業務會報提出報告
□	□	（3）其他＿＿＿＿＿＿＿＿＿＿
□	□	10.其他處理意見及方式：

出國人簽章（2 人以上，得以 1 人為代表）	計畫主辦機關審核人	一級單位主管簽章	機關首長或其授權人員簽章
經濟部水利署水利規劃試驗所所長 陳春宏		綜合企劃組組長 郭純伶	經濟部水利署署長 賴建信

說明：

一、各機關可依需要自行增列審核項目內容，出國報告審核完畢本表請自行保存。

二、審核作業應儘速完成，以不影響出國人員上傳出國報告至「公務出國報告資訊網」為原則。

摘 要

第73屆國際執行委員會會議暨第24屆國際灌溉排水研討大會於10月3日至10月10日在澳洲阿得雷德國際會議中心舉辦，此次會議共有來自53個國家、超過2,000位官員、學者與專業人士參與，同時設置展覽區，邀請國家委員會與相關廠商申請，共超過100個單位參展。

國際灌排協會中華民國國家委員會(CTCID)由吳瑞賢主席帶領，代表團成員來自農田水利署管理處、經濟部、大專院校、研究單位等共16名組成，包含工作小組委員8人、團體會員代表6人以及秘書處2人。CTCID今年度持續擴大參與工作小組，提名余化龍副主席、王聖瑋助理教授與陳志昇副秘書長等學者專家分別新加入共 5個工作小組：現代化灌溉工作小組、灌溉發展與管理工作小組、非常規水灌溉工作小組、亞洲區域工作小組，以及能力建構發展訓練與教育工作小組，以上皆為大會所接受。

第24屆國際灌溉排水研討大會主題為「邁向永續發展為目標之農業水資源管理創新與研究」，包含議題如下：

- 特別議題：發展管理灌溉水源不確定性之新工具;
- 問題集62：資訊與傳播科技在最後一哩路扮演的角色;
- 問題集63：如何透過跨學門對話達到永續發展的目標。

CTCID秘書處協助農水署蔡昇甫署長等學者、專家投稿「2020-2021臺灣嚴重乾旱事件之水文歷程與抗旱供灌策略經驗 (The Hydrological Processes of Taiwan’s Severe Drought Event During 2020-21 and the Experience of Irrigation Strategies for Fighting Drought) 」，並被大會接受。因新冠肺炎疫情，投稿人不克親自出席會議，在會場中由吳瑞賢主席代為發表論文報告，將台灣的成功抗旱經驗分享給全世界，獲得在場國際人士高度的讚揚。

因2022年國內外新冠肺炎疫情仍嚴峻，加上出國返國隔離規定嚴格，今年初，學者參與國際研討會投稿以及出席國外會議意願都不高，因此本年度，我國投稿與發表論文數目較低，本次出國的規模也較往年縮小。此外，為了避免我國代表團出國染疫，今年度不安排技術參訪活動。將重點置於參觀國際灌溉排水展覽大會，讓我國團員透過實地接觸國外廠商以及科研單位，得以完整了解國際間灌排技術發展現況。

本次CTCID籌組代表團出國宣揚我國灌排技術，並藉由國際灌溉排水協會平台與各國穩定交流互動，擴大行銷推廣台灣經驗，建立與其他國家之實務合作契機，推展農業外交。

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壹、目的

國際灌溉排水協會(International Commission on Irrigation and Drainage, ICID) 係聯合國國際糧農組織(FAO)及世界銀行等機構於 1950 年 6 月 24 日成立，為一科學、技術和非營利為目的之國際組織，於 1993 年改為非政府國際組織(NGO)，迄今計有 81 個會員國，包括 20 個非洲國家委員會、6 個美洲國家委員會、27 個亞太地區國家委員會以及 24 個歐洲國家委員會。ICID 致力於灌溉、排水、防洪及環境管理等技術研討，希望在維護永續灌溉農業環境的理念下，提升世界糧食之生產力；其主旨為以工程、農糧、經濟、生態及社會等不同專業領域應用於水土資源管理，達到永續灌溉農業環境的維護。目前 ICID 於水管理技術和處理相關問題已累積近 70 年的豐富經驗。ICID 於年會召開期間，均同時辦理大型國際灌溉排水技術研討大會，每屆 3 年為一週期，以世界灌溉論壇、ICID 灌溉排水研討大會，以及區域/技術研討會議等形式輪替辦理，並出版專題報告供各會員國參考。

ICID 於總會下設立策略與組織委員會(PCSO)及技術活動常設委員會(PCTA)，委員會下設置 26 個工作小組(Working Groups)，各工作小組委員之任期為 3 至 6 年，於每一年評估各工作小組工作任務與執行成果，並研商新設工作小組之必要性。我國 CTCID 本年度檢討參與 ICID 工作小組委員制度，調整後新提名委員 3 位(余化龍副主席、陳志昇副秘書長、王聖瑋助理教授)，擴大參與 5 個工作小組。目前我國專家學者共計 19 位參與 19 個工作小組。

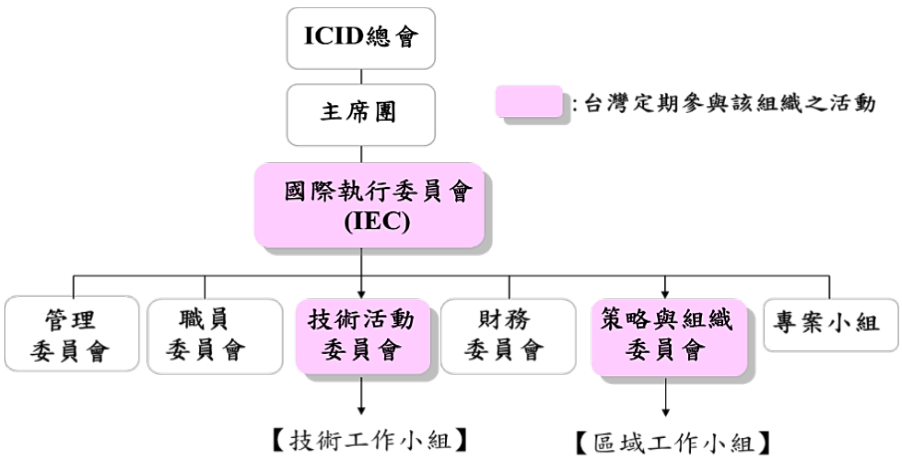

圖 1-1 國際灌溉排水協會組織圖

我國於 1969 年由農復會(現行政院農業發展委員會)申請加入國際灌溉排水協會，至 1995 年由有關機關及團體共同組成社團法人國際灌溉排水協會中華民國國家委員會(Chinese Taipei Committee, International Commission on Irrigation and Drainage, 簡稱 CTCID)，旨在透過組織，以專業化之團隊，促進國內外灌溉排水相關學術、技術之交流，以提升我國灌溉排水知識及技術水準。本委員會迄今計有官方、學術單位、農田水利會等 42 個團體會員。早期由政府機關派員參加相關國際活動，現今則由產官學各領域之團體會員每年組織代表團參與國際灌溉排水協會年會。我國國家委員會積極參與國際灌溉排水協會相關事務，除了每年參與年度大會及各項研討會議，亦曾有代表擔任研討會論文審稿委員、各相關技術工作小組主任委員及委員等。我國成員表現亮眼，且於 ICID 之工作小組擔任要職，頗具影響力。同時透過與各國專家及農田水利專業領導人交流，不僅充分吸收國外新知掌握世界趨勢，更將台灣優良的農田水利技術與政策發揚於國際，建立台灣之國際地位。歷年來，多次面對台灣國際外交之艱難處境，代表團均能妥善處理，積極貢獻心力與智慧。一則與國際友人維持良好情誼，爭取生存空間；二則致力於發表學術及技術相關論文著作，充分展現我國灌溉排水之專業實力。

本次組團出國之目的，為參加第 73 屆國際執行委員會會議暨第 24 屆國際灌溉排水研討大會，透過實質參與 ICID 年會，發揮 CTCID 國際灌排技術交流的角色，協助政府加強與他國交流契機，進而拓展國家間之交流合作活動，提升我國於國際的能見度，拓展農業外交。

貳、過程

一、2022年會參加團員

表 2-1 參加團員一覽表

序號	姓 名	機關名稱 /職稱
1	吳瑞賢	國際灌溉排水協會中華民國國家委員會 主席 中央大學土木工程系 特聘教授兼副校長
2	余化龍	國際灌溉排水協會中華民國國家委員會 副主席 臺灣大學生物環境系統工程學系 教授兼系主任
3	高瑞棋	成功大學水工試驗所 督導長
4	闕雅文	清華大學環境與文化資源學系 教授
5	丁崇峯	成功大學水工試驗所 研究員兼組長
6	劉日順	農業工程研究中心 副研究員
7	何昊哲	臺灣大學土木工程學系 助理教授
8	王聖瑋	淡江大學水資源與環境工程學系 助理教授
9	陳志昇	國際灌溉排水協會中華民國國家委員會 副秘書長 台灣水資源與農業研究院國際合作處 處長
10	張庭華	經濟部水利署中區水資源局 局長
11	陳春宏	經濟部水利署水利規劃試驗所 所長
12	陳明儀	行政院農委會農田水利署南投管理處 副處長
13	黃漢榮	行政院農委會農田水利署宜蘭管理處 主任工程師
14	楊德川	行政院農委會農田水利署新竹管理處 主計室主任
15	吳仁耀	行政院農委會農田水利署雲林管理處 助理管理師
16	倪佩君	國際灌溉排水協會中華民國國家委員會 秘書處 台灣水資源與農業研究院行政管理處 處長

註：行政院農委會農田水利署黃瓊瑤專門委員，因確診新冠肺炎，不克參加。

圖 2-1 澳洲阿德雷德國際會議中心

圖 2-2 本屆 CTCID 代表團於開幕典禮中合影

<table>
<tr><th colspan="3">吳 瑞 賢</th></tr>
<tr><td rowspan="4"></td><td>服務機關</td><td>中央大學</td></tr>
<tr><td>職　稱</td><td>特聘教授兼副校長</td></tr>
<tr><td>參與會議</td><td>• 73 屆國際執行委員會議【IEC】
• 亞洲區域工作小組
• 技術活動委員會
• 氣候變遷工作小組
• 期刊編輯工作小組
• 灌溉區蓄水工作小組</td></tr>
<tr><td>ICID
擔任職務</td><td>• 中華民國國家委員會 主席
• 亞洲區域工作小組 委員
• 氣候變遷工作小組 主任委員
• 期刊編輯工作小組 委員
• 灌溉區蓄水工作小組 委員</td></tr>
<tr><th colspan="3">余 化 龍</th></tr>
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<tr><td>職　稱</td><td>教授兼系主任</td></tr>
<tr><td>參與會議</td><td>• 現代化灌溉工作小組
• 灌溉發展與管理工作小組</td></tr>
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擔任職務</td><td>• 中華民國國家委員會 副主席
• 現代化灌溉工作小組 委員
• 灌溉發展與管理工作小組 委員</td></tr>
<tr><th colspan="3">高 瑞 棋</th></tr>
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<tr><td>職　稱</td><td>督導長</td></tr>
<tr><td>參與會議</td><td>• 技術活動委員會
• 感潮區永續發展工作小組</td></tr>
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擔任職務</td><td>感潮區域永續發展工作小組 主任委員</td></tr>
<tr><th colspan="3">闕 雅 文</th></tr>
<tr><td rowspan="4"></td><td>服務機關</td><td>清華大學環境與文化資源學系</td></tr>
<tr><td>職　稱</td><td>教授</td></tr>
<tr><td>參與會議</td><td>• 社會經濟轉型下之灌溉排水工作小組
• 價值工程工作小組</td></tr>
<tr><td>ICID
擔任職務</td><td>• 社會經濟轉型下之灌溉排水工作小組 委員
• 價值工程工作小組 委員</td></tr>
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<tr><td>職　稱</td><td>研究員兼組長</td></tr>
<tr><td>參與會議</td><td>水、糧食與能源鏈結工作小組</td></tr>
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擔任職務</td><td>水、糧食與能源鏈結工作小組 委員</td></tr>
<tr><td colspan="3">劉 日 順</td></tr>
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<tr><td>職　稱</td><td>副研究員</td></tr>
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• 灌排管理制度工作小組</td></tr>
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• 灌排管理制度工作小組 委員</td></tr>
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<tr><td>職　稱</td><td>助理教授</td></tr>
<tr><td>參與會議</td><td>• 環境工作小組
• 土地排水工作小組</td></tr>
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擔任職務</td><td>• 環境工作小組 委員
• 土地排水工作小組 委員</td></tr>
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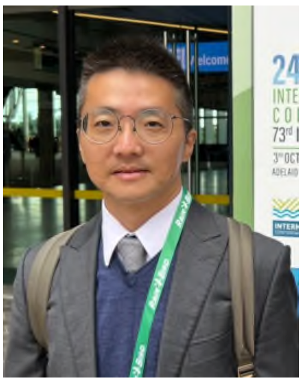
<tr><td rowspan="4"></td><td>服務機關</td><td>淡江大學水資源與環境工程學系</td></tr>
<tr><td>職　稱</td><td>助理教授</td></tr>
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• 灌溉發展與管理工作小組</td></tr>
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• 灌溉發展與管理工作小組 委員</td></tr>
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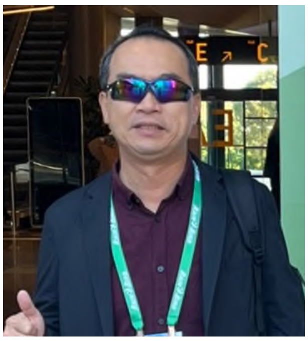
<tr><td>職　稱</td><td>國際合作處處長</td></tr>
<tr><td>參與會議</td><td>• 73 屆國際執行委員會議【IEC】
• 亞洲區域工作小組
• 能力建構發展訓練與教育工作小組
• 氣候變遷工作小組 (代理小組秘書)</td></tr>
<tr><td>ICID
擔任職務</td><td>• 中華民國國家委員會 副秘書長
• 亞洲區域工作小組 委員
• 能力建構發展訓練與教育工作小組委員</td></tr>
<tr><th colspan="3">張 庭 華</th></tr>
<tr><td rowspan="3">
</td><td>服務機關</td><td>經濟部水利署中區水資源局</td></tr>
<tr><td>職　稱</td><td>局長</td></tr>
<tr><td>參與會議</td><td>• 標的競用下的缺水管裡工作小組
• 灌排管理制度工作小組</td></tr>
<tr><th colspan="3">陳 春 宏</th></tr>
<tr><td rowspan="3">
</td><td>服務機關</td><td>經濟部水利署水利規劃試驗所</td></tr>
<tr><td>職　稱</td><td>所長</td></tr>
<tr><td>參與會議</td><td>• 亞洲區域工作小組
• 標的競用下的缺水管理工作小組</td></tr>
<tr><th colspan="3">陳 明 儀</th></tr>
<tr><td rowspan="3"></td><td>服務機關</td><td>行政院農委會農田水利署南投管理處</td></tr>
<tr><td>職　稱</td><td>副處長</td></tr>
<tr><td>參與會議</td><td>• 永續田間灌溉系統發展工作小組
• 灌溉區蓄水工作小組</td></tr>
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<table>
<tr><td colspan="3">黃 漢 榮</td></tr>
<tr><td rowspan="3">
</td><td>服務機關</td><td>行政院農委會農田水利署宜蘭管理處</td></tr>
<tr><td>職　稱</td><td>主任工程師</td></tr>
<tr><td>參與會議</td><td>• 永續田間灌溉系統發展工作小組
• 灌排管理制度工作小組</td></tr>
<tr><td colspan="3">楊 德 川</td></tr>
<tr><td rowspan="3">
</td><td>服務機關</td><td>行政院農委會農田水利署新竹管理處</td></tr>
<tr><td>職　稱</td><td>主計室主任</td></tr>
<tr><td>參與會議</td><td>• 永續田間灌溉系統發展工作小組
• 灌溉區蓄水工作小組</td></tr>
<tr><td colspan="3">吳 仁 耀</td></tr>
<tr><td rowspan="3"></td><td>服務機關</td><td>行政院農委會農田水利署雲林管理處</td></tr>
<tr><td>職　稱</td><td>助理管理師</td></tr>
<tr><td>參與會議</td><td>• 氣候變遷工作小組
• 灌溉發展與管理工作小組</td></tr>
<tr><td colspan="3">倪 佩 君</td></tr>
<tr><td rowspan="3"></td><td>服務機關</td><td>台灣水資源與農業研究院</td></tr>
<tr><td>職　稱</td><td>行政管理處處長</td></tr>
<tr><td>參與會議</td><td>• 第 73 屆國際執行委員會(IEC)</td></tr>
</table>

二、2022年會議程

第 24 屆國際灌溉排水研討大會主題:「邁向永續發展為目標之農業水資源管理創新與研究」子議題如下：

- 特別議題：發展管理灌溉水源不確定性之新工具;
- 問題集 62：資訊與傳播科技在最後一哩路扮演的角色;
- 問題集63：如何透過跨學門對話達到永續發展的目標。

表 2-2 2022 年國際灌溉排水協會年度會議議程

日期 (星期)	時間	大會議程	委員 代表	出席 人員
10/3 (一)	抵達阿得雷德		全體人員	
	14:00-17:00	國際研習會：【WG-SDTA】 感潮區永續發展工作小組	高瑞棋	丁崇峯
10/4 (二)	08:00	報到註冊	全體人員	
	08:45-13:00	國際研習會：【WG-WFE_N】 水、糧食與能源鏈結工作小組	丁崇峯	
		第 24 屆國際灌溉排水研討大會[1] 〔問題集 62.1、63.1、63.2〕	全體人員	
	18:00-19:00	國家委員會代表會議	秘書處	
10/5 (三)	08:45-10:30	大會開幕典禮	全體人員	
	11:15-13:00	第 24 屆國際灌溉排水研討大會[1] 〔問題集 62、63〕 總報告	全體人員	
	14:00-15:45	第 24 屆國際灌溉排水研討大會[1] 〔問題集 62.1〕、〔特別議題〕	全體人員	
	16:15-17:00	第 24 屆國際灌溉排水研討大會[1] 〔問題集 62.2、62.3、63.2、63.3〕	全體人員	
	17:00-18:30	大會晚宴 (Exhibition Hall)		

日期 (星期)	時間	大會議程	委員 代表	出席 人員
10/6 (四)	08:45-10:30	【IEC】國際執行委員會議 (第一場)	吳瑞賢	秘書處
	11:15-13:00	國際研習會：【WG-M&R】 現代化灌溉工作小組	余化龍	
		國際研習會：【WG-IOA】 灌排管理制度工作小組 (11:20-11:35)	章國珍	
		第 24 屆國際灌溉排水研討大會 [1] 〔特別議題〕、〔座談評論〕	全體人員	
	14:15-16:00	國際研習會：【WG-IOA】 灌排管理制度工作小組 (15:15-15:30)	吳瑞賢、劉日順	
	16:15-18:00	第 24 屆國際灌溉排水研討大會 [1] 結論報告	全體人員	
	18:00-21:00	台灣代表團全體聚餐	全體人員	
10/7 (五)	09:00-13:00	【ASRWG】 亞洲區域工作小組會議	吳瑞賢 陳志昇	陳春宏
		【WG-ENV】 環境工作小組會議	何昊哲	
		【WG-SON-FARM】永續田間 灌溉系統發展工作小組會議	余化龍	陳明儀 楊德川 黃漢榮
	09:00-10:45	【WG-NCWRI】 非常規水灌溉工作小組會議	王聖瑋	
	11:15-15:45	【WG-WFE_N】水、糧食與能源鏈結工作小組會議	丁崇峯	
	14:00-18:00	【WG-CLIMATE】 氣候變遷工作小組會議	吳瑞賢 劉日順	吳仁耀
		【WG-VE】 價值工程工作小組會議	闕雅文	

日期 (星期)	時間	大會議程	委員 代表	出席 人員
10/8 (六)	09:00-13:00	【EB-JOUR】 期刊編輯工作小組會議	吳瑞賢	
		【WG-SDTA】感潮區永續 發展工作小組會議	高瑞棋	
		【WG-IDSST】社經經濟轉型下之灌溉排水工作小組會議	闕雅文	
		【WG-WATS】 灌溉區蓄水工作小組會議	劉日順	陳明儀 楊德川
		【WG-MWSCD】標的競用下的缺水管理工作小組會議	王聖瑋	張庭華 陳春宏
	14:00-18:00	【WG-HIST】 灌溉史工作小組會議	游進裕	
		【WG-IDM】灌溉發展與管理工作小組會議	王聖瑋	吳仁耀
		【WG-M&R】 現代化灌溉工作小組會議	何昊哲	
		【WG-CDTE】 能力建構發展訓練與教育	陳志昇	
		【WG-IOA】 灌排管理制度工作小組會議	劉日順	張庭華 黃漢榮
10/9 (日)	09:00-18:00	【PCTA】 技術活動委員會會議	高瑞棋	
10/10 (一)	09:00-18:00	【IEC】 第 73 屆國際執行委員會議及 閉幕式	吳瑞賢 陳志昇	
10/11 (二)	返回台灣		全體人員	

參、心得與建議

一、心得

第73屆國際執行委員會暨第24屆國際灌溉排水研討大會於澳洲阿得雷德會議中心舉辦，此次會議共有來自53個國家、超過2,000位代表參與，同時設置國際灌溉排水設備與機具展覽區，邀請各國家委員會與國際間知名的灌溉排水設備與機具相關廠商參與，共超過100個單位參展。

因新冠肺炎疫情，旅遊與國際交通仍然受限，國際航班大減，交通費用也大幅增加，各國家委員會參與不若往年踴躍，CTCID代表團此次依然不在國際重要場合缺席，秉持讓世界看見台灣的精神，積極參與國際組織，台灣的學者專家在第73屆國際執行委員會暨第24屆國際灌溉排水研討大會，將台灣灌排成果積極與國外代表分享，讓世界各國得以完整了解台灣灌排技術發展現況。

1、第73屆國際執行委員會議(簡稱IEC大會)

本屆以1天半的時間分三階段進行，第一階段為重要事項報告及指定會員國進行專案報告，開放所有人員參與；第二、三階段則屬組織運作報告與人事調整等會務討論，僅開放會員國主席與指定代表參加。第73屆國際執行委員會議由吳瑞賢主席、陳志昇副秘書長與高瑞棋督導長出席，參與該組織會務運作之議題討論，會議中，吳瑞賢主席代表CTCID行使副主席票選之權利，以及其他重要事項之表決權。

(1) 認定世界灌溉工程遺產名錄

世界灌溉工程遺產名錄自2014年設立，目的在於追尋世界灌溉文明發展脈絡、促進灌溉工程遺產保護，總結傳統灌溉工程優秀的治水智慧，為可持續灌溉發展提供歷史經驗和啟示。2022年共有來自澳洲、印度、伊拉克、日本、韓國、斯里蘭卡等國的15個灌溉工程項目，提出申請登錄至世界灌溉工程遺產名錄。經過審核通過後，目前世界灌溉工程遺產總數量已達到140項，遍布亞洲、歐洲、非洲、北美洲和大洋洲五大洲的18個國家。

(2) 2022-2024副主席選舉投票

根據ICID組織章程規定，副主席任期為3年，本年度適逢3位副主席任期屆滿，需重新改選。我國為正式會員，可行使投票權，吳瑞賢主席於會上投出神聖的一票，最後由法國籍的Bruno Grawitz、南非籍的Sylvester Mpandeli，以及印度籍的Kushvinder Vohra當選為新任副主席。

(3) 財務委員會主席報告重點

財務委員會首先報告2021-2022年財務狀況，目前ICID營收狀況尚為平穩。不過，有數個國家連續三年未繳交會費，將暫時停權，不視為積極會員，待未來恢復繳費，才可重新行使其會員國權利。此外，委員會建議財務狀況良好的國家

委員會，能夠資助相對財務困難的弱勢國家，以期未來能有更多的國家能夠參與 ICID 的活動與會議。

(4) 國家委員會報告

今年大會邀請埃及與澳洲國家委員會分別報告該國灌溉排水現況、發展以及面臨挑戰。

(5) 今年度各獎項頒發

頒發大會相關獎項，請見表 3-1。

(6) 國際灌排協會未來會議預告

未來會議時程安排，請見表 3-2。

表 3-1 各獎項獲獎人

獲獎人	獲獎成果
節水創新水資源管理獎 Innovative Water Management Award	
Li Gendong, Su Xiaofei (中國)	Water Rights Trading of Hetao Irrigation Scheme
節水技術獎 Technology Award	
Sumith Choy, Varun Ravi, N Srinivas Reddy, and Satya N Jaddu (澳洲)	Leveraging Canal Automation Technology To Improve Karnataka’s Precious Water Resources
青年學者獎 Young Professional Award	
Ramtin Nabipour Shiri (伊朗)	Drip Tape Irrigation of Transplanted Rice in Puddled Paddy Soil
農夫獎 Farmers Award	
Nader Zarei (伊朗)	Cultivation Model Compatible With Arid And Semi-arid Climate Of Iran In Order To Increase Water’s Economic Productivity

表 3-2 年度會議預告

會議名稱	時間	地點
第 4 屆世界灌溉論壇	2023/4/16 - 4/22	中國・北京
第 74 屆國際執行委員會暨 第 25 屆國際灌溉排水研討大會	2023/11/16- 11/13	印度•維沙卡帕特南

2、技術活動委員會工作小組會議

技術工作小組會議部分，則由各工作小組委員、行政院農委會農田水利署管理處代表，以及經濟部水利署代表共同參加，整體技術活動委員會(PCTA)則由高瑞棋督導長代表出席。此次參與小組包含亞洲區域工作小組、環境工作小組、感潮區永續發展工作小組、標的競用下的缺水管理小組、氣候變遷工作小組、社會經濟轉型下之灌溉排水工作小組、期刊編輯工作小組、灌溉史工作小組、價值工程工作小組、多語言技術辭典工作小組、能力建構發展訓練與工作小組、永續田間灌溉系統發展工作小組、水與農作工作小組、非常規水灌溉工作小組、灌排管理制度工作小組、現代化灌溉工作小組、灌溉發展與管理工作小組、灌溉區蓄水工作小組等。我國代表團也有參與數場國際研習會，在工作小組會議召開之前，先就重要議題進行討論。

(1) 價值工程工作小組：

a.本年度通過提名中國會員一名。

b. 本年度再度重申 Working Group on Value Engineering (WG-VE)的目標是促進價值方法論（價值工程、價值分析、價值規劃、價值管理和價值工程變更建議(VECP)）在灌溉、排水和洪水管理項目中的應用，以增加效益 ，降低成本並確保可持續的農業灌溉。亦討論未來教育訓練之可能。價值工程亦可應用於多面向之水資源工程之管理，本年度亦說明重要價值工程的議題。

c.本次會議馬來西亞、日本亦分享該國價值工程計劃管理之實行經驗。

d. 2021 年疫情期間，WG-VE 工作小組由主席 Dr. Kamran Emami 出版-Value Engineering for Savings in Irrigation, Drainage and Flood Management Projects,書中詳述價值工程之理論與演進，並說明價值工程在加拿大、伊朗、日本、美國之執行經驗。

(2) 環境工作小組：

a.本年度未有新提名案，惟對於連續二年以上於工作小組皆未有貢獻者，將解除其委員職務。

b.工作小組的主席以屆齡退休，因此 ICID 大會副主席 Prof. Choi, Jin-Yong 有來此工作小組，建議工作小組可以討論主席換人一事，為工作小組主席此次因簽證問題沒有出席，代主席決議 2023 年 1 月召開線上會議再進行討論。

c.WG-ENV 主要是向決策者、規劃者、設計者和管理者提供有關灌排系統環境方面的指導，包括對氣候和人類健康的影響。工作組的目標是打造永續管理的環境，最大限度地發揮灌排系統的作用和減少其不利影響。

d.定期的線上會議將於 1 月的第 2 周召開，會再用郵件進行通知。

(3) 感潮區永續發展工作小組：

本次研討會由高瑞棋主席主持，因斯里蘭卡及伊朗 4 位作者無法到場報告，研討會僅韓國、印尼及印度報告該國海岸地區(潮間帶)之水庫操作、河川水質即時監控對農業灌溉之操作模式，以及強化基礎建設，提高灌溉用水效率對作物生產的貢獻。

a.由韓國以海岸地區的 Boryeong 水庫為例，分析不同標的用水間之水源調度，以最佳化用水效率。該水庫為農業及工業用水庫，作者利用妥協理論分析兩個不同標的間的水源分配情境，以兼顧農業生產及工業用水需求，創造最大用水效益。考慮社會經濟因素導致的水田面積減少、輸水效率和水田灌溉的平均回流率。在工業供水對水庫運行影響不大的情況下，水庫可通過高效用水管理和乾旱節水灌溉提供工業用水。最後，安裝足夠容量的蓄水設施可以在確保水庫運行的同時增加水田和電廠供水的供水靈活性。

b.馬來西亞某供灌河川水質狀況不佳，除鹽化外尚有硫酸鹽(Acid Sulphate)過高問題，在長達 16 公里的感潮河川中，透過即時性水質監測儀器，在乾濕季節利用不同河段的水源，例如乾季時在感潮段更上游河段引河水稀釋供灌，濕季時可在下游及取表面河水供灌。

c.印度因人口增加，為穩定糧食，計畫性擴大灌溉面積，同時希望兼顧提高用水效率，除增加滴灌系統、建置灌溉用抽水站等基礎建設外，且大量使用地下水，全印度每年地下水用量達 2,460 億噸，但因加強田間用水管理，間接提高作物產質及產量。

(4) 非常規水灌溉工作小組：

a.本年度新提名案包括王聖瑋助理教授與巴基斯坦提名之 Dr. Usman Khalid Awan，王聖瑋亦於會議進行自我介紹，且在場其他成員無異議、提名獲通過，會後將由大會正式通知。惟對於連續二年以上於工作小組皆未有貢獻者，將解除其委員職務。

b.持續推動 2030 非常規水灌溉工作小組之行動計畫方案，本工作小組主要負責策略 7 運用廢水或水質劣化水源於灌溉用水之三項行動，包括彙整可持續管理和使用非常規水資源的最佳實施方案、建立有助於廢水處理再利用於灌溉之國家政策、參與污水開發研究等。

c.本次會議前已於摩洛哥會議中討論重新檢視 2022 年的行動計畫與達成指標，並列入 2030 年整體行動計畫的一部分，本年度已召開三場次線上會議，分別討論非常規水用於糧食生產、鹽水灌溉指引文件、非常規水資源用於灌溉之培訓等。

d.討論本工作小組之工作計畫，本小組主席已於今年三月初擬非常規水運用之文件，其中有關水回收再利用於灌溉之標準，經討論後需再納入目前各國最

新資訊，以利於與以往 WHO 及 FAO 制訂的標準有所區隔，亦期望可以納入風險評估、風險預防、水質管理等篇幅，目前版本已由 Dr. Anna 完成章節架構並亟需工作小組成員協助完成各章節內容，ICID 主席 Dr. Ragab 建議邀請曾參與 FAO 制訂標準之有經驗的成員協助完成，並建議增加符合當前非常規水發展的資訊、實驗室與現地量測鹽度方法之差異、避免浪費水資源等章節內容。針對上述內容，目前並無成員自願協助完成，因此暫由本工作小組主席負責，近期將決定後續分工方式。

e.有關創新非常規水利用的相關資訊，於本年度第一次線上會議時曾建議各成員提供各國相關文獻，並由 Dr. Kato 進行彙整，目前已初步完成並將於會後提供各成員審視與修正。

f.請各委員全力配合辦理 ICID 成員個人資料登錄 (https://icid.bmeurl.co/C7D4D2E)，並請各位委員能多參與 Webinar 之線上會議，有關 Webinar 之記錄亦可由工作小組提供的 Dropbox 連結下載。

(5) 氣候變遷工作小組：

a.本次氣候變遷工作小組會議由主席吳瑞賢教授報告本年度各項工作執行情形，本年度計有來自加拿大、巴基斯坦及馬來西亞國家委員會各有新提名委員 1 名，其中馬來西亞國家委員會所提名的 Ir. Wan Noorul Hafilah Binti Wan Ariffin，並到場進行簡要報告有關「馬來西亞的氣候變化、糧食安全與用水」主題。本次會議主要討論議程含本工作小組成員的個人資料更新工作，已於 ICID 網站本工作小組網頁下可查詢、修改，經由吳主席現場說明其帳號與密碼修改方式後，並期請各委員自行登入並修改需更新之資料，以提供 ICID central office 進行更新。

b.有關達成本工作小組出版品產出之工作面向部份，主席依照先前於 6 月份召開工作小組視訊會議所討論的工作大綱、章節，並指派小組委員，分別負責該專章。因應氣候變遷、智慧灌溉用水管理方面的資訊交流，希望以各委員常態性的工作成果加以彙整後，提供於本工作小組作為相關篇章的內容，工作小組的成員 Nozar Ghahreman 提議由本小組年輕的委員產出之工作貢獻，加入本項出版品的內容。

c.本工作小組會議期間，工作小組的成員 Nozar Ghahreman 報告其使用衛星資料和氣候資料對實際蒸散量估計的不確定性分析成果，經由其說明，了解了欲使用來自不同空間分辨率的氣候數據庫的蒸散量數據，用以計算最佳水文參數，需要進行不確定性識別，而其亦提出結果表明，GLEAM 和 ERA-Interim 數據庫相關性強，平均差異較小，可作為參考使用。

(6) 社會經濟轉型下之灌溉排水工作小組：

a.社會經濟轉型下之灌溉排水工作小組的主要目標是作為在社會經濟轉型之下 ICID 國家委員會的平台，以克服社會經濟轉型之下灌溉和排水方面的各國所面對的某些共同問題。例如：可能的政府對農業、水資源管理、灌溉和排水的補貼規模和方向的變動；永續發展議題；負責支持灌溉基礎設施和水資源管理能力建設的組織之流失；年輕專業人士對灌溉和排水缺乏興趣…等各國可能產生之議題之交換與研討。WG-IDSST 旨在促進創新方法和必要工具，以確保永續發展下的灌溉和排水管理。

b.本次會議由國際灌溉排水協會中華民國國家委員會暨 WG-IDSST 委員闕雅文委員分享台灣在社會經濟轉型下的灌溉排水管理(The Evolution of Irrigation Organization in Taiwan Under Socio-Economics Transformation)。國際灌溉排水協會日本國家委員會暨 WG-IDSST 委員 Dr. Katsuyuki SHIMIZU 也分享日本在社會經濟轉型下的灌溉排水管理，此外，國際灌溉排水協會澳洲國家委員會暨 WG-IDSST 委員 Mr. Momir Vranes 分享澳洲在社會經濟轉型下的灌溉排水管理，成員在交流研究中獲益滿滿。

c.本次會議決議延續過去一年疫情下的執行方法，每三個月網路視訊會議一次，分享各國國內經驗，交流學習研討。

(7) 灌溉發展與管理工作小組：

a.本年度新提名案包括王聖瑋助理教授、余化龍教授、馬來西亞提名之 Mr. Mohamad Radzi Bin Abdul Talib、及南非提名之 Dr. Khumbulani Dhavu，王聖瑋亦於會議進行自我介紹，且在場其他成員無異議、提名獲通過，會後將由大會正式通知。惟對於連續二年以上於工作小組皆未有貢獻者，將解除其委員職務。

b.持續推動 2030 灌溉發展與管理工作小組之行動計畫方案，主要包含節水節能之作物產量提升、精進政策與實務之調整、資訊知識與技術之交流、跨區跨域合作等四大目標下的七項策略、十項行動計畫，由於本工作小組負責工作繁多，於前次摩洛哥會議已討論”Goal A - Strategy A1 - Activity 1.1. Develop a program for introducing standards for irrigation systems”、“Goal C - Strategy C4- Activity 4.17. Overview paper on the Irrigation Development for publication in Irrigation and Drainage (IRD)”等兩項工作，擬由我國成員協助完成，然由於詹明勇教授已退休，因此後續工作將由王聖瑋賡續辦理。

c.針對” Goal D - Strategy D2 - Activity 2.3. - Investigating and documenting the social and economic impacts of irrigation systems”， Dr. Akie Mukai 以完成初稿，並於本次會議進行簡報說明，由於目前版本皆以日本農業發展為例，經討論後，主席期望其他國家成員亦提供相關案例，以擴充此文件內容。

d.依據前次摩洛哥會議結論，本次會議邀請 Prof. L.B. Roy 進行演講，主要介紹

機器學習方法於蒸發散量推估的應用，由於近年來機器學習演算法發展迅速，過往以水文為基礎之數值模型可能無法獲得更精準的預測，因此許多研究以利用此類演算法嘗試提升農業用水相關參數預測之準確性。

e.工作小組已更新網站資料(https://icid-ciid.org/inner_page/118)，請委員上網流覽及提供新聞、書籍、手冊、技術論文、國際研習會相關議程、照圖片、新的應用軟體及相關網頁資訊等，俾供各國瀏灠及下載與交流分享。

(8) 水、能源、糧食國際工作小組：

a.確認申請新進委員(伊朗 2 位、中國 1 位、加拿大 1 位)，被提名未到場予以駁回申請，本屆有 2 名人員通過。

b.布達 Yella Reddy 接任副主席，Mahdi Sarai Tabrizi 接任秘書。

c.滾動檢討本工作小組三年計畫工項並追蹤 2030 工作 road map 推動進度。

d.確認國際研習會如期召開並說明本次會議共收到 23 篇摘要，經審查後篩選 15 篇，但僅收到 5 篇全文，實際有 8 篇到場口頭報告

e.本工作小組預定收錄以往經審查論文出版特刊，有關出版特刊等未決議題留至 75 屆國際執行委員會會議再行討論。

(9) 現代化灌溉工作小組：

a.本年度新的委員，台灣代表余化龍教授通過提名並當選，主席強調對於連續二年以上於工作小組皆未有貢獻者，將解除其委員職務。

b.工作小組討論出本小組論文集一事，經過爭取第五章 Sustaining revitalized I&D service 的 Responding to changing needs 將由余化龍教授負責收稿整理。

c.工作小組未來將持續關注的主題是關於改善灌溉系統的基礎設施要素，現代化服務方面缺乏的要素。工作小組將與聯合國糧農組織(FAO)密切合作，制定和推廣相關戰略和工具。

d.定期的線上會議將於 12 月召開，會再用郵件進行通知。

(10) 能力建構發展訓練與教育小組：

a. 陳志昇副秘書長與其他數國的委員先進行自我介紹，獲得主席提名並獲准為正式委員，主席期盼所有委員，未來能透過社群媒體或是手機軟體協助發展中國家進行農田水利的教育訓練。

b.能力建構發展訓練與教育小組首次的線上會議時間為 2022 年 5 月 30 日，未來工作小組成員將充分運用社群媒體進行交流互動，預計 2023 年將召開 3 次的線上會議。

c.依據工作小組成員的備忘錄，小組主席期盼委員未來能提供實體或是線上的

教育訓練課程，主席特別感謝我國提供了許多教育訓練課程給工作小組的各委員。

d.為了配合 ICID 2030 發展願景，能力建構發展訓練與教育小組希望各國能夠多舉辦線上討論或教育訓練；分析蒐集到的教育訓練資料；支援會員國的能力建構與開發；以及協助培養農田水利青年專家。

e.會議中，也分享多個青年教育訓練的會議，許多的課程與素材都已經免費提供於線上，小組主席希望各委員能發揮知識傳遞的功能，將這些珍貴的農田水利訓練課程與教材推廣到各地。

f.後疫情時代，線上學習成為主流，小組主席要求各委員能夠提更多的線上學習課程，透過 WhatsApp 等社群軟體，將學習資訊傳遞出去。

(11) 亞洲區域工作小組：

亞洲區域工作小組的總體目標是關注共同主題和問題，並強化適當的灌溉和排水技術引進或輸出亞洲區域。亞洲區域工作小組 ASRWG 的使命是鼓勵成員加入及協調該地區的活動。本次會議討論包括確認新成員、執行活動報告、技術報告及研討會視訊會議辦理、ICID 2030 願景路線圖行動計畫、與 IACID 共同舉辦於 2024 年 9 月在澳洲的第九屆亞洲區域研討會會議主題為:如何運用現代化的農業用水管理以維繫糧食安全、強化成員國國家委員會之間的聯繫、與 PAWEES 和 INWEPF 合作、工作小組臨時線上會議時間確認(預計於 2023 年 1-2 月間，將籌辦首次的線上會)、工作小組網站更新資訊(鼓勵小組委員能更新各國的網頁，也能設置個人的網頁)及 2023 年在 Tajikistan 舉辦第 14 屆國際排水研討會(IDW)等議題外，共有澳洲、中國、印度、印尼、伊拉克、日本、斯里蘭卡、土耳其、馬來西亞以及巴基斯坦等國代表，也分別針對該國的技術報告書初稿進行報告。主席希望，明年度有更多的國家能夠加入報告的行列。以下就澳洲、印尼及日本分享可供我們借鏡或思考。

a.澳洲政府方面：澳洲 65%降雨降流發生在北部，而糧食生產超過全國 40%的 Murray-Darling Basin 只有 6%降雨逕流量。自 2004 年起澳洲提出新的水倡議，如更安全的水權包括環境、改善水市場、水價及聯邦政府資助超過 7 億澳元改善水計畫等。在 2006-2007 年夏天，在東南部發生了有紀錄以來最低降雨量，流入主要水庫量及蓄水位也創最低紀錄。對於用水分配的壓力達到臨界點，西南部情況也類似，長期降雨量下降且主要城市的水庫都已跌至大約容量 30%。因此澳洲政府於 2008 年對於水的未來提出(a)回應乾旱及其他水問題挑戰(b)在國家水倡議文件中提出超過 20 年策略計畫包括氣候變遷行動計畫、更智慧的使用水、供水穩定性、健康河流及水道等。

其倡議未來 10 年投資超過 100 億澳幣辦理事項包括(a)可持續農村用水及基礎設施計畫-國家投資計畫在農村用水、灌溉現代化和效率包括改善水知識

及市場改革(b)恢復集水區平衡(包括水權購買)(c)都市用水及海淡水計畫(d)澳洲智慧水(e)驅動集水區改革(f)改善水資訊(g)城鎮水安全計畫(h)國家雨水及二次用水計畫(i)提高國家水標準(j)實踐 Morray 倡議(k)澳洲北部計畫等。其中對於農場工作以更有效率輸水提高生產率例如改善農場儲存用水及尾水再循環系統、安裝加壓滴灌系統和中控系統之灌溉等。

在此改革中澳洲政府提供執行期間學習到的經驗，(a)僅僅有現代化灌溉系統是不足夠的，必須與其他改革一起推動，例如有可用的水監測系統、水交易、安全水權、教育及技術提升等。(b)需要時間來推動，農業及農村社區通常有他們自己的步調，不是任意配合政府節奏。(c)需要政黨的支持。(d)需要足夠經費，大多數利害關係者於改革結束時感覺比以往更好。

另外執行至今已略具成效有(a)和平分享稀少的水資源，涉及水訴訟案件非常少。(b)使用灌溉現代化設施及水市場交易實現社會利益。(c)維持農業生產率同時將水回歸環境。(d)強化基礎來調適氣候變化。(e)在水權及農場基礎下增加灌溉者的整體資產價值。對於未來展望澳洲希望透過持續農田使用和技術創新來增加國內農田生產力。以及提供開發中國家的協助，促進全球食品產業發展。

b.印尼政府方面：印尼人口於 2015 年為 2 億 5500 萬人預估至 2044 年人口為 3 億 1000 萬人，全國總農業面積於 2019 年為 746 萬公頃，總灌溉面積為 714 萬公頃，2015 年總生產量為 6870 萬噸。

目前印尼在水資源管理任務包括(a)在水資源發展方面主要為興建新水庫、粗放 50 萬公頃土地，復原 200 萬公頃土地。(b)在水政策治理方面管理權責主要分為中央、省及區單位，以單一管理為政策。(c)在灌溉基礎設施投資方面於 2005 年 2.6 萬億印尼盾，至 2016 年 16.6 萬億印尼盾增加約 540%，其中公共工程部分佔 55%，特定分配 25%，農業部分為 20%。(d)在灌溉現代化方面包括供水系統、基礎設施、灌溉管理、管理機構及人力資源等。對於未來糧食安全政策包括(a)新開發農地 150 萬公頃，並修復及維護灌溉網路系統。(b)現代化灌溉-鼓勵較好管理減少修復或新開發成本及在維持基礎設施能力下增加水分配效能。(c)收成後技術-為增加農民福利，從收成米到乾燥米一直到市場價格管理讓價值變換最小。(d)維護灌溉面積-保持土地利用變化，執行灌溉農業區的保護。

c.日本政府方面目前面臨的挑戰為農業產出及收入減少、從事農業人口減少及老化、農業耕作面積減少及食物自給自足能力下降，為因應這些挑戰，日本政府訂定目標來改善包括農業轉型至產業成長、促進農村地區多元化使人可以繼續生活、強化農業及農村韌性、發展可持續性食品系統。在行動策略部分(a)制定新的長期土地改良計畫-從 2021 年到 2025 年為期限，其土地改善設

定目標和數量每一階段執行五年。政策問題包括以強化農業生產設施將農業轉型至產業發展、促進農村地區多元化使人可以繼續生活、強化農業及農村韌性等。除此之外，政府還立了以下 KPI:加速推動智慧農業、強化及系统化推動重要水庫預防災難措施，以及推動河川集水區災害韌性及可持續性。(b) 可持續食品系統策略-利用創新方法達到減碳及韌性，開發創新的技術在農業、林業及漁業並加執行可實現零排放二氧化碳的目標。推動利害關係人在糧食系統的行為改變及動作包括農民、商人及消費者。分享可持續性食物系統觀念與亞洲地區受颱風侵襲的國家於國際會議溝通例如聯合國食品系統峰會。

(12) 標的競用下的缺水管理工作小組：

a.本年度有三位新提名案，包括巴基斯坦提名之 Mr. Zafar Iqbal、馬來西亞提名之 Mr. Thayalam Sekaran 及 Ir. Wan Noorul Hafilah Binti Wan Ariffin。另對於連續二年以上於工作小組皆未有貢獻者，將解除其委員職務。

b.持續推動 2030 標的競用下的缺水管理工作小組之行動計畫方案，主要包含推動風險管理、發展乾旱管理政策、宣導保持發展與環境的平衡等三項策略下之五項行動計畫，然而近年受到疫情影響而導致各項工作略有延遲，因此已於前次會議決議修正行動計畫方案的期程，本次會議主要討論原訂今年度完成的工作延後至明年完成，包含各項評估指標、指引、技術報告等，其中評估指標已由 Mr. Amali Abraham Amali 自願完成初稿、指引則將與其他類似行動計畫的工作小組合力編撰。

c.本工作小組於本次大會期間舉辦國際工作坊” Managing, on the Regional, State or Local Level, Water Scarcity Resulting from Conflicting Demands” ，工作小組成員建議工作坊的具體結論應於會後提供各成員參考。

d.本次討論過程受到高度關注的議題為氣候變遷下標的競用的缺水問題將更加嚴重，受到氣候影響，各國用水標的優先順序已發生改變，連帶影響水資源供給的方式與比重，例如增加地下水或回收水的利用，而當前解標的競用的重點應為水資源供給的有效控管，並應盡速導入軟硬體的創新技術、及公私領域的跨域合作。

e.請各委員全力配合辦理 ICID 成員個人資料登錄 (https://icid.bmeurl.co/C7D4D2E)，並請各位委員能多參與 Webinar 之線上會議，有關 Webinar 之記錄亦可由工作小組提供的 Dropbox 連結下載。

f.工作小組已更新網站資料(http://icid-ciid.org/inner_page/110)，請委員上網流覽及提供新聞、書籍、手冊、技術論文、國際研習會相關議程、照圖片、新的應用軟體及相關網頁資訊等，俾供各國瀏灠及下載與交流分享。

3、國際灌溉排水展覽大會

本次國際灌溉排水協會「第 73 屆國際執行委員會暨第 24 屆國際灌溉排水研討大會」會場旁設有農業灌溉用水設備展場，來自各國的廠商均積極向世界各國的代表介紹其產品功能與效益，合計一百多家廠商聯合展示。

會場中，有關於管路灌溉與精密灌溉的部分，廠商們展示各式各樣的噴灑設施技術、接頭、管材結合電子感知設備可隨時紀錄詳細訊息，亦可透過手機 APP 的軟件功能經雲端儲存大量數據，並藉由數值模擬達到最佳化的灌溉模組經驗，從而演算出決策系統，以因應氣候變遷而達到最佳生產化之目的。

在展覽中，RAIN BIRD 公司現場展示模擬的噴灌系統，包括中央控制系統、控制器與智慧閥門、噴滴灌設施、旋轉噴嘴與噴灑物件等設備一應具全。其中央控制系統可藉由任何網路設備監控、操作與儲存裝置於管線末端設備的感知器，如此一來方便農家掌握作物現況並節省人力物力與水資源的耗損，再藉由農家的種植經驗達到全面進化的目的，對青年投入農場經營是很大的誘因。如此的設備更可投入應用於各式的學術研究試驗，實在讓我腦力倍增啟發更多層次的現地應用探討，來改善農作效益操作空間。

MAIT industries 公司現場的器具擺設與材質有高度專業性，其從事農業、草皮與環境監控與灌溉控制方案改善的公司，致力於改善種植者、園藝師、草坪維護人，其於水資源的維護管理改善，公司成員特色包含農藝與工程背景結合的專業人員，以用戶端需求為主的客製化公司，多年來藉由用戶者的需求開發出多種實用的監測和灌溉控制系統，並累積足夠的決策模組供客戶選擇利用。相關設施可藉由雷達系統、電纜系統及網路系統等達到監控之目的，以符合經營者想要的結果。

而 GRUNDFOS PUMPS PTY LTD 是全球 80 多個國家曾有使用的泵送馬達專業技術公司其透過性能、材料、特殊應用、電源和運行效率的提升改善了抽水馬達的性能也是值得參考的重點攤位。

K RAIN 是一家專業的管路灌溉噴灌系統結合各式定時器、控制器與控制閥的製造廠商，巧妙的設計出各式的自動噴灑系統，多元可替代的材料配件玲瑯滿目，台灣國內的市場很難披敵，其結合控制計量器、無線傳輸與手機 APP 的開發，讓從事農業生產者由勞力階段進階到動腦動手指管理階層，僅透過螢幕即可隨時隨地瞭解並改善維護自己的農園。這些業者的成果發表真的可讓農業產業起死回升，吸引年輕人的志向投入。

4、第 24 屆國際灌溉排水研討大會

國際灌溉排水協會於年會召開期間，均同時辦理大型國際灌溉排水技術研討大會，並以每屆 3 年為一週期，以世界灌溉論壇、ICID 灌溉排水研討大會，以及區域/技術研討會亦等形式輪流辦理。第 24 屆國際灌溉排水研討大會主題為「邁向永續發展為目標之農業水資源管理創新與研究 (Innovation and research in agriculture water management to achieve sustainable development goals)」，包含議題如下 (子議題列於表 2-1)：

- 特別議題：發展管理灌溉水源不確定性之新工具;
- 問題集 62：資訊與傳播科技在最後一哩路扮演的角色;
- 問題集 63：如何透過跨學門對話達到永續發展的目標。

表 3-3 ICID 第 24 屆國際灌溉排水研討大會主題

類別	徵稿主題
大會主題	Innovation and Research in Agricultural Water Management to Achieve Sustainable Development Goals 達到永續發展目標之農業用水管理創新與研究
子項議題 62	What role can information and communication technology play in travelling the last mile (i.e. the greater adaptation of research outputs) 資訊與通訊科技如何扮演(研究與實務間)最後一哩路
62.1	Technical-Technology Aspects 技術-科技層面
62.2	Social side- socio-economic Infrastructure Context: appropriate technology for appropriate resources (for diverse groupings of people) including using social media 社會層面-社會經濟建設脈絡：針對不同族群，用適合的科技提供適合的資源，包含運用社群媒體
62.3	Water Trading 水貿易
子項議題 63	What role is played by multi-disciplinary dialogue to achieve sustainable development goals? 為達到永續發展目標，跨領域對話扮演的角色為何？
63.1	Social, Consumer, Supply Chain QA, Reputation & Regulatory Dialogue 社會、消費者、供應鏈、聲望與管理的對話
63.2	Technical level dialogue vs other “levels” 科技層面對話 vs 其他層面
63.3	What parties should be addressing SDG: 12 ‘Responsible Consumption and production’ 針對《永續發展目標 12：確保永續消費及生產模式》，哪些團體應參與
特別場次	Developing the future tools for managing uncertainty in irrigation water supply 發展未來工具以管理灌溉水供應的不確定性
子議題 1	Institutional arrangements 制度安排
子議題 2	System modelling 系統模型
子議題 3	Crop agronomic and Social adaptation 作物農藝與社會適應

CTCID 秘書處協助農水署蔡昇甫署長等學者、專家投稿「2020-2021 臺灣嚴重乾旱事件之水文歷程與抗旱供灌策略經驗 (The Hydrological Processes of Taiwan's Severe Drought Event During 2020-21 and the Experience of Irrigation Strategies for Fighting Drought) 」，並被大會接受。因疫情，投稿人不克親自出席會議，在會場中由吳瑞賢主席代為發表論文報告(研究論文詳如附件一)，將台灣的成功抗旱經驗分享給全世界，獲得在場國際人士高度讚揚。

圖 3-1 吳瑞賢主席代表發表我國抗旱研究論文：2020-2021 臺灣嚴重乾旱事件之水文歷程與抗旱供灌策略經驗

此外，並有數名台灣學者、專家於國際研習會及工作小組發表數篇研究。例如:台灣水利環境科技研究發展教育基金會的章國珍於灌排管理制度工作小組國際研習會，針對台中綠川發表「Taichung Luchuan Metamorphosis from an Irrigation Canal to an Urban Multifunctional Waterway toward Sustainable Development Goals」的研究(詳如附件二)。

章國珍工程師從綠川從最早扮演灌溉圳路的生產糧食角色，到適應著時代變遷與都市發展進行研究分析。使國外學者專家了解到綠川如何蛻變成兼具水安全、水環境、與水文化的多功能都市水道，更難得的是成為接納不同群體與支持社會弱勢群體的溫暖家園角色。起初的農田灌溉作用，仍可在綠川下游的農田中尋見。歷經調整後，綠川的蛻變沒有停下腳步，而是朝著永續發展的方向前進。

圖 3-2 章國珍工程師發表台中綠川研究論文

劉日順博士也就其論文「Taiwan Modernized Irrigation Technical Support to Cooperative Demo Farm in Indonesia on Public-Private-Partnership (PPPs) in Irrigation and Drainage Operation and Maintenance」於灌排管理制度工作小組（WG-IOA）會議中進行報告，介紹我國以技術支援印尼發展田間灌溉排水設施提升、用水管理組織差異比較分析及雙方可精進改善之面向。

劉日順博士表示，藉由灌排管理制度工作小組會議，我國可了解世界各地的國家均積極推動灌溉排水在公私立部門間的合作。由於灌排工作本即為具有且需仰賴民間力量自主貢獻的一環，各國均不遺餘力地設法因應或是克服相關挑戰，臺灣身為世界的一份子，更應善加發揮己身的優勢，協助各國辦理相關灌溉及排水技術提升的工作。

劉博士以過去在印尼協助建立合作農場的推動經驗及對印尼當地灌溉管理組織的了解進行報告，會後獲得該工作小組主席 Dr. Hafied A. Gany, P.Eng.稱許。由於小組主席為印尼籍，對於自己國家的了解，自不在話下，主席表示同意我國所提出的觀點，並也積極鼓勵我方多加協助印尼進行相關灌溉排水管理各項現代化的工作，以提升其國內農民的生活水準及收入，劉博士的報告及交流，為台印雙方未來的農田水利合作奠定了基礎。

圖 3-3 劉日順博士發表灌排管理制度研究論文

5、擴大參與工作小組分享專業知識

CTCID 本年度代表團由吳瑞賢主席帶領，代表團成員來自農田水署管理處、經濟部水利署、大專院校、研究單位等共 16 名學者專家組成，包含工作小組委員 8 人、團體會員代表 6 人以及秘書處 2 人。CTCID 今年度持續擴大參與工作小組，提名余化龍副主席、王聖瑋助理教授與陳志昇副秘書長等學者、專家分別新加入共 5 個工作小組：現代化灌溉工作小組、灌溉發展與管理工作小組、非常規水灌溉工作小組、亞洲區域工作小組，以及能力建構發展訓練與教育工作小組，以上皆為大會所接受。

自去年度開始，工作小組委員的篩選更加嚴格，若是委員連續兩年未出席會議、未有實質貢獻，將會取消工作小組委員資格，開放其他新成員加入，以鼓勵委員能夠積極參與。

圖 3-4 王聖瑋助理教授加入非常規水灌溉工作小組

圖 3-5 闕雅文教授參與社會經濟轉型下之灌溉排水工作小組

圖 3-6 陳志昇副秘書長加入能力建構發展訓練與教育工作小組

圖 3-7 吳瑞賢主席主持氣候變遷工作小組會議 會中由陳志昇副秘書長代理氣候變遷工作小組秘書

圖 3-8 陳志昇副秘書長加入亞洲工作小組

圖 3-9 亞洲工作小組會議人員合影(吳瑞賢主席、高瑞棋督導長、余化龍副主席、陳志昇副秘書長及陳春宏所長)

圖 3-10 高瑞棋督導長參與永續排水工作小組

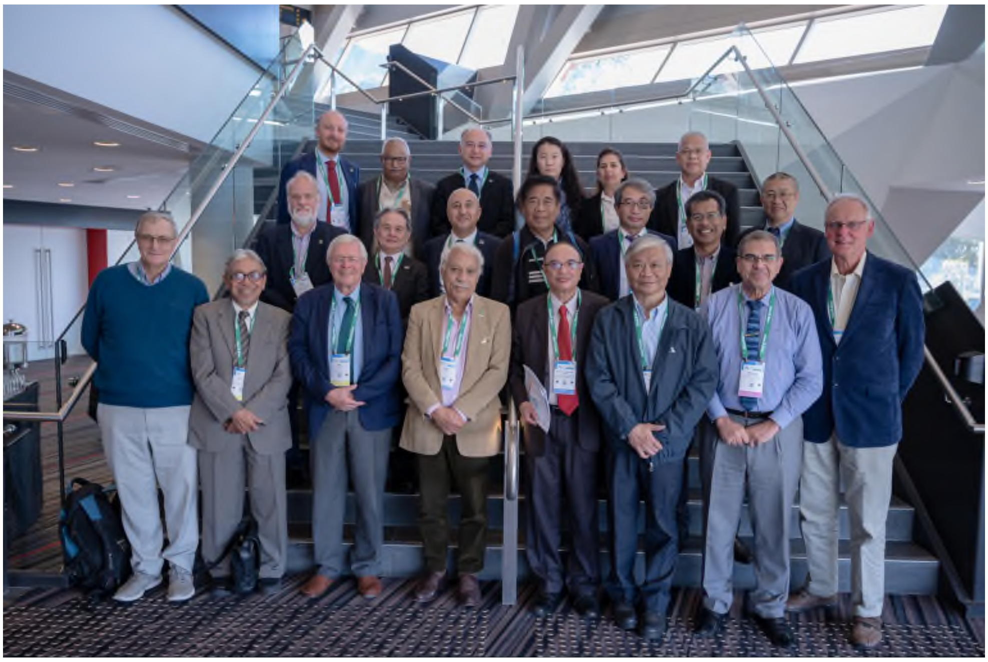

圖 3-11 吳瑞賢主席(第三排左三)與高瑞棋督導長(第一排右三)與技術活動委員會成員合影

圖 3-12 高瑞棋督導長主持感潮區永續發展工作小組會議

圖 3-13 余化龍副主席、丁崇峯博士、闕雅文教授、劉日順博士與水糧食與能源工作小組參與人員合影

圖 3-14 王聖瑋助理教授、中水局張庭華局長及水規所陳春宏所長參加標的競用下的缺水管理工作小組

6、參加會議及展覽心得

(1). ICID 會議

在會議中各國分享水資源與糧食管理方向，可見各國對於水資源管理及灌溉皆已朝向智慧管理及現代化灌溉技術方向邁進，有效及精確掌握水資訊及灌溉量，除可穩定糧食生產亦可降低成本。另對於穩定供水部分海水淡化、合理水價、水權及興建蓄水設施亦為重要選項之一，以上措施台灣已推動多年，且對於區域水資源調度部分國內經驗豐富亦值得與國外分享，在大型水庫推動因受環保團體抗議受阻，在蓄水空間有限條件下，對於有限水資源有效利用更顯得重要，尤其台灣地區北、中、南氣候環境不同，如何利用區域調度、跨流域支援及水資源備援設施等實為台灣度過民國 109-110 百年大旱重要關鍵。另對於因應氣候變遷之調適及減碳部分亦為各國所重視，雖此次報告著重於策略及方向尚無說明具體做法，建議後續持續與各國交流分享及吸收各國經驗。

台灣歷經 109-110 百年大旱，無論民生、工業或農業用水在有限水資源條件下調度得宜，在適度溝通、補償及調度政策下，避免造成民怨進而演變為社會事件，雖此次百年大旱造成部分地區休耕停灌及部分地區限水，大家仍能共體時艱安然度過。在此期間

政府單位積極找水相關措施也為未來面臨抗旱下水資源備援立下基礎。此種珍貴經驗亦值得與國外分享。建議針對 ICID 工作小組彙集各國經驗資料加以收集可作為未來在面臨抗旱時參考。

澳大利亞是地球上最乾旱的陸地，年平均降雨量大約 200-500mm 不等，天然水資源有限面對艱困的環境，累積水資源管理的成果全球首屈一指，因此能發展成農業大國，在於其透過灌溉經驗的創新與挑戰，由政府機構或民營化政府組織持有、建造、維護或營運，這模式與台灣目前的發展趨勢是一致的。其因地廣人稀勞動力不足，天然地理環境亦非良善，只能嘗試著不斷利用最新的灌溉科技並持續研發一系列的精進節水雲端技術系統和農場經營等兩大層面，藉由永續農村用水和基礎設施計畫(Sustainable Rural Water Use and Infrastructure Program ,SRWUIP) 及重要投資，來大幅改善系統性的用水效率，因此他們擁有大量灌溉、排水和水管理領域的寶貴經驗值得我國借鏡與學習。

(2). 設備展覽

現場亦展示大型之現代化機具，以取代傳統需大量勞力之窘竟，此議題對台灣而言是需要被正視的一門功課。台灣目前人口老化，年輕人投入農業的動機不足，如果能從農業機具效能的開發，吸引青農投入產業，減少勞動力的付出，並帶來豐厚的收入，相信這是一條重要的大道值得推展。另外面對能源、電力的短缺，許多廠商紛紛結合風力、太陽能及高效率機件的轉換，透過電腦輔助運算之模擬，解決當前農業面對現代化的衝擊，已有相當的基礎，很值得台灣農業學習及交流，針對目前農水署推動的綠能工作有正向的幫助。

對於渠道滲漏與管材因老化或外力的衝擊，以往於現地難以克服的嚴重滲漏損失，此次的展出有多家廠商開發最新防漏施作技術，依其現場的介紹說明，效果均有顯著的提升，這課題對管理處而言極具吸引力，頗值得參考並進一步嘗試施作。

此外，噴灌技術材料的多元化與結合各項氣候因子的變異與地文條件的收集，業界所開發的器具琳瑯滿目，對專業的農事從事者，可有一次性滿足式的饗宴，當場激發出各式組合應用的遐想，如此多元多層次的系列展廳可謂本次大會的精華所在之處。

以色列的滴灌技術領先國際，該國對於水資源競爭使用區轉旱作之節水方式，中一家代理以色列滴灌技術(Drip irrigation technology)廠商提供之經驗可供我國參考。以色列國土有 67%為沙漠荒地，卻是歐洲冬天的蔬菜供應國，以色列獨特的滴灌技術，配合供水管路極低的漏水率來節省水源，創造農業奇蹟。滴灌系統的管路上有精細的出水孔，藉著調整水壓的變化來控制灌溉所需水量，將水和液肥輸送到植物根部附近，用水效率高達 95%，同時節省水和肥料。設備開發公司利用智慧水網以電腦來監測滴灌水量及管路是否有異常情形，透過雲端軟體蒐集供水網的大數據及整合地理資訊等資料進行運算及智慧分析後，即時通報供水網路的各種事件，提供智慧水網中的自動事件偵測、通知與維護作業，有效控制滴灌水量。

節省農業用水、提高水資源利用率，同時滿足枯旱時期作物灌溉與各標的用水需求是政府有關部門長期努力之目標。隨著經濟發展及國人生活水準提高，對於蔬菜、花卉

及雜糧之需求量日漸增加，旱作栽培技術已受到重視，旱作管路灌溉方式如能引進以色列的滴灌技術，鼓勵農民應用精準控制灌溉技術，提倡適時、適量的高效率灌溉來節約農業用水，將能使農業發展更加穩定。

二、建議

1. 氣候變遷下水資源議題在國際間更形重要，本次會議共計有來自世界各國逾2,000人參加，為後疫情之下聯合國外圍非政府組織的重要大型國際研討會。而我國並非聯合國成員，定常參與聯合國外圍非政府組織的國際灌溉排水協會之國際執行委員會會議暨國際灌溉排水研討大會有助我國國際學研推展，會議代表積極參與各工作小組研討水資源管理與灌溉排水之重要議題，亦可提升我國國際事務之參與。因此，建議我國應該持續參加，並讓我國專家學者加入各工作小組，多發表相關研究或試驗成果，以利與國際分享相關研究成果、學研技術及經驗。
2. 歷年來在水資源管理、農業及漁業養殖技術上具有世界領先實力，鑑於近年來國內農業技術專家對於投稿ICID研討會似乎較不熱衷，也可能是訊息未廣泛推播，故建議可廣邀農業技術專業人員，例如水資源管理、農業試驗、各地農業改良場之專家共同參與發表試驗成果，又例如我國刻正推動整合運用IOT技術精進灌溉及田間管理工作，期可提升用水效率及作物產值產量等，建議可分享我國現地試驗成果與經驗，以技術本位彰顯我國國際地位與能見度。
3. 近年來中國、日本、韓國及臺灣每年均積極派員參與ICID年會會議，基本上ICID為友好我國之世界性組織，建議未來可以此為國際舞台，整合外交部國合會資源，以專題式或區域性籌辦短期講習課程，邀請ICID總部及各工作小組成員來台參與短期課程，透過課程講授及現地參觀，以及與設備廠商的互動，整合行銷國內廠商研發產品。
4. 本次會議多數國家皆派員參加，我國代表團為人數最多之團體，除向其他國家展現學術我國對於農業發展之重視，亦有助於我國多元掌握各工作小組目前推動情形，以利持續積極參與國際合作與交流。由於ICID以農業灌溉排水技術及經驗交流，扶助開發中國家發展農業生產為目標，且本次會議同時包含執行委員會會議、學術研討會、及廠商展覽等活動，為一結合產官學研推動量能之重要場合，因此，建議未來籌組代表團可增加邀請學研單位之學術發表、農業技術部門之實務交流、本土設備廠商之技術交流，以利與國際同業分享相關技術及經驗。
5. 本次由於會議行程滿檔，所有時間都在會場開會，無法安排前往當地較具規模的水利設施或建造物進行技術參訪，甚為可惜。建議後續可增加規劃相關水利或灌溉系統設施工程之技術考察行程，俾利我方代表團學習該國農田水利工程技術，未來可將其應用於國內灌溉排水、組織管理業務及現代化之提升，使我國用水管理及農業生產更具競爭力。
6. ICID為有歷史性與專業性的大型國際機構，均為各國頂尖的專業人士組成，以台灣產

官學界的素養及能量，目前參與的專家學者仍稍不足，建議廣為宣傳加強擴大人才積極參與ICID的相關國際活動，讓世界有認識台灣的機會。台灣科技業引領全球，IT設計更是翹楚，藉由專家學者的積極參與除可宣揚國力，藉由交流後也可為國內農業帶來新的契機。甚至藉由與會的認識可以協助較技術發展較慢的國家，建立相當的基礎與國家情誼，進而達到產業輸出的效果。

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附件一 第 24 屆國際灌溉排水研討大會發表論文

THE HYDROLOGICAL PROCESSES OF TAIWAN'S SEVERE DROUGHT EVENT DURING 2020-21

AND THE EXPERIENCE OF IRRIGATION STRATEGIES FOR FIGHTING DROUGHT

Sheng-Fu Tsai [1], Ming-Tee Hung [1], Chih-Bin Chu [1], Lung-Sheng Hsieh [2]
and Peng-Jui Wang [2]

ABSTRACT

From October 2020 to June 2021, Taiwan suffered one of the most severe drought events in history as no typhoon hit Taiwan for the first time since 1964. The rainfall in the catchment areas of reservoirs was only 20% to 60% of the average, and the reservoir storage was seriously insufficient. Later in 2021, even during the wet season in May, there was no significant rainfall and all the major reservoirs almost dried up. In response to such an emergency, the authorities announced the irrigation suspension in reservoir irrigation areas during the first crop period in 2021, covering a total area of 74,000 hectares. Considering the rights of farmers and the fairness of agricultural and food policies, the Shimen reservoir continued to irrigate the 3rd sub-district in Taoyuan.

First, this paper analyzes the hydrological process of drought event from June 2020 to May 2021, including rainfall, runoff volume, river flow, and reservoir water storage in important reservoirs and upstream catchment area of the dams. The hydrological analysis of the drought is compared with the historical records and statistics of the past years. Second, during the process of fighting drought, governments at all levels proactively formulated various strategies, measures, and decision-making processes. The practical cases include, for example, looking for alternative water sources when the Shimen Reservoir experienced a lack of water, and prioritizing using the water of ponds, rivers, and regional water resources to save up almost 80% of the reservoir irrigation water. Therefore, the 3rd sub-district in Taoyuan managed to irrigate 7,174 hectares during the first crop period in 2021. However, because the drought-fighting process involves complex approaches different from the farmers' habits, it was necessary for the Irrigation Agency to proactively communicate with farmers as gaining farmers' trust helps reduce water disputes greatly. Later in June 2021, even it was time to supply irrigation water for the second crop, the water storage capacity of all reservoirs hadn't fully recovered yet. Therefore, irrigation must be carried out in separate groups, especially the larger reservoir irrigation areas such as Chianan only allow some areas to start irrigation. Finally in August, the water storage of all reservoirs in Taiwan recovered to full level, marking the end of the historical drought in Taiwan.

Owing to the restructuring of Taiwan's irrigation associations into the public agency, the central government was able to work with local authorities and farmers and to put collaborative, cross-ministerial efforts to fight the severe drought by using innovative approaches. Finally, this paper presents the strategic framework of the technical management of agricultural water and irrigation in the future.

Keywords: Irrigation water, Reservoir water competition, Hydrological process, Drought-fighting strategies.

1 Irrigation Agency, Council of Agriculture, Executive Yuan, R.O.C. chihbin@ia.gov.tw
2 Taiwan Research Institute on Water Resources and Agriculture. armo@triwra.org.tw

1. Introduction

1.1 Taiwan's geographic features, climate and hydrology

The total land area of Taiwan is about 36,000 km^2, 70% of which is mountainous area. The Central Mountain stretching from the north to south forms the mountains and valleys in the east and plains in the west, accounting for 30% of the total area (Fig. 1). Taiwan island's subtropical climate is hot, humid and windy due to the influence of the continental flow. Regional rainfall varies greatly; it is usually dry in summer and rainy in winter in northeast Taiwan while rainy in summer and dry in winter in the southwest area.

The annual rainfall in Taiwan varies significantly over dry and wet years, ranging from 1,572 mm to 3,322 mm. The average rainfall accounts for 2,507 mm (90,500 (M) m^3), 2.6 times of the world average. However, the precipitation in Taiwan varies seasonally; nearly 80% of the rainfall occurs between May and October, whose main sources include typhoon and plum rain. Hence the period between November and April is the dry season. In addition, in the north, the ratio of rainfall in the wet season to the rainfall in the dry season is 6:4 but even up to 9:1 in the south(Water resources agency, 2020). The fact that rainfall varies significantly in different seasons and regions makes water management a tough issue. Finally, short rivers and steep slopes in the mountains make it hard to build reservoirs in Taiwan. The valid capacity of reservoirs and dams accounts for merely 1,980 (M) m^3, only 1/9 of the annual water use. Despite Taiwan's abundant rainfall, storing water and making use of water resources are still quite difficult.

1.2 Agricultural irrigation water

According to the statistics between 2010 and 2019 provided by the Water Resources Agency, the average annual water use in Taiwan is 16,956 (M) m^3, accounting for 22% of the total rainfall. Among the total water use, agricultural water use accounts for 71.8% (12,182 (M) m^3), domestic water use for 18.6% and industrial water use for 9.5%. Irrigation water takes up most of the agricultural water (65.9%) at 11,170 (M) m^3 (Fig. 2), with 7,329 (M) m^3 (66%) of irrigation water coming from rivers, 2,316 (M) m^3 (21%) from dams, 1,112 (M) m^3 (10%) from reservoirs and 400 (M) m^3 (4%) from groundwater(Council of Agriculture, 2009).

Located in the hot monsoon region, Taiwan mainly grows rice and upland crops. The commonly adopted cropping patterns include double rice cropping, single rice cropping and rotational cropping (farmers taking turns to grow rice once or twice in two or three years). The first crop is grown during the dry season when there is less rain while the second crop is grown during the wet season. Compared to domestic and industrial water use, growing crop has better water-stress tolerance so irrigation water can flexibly adapt to the variation during dry and wet season. In the wet season with more effective rainfall, paddy fields are filled with water to recharge groundwater. In the dry season, it is necessary to decrease the water demand through various irrigation management measures so that irrigation water can support other types of water demand.

It is worth mentioning that most irrigation water comes directly from rivers, so it is not suitable to support domestic and industrial water use due to unstable water quality. Domestic and industrial water comes mainly from reservoirs and is more stable, but reservoirs face the problem of sedimentation and low capacity due to limited storage. Recently under the climate change, water demands of irrigation, domestic use and industrial use become competitive. In addition, if drought occurs during the first crop season, the government often implements irrigation suspension in reservoir irrigated area to support other demands. Due to the impact of climate change, the risk of reservoir water shortage has increased, and the events of irrigation suspension become more frequent, forming several "reservoir water competition areas" in Taiwan (Fig. 3). If farmers continue to apply double rice cropping, higher risks of irrigation suspension in these areas are unavoidable.

Over the past 20 years (2002-2021), 9 announcements of large-scale irrigation suspension occurred in the reservoir water competition areas. The affected total area kept increasing, reaching a record high of 74,000 hectares in 2021 (Fig. 4). Therefore, it is important to look closely at the current measures of cultivation and irrigation and to help them adapt to extreme weather and hydrologic conditions and agricultural irrigation risks. Meanwhile, it is also necessary to consider major factors such as food security, ecology, social economy, agronomy technology, etc. and to include the stakeholders' opinions.

2. Hydrologic analysis of Taiwan's historical drought in 2020-21

2.1 Hydrologic analysis of the drought

In general, the wet season starts in May as the rainfall becomes abundant in Taiwan. In May and June, the stationary front brings heavy rain, which is named "plum rain". As the plum rain season ends in June, the typical convectional rain occurs, bringing short-duration, intense rainfall. However, the major and most important source of water in the wet season is the abundant precipitation caused by typhoons or tropical cyclones. With this type of precipitation, the reservoirs tend to be full by the end of the wet season and to be able to meet for the demand in the dry season.

However, for the first time since 1964, no typhoon affected Taiwan since June; therefore, at the end of the wet season in October 2020, the water levels of reservoirs were low – some of the reservoirs only had half the storage compared to the same time last year, or even lower. Obviously, the reservoir storage could not meet the demands during the upcoming dry season. Hence the government decided to implement the irrigation suspension in the north, including the reservoir irrigated areas in Taoyuan, Hsinchu and Miaoli. Unfortunately, the rainfall between November 2020 and spring 2021 was even less than before and the drought became more severe. Despite the official announcement about the irrigation suspension for the first crop, the water conditions remained severe when all the reservoirs in Taiwan were almost empty by the end of May. Finally, the plum rain came at the end of June, the tropic cyclones in July and the heavy convectional rain in August, all helping to replenish the reservoirs. The irrigation for the second crop in 2021 was able to be provided in a normal pattern.

This paper aims to analyze the drought between June 2020 and May 2021, exploring the rainfall in major reservoir area and the catchment area of upstream weirs, the runoff volume, river flow and reservoir storage, etc. The data are also analyzed by comparison to the records and statistics in the past years. The main idea is to increase the understanding of the extreme drought by providing related data analysis.

2.2 The analysis of rainfall and inflow in major reservoir area and the catchment area of upstream weirs

The data of 5 reservoirs and 2 weirs are shown in Table 1-2 and Fig. 5-7 and explained below:

(1) In Northern Taiwan: For Shimen Reservoir, the rainfall between June 2020 and May 2021 was 50% of the past years' average and the inflow only 30%. For Mingde

Reservoir, the rainfall was only 46% of the past years' average and the inflow as low as 10%.

(2) In Central Taiwan: For Liyutan Reservoir (one of the off-stream reservoirs in Taiwan), both the rainfall and inflow accounted for 47% of the past years' average. Besides, for Jiji Weir, which draws water from Choshui River (the longest river in Taiwan), the rainfall was only 34% of the average. After August 2020, the river flow not only was reduced to $Q_{95\%}$ flow (almost to the base flow), but kept reducing to less than $Q_{95\%}$. The lowest flow of 16.2 cm was recorded on January 4, 2021. Despite a mild increase, the river flow kept falling to below $Q_{95\%}$, making its runoff only 32% of the average.

(3) In Southern Taiwan: The rainfall of Tsengwen and Wushantou Reservoir was 45% of the past years' average. For Gaoping Weir, which draws water from Gaoping River (the river with the largest basin in Taiwan), the rainfall was only 33% of the average. After November 2020, the river flow was reduced to $Q_{80\%}$ flow and kept reducing to less than $Q_{95\%}$ by January 2021. The lowest flow of 3.8 cms was recorded on April 14, 2021 (the lowest record in history at 6.9 cms, May 7, 2020). Its runoff accounted for only 14% of the average.

2.3 The analysis of reservoir storage and storage rate

The drought lasted for 300 days when the rainfall in all catchment area only accounted for 20-60% of the historical average and the inflow volume for 10-40%. Although the discharge of reservoir was carefully managed, the storage of all the reservoirs kept reducing due to low inflow, and almost all reservoirs were dried out by the end of May (as shown in Table 3). The change in reservoir storage during the drought event is described as follows:

(1) In Northern Taiwan: In October 2020, the storage in Shimen Reservoir was only 85 (M) m^3, lower than 50% of valid capacity of 202.66 (M) m^3. Later in May 2021, the storage was as low as 20 (M) m^3 at only 10% of the storage rate, which gradually recovered as 70% by the end of June with a storage of 140 (M) m^3. The reservoir was full again in August and remained full till October. Mingde Reservoir has a small capacity, the storage rate was lower than 20% in October 2020 and dropped to 7% in May 2021 despite the implementation of irrigation suspension. After June, as the storage rate increased, the reservoir water was used to irrigate the second crop. The storage rate remained up to 80% between August and October.

(2) In Central Taiwan: In October 2020, the storage in Liyutan Reservoir was less than 60 (M) m^3 at about 50% of valid capacity of 114.46 (M) m^3. Later in May 2021, the storage was as low as 1 (M) m^3 at less than 1% of the storage rate. Although the storage rate slowly recovered to only 64% by the end of June. However, the reservoir was full again in August and remained full till October.

(3) In Southern Taiwan: For Tsengwen and Wushantou Reservoir, the storage rate was less than 190 (M) m^3 in October 2020, accounting for 33% the valid capacity of 587.07 (M) m^3. By the end of May, the storage was reduced to 55 (M) m^3 at a storage rate of less than 10%. The reservoir storage only recovered to 56% and the water supply was still at risk. Later in August, the reservoir was full again and the storage remained sufficient till October.

3. The process of fighting drought: our experience

The process of fighting drought is divided into three stages: the second crop period in 2020, and the first and second crop period in 2021. Two practical cases are proposed – Taoyuan third irrigated area during the first crop period in 2021 and the irrigation grouping policy in Chianan irrigated area during the second crop period – both for the readers' reference and for future enhancement of drought resilience regarding agricultural water management.

3.1 The process of fighting drought

(1) During the second crop period of 2020 (2020.7~2020.11):Taiwan's Irrigation Agency, the Council of Agriculture (COA), took proactive measures in response to critical water conditions, such as canal checkups, precise water allocation, providing irrigation in turns, using backup wells, introducing farm pond water, etc. In face of severe water scarcity, the Ministry of Economic Affairs (MOEA) called for a cross-sectoral drought response center on October 14, 2020. To ensure the water storage for public use for at least two months, irrigation suspension was implemented in 19,000 hectares of farmland in the reservoir irrigated areas in Taoyuan, Hsinchu and Miaoli during the second crop period. Among 312,000 ha of irrigated area all over Taiwan, the second crop in 293,000 ha was irrigated according to normal schedule.

(2) Before and during the first crop period of 2021 (2020.11~2021.6): By the end of November, the drought response center decided to stop the irrigation in the reservoir irrigated areas of 46,000 ha in Chianan, Taichung, Hsinchu and Miaoli during the first crop period of 2021. In Taoyuan, the main supply comes from Shimen Reservoir. Although its storage returned to 130 (M) m^3 by January 2021, it was still unable to meet the irrigation need of 35,000 ha in Taoyuan. Therefore, the response center decided in a meeting on January 5, 2021, to hold irrigation for the first and second district in Taoyuan during the first crop period in 2021, affecting 28,000 ha of farmland in total. However, the irrigation for 7,174 ha farmland in the third district was kept (Fig. 8) due to the fallow plan in the first crop period in 2020 and the suspension in the second.

Before providing irrigation water to the third district, the reservoir water for irrigation water was under total amount control so the Shihmen Reservoir was approved to provide 41 (M) m^3, and the date of irrigation was postponed till February 21. In face of water scarcity, the Taoyuan Management Office (MO) voluntarily reduced the use of reservoir water and used alternative water sources – river water withdrawal – instead. Since February 21, the water use of farm pond was monitored on a daily basis to carefully managed the water outflow. In mid-May, service groups were established to determine the irrigation schedule for farm ponds and to help the irrigation groups manage outflow operation, supporting on-farm water allocation. Finally, the irrigation operation in the third district in Taoyuan was sufficiently completed.

In addition to the aforementioned cases, the farmland using river water for irrigation accounted for up to 100,000 ha during the first crop period despite water scarcity. The water-saving measures include enhanced irrigation management, regional irrigation applied in turns, intermediate irrigation, etc.

(3) During the second crop period of 2021(2021.6~2021.10)

Later in May and early June, the plum rain fronts brought significant rain, but the situation wasn't relieved immediately because the water level in the long dried-out reservoirs only rose slowly before returning to normal storage. Therefore, to prepare for the second crop period in the June and July, it is necessary to implement land preparing during June and to evaluate the irrigation programs for the future. For example, for smaller reservoirs like Minge, the irrigation should begin on time so that there would be more space for rainfall collection during wet season. For larger reservoirs in Central Taiwan such as Liyutan, the water was supposed to flow into downstream river to help land preparing before the irrigation began. For larger irrigated area like Chinan, the irrigation was applied to different groups to reduce the risk of providing irrigation all at once.

With the plum rain season ending in June, the typical convectional summer rain and tropical southwest monsoon occurred in July and August and all the reservoirs were almost full by the end of August, even remaining full till mid-October(Table 3). The irrigation for the second crop period all over Taiwan was provided as usual.

3.2 Our experience of fighting drought

(1) Case 1: Providing irrigation for the third district in Taoyuan (2021)

In Taoyuan, farmland irrigation mainly relies on water resources from farm ponds, weirs and reservoirs and also on the distributing canals of the Taoyuan Canal and Shimen Canal. In Taoyuan's irrigation system, there are connecting waterways to channel irrigation water during dry season. Return flow is also collected in the drain channels for reuse(Northern region water resources office, 2014, 2010).

To help farmers adapt to the cropping patterns under climate change, the COA promoted a program to divide the Shimen Reservoir irrigated area under the Taoyuan and Shimen MO into 3 and 2 districts respectively(Fig. 12). For the water-saving incentive measures during the first crop period of 2019, the irrigation water was provided in turns to each district, so the crop harvest reduced and less water was consumed.

The third district in Taoyuan is an important food producer in Northern Taiwan governed by Xinwu Workstation and Hukou Workstation of the Taoyuan MO. Xinwu and Hukou Workstation are in charge of 100 farm ponds, 35 and 65 respectively, with a maximum water storage of 15.27(M) m^3. The source of water for the third district comes from the Shimen Reservoir (56%), rivers (44%, with 25% return flow). Located at the edge of the irrigated area, the water channel is 43 km long; hence it is difficult to provide sufficient water. As the farmland was left fallow during the first crop period of 2020 and the irrigation for the second crop period was cut off, it was necessary to maintain the irrigation for the farmland of 7,174 ha in the third district during the first crop period of 2021 for the wellbeing of the farmers.

Based on the Shimen Reservoir's storage of 135.2 (M) m^3 on January 1, 2021, a simulation was made under conditions that the inflow of Q95 between January and May and the Shimen Reservoir's supply for agriculture aiming at less than 41 (M) m^3. It was found that postponing the irrigation for the third district by 20 days would help keep the storage of Shimen Reservoir at about 20.1 (M) m^3, close to two months of domestic water use of 24 (M) m^3 (Fig. 9). As another simulation was made with the reservoir storage of 126.95 (M) m^3 on January 29, the result showed that by the end of May the storage would be 22.58 (M) m^3 and that such measure of providing irrigation was viable. Therefore, it was officially determined on February 17 that Shimen Reservoir would provide agriculture water of 41 (M) m^3 and that the irrigation would be provided 20 days later.

Before the irrigation, the Taoyuan MO proactively restored water in farm ponds, withdrew river water and introduced water from Shezi River into the canal along with Shimen MO. In addition, the Taoyuan Government and the Water Resources Agency, MOEA set up withdrawal pumps to provide water for the Taoyuan Canal to reduce the third district's water use from the reservoir.

Before the irrigation was provided on February 21, the Taoyuan MO took the following measures to supplement 8 farm ponds along the Guangfu Canal in Hukou irrigated area:

(a) Concentration of side inflow : The water gate was closed in mid-January to concentrate the side inflow in Bade and Zhongli District.

(b) Arranging regional water in irrigation suspension area: After mid-January, Shimen MO rationed the canal water in Shezi system to recharge the Guangfu Canal.

(c) Withdrawing regional river water with pumps: When arranging pumps, it was necessary to consider the river hinterland, river water quality and quantity as well as the principle of not affecting domestic water use and the rights of farmers in the third district.

Therefore, the Taoyuan MO worked with the Taoyuan Government and the Water Resources Agency to arrange withdrawal pumps (Fig. 10). A maximum of 20 pumps operated at the same time daily to recharge the Taoyuan Canal as agricultural water with the largest amount of 0.3 (M) m^3. The rest of water was store in farm ponds in response to drought conditions. Besides, the Taoyuan MO set up 137 river weirs or dams to retain rainfall, make use of return flow and finally to store water in the farm ponds. To ensure the quality of withdrawn water, the MO established 5 monitoring sites in the Taoyuan Canal and conducted weekly testing by taking water sample (heavy metal test included).

During the first crop period of 2021, the third district in Taoyuan made good use farm ponds and river water for supplementary water source. With the storage of farm ponds and the plum rain in June, 27.48 (M) m^3 of reservoir water was saved and the actual irrigation water provided by the reservoir was 13.52 (M) m^3, much less than the originally approved 41 (M) m^3. As the reservoir storage on June 1 of 29.33 (M) m^3, the irrigation for the third district during the first crop period was completed and water for domestic use of two months was ensured(Fig. 15).

(2) Case 2: The irrigation grouping policy in Chianan irrigated area in the second crop period (2021)

In the irrigated area of Chianan MO, cropping patterns include two harvests in three years, double rice cropping, single rice cropping and growing sugarcanes (Fig. 12). In general, the first crop period comes in dry season, so only the double-cropping fields can grow paddy and the total area is around 18,000 ha. As the wet season comes in June, the harvested area during the second crop period increases due to abundant rainfall. In Chianan irrigated area, the second crop is divided into 6 groups. Group 1 and 2 are irrigated first, then group 3 and 4, and finally 5 and 6 (see Table 4). If the irrigation is provided to all groups at the same time, the Tsengwen and Wushantou Reservoir needs a storage over 400 (M) m^3. However, the storage in June may not be sufficient as the wet season just begin. It is important to assess the rainfall, reservoir inflow and storage in May and June so that the irrigation schedule can be adjusted and the irrigation for all groups are ensured.

In 2021, the storage of Tsengwen and Wushantou Reservoir on June 1 was only 58.28 (M) m^3, accounting for 30% of the average storage of 210 (M) m^3 in the past ten years. Therefore, the irrigation for the second crop may not be provided in June and it was necessary to postpone the irrigation for each group.

(a) On June 9, the storage of Tsengwen and Wushantou Reservoir increased to 123.68 (M) m^3. If the inflow between June and September remains $Q_{70\%}$ and that between October and December $Q_{90\%}$, after providing irrigation to group 1 and 2 in mid-July, the storage at the end of November would range between 180.79-226.55 (M) m^3, ensuring the domestic water use for 6 months at 120 (M) m^3 (Fig. 13). However, if providing irrigation to group 1 to 4 in mid-July, the storage at the end of November would only range between 71.32-117.08 (M) m^3, putting the domestic supply for 6 months at risk (Fig. 14).

(b) By June 24, the reservoir storage kept increasing to 271.01 (M) m^3. Considering the storage at that time, a simulation was made under the conditions that the inflow in June was $Q_{50\%}$, that between July and September $Q_{60\%}$ and that between October and December $Q_{90\%}$. Results showed that if providing irrigation to group 1 to 6 in mid-July, the storage at the end of November would range between 100.31-195.73 (M) m^3, and it was still questionable if there'd be sufficient water for the domestic supply for 6 months (Fig. 15).

(c) By June 28, the reservoir storage increased to about 300 (M) m^3, based on which a simulation was made under the conditions that the inflow in June was $Q_{50\%}$, that between July and September $Q_{60\%}$ and that between October and December $Q_{90\%}$. Results showed that if providing irrigation to group 1 to 6 in mid-July, the storage at the end of November would range between 128.97-215.43 (M) m^3, and the domestic supply for 6 months was ensured. Therefore, the Irrigation Agency suggested the irrigation for the second crop in Chianan area begin as usual – group 1 to 4 on July 12 and group 5 and 6 on July 26.

(d) The rainfall between June and October remained abundant, owing to the plum rain, the convectional summer rain and tropical southwest monsoon occurred in July and August. After mid-August, the Tsengwen and Wushantou Reservoirs were almost full, with a storage of about 560 (M) m^3, which was much more than the anticipated result, so the irrigation for the crop period was ensured (Fig. 16). The historic drought that took place in June 2020 and lasted for 300 days finally ended.

3.3 An assessment of the impact of the transition from an irrigation association to a government agency

In October 2020, the irrigation association was transformed into a government agency under the newly established Irrigation Agency. Review the drought-fighting process, assessing the impact of the transition from an irrigation association to a government agency is as follows:

(1) The irrigation association was a private unit in the past, which is more flexible and has a close relationship with the farmers. It is suitable for the role of bridging and communication between the government and farmers. Furthermore, some properties of the association and the land used by irrigation facilities are private property of farmers. The association plays the role of farmers' agent and assists farmers to complete the irrigation work in each period.

(2) Therefore, when the government incorporated the association as a government agency, it caused unease and doubts among farmers and employees of the association. On the one hand, they feel that their property and rights will be exploited. At the same time, they worry that after the association becomes a government agency, it will not be able to reflect the real problems encountered by local and contract farmers and will lose the role of irrigation agents that they played in the past. It is even widely believed that in the future, more and more agricultural water may be allocated to other targets, such as industrial water, which will have a severe impact on farmers' livelihoods.

(3) However, while the association was transformed into a government agency, not only the property continued to be used under the working funds required for the association's irrigation management and business operations. Furthermore, the government will continue to invest in the construction and maintenance of irrigation facilities in the Management Office (former Association) every year. Besides, most of the association's employees are still non-civil servants, continue to carry out the current work of irrigation management, and maintain close relations with farmers.

(4) Taking the irrigation for the third district in Taoyuan as an example, farmers typically plough their fields twice before cropping, so the period often results in the highest water demand each time. Before the start of the first crop period of irrigation in 2021, the Irrigation Agency held various dialogues and proposed to farmers in using dry ploughing as the primary method. The farmers in the 3rd Irrigation District of Taoyuan followed the recommendations, and over 80% completed two ploughing in accordance with dry ploughing methods. Besides, the leaders of each office in the 3rd Irrigation District and local farmers combined to form 90 groups with a total of 225 people to monitor the status of the ponds and gates, and to reinforce the scheduled release of water, which is one of the important factors for successful drought fighting.

(5) In terms of comprehensive assessment, it has been proved that the Management Office (former Association), as a bridge for communication with farmers and public-private cooperation, can still play an active role in the future. However, it must also be based on the continued strengthening and encouragement of dialogue between government and farmers at different levels.

4. Our suggestions and plans on drought response

After the severe drought in 2020-21, drought events may become more and more frequent in the future. In face of climate change and unstable water conditions, the IA aims to improve various service for farmers, increase water efficiency and economic revenues by enhancing agricultural facilities, examine the mechanisms of agricultural water use and allocation, and to maintain food production by optimizing water management so that the impact on agriculture could be reduced. As improving drought resilience has become the cross-sectoral focus of the Irrigation Agency, the Agriculture and Food Agency, the Taiwan Agricultural Research Institute and regional Agricultural Research and Extension Stations, short-, mid- and long-term measures have been widely implemented(P. Ronco, 2017; Karmen, 2019; Ching-Tien Chen, 2014; Tatiana Ortega, 2019; IPCC, 2014a; IPCC, 2014b; Hwa Young Kim, 2018).

4.1 Short-term measures – helping farmers to adapt to water-saving policies

(1) To hold technical trainings for farmers according to crop types, techniques required and regional water conditions.

(2) To establish demonstration site of water-saving irrigation pipeline facilities by regional Agricultural Research and Extension Stations according to crop types.

(3) To promote multi-purpose irrigation pipeline facilities (for irrigation, fertilizer and pesticide) based on local conditions to save up water and lower the production cost.

4.2 Mid-term measures – enhancing the water-use program

(1) To upgrade the channel and storage facilities, especially in high water-risk and land subsidence area, along with farmland planning for better supply of water by making assessment of regional water resource, geological conditions and building farm ponds.

(2) To make plans regarding rotational cropping patterns, in which the government promotes growing upland crop during the first crop period, since the water deficit rate coming at 40% in the northern irrigated area.

(3) To provide precision irrigation according to the crop types with different levels of drought sensitivity in order to reduce the impact of water scarcity.

4.3 Long-term measures – increasing agricultural drought resilience

(1) To develop drought-resistant crops such as upland rice, pigeon pea, millet, Taiwanese quinoa, etc. by improving drought management techniques, water utilization and pest proofing tools.

(2) To deploy smart irrigation systems with IoT and 5G to achieve real-time monitoring of water levels and the estimation of available agricultural water resources.

(3) To expand the scope of agricultural investment based on the officially suggested crop sensitivity levels by promoting less-sensitive crops, covering more crop types and increasing the coverage subsidies.

5. Conclusions

In recent years, drought occurred more and more frequently in Taiwan. As climate change intensifies the rainfall difference between the dry and wet season, the river flows and groundwater recharge has been seriously affected and the reservoir capacity reduced, further increasing the risk of water scarcity in the future. Besides, agricultural water use has been competing with other types of water use, threatening the security of agricultural water. More severe challenges regarding climate change are inevitable. Taiwan has earned valuable experience by gathering official ministries and local governments to fight drought together for about 300 days. Practical measures taken proactively significantly reduced the damage caused by the drought.

Despite the responsive measures taken in the third district in Taoyuan area, the fundamental solution to reducing risk of water scarcity is to guide farmers through growing upland crops during the first crop period instead of rice. Therefore, the COA has developed the 2.0 program of changing cropping patterns in the reservoir water competition area, aiming to apply rotational harvest thoroughly and regularly, to help farmers adapt to climate change as soon as possible. Short-, mid- and long-term measures are also proposed to enhance the government's services for farmers and establish mechanisms of public water management, including improving farm ponds and agricultural reservoirs, making good use of water storage facilities and supplementary source of water, promoting canal upgrades, pipeline irrigation and smart irrigation, all for better agricultural resilience and less impact of climate change.

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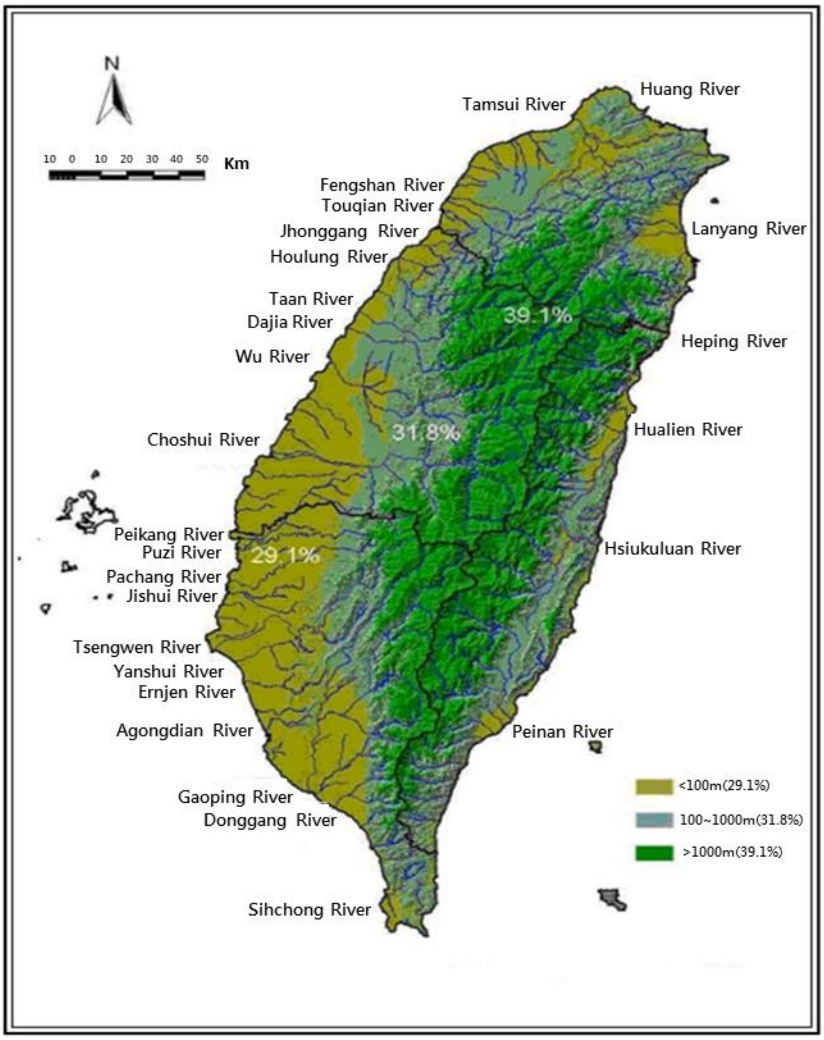

Figure 1. The geography and major river basins in Taiwan

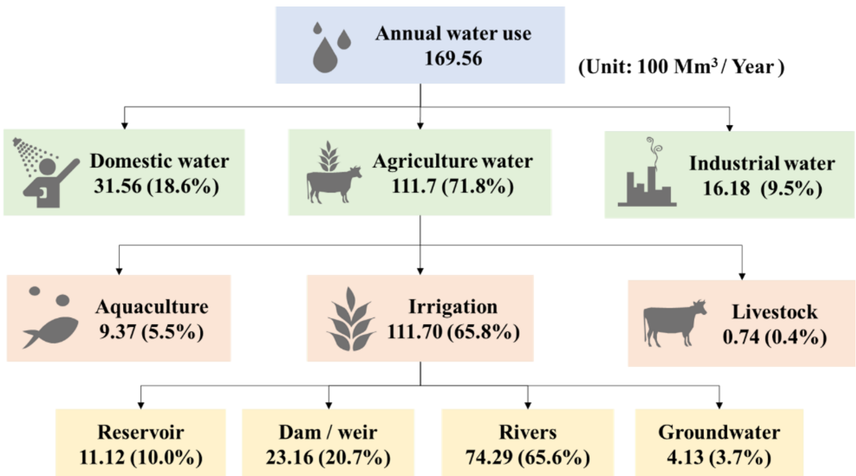

Figure 2. Statistics of water use for different targets

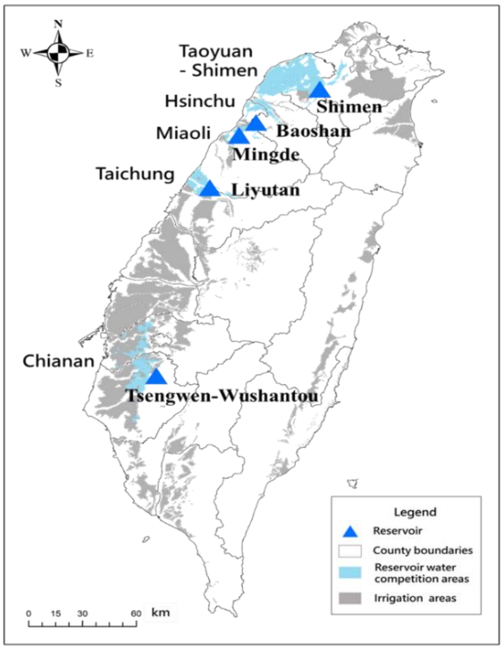

Figure 3. The scope of reservoir water resources competition area

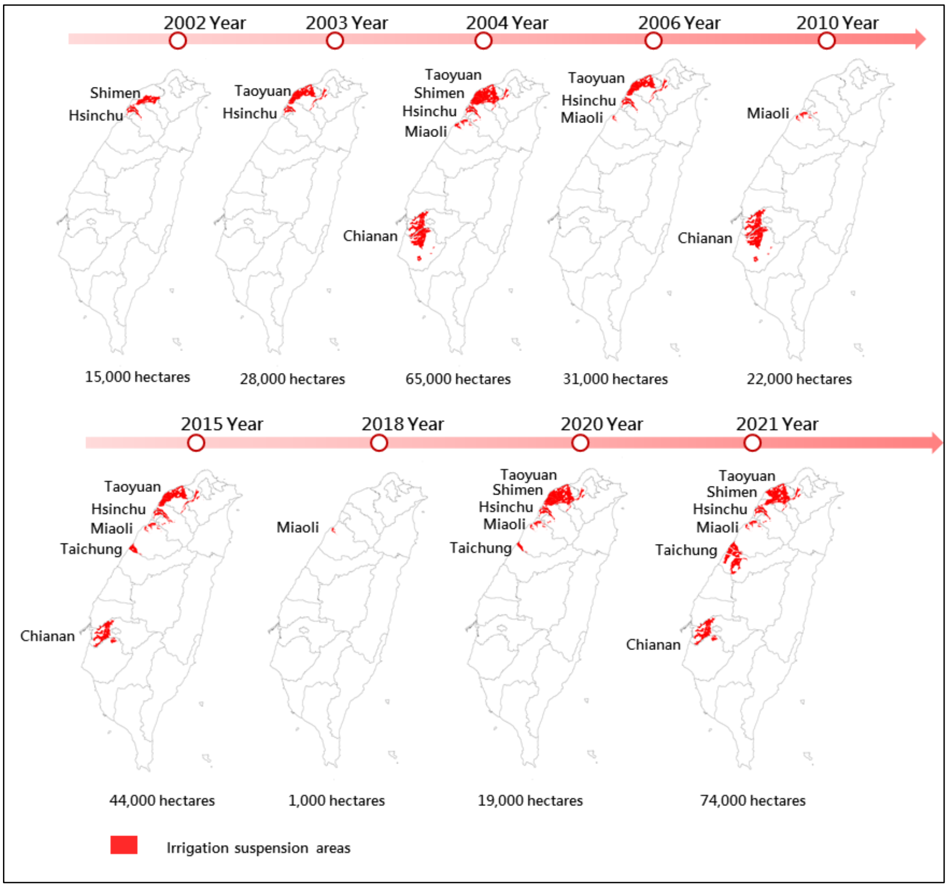

Figure 4. Irrigation suspension in water resources competition area over the past 20 years

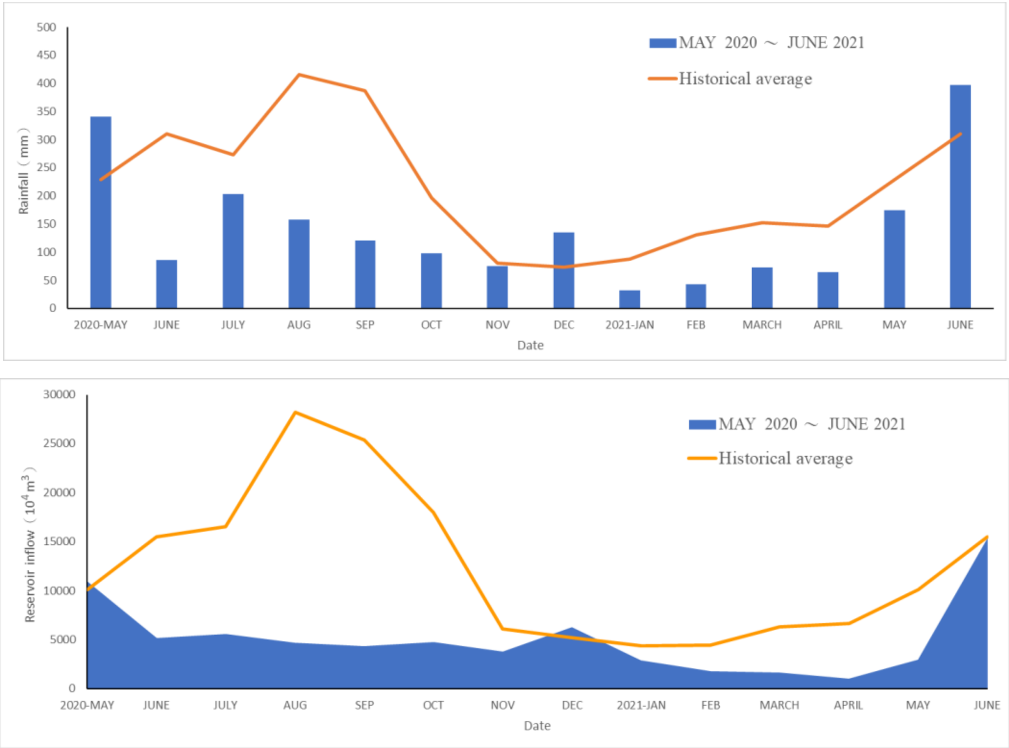

Figure 5. The rainfall and runoff of Shimen Reservoir during the drought compared to historical average

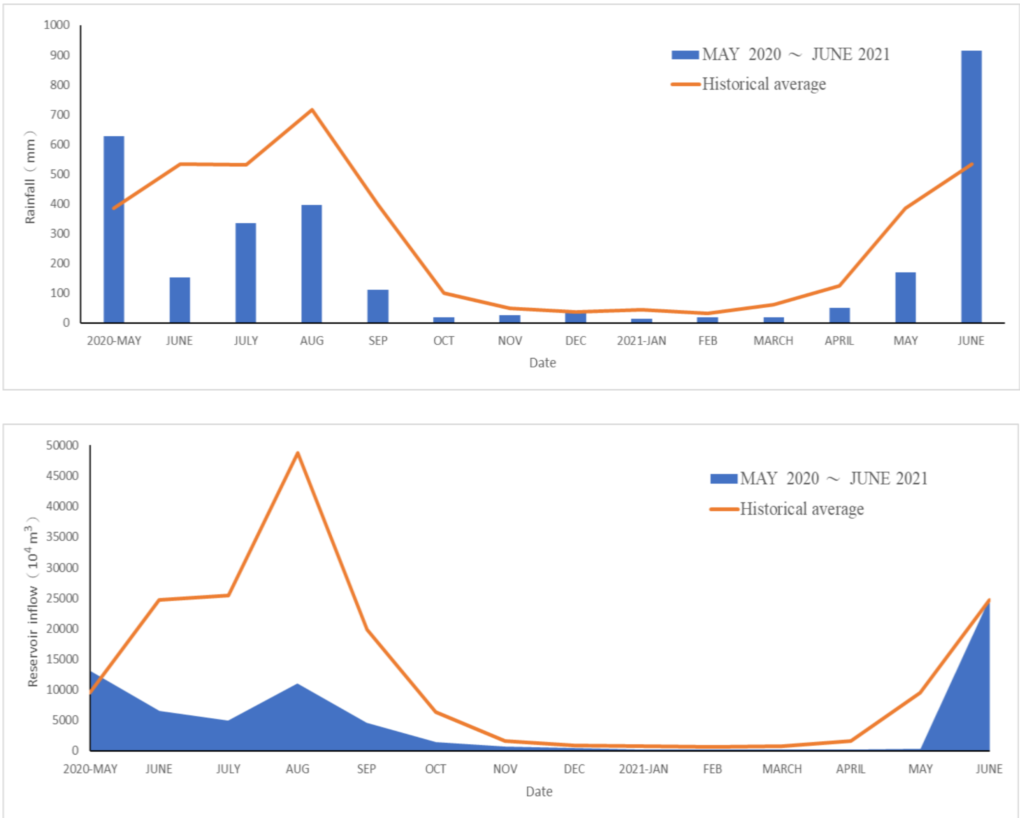

Figure 6. The rainfall and runoff of Tsengwen Reservoir during the drought compared to historical average

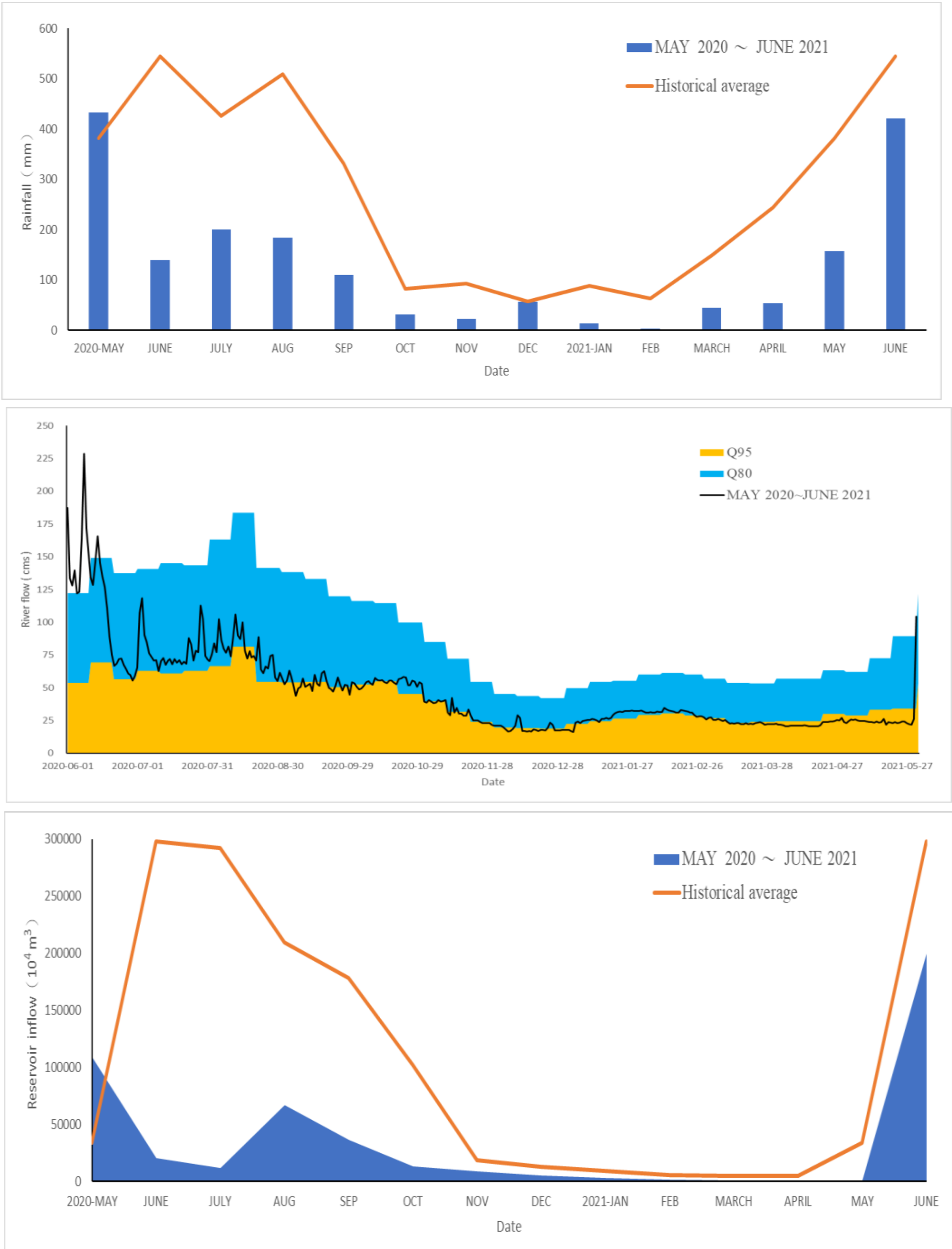

Figure 7. The rainfall, runoff and river flow of Jiji Weir at Choshui River during the drought compared to historical average

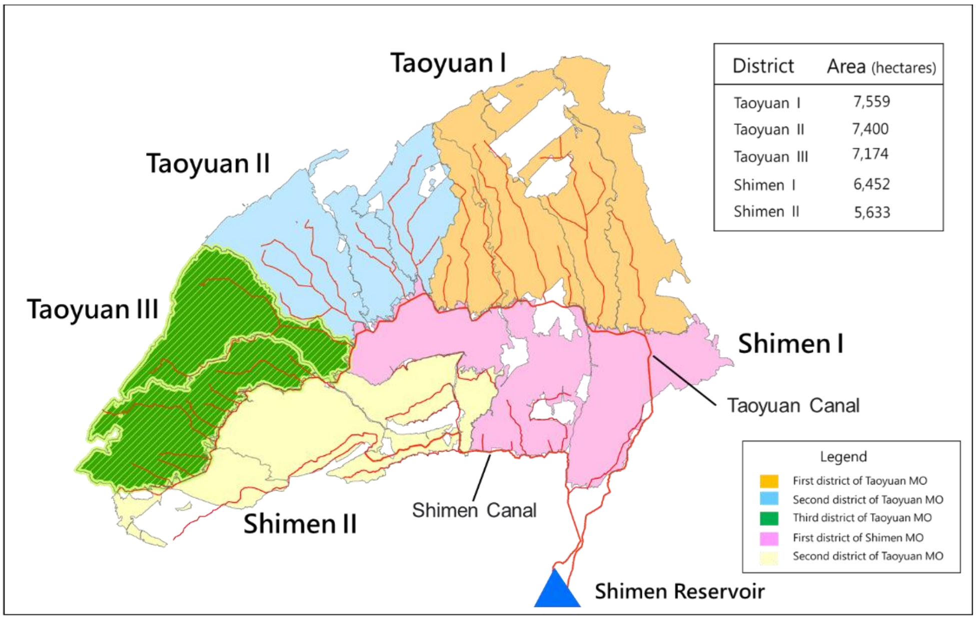

Figure 8. District of irrigated area in Taoyuan and Shimen management office

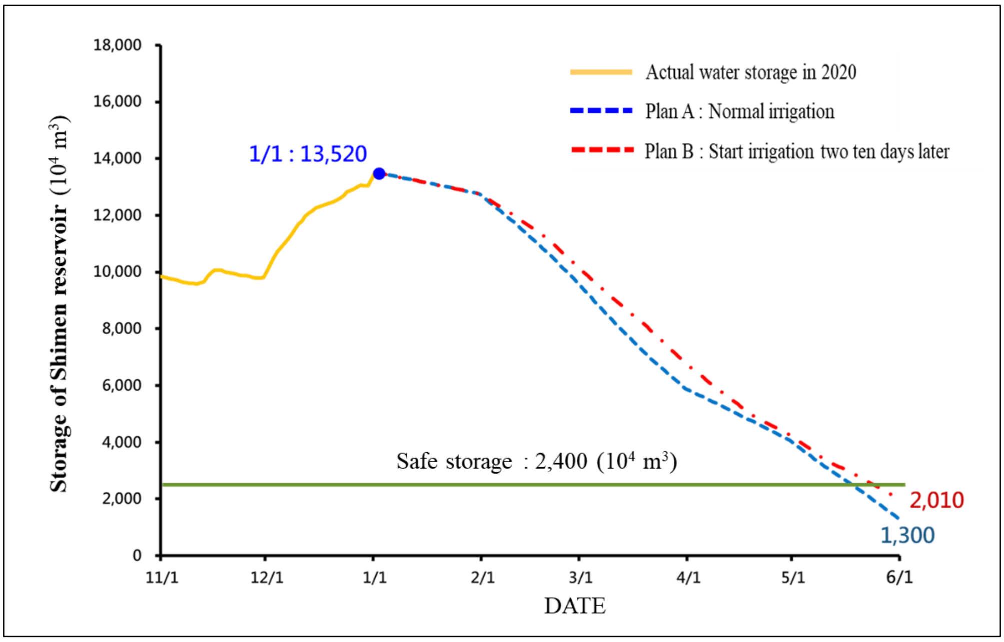

Figure 9. A simulation of water use in the Shimen Reservoir (2021.1.1)

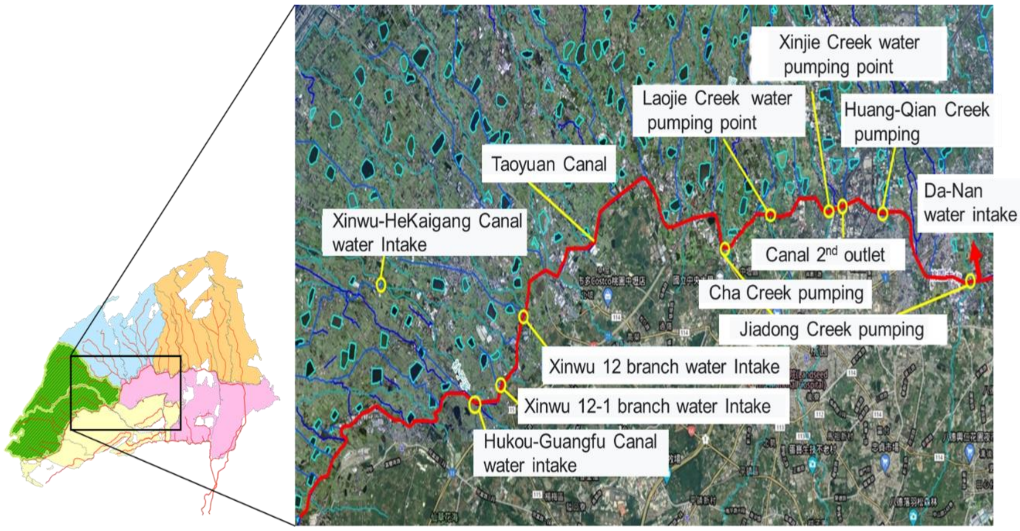

Figure 10. Regional water withdrawal and river intake in the third district of Taoyuan irrigated area

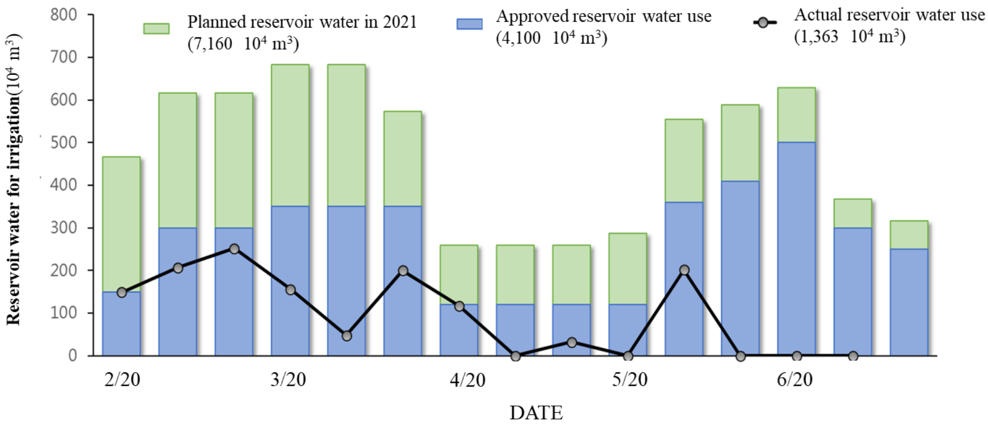

Figure 11. The comparison between approved and actual amount of used reservoir water in the third district of Taoyuan irrigated area

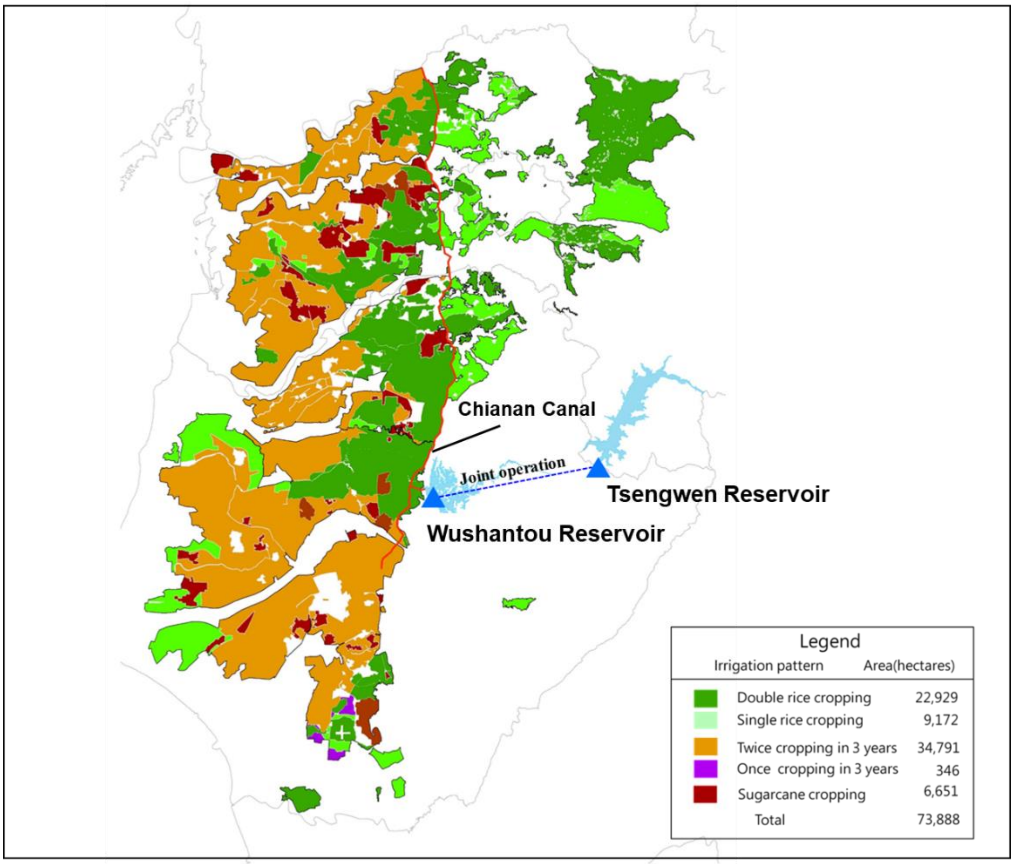

Figure 12. Current cropping and irrigation patterns in Chianan irrigated area

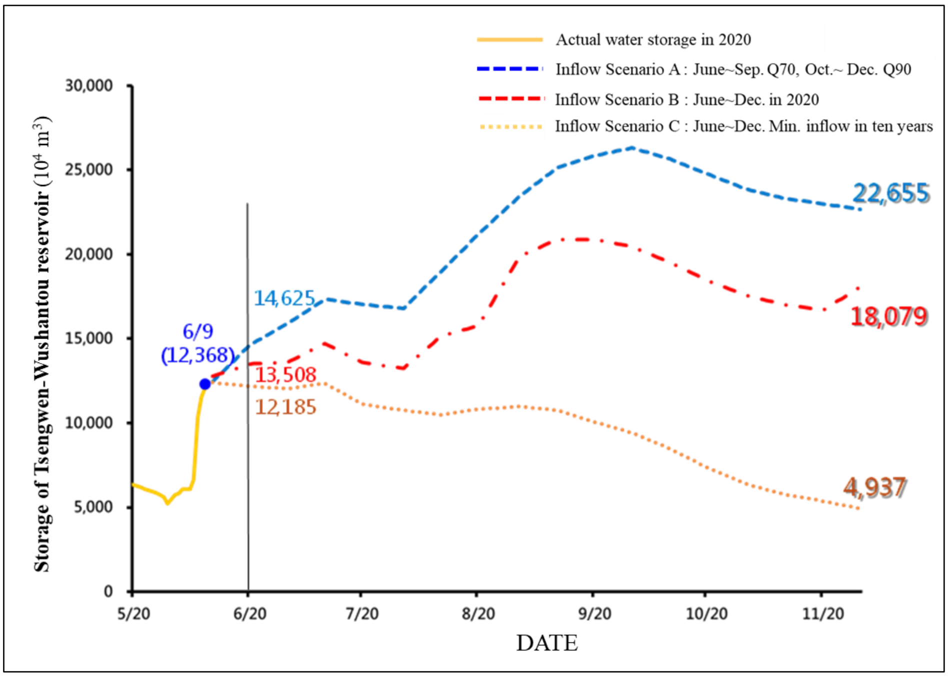

Figure 13. A simulation of water use in the Tsengwen-Wushantou Reservoir (Group 1-2, 2021.6.9)

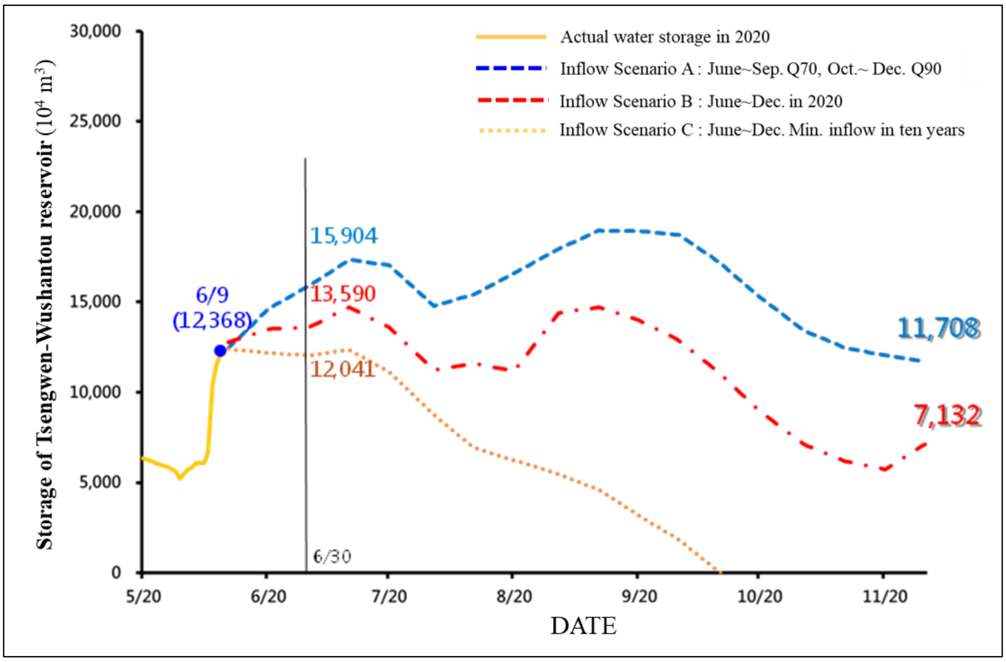

Figure 14. A simulation of water use in the Tsengwen-Wushantou Reservoir (Group 1-4, 2021.6.9)

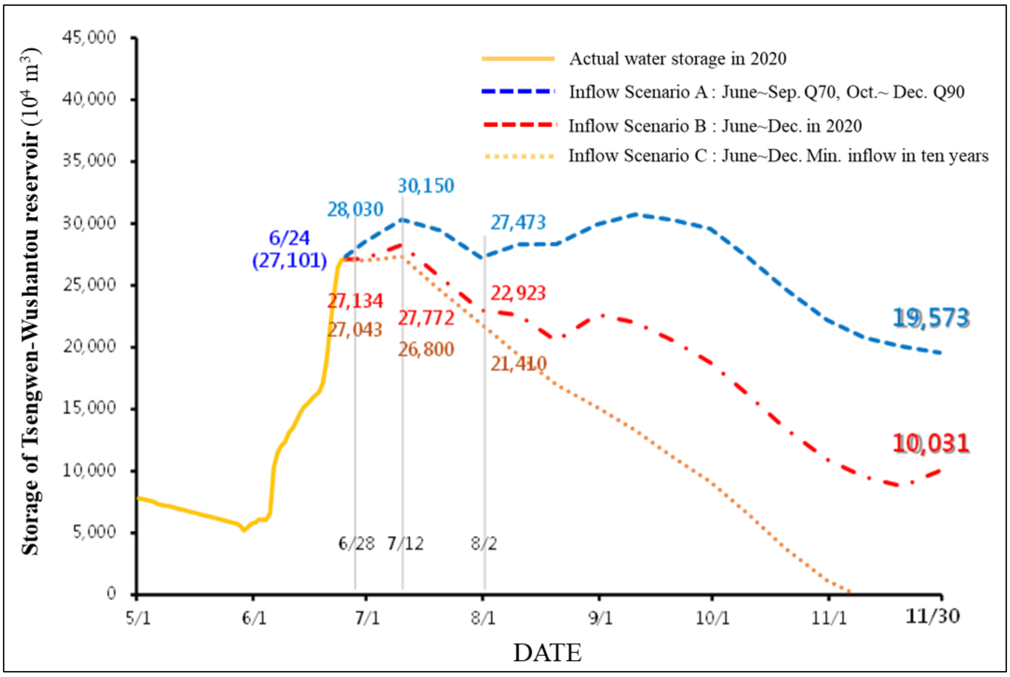

Figure 15. A simulation of water use in the Tsengwen-Wushantou Reservoir (Group 1-6, 2021.6.24)

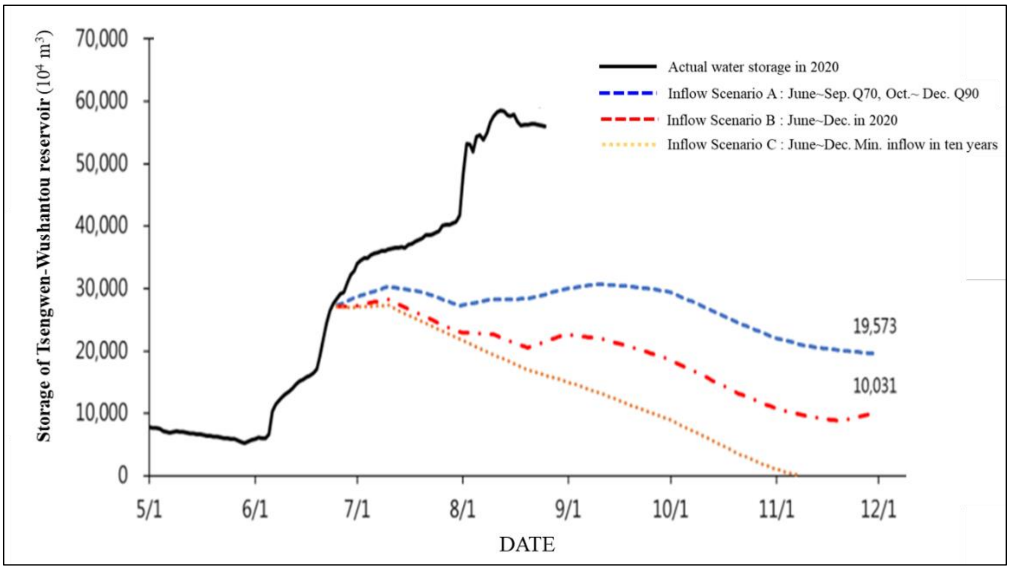

Figure 16. A simulation of water use in the Tsengwen-Wushantou Reservoir (Group 1-6, 2021.8.25)

Table 1. Hydrologic analysis of major reservoirs and weirs during the 2020-21 drought

Reservoir/Weir	Capacity (Mm^3)	Area (Km^2)	Rainfall (mm) (2020.6~2021.5) vs. Average			Runoff (Mm^3) (2020.6~2021.5) vs. Average		
			Drought Event	Historical Average	(%)	Drought Event	Historical Average	(%)
Shimen	202.66	763	1,262	2,483	50.8	449.16	1,467.53	30.6
Mingde	12.22	61	855	1,854	46.0	10.06	107.20	9.3
Liyutan	114.46	53	1,282	2,704	47.4	199.82	416.70	48.0
Tsengwen-Wushantou	587.07	481	1,351	3,018	44.8	312.54	1,410.62	22.1
Jiji Weir	-	2,034	1,014	2,969	34.2	1,465.98	4,541.55	32.3
Gaoping Weir	-	3,007	1,085	3,208	33.8	1,713.76	11,701.08	14.6

Table 2. River flow of major weirs during the 2020-21 drought

Weir	Flow (2020.11.1)		Flow (2021.3.1)		Flow (2021.4.1)		Min. during the drought		Min. in history	
	(cms)	Qp%	(cms)	Qp%	(cms)	Qp%	(cms)	record	(cms)	record
Jiji Weir	39.28	$< Q_{95}$	27.54	$< Q_{90}$	22.45	$< Q_{95}$	16.20	2021.1.3	13.58	2003.12.17
Gaoping Weir	43.52	$< Q_{80}$	7.32	$< Q_{95}$	4.12	$< Q_{95}$	3.80	2021.4.14	6.90	2020.5.7

Table 3. Storage of major reservoirs during the 2020-21 drought

Reservoir	Storage (2020.10.31)		Storage (2021.5.30)		Storage (2021.6.30)		Storage (2021.8.31)		Storage (2021.10.12)	
	(Mm^3)	(%)	(Mm^3)	(%)	(Mm^3)	(%)	(Mm^3)	(%)	(Mm^3)	(%)
Shimen	98.47	49	17.82	9	143.59	71	200.7	99	200.45	98
Mingde	2.47	20	0.81	7	8.39	69	11.19	92	9.96	82
Liyutan	60.20	53	2.01	2	73.71	64	114.46	100	112.08	99
Tsengwen-Wushantou	189.94	32	54.54	9	328.40	56	572.83	98	543.41	92

Table 4. The irrigation plan of Chianan irrigated area during the second crop period 2021

Group	Date for irrigation	Irrigation patterns	Irri. plan areas (hectares)	Irri. plan water (Mm^3)
1	7.12~10.30	• Single rice cropping	5,149	67.81
2		• Twice cropping/3yrs	7,517	89.61
3		• Once cropping/3yrs	7,983	91.95
4			4,912	57.22
5	7.26~11.10	• Double rice cropping	8,536	67.44
6			7,179	56.22
		Total	41,276	445.76

附件二 2022 ICID 年會國際研習會灌排管理制度工作小組論文

Title

Taichung Luchuan Metamorphosis from an Irrigation Canal to an Urban Multifunctional Waterway toward Sustainable Development Goals

Authors

Kuojen (Crystal) CHANG[1], Yuhsiang WANG[2], Yihsuan CHEN[3], Chingmei LIN[3], Chiaying WU[2], Sinite YU[4]

Abstract

Since 1723 in the Qing Dynasty, Taichung Luchuan Irrigation Canal has been a sub-branch of Huludun Irrigation Canal system, which was constructed and developed by the private sector. In the 1800's, Huludun Irrigation Canal system made more than 3000 hectares of wastelands into fertile agricultural lands. During the Japanese colonial period, the authority started promoting urban development planning for Taichung City in 1896. The function of Luchuan Irrigation Canal located in the center of Taichung City was gradually converted from irrigation into urban waterway.

After World War II, a lot of shield houses were built along Luchuan Irrigation Canal to accommodate numerous migrated people from mainland China. Those refuge residents made canal water severely polluted and difficultly for downstream farmer uses. Eventually, the city government upheld the policy with the "out of sight" concept and covered up the canal top in the 1980's to avoid residents nearby to contact with the deteriorated water of Luchuan Irrigation Canal. This practice kept people away from the waterway, and the life brought from irrigation canal dimmed to be neglected by people.

In the beginning of this century, several advocates from irrigation association, historical groups, and urban renewal associates initiated to uncover the canal and bring the canal memory back. Since 2015, along with society change and expectations, the city government accompanied with interested citizens are devising new ways of relating to each other and working together to get Luchuan Irrigation Canal better in the aspects of safety, environment, and culture of water.

In the Luchuan Irrigation Canal renovation movement, the public-private-partnership (PPP) process was implemented to carry out Sustainable Development Goals (SDGs). At first, the idea of social inclusion has been conducted by inviting vulnerable peoples such as vagabonds and foreign workers resided close to Luchuan Irrigation Canal to participate in sorts of discussions. In addition of participants from official water management sectors, such as water bureau, water company and irrigation association, the residents, businessmen, community school kids, and NGO representatives within the watershed were all involved. Until now for seven years of the PPP process, the Luchuan Irrigation Canal waterfront renovation has become one of the most attractive civil and tourist spots in Taichung City. As a result, the Luchuan Irrigation Canal has been selected as one of the vivid examples of resilient cities with SDGs presented in 2021 Glasgow UN Climate Change Conference.

Keywords

Taichung Luchuan Irrigation Canal, water environment improvement, public-private partnership, Sustainable Development Goals (SDGs)

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[1] Project Engineer of Taiwan International Institute for Water Education.
Corresponding author, email: crystal.chang.tiiwe@gmail.com
[2] Associate Researcher of Taiwan International Institute for Water Education
[3] Project Engineer of Taiwan International Institute for Water Education
[4] Research Fellow and Director of Taiwan International Institute for Water Education

Main Text

1. Luchuan Irrigation Canal History

1.1. Millennia of Culture

Taichung City is located in the heart of Taiwan, where human settlement has been documented since 4,000 years ago. Following the Dutch occupation in the early 17th century and followed by the Zheng, Qing, Japanese, and Republic of China periods, Dutch, Tangshan Han, Japanese, mainland Chinese, and foreign migrant workers moved in one after another, blending with the local culture to form this multi-cultural city.

1.2. Irrigation and Land Reclamation

Before the Qing Dynasty, the Taichung Basin was inhabited by the Taiwanese Plains Indigenous Peoples, who lived by hunting and gathering. The development of farming land was limited by irrigation technology. At the beginning of the Qing Dynasty, the Han Chinese migrated to the Taichung Basin on a large scale. Their reclamation was mainly carried out in two ways: (1) the southern side - from the northern bank of Wu Creek to the northern side of the basin; (2) the northern side - on the southern bank of Dachia Creek, led by Zhang Dajing, drew Dachia Creek water for irrigation and gradually expanded to the southern side of the basin from Feng Yuan.

In the middle of the Qing Dynasty (1723~1735), the Huludun Irrigation Canal system, led by Zhang Dajing, had the most profound impact on the land's development and the irrigation construction system in the Taichung Basin. By the end of the 18th century, the Huludun Irrigation Canal System had irrigated more than 3,000 hectares of land, and the landscape of the Taichung Basin had been radically changed.

A map of the irrigation area within the Taichung State irrigation system drawn in the Japanese period (1933) (Figure 1) clearly shows the main canal routes (red line in Figure 1) and irrigation areas (yellow region in Figure 1) in the Taichung Basin at that time. The Huludun Irrigation Canal system crosses Feng Yuan and forks eastward into another canal that leads to Tanzi and Beitun, among others. This waterway continues southward into the old Taichung city, crosses the railroad tracks near the Taichung station, and turns southwestward, eventually merging into Wu Creek. The waterway connecting Dachia Creek and Wu Creek is the Luchuan Irrigation Canal (blue line in Figure 1).

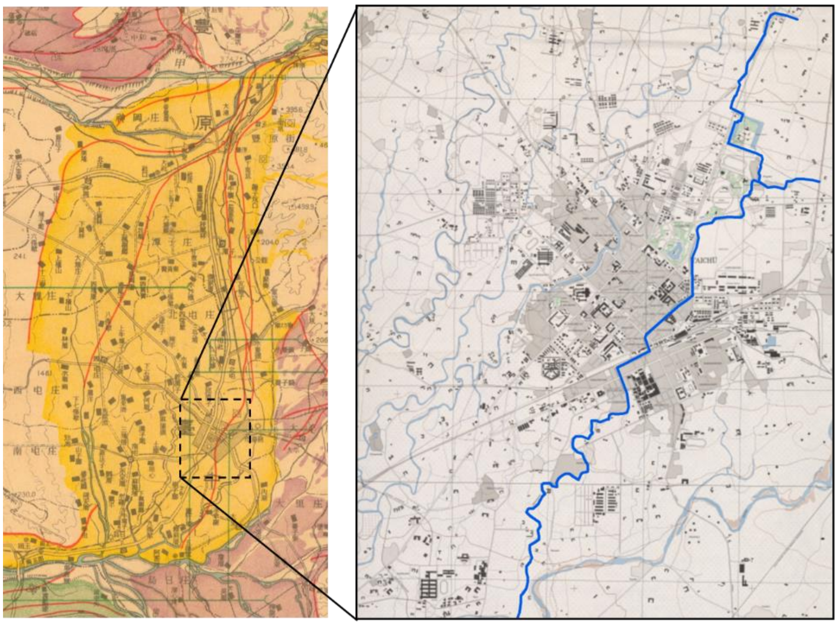

Figure 1. Left: Widespread distribution of Huludun Canal Irrigation system in the Taichung Basin (yellow region) ('Taichung State Irrigation Canals Managing Associations (part), 1939, Center for GIS, RCHSS, Academia Sinica). Right: The waterway connecting Dachia Creek and Wu Creek is the Luchuan Irrigation Canal (blue line), 1945, Center for GIS, RCHSS, Academia Sinica).

1.3. Subsurface Flow Utilization

The water source of the Luchuan Irrigation Canal is not only from the upstream canal and the plentiful rainwater but also the abundant subsurface flow. Situated next to the Luchuan Irrigation Canal is the water source of Taichung Park. In 1914, a well was drilled to draw groundwater, Taichung's earliest source of domestic water (Figure 2). The former site of the Taichung Brewery, built next to the Luchuan Irrigation Canal, was also built for its excellent groundwater quality, so in 1916, the Taisho Brewery Company established the Taichung Factory, specializing in the production of sake and rice wine.

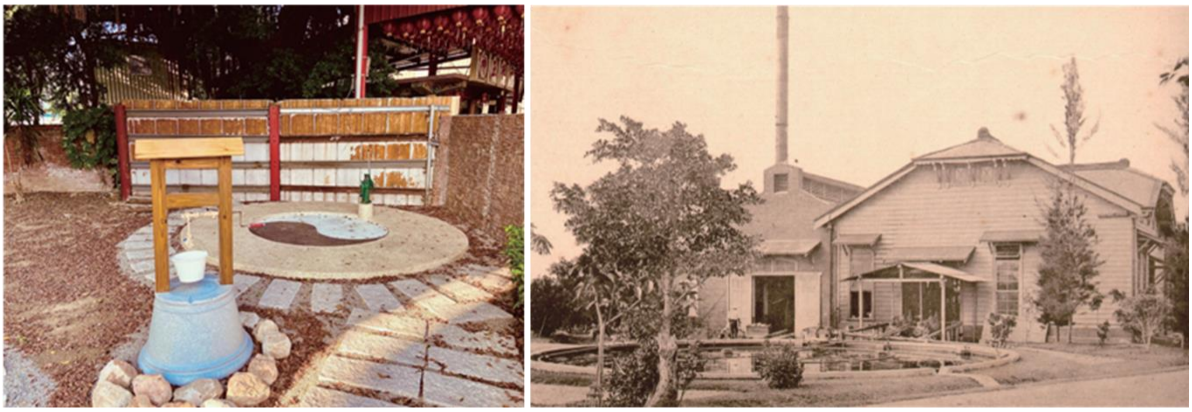

Figure 2. An example of an ancient well with abundant groundwater in South District, Taichung (as shown on the left side). "Taichung Water Source Site Pumping Room", the birth of Taichung City’s modern drinking-water facilities, was built in 1914 in the Japanese period (as shown on the right side). (《市街之味：臺中第二市場的百年風味》, Poching YU, 2017, published by Vista Publishing Co., Ltd.)

1.4. Transformations of the Farms

The Luchuan Irrigation Canal flows downstream from the central district of Taichung to the southern district and passes through the top of Qiaotou, the central transportation hub between Dadun Street, Dali, Wuri, and Wubong. Because of the well-developed water system and fertile land, it has created the largest rice cultivation area in Taichung and the top-ranked "first-class farmland" in Taiwan, establishing the largest settlement in Taichung. During the Japanese era, in 1943, the Governor's Office of Taiwan saw the excellent soil and abundant irrigation water in the Luchuan Irrigation Canal in Dingqiao. As a result, it moved the High School of Agriculture and Forestry in Taipei to this area, laying the foundation for the development of National Chung Hsing University (NCHU), which was the first university founded for agriculture in Taiwan.

Prior to World War II, the Luchuan Irrigation Canal in the urban area had become a neat urban river, while several sections of the Luchuan Irrigation Canal downstream still maintain a natural meandering stream appearance (blue line in Figure 1 left). In 1990, the winding Luchuan Irrigation Canal next to NCHU was straightened, landscaped, and linked to the campus to become a lush green open space. In addition, a large amount of farmland in the area was initially developed under the urban plan with the widening roads and land construction, creating a new urban space.

1.5. Management System Turnover

Most of the irrigation canals in Taiwan from the Qing Dynasty onward were developed with private funds, and water rents were collected from the beneficiary farmers, who elected representatives to manage and operate them. In the Japanese era, a publicly managed water consortium was established in 1921, bringing in government financial resources and technology and transforming the private irrigation organization into a public organization with the public interest. After the war, in 1945, the government changed the management of irrigation to a private organization elected by the farmers in the irrigation area, with government subsidy funding; in 2020, the private irrigation organization was transformed into a public agency, and its private property was shifted to public ownership. The Luchuan Irrigation Canal is also in the process of adjustment and changes with the system change.

2. Luchuan Irrigation Canal and the Transformation and Development of Taichung City

2.1. Taichung Urban Plan and Luchuan Irrigation Canal Improvement

The Japanese Governorate introduced the modern European urban planning system and actively developed urban plans for various regions of Taiwan to transform the traditional urban space of the time. In 1896, William Kinninmond Burton (1855-1899), a technician in the Japanese Ministry of Internal Affairs, and Hamano Yashiro (1869-1932), a student, were invited to Taiwan by the Governor General's Office to conduct a sanitary survey and to understand the environmental problems of the time. After understanding the environmental problems of the time, he proposed a set of urban planning designs based on the sanitary survey, namely the "New Urban Design of Taichung" and the "Report on the Design of Taichung City Street (Figure 3). "

Burton and Hamano's urban planning and design were based on the "chessboard street contour", which Burton believed was a square, grid-like contour that allowed for the proper distribution of critical public buildings and straight lines for important traffic movements in the city, as well as the necessary adjustment of the direction of the rivers and waterways in the city to avoid flooding.

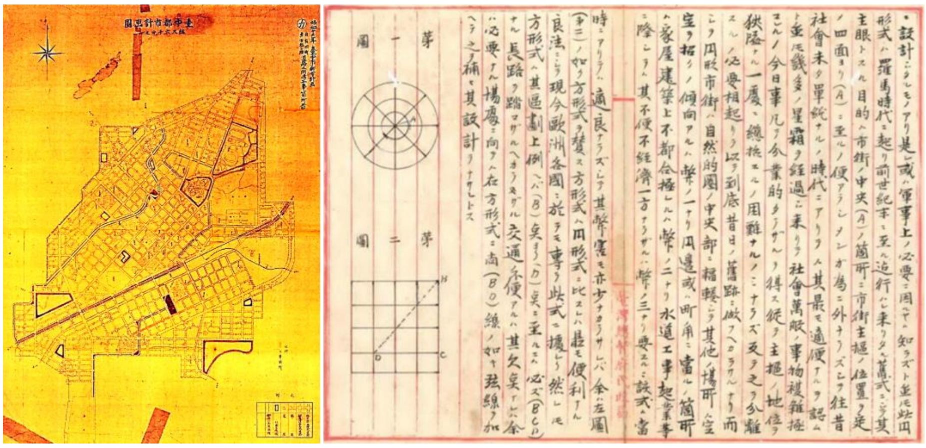

Figure 3. Burton, W. K., and Yashiro, H. proposed the 'Report on the Design of Taichung City Street' (as shown on the left side) and illustrated the difference between roundabout street contour and chessboard street contour (as shown on the right side). (《台灣總督府檔案》, Vol.101 No.42, Library of Taiwan Historica)

2.2. The Pioneering River of Epidemic Prevention

Based on Burton's and Hamano's plans, the Governor's Office of Taiwan implemented several urban plans for the urban area of Taichung after 1900, among which the "45-degree skewed street profile" and the "urban river correction" are closely related to the formation of the present urban landscape of Taichung.

Burton's concept of a 45-degree skewed street profile was first announced in the "Taichung Urban Plan" in 1900. Based on a checkerboard street profile, the original east-west and north-south roads were slanted at an overall angle of 45 degrees. From the perspective of environmental sanitation, this planning approach can increase the sunlight exposure of streets and buildings and improve the efficiency of daylight exposure for sanitation.

The urban plan corrects the existing rivers by straightening them and moving them between the city streets, hoping to achieve sanitation and disinfection through sunlight to prevent the spread of diseases. As a result, the city's rivers not only overflowed but also improved environmental sanitation and slowed the spread of infectious diseases. In 1943, the Luchuan Irrigation Canal south of the railroad tracks was partially modified for the last time by the Taiwan Governor's Office, and the shape of the Luchuan Irrigation Canal has been largely finalized since then. Through successive urban plans, the Luchuan Irrigation Canal was transformed from a plain river with a diffuse flow to a neat urban river.

These "forward-deployed" improvement measures have laid the foundation for the development of Taichung today. It is also the first water management project in Taiwan with the goal of public health, which has a special significance in the history of river improvement in Taiwan.

3. Overloaded Luchuan Irrigation Canal during Urban Development

3.1. Waterfront Refugee Houses

After the Nationalist government moved to Taiwan in 1949, it brought many soldiers, officers, immigrants from other provinces of mainland China to the city, and it is estimated that about 100,000 people came to Taichung. Some of the immigrants had no place to live, so they cut down the willow trees along the Luchuan Irrigation Canal and built dry-rail buildings along the riverbank, using simple timber panels to build roofing walls to live, with half of the houses on land and half on the Luchuan Irrigation Canal. This is how the Stilt Houses were born. As the Stilt Houses are located close to the river, all the living is here, and much domestic sewage is discharged into the Luchuan Irrigation Canal (Figure 4). Thus, the river and stream are sacrificed for urban development.

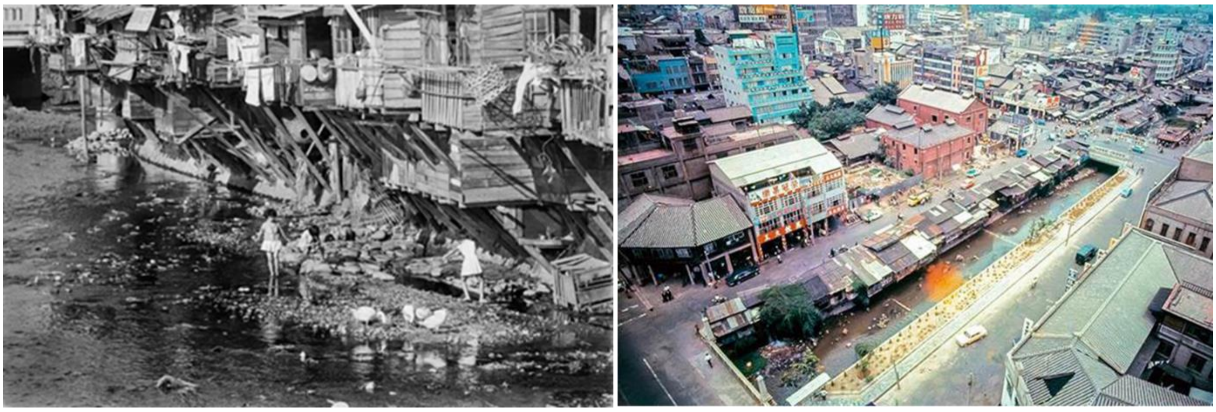

Figure 4. Refugee houses along the riverbank. (Ruji YU and Xiuzhu Zhang)

3.2. Stilt Houses Demolitions

In 1968, Taichung City adopted the "build first, demolish later" approach and contracted out the market's construction, then demolished the illegal structures after the market was completed in 1971 to accommodate the tenants that had their houses demolished to make a living.

At the same time, photographer Mr. Yu Ru-ji carefully planned the Luchuan Irrigation Canal "Concentric Garden" greening campaign, which the government and the people promoted. Also, he invited students from universities and colleges near Taichung and nearby residents to complete the campaign together. The geographic advantage of Jianguo Market's proximity to the train station has led to the area's development and the market's expansion, making the central district of Taichung City an essential economic and trade hub in central Taiwan.

3.3. Forgotten Memories following Waterway Covering

As the population of Taichung City continues to grow and many vehicles circulate, the train station has become the most critical point for travel from north to south. In response to the enormous traffic demand, the city government covered the waterway as a road, a parking lot, and a temporary market for vendors.

The First Square along the Luchuan Irrigation Canal was completed in 1990 and became the busiest new landmark in Taichung. However, after 2000, with the shift of business focus, it gradually became a holiday gathering place for Southeast Asian migrant workers due to its convenient transportation and the rise of Southeast Asian stores. Although the Luchuan Irrigation Canal in front of Dongxie Plaza has been transformed into urban park, it is still not in sight, and the beautiful waterway has been reduced to an urban underground gutter.

4. The Luchuan Irrigation Canal Protected by Public-Private Partnerships

4.1. The Voices of Farmers Residing in Luchuan Irrigation Canal

During the urban expansion, farmers downstream suffered from the pollution of the Luchuan Irrigation Canal by urban sewage, resulting in the gradual disappearance of farmland. However, today, fortunately, there are still 13 hectares more of farmland downstream of the Luchuan Irrigation Canal that has not been zoned as urban land and continues to be used for irrigation purposes as a food supply area (Figure 5). The irrigation canal of this farmland is now called the "Luchuan Subbranch of Liangyi Waterway." In 2015, the responsibility for river management was transferred from the central government to the

Water Resource Bureau of Taichung City Government (Taichung WRB), which initiated the ***Water Environment Improvement of Taichung Luchuan Canal*** (**WEI-Luchuan**). As a result of the water environment improvement of the Luchuan Irrigation Canal in the middle and upper reaches of the city, the water quality downstream is much cleaner than before, and as a result, fish can now be found swimming in the canal and rocks can be seen under the water (Figure 6). Although the irrigation area is not as large as before, the "Luchuan Subbranch of Liangyi Waterway" is still rich in vegetation, beautifying the landscape and making it easier to control water intake and facilitate water management on farmland.

Figure 5. The irrigation areas of Luchuan Subbranch of Liangyi Waterway and its farmland.

Figure 6. A clearly visible school of fish can be seen in the canal inlet.

The farmers who are still operating the farmland have been in the area for at least a century, and most of them are old, describing that they are losing the meaning of farming and the hope of future farming as the area of farmland is gradually declining, which genuinely reflects the voices of farmers' worries.

4.2. Long-term Conservation Communities of the Luchuan Irrigation Canal

As time evolved, the Luchuan Irrigation Canal attracted many foreign populations along its shores. From the Japanese era, when more than 50,000 people lived there, to the post-war period, when nearly 100,000 immigrants moved in, the symbiosis of the Luchuan Irrigation Canal basin is now populated by different groups of people, such as residents, farmers, local opinion leaders, NGOs, newcomers, migrant workers, and street people. Before the government started WEI-Luchuan, a group of local citizen groups had long been concerned about the Luchuan Irrigation Canal, and they each cared about the Luchuan Irrigation Canal from different aspects.

4.3. Launch of WEI-Luchuan

The Luchuan Irrigation Canal is currently approximately 6 kilometers long. With urban development and the population living near the water, the water quality has deteriorated, turning the Luchuan Irrigation Canal into a foul ditch. The waterway is covered, forming a barrier between people and the water, reflecting the speculative mentality that not seeing is not seeing. Due to the various problems arising from the Luchuan Irrigation Canal, Taichung WRB has been actively promoting the WEI-Luchuan since 2015, starting with the opening of the waterway cover, combined with the railway elevation project, extending south to the campus of National Chung Hsing University. To upgrade the level of improvement from water safety, water environment, and sublimation to water culture, introducing humanities, history, ecological restoration, and environmental education, the vision of the Luchuan Irrigation Canal is gradually realized (Figure 8).

Figure 7. Comparison of the Luchuan Irrigation Canal with the WEI-Luchuan (1971 left vs 2021 right). (Yu Ru-ji and TIIWE)

Figure 8. The WEI-Luchuan nearby NCHU

4.4. Developing Cross-community Partnerships

Through a series of activities organized by WEI-Luchuan, Taichung WRB has been able to foster more connections with local organizations so that the voices of those who care about the Luchuan Irrigation Canal can be heard.

The Taichung City Government values the diverse and compatible water culture of the Luchuan Irrigation Canal and hopes to create a tight and cohesive living circle in the Luchuan Irrigation Canal to remove the cultural barrier between each other so that this group of foreigners can feel warm and fuzzy. For example, the second generation of new aborigines will be allowed to sing songs in their native language to convey the meaning that Luchuan Irrigation Canal nurtures multiple cultures, allowing new aborigines to introduce their home water environment and share their expectations for Luchuan Irrigation Canal; the second generation of new aborigines will be invited to join the river cleaning activities to transform their love for the land and rivers into action (Figure 9). In order to alleviate the anxiety of migrant workers during the construction period of WEI-Luchuan, the city government produced the first signboard in six languages and multi-language transportation guidelines for migrant workers in need. In addition, a large mosaic wall was created using the "water market" as the base picture to enhance the memories and sense of identity of migrant workers and new residents of the Luchuan Irrigation Canal (Figure10).

Figure 9. The activities for new aborigines to get closer to Luchuan Irrigation Canal, especially the second generation of new aborigines.

Figure 10. The first signboard in six languages (as shown above) and the large water market mosaic made of migrant workers' photos (as shown below with a red square).

In addition, the Luchuan Irrigation Canal is surrounded by a group of neighbors who are often regarded as negative assets of the city. In promoting WEI-Luchuan, the city began to consider the issue of counseling and resettlement of the residents along the Luchuan Irrigation Canal, and with the joint efforts of the government and community groups, a win-win situation was created. The city held a Dragon Boat Festival at the Luchuan Irrigation

Canal, where trained street people served as city guides to explain the cultural connotations of the Luchuan Irrigation Canal and the origins of Taichung's old city development to the participants (Figure 11). This group of friends, who call the street their home, will use their life experiences to lead visitors to experience the land. Through the Luchuan Irrigation Canal, the government has built a bridge between different communities so that the Luchuan Irrigation Canal is no longer a specific community but the guardian river of Taichung's symbiotic community.

Figure 11. The city tour guide, who was a street resident near the Taichung Railway Station, guided tourists through the Luchuan Irrigation Canal at Dragon Boat Festival in 2020.

4.5. Luchuan Irrigation Canal Water Culture Showcase

In order to continue to deepen and expand the education on the Luchuan Irrigation Canal water culture and environment, Taichung WRB has built the "Luchuan Irrigation Canal Water Culture and Environmental Education Center." It will also serve as an essential base to care for the underprivileged and to train the residents as city guides, allowing the public to witness the story of Luchuan Irrigation Canal's life transformation (Figure 12).

A book published in 2021 will document the humanistic development and renovation process of the Luchuan Irrigation Canal, emphasizing that water conservation projects are not only about water treatment but also cultural and historical preservation (Figure 13)

Figure 12. View of the ‘Luchuan Irrigation Canal Water Culture and Environmental Education Center’ from outside (as shown on the left side, Xiuzhu, Zhang) and inside.

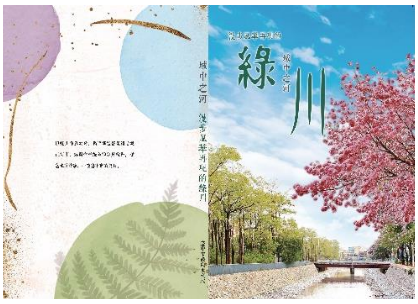

Figure 13. A book about the Luchuan Irrigation Canal published by Taichung City Government.

4.6. Luchuan Irrigation Canal Selected as a Representative Case of SDGs Resilient Cities

After seven years of public-private-participation, the collaboration and remediation of Luchuan Irrigation Canal has evolved into not only a part of the local community's life cycle but also a tourist attraction (Figure 14). As a result, Luchuan Irrigation Canal was selected as one of the SDGs resilient cities case studies in the report "The Role of Culture in Climate Resilient Development," which was co-presented at the United Nations Climate Change Conference (COP26) in 2021 (Figure 15).

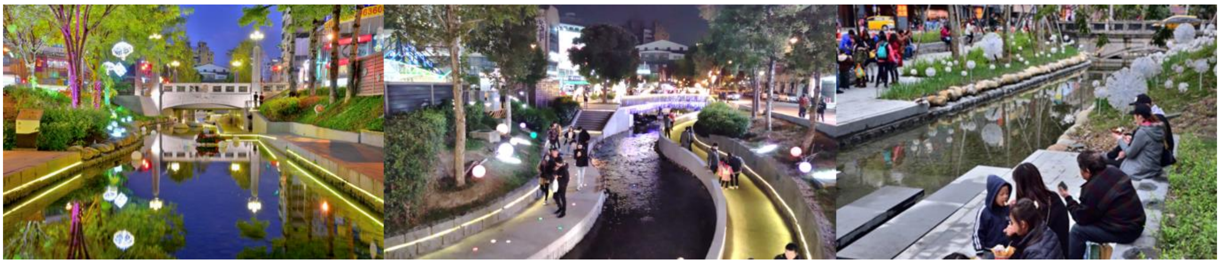

Figure 14. After the water improvement, this renovated waterfront of the urban canal, in the middle and upper of the Luchuan Irrigation Canal, has become one of the most attractive civil and tourist spots in Taichung City.

Figure 15. "Water Environment Improvement of Luchuan Canal" was selected as one of the SDGs resilient cities case studies in the report "The Role of Culture in Climate Resilient Development," which was co-presented at the United Nations Climate Change Conference (COP26) in 2021. Luchuan Canal was rewarded SDG3 (Good Health and Well-Being), SDG6 (Clean Water and Sanitation), SDG9 (Industry, Innovation and Infrastructure), SDG10 (Reduced Inequalities), SDG11 (Sustainable Cities and Communities), SDG13 (Climate Action), SDG15 (Life on Land), SDG17 (Partnerships for the Goal) (as shown on the right side with a red square).

5. Conclusion

The Luchuan Irrigation Canal has evolved from its earliest role as an irrigation canal for food production to a multifunctional urban waterway with water safety, water environment, and water culture in response to the changing times and urban development, and more importantly, it has become a warm home for accepting different groups and supporting the socially disadvantaged. Nevertheless, the initial role of the irrigation canal can still be found in the agricultural fields downstream of the Luchuan Irrigation Canal. With these adjustments, the transformation of the Luchuan Irrigation Canal is not stopping but moving in the direction of sustainable development.

Acknowledge

Since 2015, the Water Resource Bureau of Taichung City Government has supported a series of public-private participation plans to enhance the Water Environment Improvement of Taichung Luchuan Canal (WEI-Luchuan) to be more sustainable for the city. The achievement in this article is mainly the outcomes of these supports.

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