出國報告（出國類別：開會）

赴馬來西亞吉隆坡參加
第 76 屆國際執行委員會議
暨第 4 屆世界灌溉論壇

服務機關：農業部農田水利署

姓名職稱：王歆涵副工程司、范綱翰組長、吳信輝股長、王建安股長、黃婉琦股長、李柏澍股長、劉斯勇股長

派赴國家：馬來西亞

出國期間：中華民國 114 年 9 月 6 日至 9 月 10 日

報告日期：中華民國 114 年 12 月 8 日

摘 要

第 76 屆國際執行委員會暨第 4 屆世界灌溉論壇於 9 月 7 日至 9 月 14 日在馬來西亞吉隆坡太子世界貿易中心舉辦，此次會議及論壇共有近來自全球千位官員、學者與專業人士參與。

國際灌溉排水協會中華民國國家委員會（CTCID）由吳瑞賢主席率團與會，此次代表團成員來自全臺農田水利署各管理處、大專院校、研究單位等，共 28 位團員，包含工作小組委員 12 位、團體會員代表 9 位、學研機關及論文發表人員 4 位以及秘書處行政人員 2 位。

今年度持續擴大參與工作小組，提名闕雅文教授擔任社會經濟轉型下之灌溉排水工作小組（WG-IDSST）副主席、江莉琦教授加入水資源匱乏管理集水工作小組（WG-WHMWS），以上皆為大會所接受。其中闕雅文教授榮任 WG-IDSST 副主席一職更加擴大臺灣在國際灌排界之影響力，同時亦是大會對臺灣在農田水利方面貢獻的肯定。

第 4 屆世界灌溉論壇主題為《灌溉是否為夕陽產業？》(Is Irrigation a Sunset Industry?)，共四個子題如下：

一、 灌溉與排水在變化世界中對糧食安全所面臨之挑戰；
二、 農業部門的技術與現代化如何促進糧食安全；
三、 創新政策、服務提供和融資機制，如何應對未來的挑戰；
四、 農業中以自然為本的解決方案，如何促進生態韌性。

此次年會主題及四項子題不但是現今農業與糧食安全最重要的課題之一，亦是臺灣在維護農業韌性所面臨之挑戰。期能透過此次參與年會，

借鏡他國經驗，為臺灣在農業轉型上提供新的政策思維，促進灌排技術發展的同時亦保障臺灣糧食安全。代表國家擔任國際灌溉排水協會工作小組委員是榮譽，亦是沉重的負擔，除平時需配合小組決議推動國際事務，每年亦需排除自身工作，參與年會活動，需有相當的服務熱誠及經費支援以為支撐。感謝農業部的支持，讓 CTCID 能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。CTCID 將持續致力於發展與各國和諧共處之道，擴大行銷推廣臺灣經驗，建立與其他國家之實務合作契機，推展農業外交。

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一、 國際灌溉排水協會介紹

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，為二次世界大戰後綠色革命的前線組織，以科學傳播、技術交流和非營利為目的，促進全球灌排技術交流及農業發展，並於 1993 年改為國際非政府組織（INGO）。ICID 目前計有 111 個會員國，包括 45 個積極會員國與 66 個聯繫會員國。在非洲、美洲、亞洲、大洋洲與歐洲各設有一個委員會，全球逾 95%灌溉區域皆為 ICID 的服務範圍。

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，提升世界糧食生產力；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。作為全球當前最重要的國際農田水利組織，ICID 不但積極傳播灌排科學新知，同時也積極回應當前全球急迫議題：氣候變遷與極端洪災旱災、非常規水資源開發運用、水資源管理、水、糧食與能源鏈結、水資源與糧食安全、生質能，以及灌溉排水帶來的環境衝擊等。ICID 的終極目標為透過鄉村發展脫離貧窮與飢餓，建立用水安全的世界，維護全球糧食安全及促進農業永續韌性。ICID 對全球對話及倡議行動貢獻良多，如世界灌溉論壇、世界水資源發展報告等參與，確保在資源整理及系統性的管理架構下推動農業灌排實務，以達永續發展的共同目標，並與聯合國永續發展目標（SDGs）相呼應。

目前 ICID 於灌排管理技術和處理相關問題已累積超過 70 年的豐富經驗，每年定期舉行國際執行委員會議及技術活動委員會所屬之工作小組會議，並輪流搭配國際灌溉排水研討大會、區域研討會以及世界灌溉論壇。

此外，ICID 每年亦分區辦理非洲區域研討會、亞洲區域研討會、歐洲區域研討會及美洲區域研討會，以討論該區域的特色及全球性議題，並出版專題報告供各會員國參考。ICID 亦集結專家創立國際著名《灌溉與排水》（Irrigation and Drainage）期刊，由 Wiley 發行出版，為農田水利領域的重要參考刊物。ICID 認同未來世代的農業實作人員需要接受更好的培訓，因此建立全球青年專家社群，目前涵蓋 4,000 名青年專家，由 ICID 資深前輩提供訓練指導。作為全球關懷與知識分享型組織，這種因應青年學者專業生涯發展需求的行動可為 ICID 特有作法。

表 1-1 ICID 積極會員國

號碼	國家（按 A 到 Z）		縮寫
1	Australia	澳洲	IACID
2	Bangladesh	孟加拉	BANCID
3	Burkina Faso	布吉納法索	CNID-B
4	Canada	加拿大	CANCID
5	China	中國	CNCID
6	Egypt	埃及	ENCID
7	Estonia	愛沙尼亞	ESTICID
8	Finland	芬蘭	FINCID
9	France	法國	E.A.T.
10	Georgia	喬治亞	GENCID
11	Hungary	匈牙利	HUCID
12	India	印度	INCID
13	Indonesia	印尼	INACID

號碼	國家（按 A 到 Z）		縮寫
14	Iran	伊朗	IRNCID
15	Iraq	伊拉克	IRQCID
16	Ireland	愛爾蘭	IRCID
17	Italy	義大利	ITAL-ICID
18	Jamaica	牙買加	JAM-ICID
19	Japan	日本	JNC-ICID
20	Kazakhstan	哈薩克	KAZCID
21	Malawi	馬拉威	MALCID
22	Malaysia	馬來西亞	MANCID
23	Morocco	摩洛哥	ANAFIDE
24	Myanmar	緬甸	MNCID
25	Nepal	尼泊爾	NENCID
26	Niger	尼日	ANID
27	Nigeria	奈及利亞	NINCID
28	Pakistan	巴基斯坦	PANCID
29	Philippines	菲律賓	PNC-ICID
30	Portugal	葡萄牙	PNCID
31	Russia	俄羅斯	RUCID
32	Saudi Arabia	沙烏地阿拉伯	SACID
33	South Africa	南非	SANCID
34	South Korea	韓國	KCID

號碼	國家（按 A 到 Z）		縮寫
35	Spain	西班牙	CERYD
36	Sri Lanka	斯里蘭卡	SLNICID
37	Sudan	蘇丹	SNCID
38	Tajikistan	塔吉克	TajNCID
39	Thailand	泰國	THAICID
40	Turkey	土耳其	TUCID
41	Ukraine	烏克蘭	UACID
42	Uzbekistan	烏茲別克	UzNCID
43	Zambia	尚比亞	ZACID
44	Zimbabwe	辛巴威	ZwCID
45	Chinese Taipei Committee	臺灣	CTCID

二、年會目標

我國於 1969 年由農復會（現農業部）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、農田水利署等 41 個團體會員。早期由政府機關派員參加相關國際活動，現今則由產官學研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，除每年參與年度大會及各項研討會議，亦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；此外我國委員於多個 ICID 之工作小組擔任要職，表現亮眼，顯見臺灣在國際灌溉界的影響力。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，更將臺灣優良的農田水利技術與政策發揚於國際，建立臺灣之國際地位。

參與年會以來，臺灣多次面對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。作為 ICID 的積極會員國，每年均派員參 ICID 年會，致力促進臺灣與國際間的灌排技術交流與合作。例如，臺灣分別於 2017 年與韓國、2018 年與印尼簽署國際合作備忘錄，不僅展現臺灣在灌排領域的專業實力，也為國際外交做出積極貢獻。

三、2025 年會代表團團員

表 1-2 代表團成員

序號	姓名	機關名稱 /職稱
1	吳瑞賢	中央大學土木工程系 特聘教授 國際灌溉排水協會中華民國國家委員會 主席 氣候變遷工作小組 主席 亞洲區域工作小組 委員 技術活動委員會 委員
2	廖國偉	臺灣大學生物環境系統工程學系 教授兼系主任 國際灌溉排水協會中華民國國家委員會 副主席 氣候變遷工作小組 委員
3	丁崇峯	成功大學水工試驗所 研究員兼組長 永續海岸環境再生工作小組 委員 水、糧食與能源鏈結工作小組 委員
4	胡明哲	臺灣大學生物環境系統工程學系 教授 水、糧食與能源鏈結工作小組 秘書 土地排水工作小組 委員 氣候變遷工作小組 委員
5	高瑞棋	成功大學水工試驗所 博士 技術活動委員會 委員 永續海岸環境再生工作小組 主席
6	陳豐文	財團法人農業工程研究中心 研究員 非常規水與環境保護工作小組 委員 應對水資源匱乏之集水工作小組 秘書
7	闕雅文	清華大學環境與文化資源學系 教授 七星農業發展基金會 會議代表 社會經濟轉型下之灌溉排水工作小組 副主席 組織與制度管理工作小組 委員 灌溉史工作小組 委員

序號	姓名	機關名稱 /職稱
8	許少瑜	臺灣大學生物環境系統工程學系 教授 土地排水工作小組 秘書 灌溉用水與發展工作小組 委員 應對水資源匱乏之集水工作小組 委員
9	劉日順	財團法人農業工程研究中心 研究員 氣候變遷工作小組 委員 組織與制度管理工作小組 委員
10	江莉琦	臺灣大學生物環境系統工程學系 教授 非常規水與環境保護工作小組 委員 水資源管理中的女性賦權工作小組 委員 應對水資源匱乏管理集水工作小組 委員
11	林遠見	中央大學土木工程學系 教授兼校友服務中心主任 土地排水工作小組 委員 應對水資源匱乏之集水工作小組 委員
12	鍾秉宸	中山大學海洋環境及工程學系 助理教授 應對水資源匱乏之集水工作小組 委員
13	李祖川	財團法人臺灣水利環境科技研究發展教育基金會 副研究員 組織與制度管理工作小組 委員 灌溉史工作小組 委員
14	王歆涵	農業部農田水利署 副工程司
15	范綱翰	農業部農田水利署新竹管理處 財務組長
16	吳信輝	農業部農田水利署臺中管理處 股長
17	王建安	農業部農田水利署嘉南管理處 副工程司兼股長
18	黃婉琦	農業部農田水利署高雄管理處 股長
19	李柏澍	農業部農田水利署屏東管理處 股長
20	劉斯勇	農業部農田水利署臺東管理處 灌溉股長
21	李岳洋	中興工程顧問股份有限公司 水利技師
22	譚允維	財團法人農業工程研究中心 副研究員
23	張惠媛	臺灣水資源與農業研究院 研究一所研究專員
24	徐　顥	臺灣水資源與農業研究院 所究四所所長

序號	姓名	機關名稱 /職稱
25	魏錞妍	臺灣大學公共衛生學院食品安全與健康研究所 研究生
26	陳品萱	臺灣大學公共衛生學院食品安全與健康研究所 研究生
27	廖宜泰	臺灣大學生物環境系統工程學系 研究生
28	鄭皓天	國際灌溉排水協會中華民國國家委員會 秘書

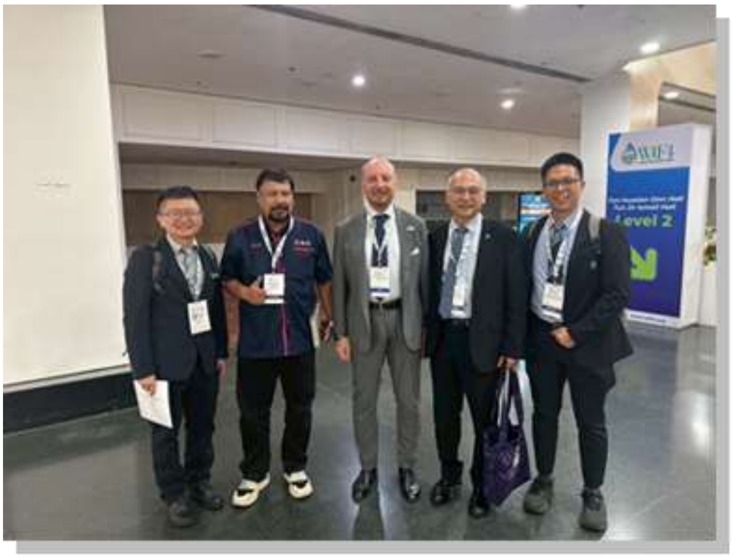

圖 1-1 吳瑞賢主席（右二）與 ICID 主席合影（中）

圖 1-2 CTCID 代表團於開幕典禮會場合影

<table>
<tr><th colspan="3">吳 瑞 賢</th></tr>
<tr><td rowspan="4">
</td><td>服務機關</td><td>中央大學土木工程學系</td></tr>
<tr><td>職　稱</td><td>特聘教授</td></tr>
<tr><td>參與會議</td><td>• 氣候變遷工作小組國際研習會
• 第 76 屆國際執行委員會會議（IEC）
• 技術活動委員會會議
• 氣候變遷工作小組會議</td></tr>
<tr><td>ICID
擔任職務</td><td>• 國際灌溉排水協會中華民國國家委員會 主席
• 氣候變遷工作小組 主席
• 亞洲區域工作小組 委員
• 技術活動委員會 委員</td></tr>
<tr><th colspan="3">廖 國 偉</th></tr>
<tr><td rowspan="4">
</td><td>服務機關</td><td>臺灣大學生物環境系統工程學系</td></tr>
<tr><td>職　稱</td><td>教授兼系主任</td></tr>
<tr><td>參與會議</td><td>• 氣候變遷工作小組國際研習會
• 亞洲區域工作小組會議</td></tr>
<tr><td>ICID
擔任職務</td><td>• 國際灌溉排水協會中華民國國家委員會 副主席
• 氣候變遷工作小組 委員</td></tr>
<tr><th colspan="3">丁 崇 峯</th></tr>
<tr><td rowspan="4">
</td><td>服務機關</td><td>成功大學水工試驗所</td></tr>
<tr><td>職　稱</td><td>研究員兼組長</td></tr>
<tr><td>參與會議</td><td>• 氣候變遷工作小組國際研習會
• 永續海岸環境再生國際研習會
• 灌溉史工作小組會議
• 永續海岸環境再生工作小組會議
• 水、糧食與能源鏈結工作小組會議</td></tr>
<tr><td>ICID
擔任職務</td><td>• 永續海岸環境再生工作小組 委員
• 水、糧食與能源鏈結工作小組 委員</td></tr>
</table>

胡 明 哲

	服務機關	臺灣大學生物環境系統工程學系
	職　稱	教授
	參與會議	• 水、糧食與能源鏈結工作小組國際研習會 • 水、糧食與能源鏈結工作小組會議 • 氣候變遷工作小組會議
	ICID 擔任職務	• 水、糧食與能源鏈結工作小組 秘書 • 土地排水工作小組 委員 • 氣候變遷工作小組 委員

高 瑞 棋

	服務機關	成功大學水工試驗所
	職　稱	博士
	參與會議	• 永續海岸環境再生國際研習會 • 第 76 屆國際執行委員會會議（IEC） • 技術活動委員會會議 • 永續海岸環境再生小組會議
	ICID 擔任職務	• 永續海岸環境再生工作小組 主席 • 技術活動委員會 委員

陳 豐 文

	服務機關	財團法人農業工程研究中心
	職　稱	研究員
	參與會議	• 氣候變遷工作小組國際研習會 • 應對水資源匱乏之集水工作小組會議 • 非常規水與環境保護工作小組會議
	ICID 擔任職務	• 非常規水與環境保護工作小組 委員 • 應對水資源匱乏之集水工作小組 秘書

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• 社會經濟轉型下之灌溉排水工作小組會議
• 組織與制度管理工作小組會議
• 灌溉史工作小組 會議</td></tr>
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• 組織與制度管理工作小組 委員
• 灌溉史工作小組 委員</td></tr>
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• 灌溉用水與發展工作小組會議</td></tr>
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• 組織與制度管理工作小組會議</td></tr>
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擔任職務</td><td>• 氣候變遷工作小組 委員
• 組織與制度管理工作小組 委員</td></tr>
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江 莉 琦

服務機關	臺灣大學生物環境系統工程學系
職　稱	教授
參與會議	• 氣候變遷工作小組國際研習會 • 應對水資源匱乏管理集水工作小組會議 • 非常規水與環境保護工作小組會議 • 水資源管理中的女性賦權工作小組
ICID 擔任職務	• 應對水資源匱乏管理集水工作小組 委員 • 非常規水與環境保護工作小組 委員 • 水資源管理中的女性賦權工作小組 委員

林 遠 見

服務機關	中央大學土木工程學系
職　稱	教授
參與會議	• 氣候變遷工作小組國際研習會 • 應對水資源匱乏管理集水工作小組會議 • 土地排水工作小組會議
ICID 擔任職務	• 土地排水工作小組 委員 • 應對水資源匱乏之集水工作小組 委員

鍾 秉 宸

服務機關	中山大學海洋環境及工程學系
職　稱	助理教授
參與會議	• 氣候變遷工作小組國際研習會 • 應對水資源匱乏管理集水工作小組會議
ICID 擔任職務	• 應對水資源匱乏之集水工作小組 委員

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• 組織與制度管理工作小組會議
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• 灌溉史工作小組 委員</td></tr>
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• 第 4 屆世界灌溉論壇</td></tr>
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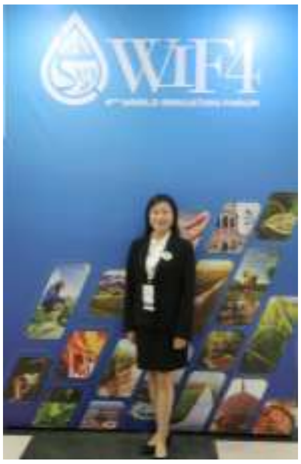
吳 信 輝		
	服務機關	農業部農田水利署臺中管理處
	職　稱	股長
	參與會議	• 氣候變遷工作小組國際研習會 • 第 4 屆世界灌溉論壇

王 建 安		
	服務機關	農業部農田水利署嘉南管理處
	職　稱	股長
	參與會議	• 氣候變遷工作小組國際研習會 • 第 4 屆世界灌溉論壇

黃 婉 琦		
	服務機關	農業部農田水利署高雄管理處
	職　稱	股長
	參與會議	• 氣候變遷工作小組國際研習會 • 第 4 屆世界灌溉論壇

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• 非常規水與環境保護工作小組會議</td></tr>
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<tr><td rowspan="3">
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• 氣候變遷工作小組會議</td></tr>
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魏 錞 妍

服務機關	臺灣大學公共衛生學院食品安全與健康研究所
職　稱	研究生
參與會議	• 氣候變遷工作小組國際研習會 • 第 4 屆世界灌溉論壇

陳 品 萱

服務機關	臺灣大學公共衛生學院食品安全與健康研究所
職　稱	研究生
參與會議	• 氣候變遷工作小組國際研習會 • 第 4 屆世界灌溉論壇

廖 宜 泰

服務機關	臺灣大學生物環境系統工程學系
職　稱	研究生
參與會議	• 氣候變遷工作小組國際研習會 • 第 4 屆世界灌溉論壇

鄭 皓 天

服務機關	國際灌溉排水協會中華民國國家委員會
職　稱	秘書
參與會議	• 氣候變遷工作小組國際研習會 • 第 76 屆國際執行委員會會議（IEC） • 亞洲區域工作小組會議 • 氣候變遷工作小組會議

四、2025 年年會議程

表 1-3 年會議程

日期（星期）	行程內容	地點
9/6（六）	● 臺灣出發前往馬來西亞 ● 抵達馬來西亞·吉隆坡	臺灣·桃園
9/7（日）	● 大會報到註冊 ● 永續海岸環境再生國際研習會 ● 氣候變遷國際研習會 ● 水、糧食與能源鏈結工作小組國際研習會	馬來西亞·吉隆坡
9/8（一）	● 大會開幕典禮 ● 第 4 屆世界灌溉論壇 ● 大會晚宴	
9/9（二）	● 技術參訪 ● 第 4 屆世界灌溉論壇	
9/10（三）	● 馬來西亞出發返回臺灣 ● 抵達臺灣	臺灣·桃園

日期	時間	議程	出席代表
9/6（六）	9:30	臺灣出發前往馬來西亞	全體人員
	14:15	抵達馬來西亞	
9/7（日）	9:30-12:30	【WG-SCER】 永續海岸環境再生國際研習會	高瑞棋 丁崇峯
	14:00-17:30	【WG-WFE-N】 水、糧食與能源鏈結工作小組 國際研習會	胡明哲
	14:00-17:30	【WG-CLIMATE】 氣候變遷國際研習會	全體人員
9/8（一）	9:00-9:30	大會開幕典禮	全體人員
	9:30-12:30	第 4 屆世界灌溉論壇	全體人員
	14:00-17:30		
	19:00-21:00	大會晚宴	全體人員
9/9（二）	8:30-18:00	技術參訪	全體人員（除李柏澍、吳信輝）
9/10（三）	12:50	馬來西亞出發前往臺灣	王歆涵 吳信輝 王建安 黃婉琦 李柏澍 劉斯勇 張惠媛
	17:40	抵達臺灣	

貳、重大成果

第 76 屆國際執行委員會議暨第 4 屆世界灌溉論壇於馬來西亞舉辦，此次會議有近千位代表參與。CTCID 代表團此次表現亮眼，透過國際研習會及擴大參與工作小組踴躍投稿第 76 屆國際執行委員會議暨第 4 屆世界灌溉論壇，共 6 位學者專家於此次年會發表論文；同時也籌辦本屆年會最盛大之國際研習會，近 50 位國際專家出席吳瑞賢主席所主辦之氣候變遷國際研習會，將臺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臺灣灌排技術發展現況。

一、臺灣經驗對外分享

(一) 擴大參與工作小組分享專業知識

國際灌溉排水協會中華民國國家委員會（CTCID）由吳瑞賢主席帶領，代表團成員來自全臺農水署各管理處、大專院校、研究單位等共 28 位。

CTCID 目前共 23 位委員加入 14 個 ICID 工作小組，其中個工作小組由本會委員擔任核心職務，分別為吳瑞賢主席擔任氣候變遷工作小組主席、高瑞棋博士擔任永續海岸環境再生工作小組主席、張煜權教授擔任價值工程下的現代灌溉發展：組織與制度管理工作小組副主席、余化龍教授擔任灌溉用水與發展工作小組副主席、胡明哲教授擔任水、糧食與能源鏈結工作小組秘書、雨水集蓄工作小組秘書、許少瑜教授擔任土地與排水工作小組秘書，以及 2025 年由闕雅文教授新任社會經濟轉型下之灌溉排水工作小組副主席。

(二) 第 4 屆世界灌溉論壇

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/技術研討會議等形式輪流辦理。今年大會以「在灌溉是否為夕陽產業？（Is Irrigation a Sunset Industry?）」為主題辦理第 4 屆世界灌溉論壇，共包含四大子題：

1. 灌溉與排水在變化世界中對糧食安全所面臨之挑戰；
2. 農業部門的技術與現代化如何促進糧食安全；
3. 創新政策、服務提供和融資機制，如何應對未來的挑戰；
4. 農業中以自然為本的解決方案，如何促進生態韌性。

(三) 氣候變遷工作小組國際研習會

本次馬來西亞年會由吳瑞賢主席領軍，舉辦氣候變遷小組國際研習會（WG-CLIMATE International Workshop），現場參與人數近 50 人，為本次年會中最多人共襄盛舉之研習會，同時也邀請到 ICID 前副主席日籍教授渡邊紹裕（Tsugihiro Watanabe）教授開場致辭。本次氣候變遷國際研習會上共計發表 10 篇論文，分別來自臺灣、尼泊爾、巴基斯坦及印度，顯示本次研習會的國際影響力與多元性，其中臺灣學者包含胡明哲教授、江莉琦教授、林遠見教授等於會上發表 6 篇論文，並和與會學者交流互動熱烈，彰顯臺灣在氣候變遷研究上之重視及深厚學養。（研習會議程見附件一）

圖 2-1 吳瑞賢主席於氣候變遷小組國際研習會開場致辭

圖 2-2 胡明哲教授於氣候變遷小組國際研習會專題報告

圖 2-3 氣候變遷小組國際研習會與會專家學者合影

(四) 專題論文發表

臺灣在農田水利及灌排技術上的專業學養向為國際深知，每年年會均踴躍投稿發表論文，讓國際深入了解臺灣在灌溉技術上的進展。本屆年會在吳瑞賢主席帶領下共發表 6 篇論文（詳見表 2-1），發表論文之專家學者於發表期間與與會來賓就論文內容及灌排專業知識熱烈討論、積極互動，充分達到學術新知交流與國際外交的目的。

表 2-1 2025 ICID 臺灣論文發表		
序號	**論文題目**	**發表者**
1	Improving Inundation Forecasting Model Accuracy through Deep Learning Based on an Optimization Algorithm	鐘秉宸
2	Long-Term Irrigation Water Quality Monitoring and Spatialtemporal Analysis in the Rinan Irrigation District of Central Taiwan	胡明哲
3	Developing a New Wavelet-Based Spatiotemporal Drought Index and Risk under Climate Change	林遠見
4	Domestic Wastewater Micropollutant Screening Using High-Resolution Mass Spectrometry for Application of Reclaimed Water Monitoring	陳品萱
5	Application of High-Resolution Mass Spectrometry to Fingerprinting Contaminants in Soil Irrigated by Reclaimed Water	魏錞妍
6	Analysis of the Trends of Rice Cultivation through Rasterisation Data	張惠媛

(五)《氣候變遷下創新灌溉與排水管理指引》

由吳瑞賢主席所率領之氣候變遷小組所編纂之《氣候變遷下創新灌溉與排水管理指引手冊》（Guide to Innovated Irrigation and Drainage Management under the Changing Climate），於 2025 付梓並順利出版，並於年會開幕典禮舉辦新書發表會及致贈儀式。（指引手冊詳見附件二）。

圖 2-4 ICID 新書發表會及致贈儀式

INTRODUCTION

Agriculture is a significant global user of freshwater resources, accounting for 70% of usage and contributing up to 30% of greenhouse gas emissions. Therefore, it is both a contributor to and a victim of climate change. The Working Group on Climate is dedicated to addressing the mitigation and adaptation challenges faced by agricultural water management in the context of a changing climate. The group is actively compiling valuable information and case studies on climate change to assist in impact assessments and the development of adaptation strategies.

The current urgency of climate change, highlighted by the IPCC scientists' warnings that global warming of 2°C will be exceeded during the 21st century unless immediate, rapid, and large-scale reductions in greenhouse gas emissions occur, underscores the need for immediate and effective adaptation measures. These measures must be based on the best available information, including infrastructure improvements, institutional reorganization, revised design criteria, and management strategies for extreme events. Despite the wealth of research conducted globally, the challenges posed by climate change to irrigation, drainage, and related sectors are expected to be long-lasting, necessitating focused and concerted efforts from all stakeholders.

The WG-Climate was established in 2005, coinciding with the release of the IPCC Second Assessment Report, originally named the "WG on Global Climate Change and Irrigation". This initiative was led by VPH Dr. Mark Svendsen, a devoted leader whose strategic coordination was instrumental in its formation. In 2007, the working group was renamed "WG on Climate Change and Agricultural Water Management," broadening its scope from solely "irrigation" to encompass "water management" more broadly. This shift recognized the pressing need for cross-disciplinary and institutional cooperation to address the looming impacts of climate change on agricultural water management.

In response to the climate urgency, the WG-Climate has committed to publishing this book, "Guide to Innovated Irrigation and Drainage Management under the Changing Climate," to provide useful information and case studies on climate change for practical use, especially in improving impact assessment, mitigation, and adaptation development. The initial editor is VP Dr. Tsugihiro Watanabe, former Chair of WG, who drafted the outlines of the book. As the Chair of WG-Climate and the editor of this book, I have been given the demanding tasks of overseeing the review and editing of all chapters, as well as drafting the Executive Summary. This responsibility has engaged me over the past four years, during which I have been thoroughly involved in refining the content and ensuring that the book's messages are conveyed with clarity. The completion of this book would not have been possible without the invaluable contributions of the authors, who are esteemed members of the WG-Climate. Their dedication, knowledge, and experience in their specific fields have enriched this publication, making it a comprehensive and insightful guide. We believe that the lessons and insights offered in this book will inspire and guide engineers, scientists, managers, and others facing the critical water challenges of the 21st century across various regions of the world.

Ray-Shyan Wu (PhD)
President of Chinese Taipei Committee on Irrigation and Drainage
Chair WG-Climate

圖 2-5 吳瑞賢主席為《氣候變遷下創新灌溉與排水管理指引》所著之引言

二、與各國國家委員會積極交流

國際灌溉排水協會為目前農業灌溉排水領域最重要之國際交流舞台，除積極參與各技術工作小組或活動委員會，我國更藉以與其他國家建立良好關係，進而建立實質合作管道。

吳瑞賢主席、秘書處與多位委員參與馬來西亞舉辦之各項會議、技術參訪及 ICID 晚宴，與多國政要以及國際灌溉排水專家學者進行互動，國際合作交流成果卓著，高瑞棋博士於開幕典禮上應馬來西亞農業部部長 Mohamad Sabu 邀約，與部長共進午餐，為我國拓展農田水利外交工作，奠定良好的基礎。

圖 2-6 高瑞棋博士（右）於馬來西亞農業部部長 Mohamad Sabu（左）於開幕典禮合影

圖 2-7 吳瑞賢主席於馬來西亞灌排署精明隧道控制中心聽取工作人員簡報說明

參、新知蒐整

第 76 屆國際執行委員會議（International Executive Council, 簡稱 IEC 大會）由吳瑞賢主席、高瑞棋博士與鄭皓天秘書出席，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 行使主席、副主席票選之權利，以及其他重要事項之表決權。

圖 3-1 吳瑞賢主席於第 76 屆 IEC 會議上行使我國代表團權利投票選舉 ICID 副主席

技術工作小組會議由各工作小組委員參加，整體技術活動委員會會議由吳瑞賢主席與高瑞棋博士代表出席。此次參與小組包含亞洲區域工作小組、氣候變遷工作小組、灌溉用水與發展工作小組、雨水集蓄工作小組、水、糧食與能源鏈結工作小組、永續海岸環境再生工作小組、非常規水與環境保護工作小組、期刊編輯工作小組、社會經濟轉型下之灌溉排水工作

小組、灌溉史工作小組、價值工程下的現代灌溉發展：組織與制度管理工作小組、土地排水工作小組等。本年度亦於各工作小組會議舉辦前辦理國際研習會，在工作小組會議之前先就重要議題進行討論。相關內容由此次計畫補助學者提供工作小組重點決議整理如下。

一、IEC 大會重點決議

本屆循例分三階段進行，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。

(一) 2025-2028 總會副主席選舉：根據 ICID 組織章程規定，主席、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，吳瑞賢主席代表臺灣代表團於第 76 屆國際執行委員會執行我國會員權益，投票選舉出 ICID 新任副主席，分別為西班牙籍的 Cristina Clemente Martinez、尼泊爾籍的 Sanjeeb Baral 與奈及利亞籍的 Esther Oyeronke Oluniyi。

(二) 財務常設委員會（PFC）報告：2024-2025 年財務決算，並同意 2025-2026 年預算金額。

(三) 本屆年會共出版四本刊物：《ICID 2030 願景路線圖及三年滾動計畫》（Road Map to ICID Vision 2030- and Three-Year Rolling Plan）、《再生水灌溉指南》（Guidelines for Irrigation with Reclaimed Water）、《環境排水指南》（Environmental Drainage）及《氣候變遷下創新灌溉與排水管理指引手冊》（Guide to Innovated Irrigation and Drainage Management under the Changing Climate）。

(四) 《吉隆坡聯合宣言》（Kuala Lumpur Joint Declaration）之簽署。

(五) 國際灌溉排水協會未來會議預告：如表 3-1。

表 3-1 年會預告

會議	通訊內容
2026 年第 77 屆國際執行委員會議暨 第 26 屆國際灌溉排水研討大會	• 地點：法國馬賽夏諾會議暨展覽中心 • 2026/10/12~10/18
2027 年第 78 屆國際執行委員會議暨 第 5 屆國際灌溉論壇	• 地點：中國北京 • 時間待定

二、工作小組重點決議

(一) 亞洲區域工作小組會議

出席委員：廖國偉副主席（代理）及鄭皓天秘書（代理）。

1. 會員檢討：亞洲區域工作小組新增塔吉克、沙烏地阿拉伯代表；巴基斯坦、孟加拉代表續任；未參與年會超過兩年者，由 ICID 秘書處已聯繫確認是否要延續代表。另，蒙古、伊朗、北韓表達加入意願，並留待下次會議表決。
2. 2024 澳洲雪黎會議決議事項回顧：完成農業水資源管理與糧食安全國際工作坊及《亞洲地區的灌溉與排水及糧食安全》技術報告發表。
3. 年度線上會議（Virtual Meetings）舉辦：2025 年年度線上會議已於 3 月、5 月及 7 月辦理完畢，並完 Vision 2030、成員資格、技術會議等事項之討論。
4. Vision 2030 願景路線圖進展（Road Map Progress）報告：已完成 2024 年農業水資源管理工作坊及技術報告；並確認 2025 年舉辦先進感測技術特別會議事宜。

5. 特別會議（Special Session）報告：展示遙測、AI、IoT、衛星、滴灌、自動進水等應用，顯著提升效率與永續性。同時今年年會（2025 年 9 月 10 日）以「利用先進感測技術優化稻田灌溉用水」為題，邀請泰國、韓國、日本、塔吉克等國專家，探討遙測、感測技術、數據驅動稻田管理促進水資源節約、提升作物產量與效率。
6. 內部工作坊（Internal Workshop）報告：尼泊爾及烏茲別克等國報告工作坊之成果，並出版技術報告《Irrigation and Drainage for Food Security in Asia》。
7. 國際合作（International Cooperation）報告：伊朗與塔吉克於 2024 年 9 月在德黑蘭舉行聯合會議，推動水資源與農業合作，強化水管理合作。
8. 建議事項：1. PCSO 建議成立「中東區域工作小組」，應對該區的水資源短缺、氣候變遷和糧食安全問題。該小組將促進跨國合作與知識交流，並推動量身訂製的永續水土管理方案；2. PCSO 決議將主席、副主席、秘書職務設定固定任期。該決議適用於包括亞洲區域工作小組（ASRWG）在內的多個區域與專業工作組，以促進領導層的輪替與組織活力。

(二) 應對水資源匱乏之集水工作小組

出席委員：陳豐文博士、林遠見教授、江莉琦教授、鍾秉宸助理教授、譚允維副研究員。

1. 新任會員提名：2025 年共 3 國灌溉排水協會提名推薦新會員 8 位，出席本次會議的新會員共 5 位，分別為 Mr. J. Mohan、Ms. Suchana

Acharya、Prof. Ma Chengxiang、Prof. Xining Zhao、及 Prof. Yaohui Cai。未出席者共 3 位，分別為 Dr. Ahmad Taufiq、Mr. V. Venkatesan 及 Dr. Zou Zhike。另，CTCID 現場推薦江莉琦教授加入為新會員，獲得全場同意通過，為我國在工作小組新增一席位。

2. 工作小組整併：因 WG-MWSCD 及 WG-RWH 之二工作小組任務議題相似，經去年討論，將此二工作小組合併成本工作小組（WG-WHMWS），並取得全員同意。
3. Draft scoping document 之導讀及修改：主席介紹工作小組背景並引領委員確認 Draft scoping document 細部章節是否需修改調整：

   (1) Water harvesting 小節決議不需修改但可將透過收集土壤含水量所得之水源引入 water harvesting 之範疇。
   (2) Proposed Mandate 小節之修改調整上，鍾秉宸助理教授提出在氣候變遷的影響下，氣候調適作為的重要性不言自喻。農民可在暴雨事件期間嘗試儲存淹水（即多餘的水）儲存起來，以備乾旱期間所需；江莉琦教授建議 Proposed Mandate 小節中第（a）項中的“rainwater”應改為“precipitation”。此兩項建議均獲主席及現場委員全數同意。

圖 3-2 江莉琦教授於應對水資源匱乏之集水工作小組
發表意見並獲全場一致同意

4. 工作小組未來規劃：

(1) 2026 年法國馬賽年會：各國家會員需準備 water harvesting 相關的國家報告，同時舉辦應對水資源匱乏之集水研習會。

(2) 2027 年中國北京年會：辦應對水資源匱乏之集水工作小且擬舉辦技術研習會。

(3) 在未來 6 年規劃的最後一年，應對水資源匱乏之集工作小組需產出各國關於 water harvesting 研究議題的指引手冊及年版品予 ICID 總部。

(三) 非常規水與環境保護工作小組

出席委員：陳豐文博士、江莉琦教授、譚允維副研究員。

1. 工作小組重要職務選舉：2025 年適逢工作小組內部重要職務改選，新任主席為中國籍的吳文勇教授、新任副主席為日本籍的加藤教授（任職於東京農業大學）、新任秘書為中國籍的胡雅琪博士（任職於中國水利水電科學研究院）。
2. 新任會員提名：本屆新提名 6 位會員，分別為 3 位中國會員、1 位印尼會員、1 位伊拉克會員及 1 位白俄羅斯會員。

(一) 組織與制度管理工作小組

出席委員：闕雅文教授、劉日順研究員、李祖川副研究員

1. 2024 澳洲雪黎會議決議事項回顧：2025 年 3 月已舉行工作小組線上籌備會議及 2025 年 6 月底前完成之 scoping document。
2. 新任會員提名：印尼國家灌排委員會（INACID）提名 Adi Prasetyo 為新任會員。
3. 工作小組成員名單更新。
4. 待辦事項報告：WG-IOA 小組需完成《灌溉與排水部門的制度與組織改革：邁向永續農業水資源管理》最終報告；WG-VE 小組需完成灌溉與糧食專案之 VE 應用的培訓教材；WG-M&R 小組需完成《灌溉與排水服務現代化指南》。

圖 3-3 關雅文教授（右四）、李祖川副研究員（右三）及為劉日順研究員（右二）與組織與制度管理工作小組其他成員會後合影

(二) 永續海岸環境再生工作小組

出席委員：高瑞棋博士、丁崇峯研究員兼組長

1. 2024 澳洲雪黎會議決議事項回顧：1. 整合原 WG-AFM、WG-IDM、WG-M&R 及 WG-SDTA 四個工作組之相關任務範疇，正式核准成立「永續海岸環境再生工作組」（WG-SCER），並納入「自然資源」策略主題項下；2. 2024 年 11 月於國立成功大學（臺南市）舉辦「地層下陷與潮間帶水產業：挑戰與契機」國際短期課程。
2. 新任會員提名：本屆提名 4 位新任會員，分別為印尼籍的 Mr. Sudarto、印尼籍的 Dr. Sanidhya Nika Purnomo、馬來西亞籍的

Mr. Dhamson Polus Masundang 及泰國籍的 Dr. Sanit Wongsa。除 Mr. Sudarto 暫時准予加入（一年觀察期），其餘 3 位均獲同意加入。

3. Vision 2030 願景路線圖進展（Road Map Progress）報告：

(1) 討論並檢視以新成立 WG-SCER 任務範疇為基礎之六年滾動計畫。主席高瑞琪博士說明新工作小組涵蓋多樣且跨專業領域，將於三個月內提名六項擬議任務負責人，以推動任務完成。會議中高博士更新了六年滾動計畫。

(2) 主席高瑞棋博士說明新成立 WG-SCER scoping document 之重點，聚焦於沿海灌排之創新技術與適應性管理策略。成員檢視文件所列目標與任務，一致同意需儘速完成工作計畫。

(3) 主席高瑞琪博士說明為達成任務範疇所提六項任務，鼓勵原工作組成員持續參與並建議帶領任務。

4. Vision 2030 願景路線圖進展（Road Map Progress）擬議任務報告：

(1) 任務 1：由 Dr. Sanidhya Nika Purnomo、Mr. Sudarto（印尼）及 Mr. Dhamson Polus Masundang（馬來西亞）帶領調查並分享區域與地方沿海地區海側、陸側及河口之環境資源與災害實務案例。

(2) 任務 2：由清水勝之教授（日本）及王聖偉教授（臺灣）帶領諮詢並指導沿海區陸側潛在環境威脅之探勘方法，發展策略與整合解決方案。

(3) 任務 3：由 Paavan Kumar Reddy 秘書（印度）及丁崇峯博士（臺灣）帶領評估並分析沿海區地下水開發管理、地表水與

地下水聯合運用對灌溉之影響，估算地層下陷潛勢及地下水鹽化可能性。

(4) 任務 4：由 Mona Liza Delos Reyes 教授（菲律賓）及皆川洋樹博士（日本）帶領強化推動 ICID 沿海會員國精確調查沿海區灌排與防洪能力及海岸管理總體計畫，制定洪水管理等級，劃定適應性洪水管理區。

(5) 任務 5：由 Sunil D. Gorantiwar 博士（印度）及 Sanit Wongsa 博士（泰國）帶領實踐並規劃沿海環境及灌溉、排水、防洪管理之現代化、自動監測與控制系統。

(6) 任務 6：由主席高瑞琪博士及副主席 Nor Hisham Bin Mohd Ghazali 博士帶領組織並舉辦工作組國際活動（如邊會、短期課程、工作坊、專題研討會、專刊等）。

5. 本年度延續沿續去年辦理研習會之成果，於 2025 年 9 月馬來西亞吉隆坡年會期間舉辦永續海岸環境再生小組國際研習會，會中共發表 8 篇論文，分別為孟加拉 1 篇、荷蘭 1 篇、印度 2 篇、印尼 2 篇、馬來西亞 1 篇及臺灣 1 篇。

(三) 氣候變遷工作小組

出席委員：吳瑞賢主席、胡明哲教授、劉日順研究員

1. 2024 澳洲雪黎會議決議事項回顧：吳瑞賢主席於工作小組會議之始報告議程及本年度各項工作執行情形，所有工作進度及狀況執行良好。
2. 新任會員提名：本屆共提名中國籍會員 2 位，均獲同意通過。
3. 本年度延續沿續去年辦理研習會之成果，於 2025 年 9 月馬來西

亞吉隆坡年會期間舉辦氣候變遷小組國際研習會，會中共發表 10 篇論文，分別為臺灣 6 篇、印度 2 篇、巴基斯坦 1 篇及尼泊爾 1 篇。

4. 氣候變遷工作小組在吳瑞賢主席帶領下完成《氣候變遷下創新灌溉與排水管理指引手冊》（Guide to Innovated Irrigation and Drainage Management under the Changing Climate），手冊第六章由吳瑞賢主席與 Fiaz Hussain 合著撰寫，第四章則由劉日順博士與日籍學者 Takanori Nagano 合力撰寫。該手冊為本工作小組重要成就，於工作小組會議時特別邀請 ICID 大會前主席 President Dr. Ragab Ragab 到場致詞；ICID 總會亦特別於開幕典禮上舉行致贈儀式贈書予 ICID 主席及馬來西亞農業部部長。

圖 3-4 吳瑞賢主席主持氣候變遷工作小組會議

圖 3-5 胡明哲教授於氣候變遷工作小組會議上進行專題報告

(四) 水、糧食與能源鏈結工作小組會議

出席委員：胡明哲教授、丁崇峯研究員兼組長

1. 2024 澳洲雪黎會議決議事項回顧：2025 年 4 月線上會議順利舉辦；另，本年度延續沿續去年辦理研習會之成果，於 2025 年 9 月馬來西亞吉隆坡年會期間舉辦水、糧食與能源鏈結工作小組國際研習會，會中共發表 10 篇論文。值得一提的一點是，《灌溉與排水期刊》（Irrigation and Drainage Journal）亦派代表出席，挑選潛力稿件邀請投稿。
2. 新任會員提名：會議確認多位新成員加入，包括研究人員與工程師。同時就成員資格提名方式進行討論，釐清由各國國家委員會或直接會員提名新會員之規範。
3. 2026 年馬賽年會相關規劃：同意 2026 年馬賽年會需延續辦理國際研習之優良傳統，聚焦 Nexus 成效與多尺度影響，同時涵蓋社經影響及 女性參與等議題辦理水、糧食與能源鏈結工作小組研習會，並新增海報展覽以鼓勵青年學者與學生參與。
4. 未來工作規劃：檢視三年滾動計畫（rolling plan），決議合併並整合最先進之型與案例研究，並於半年內產出綜合報告。此外，會議也強調出版物之貢獻，包括過去在印度的維薩喀巴坦及澳洲雪黎等地研習會會議論文集，以及後續專書或期刊專刊出版的可能性
5. 能力建構：會議分享南非與中東地區的培訓課程經驗，並討論未來在 馬賽與氣候變遷工作小組合作開設能力建構短期課程，由各國專家提供訓練，且需著重在青年專業人員之培育。

(五) 灌溉史工作小組會議

出席委員：闕雅文教授、丁崇峯研究員兼組長、李祖川副研究員

1. 2024 澳洲雪黎會議決議事項回顧：主席於工作小組會議之始報告議程及本年度各項工作執行情形，所有工作進度及狀況執行良好。
2. 新任會員提名：本屆共提名 8 位新任會員，包括日本籍的 Naoko Koshiyama 博士和 Mikiko Sugiura 博士；中國籍的劉晶博士和周波博士；印尼籍的 Tesar Hidayat Musouwir 工程師；伊朗籍的 Shima Kabiri 博士及印度籍的 S. Elamuhil 博士與 Thiagarajan 博士。其中 Naoko Koshiyama 博士、Mikiko Sugiura 博士、劉晶博士、周波博士及 Shima Kabiri 博士 5 位已獲會議同意通過
3. Vision 2030 願景路線圖（Road Map Progress）任務進度報告：

   (1) 2024 年 12 月第一次線上會議共 7 位會員參與，並討論願景路線圖相關活動、審查前任工作小組結案報告及新工作小組的任務與範疇之概述。

   (2) 2025 年 6 月第二次線上會議共 11 位成員參與會，並討論 WHIS、ICID 2030 願景路線圖之更新、WHIS 國際研討會籌辦、會員資料更新及 2025 ICOMOS ISC 水資源科學研討會等事項。

   (3) 任務 3：由 Paavan Kumar Reddy 秘書（印度）及丁崇峯博士（臺灣）帶領評估並分析沿海區地下水開發管理、地表水與地下水聯合運用對灌溉之影響，估算地層下陷潛勢及地下水鹽化可能性。

4. ICID 世界遺產灌溉工程（WHIS）更新：2025 年共收到 23 件 WHIS 提名：分別來為中國 4 件、印度 4 件、義大利 4 件、日本 2 件、馬來西亞 1 件、南非 4 件、泰國 1 件、土耳其 1 件及烏茲別克 2 件。
5. 未來工作規劃：2024 年已出版專書《生命之水–拉丁美洲水之故事揭秘》（Aqua Vitae – Unraveling the Story of Water in Latin America），並決議於未來 6 年滾動計畫中再次出版專書，並請會員提供構想，主題可為《歷史水資源永續性》新卷或其他議題。同時決議專書由中國與伊朗會員負責起草案例及撰寫指引，定稿則由主席負責。

(六) 社會經濟轉型下灌溉與排水工作小組會議

出席委員：闕雅文教授、丁崇峯研究員兼組長

1. 工作小組重要職務選舉：因應工作小組改組，重新選舉工作小組內部之重要職務，新任主席為泰國籍的 Pongsak Suttinon 博士；副主席為我國的闕雅文教授；秘書為日本籍的清水克之博士。其中副主席選舉由全場一致鼓掌通過由闕雅文教授出任副主席一職，臺灣在國際灌排界上深受重視的程度可見一斑。
2. 新任會員提名：本屆提名中國籍李宏教授為新任會員，並獲同意通過。

圖 3-6 闕雅文教授（左四）榮任社會經濟轉型下灌溉與排水工作小組副主席

(七) 灌溉水管理與發展工作小組會議

出席委員：許少瑜教授

1. 2024 澳洲雪梨會議決議事項回顧：主席於工作小組會議之始報告議程及本年度各項工作執行情形，所有工作進度及狀況執行良好。
2. 會員名單調整：中國及土耳其需調整其會員人數以符合最多 10 位的規定；印尼新提名 1 位會員加入工作小組，若該新提名會員未出席會議則暫列「一年觀察會員」。
3. 各小組工作進度報告：

(1) WG-SON-FARM：日本森琢（Taku Mori）博士論文延宕；伊朗 Hossein 博士進度不明；中國羅玉峰博士將於會議報告。

(2) WG-WATS：伊拉克 Rafat Nael 提案納入新議題；水費政策調查持續中。

(3) WG-M&R：Ian Makin 持續進行「灌溉排水服務現代化指引」之編纂；Mona Liza 目前蒐集 25 份問卷，正在進行後續分析。

(4) WG-IDM：王聖瑋助理教授共提交兩份報告；日本向井明枝博士協助修改統整為「灌溉系統社會影響」報告。

4. 出版準備：主席邀請成員準備立場文件或技術論文為小組出來出版刊物作準備，目前規劃為：Tasuka Kato 博士負責氣候變遷調適案例研究、Akie Mukai 提供農業水庫淤積與防洪功能相關論文、許少瑜教授蒐整人為乾旱與水資源管理政策的因果評估研究。

(八) 土地排水工作小組會議

出席委員：許少瑜教授

1. 2024 澳洲雪黎會議決議事項回顧：主席於工作小組會議之始報告議程及本年度各項工作執行情形，所有工作進度及狀況執行良好。
2. 新任會員提名及會員名單調整：本屆新提名 3 位會員：印尼籍的 Riza Fahlefi、中國籍的陳浩瑞教授及何玉璞博士，其中陳浩瑞教授獲得會議同意通過，Riza Fahlefi 何玉璞博士因未出席會議暫列觀察名單。另，主席檢視超過 2 年未出席會議之成員並移除之。
3. Vision 2030 願景路線圖（Road Map Progress）任務進度報告：

(1) 澳洲、荷蘭之排水報告已上網；伊朗、印度、日本、尚比亞已聯繫；孟加拉之排水報告目前正由工作組小審查中。

(2) 芬蘭的排水報告於吉隆坡會議提交，並已與芬蘭代表舉行線上會議，建議作者另撰寫 900 字摘要投遞 ICID 季刊。

(3) 每位成員需撰寫其國家報告，指引已上傳至 WG 網站。

(4) 馬來西亞排水報告簡報因講者缺席未能進行。

4. 未來工作規劃：

(1) 工作計畫完成期限原訂至 2025 年，決議延長至 2027 年。持續任務包括維護全球排水面積資料庫、多語技術辭典更新、以及會議簡報。

(2) Mojtaba Akram 博士預計發表新書《環境排水》。

(3) 專題簡報：由 Momon Sodik Imanudin 博士介紹印尼泥炭地油棕排水模型；Mohamad Salikin Marudin 博士介紹控制式排水。

(4) 網站資訊整合：重整 WG-LDRG 網站架構，刪除或合併部分模組。

(5) 三年滾動計畫預計辦理事項：全球排水面積資料由中央辦公室持續更新、多語技術辭典由中央辦公室定期維護、持續追蹤芬蘭、孟加拉、馬來西亞排水報告提交情形、決議第 15 屆 IDW 研討會由印尼蘇門答臘提案並辦理。

肆、整體建議事項

針對此次參加 ICID 年會，代表團分別就下列事項提供建議。

(一) 本年度（2025）國際灌溉排水協會第 76 屆國際執行委員會會議暨第 4 屆世界灌溉論壇，在我國灌溉排水協會中華民國國家委員會的組團之下，參與者計有臺灣大學、清華大學、成功大學、中山大學、中央大學等多所大專院校教授及農田水利署本部與新竹、臺中、嘉南、高雄、屏東、臺東等管理處代表以及財團法人農業工程研究中心及相關專業單位代表的參與，總計團員達 28 位，顯示我國對於參與國際灌溉排水會議及相關業務的重視及重要性，建議後續應持續積極參與，以彰顯我國在各項國際灌排事務交流中的軟實力，以及 CTCID 吳瑞賢主席、秘書及各工作小組委員的努力成果。

(二) 本次經由參與氣候變遷工作小組【WG-CLIMATE】所舉辦之氣候變遷國際研習會，為 CTCID 吳瑞賢主席率各委員籌辦，為本次屆年會出席及投稿人數最多之研習會，足見國際間對於氣候變遷工作小組之重視。由於今年部分投稿者因行程之故未能出席，故於現場調整報告次序；另，考量研習會受重視程度及現場與會者之高出席率，導致空間安排上較為擁擠。有鑑於以上兩點，建議後續舉辦研習會，可以本次經驗為借鏡：1. 於會前先行向講者確認是否出席，以避免現場臨時調整之情況；2. 向大會爭取更大的會議室空間，以滿足各國代表對於氣候變遷及農業灌溉用水相關議題的重視。

(三) 本屆年會以「灌溉是否為夕陽產業？(Is Irrigation a Sunset Industry?)」為主題，會中結合科技創新（AI、IoT、遙測）、跨域整合（水-能源-食物）、自然基礎解方及精準水資源管理等趨勢，明確宣示灌溉不僅不是夕陽產業，在技術及管理策略配合輔助下，更是農業及其他

產業的重要基石。考量臺灣為水資源有限之地區，可優先導入精準農業與水資源智慧管理技術，並加強與國際學術界合作，結合國際趨勢以緩解臺灣水資源緊張之情況。未來政策擬訂方向上可參考韓國 SNAC 與 NEWS 平台經驗，建立水-能源-食物連結的整合分析平台，透過跨部門資料整合，提升水資源調配效率。平台應具備碳排放模擬、氣候改善情境評估等功能，支援政策決策制定。

(四) 近年氣候變遷已對全球農業及灌排造成嚴重衝擊，如旱災及洪災；建議未來年會可增加規劃相關智慧灌溉系統設施工程之技術考察行程，俾利我方代表學習各國經驗知識以應對氣候變遷的影響，並將其應用於國內灌溉排水、精密灌溉、智慧農業及現代化之提升，使我國在面對氣候變遷的影響時，能夠更有韌性地使用水源，提升用水管理及作物生產的質與量。

(五) 應對氣候變遷並非單一部門之責任亦非一蹴可及之事，參考此次年會各國經驗，我國應強化跨部門整合機制，建立協調平台整合水利、交通、都市計畫等部門之協調，統籌規劃複合功能基礎設施。透過定期會議、資訊共享等機制，提升跨部門合作效率。在技術標準制定上亦應制定複合功能基礎設施的設計標準與營運規範，包括結構設計、安全防護、維護管理等面向。標準應參考國際先進經驗，結合臺灣本土條件進行調整。

(六) 本屆年會另一重要討論主題為世代交替。農業作為第一級產業對於年世代的吸引力相對於其他二、三產業較為薄弱；本屆年會主題「灌溉是否為夕陽產業？(Is Irrigation a Sunset Industry?)」亦是對此現象之反思及提問。在此前提下，建議政府可強化對於青年農業人才之培育以及智慧農業轉型吸引年輕世代投入農業相關產業，同時積極鼓勵研究生與年輕工程師參與國際平台，提升國際能見度與貢獻度。

(七) 針對「灌溉是否為夕陽產業？(Is Irrigation a Sunset Industry?)」此一議題，本屆論壇結語「灌溉並非必然成為夕陽產業，但必須轉型」精準點出灌排事業未來趨勢。我國目前面臨地層下陷、土地鹽化、農業用水效率偏低、設備老舊等問題，近年來已引入 loT 感測、遙測、AI 預測模型等技術提升管理效率以節約用水，強化農業生產韌性且取得不錯成效。未來政策方向可落實把「灌溉」從純工程或興建、改善供水系統轉型為智慧及效率管理、兼顧自然生態與環境永續，以及穩定而長期預算支援的整合服務，將灌溉成為適應氣候與保障糧食安全的重要產業。

(八) ICID 以農業灌溉排水技術及成功經驗交流，扶助開發中國家發展農業生產為目標。本屆大會各會員國分享因應氣候變遷課題在洪水、乾旱等極端事件下，如何因應衝擊以達到保護農業之終極目的。除水資源管理、防洪技術提升等策略和科技上的措施外，會中多數國家提出自然基礎方以應對氣候變遷，根據聯合國環境大會所出之定義，所謂自然基礎解方為：「採取行動保護（protect）、養護（conserve）、恢復（restore）、可持續利用和管理自然或經改造的陸地、淡水、沿海和海洋生態系統，以有效和適應性地應對社會、經濟和環境挑戰，同時對人類福祉、生態系統服務 7（ecosystem service）、復原力（resilience）和生物多樣性產生惠益」。基於此概念，我國政府及產業界在未來應可投入更多資源於自然基礎解決方案，如都市綠建設、農業涵養水源系統，以強化氣候調適能力。

(九) 本屆大會所安排的技術參訪為馬來西亞舉世聞名的精明隧道（SMART Tunnel）系統。精明隧道本身除具有排除山洪以避免造成市區淹水功能之外，其管理中心（Pusat Kawalan SMART）具備完善硬體設計規劃及完整的監控系統與相關模式的應用，同時於管理中心建物及週邊涼亭均可見其建置雨水收集系統，利用模組化儲水槽

進行雨水回收，儲存後可供灌溉、沖廁或其他非飲水用途，透過簡單過濾與管線連接，可將儲存的水導入特定系統，提升水資源使用效率。此外較具特色的是，其儲水槽似以高密度聚乙烯（HDPE）或類似具耐腐蝕、耐候性材質，表面以幾何圖案設置，不僅強化結構，也方便堆疊與擴充，適合不同規模的設施需求，其安裝位置，以靠牆垂直安裝節省空間，其底部白色 PVC 管可能連接至過濾器、泵浦或排放系統，形成完整的水管理流程，加大雨水的使用便利性。此類設備於臺灣也可善加推廣利用，以減少灌溉用水時節的水量消耗，故建議農田水利相關單位，應可考量多加採用及施設類似模組化的設備，機關及公私立單位設置此類設施，亦可達提升永續經營形象，推廣環保理念。

(十) 本屆年會我國維持過往工作小組席位及重要職務之數量，並於此基礎上取得社會經濟轉型下之灌溉排水工作小組（WG-IDSST）副主席一職（闕雅文教授）及水資源匱乏管理集水工作小組（WG-WHMWS）委員一席（江莉琦教授）。臺灣在灌排方面的軟實力及經驗知識已為國際所見，成為國際外交的重要一環。為更積極爭取工作小組重要職務，同時讓國際間持續了解臺灣在農業灌排上之成就，可多舉辦國際研討會邀請專家學者共襄盛舉。

伍、參考資料

一、第 4 屆世界灌溉論壇手冊（2025），國際灌溉排水協會。

二、第 76 屆國際執行委員會會議手冊（2025），國際灌溉排水協會。

三、國際灌溉排水協會 2024-2025 年報（2025），國際灌溉排水協會。

四、代表團成員之會議紀錄與參訪報告。

陸、附件

附件一、氣候變遷工作小組國際研習會議程

INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE

ICID-CIID

International Workshop on Irrigation Water Sustainability and Food Security under Climate Change

07 September 2025, 14:00-17:30 hours; Kuala Lumpur, Malaysia

Programme

14:00-15:34	**Session I**
14:00-14:10	**Opening Remarks by Chair**
14:10-14:17	Presentation on "Estimation of shift in rice transplant timing in Japan with combined use of remote sensing and climate change scenario" by Takanori Nagano, Yueying Sui and Yifan Zhang, Japan
14:17-14:24	Presentation on "From causes to consequences for anthropogenic drought and water resource management policy evaluation" by Shao-Yiu Hsu and Che-You Liu, Chinese Taipei
14:24-14:31	Presentation on "The efficacy of applying nano bubble technology to reduce methane emissions in rice" by Michael Davidson, USA
14:31-14:38	Presentation on "Long-term irrigation water quality monitoring and spatialtemporal analysis in the Rinan irrigation district of central Taiwan" by Yun-Wei Tan, Feng-Wen Chen, Ming-Che Hu and Li-Chi Chiang, Chinese Taipei
14:38-14:45	Presentation on "Challenges to irrigated agriculture in Nepal in the context of climate change" by Saroj Karki, Nepal
14:45-14:52	Presentation on "Water governance for irrigation water sustainability and food security under climate change in India" by Shivaji Sangle and Shivani Sangle, India
14:52-14:59	Presentation on "Comparison of projected evapotranspiration of selected CMIP6 models in Karkhe basin, Iran using ESMval Tool" by Nozar Ghahreman, Mohammad Mousavi and Parviz Irannejad, Iran
14:59-15:06	Presentation on "An innovative experience for sustainable and resilient approach by pipeline irrigation with food and agricultural education on terraced tea farms" by Crystal Chang, Sinite Yu and Yuchuan Chang, Chinese Taipei
15:06-15:13	Presentation on "Addressing climate change risks in irrigated agriculture through adaptation pathways: The case of lower bhavani irrigation project, India" by Ambili G K and Mukand S Babel, India
15:13-15:20	Presentation on "Domestic wastewater micropollutant screening using high-resolution mass spectrometry for application of reclaimed water monitoring" by Pin-Hsuan Chen, Wen-Ling Chen, Feng-Wen Chen, Yu-Chien Cho, Jin-Jing Lee and Shan-Li Wang, Chinese Taipei

15:20-15:27	Presentation on "Mitigating climate change through crop and water adaptations - An effort by WALMI, Dharwad, Karnataka, India" by Rajendra S Poddar, Suvarna M Doddamani, Sunanda D Sitole, Mahadevgouda Huttanagoudar, Indudhar Hiremath and Nagaratna S Hosamani, India
15:27-15:34	Presentation on "Integrated watershed management: A strategic framework for climate change adaptation" by Alok Sikka, Gopal Kumar, D.R. Sena and M. Madhu, India
15:34-16:00	**Tea Break**
16:00-17:30	**Session II**
16:00-16:07	Presentation on "E-Flows and wetland conservation for sustainable agriculture : Chilika Lake" by Karishma Bhatnagar Malhotra and Shri Karambeer, India
16:07-16:14	Presentation on "Application of high-resolution mass spectrometry to fingerprinting contaminants in soil irrigated by reclaimed water" by Chun-Yen Wei, Wen-Ling Chen, Feng-Wen Chen, Yu-Chien Cho, Jin-Jing Lee and Shan-Li Wang, Chinese Taipei
16:14-16:21	Presentation on "Impact of nutrient management and planting methods on crop and water productivity of aerobic rice and optimizing irrigation requirements with CROPWAT model" by P. Sruthi, U. Surendran, Kumar Veluswamy, and P. Raja, India
16:21-16:28	Presentation on "Portfolio theory analysis of water resource system management under climate change uncertainty" by Ming-Che Hu and Li-Kuan Wang, Chinese Taipei
16:28-16:35	Presentation on "Irrigation sustainability through managed aquifer recharge by diverting flood water- A case study from Punjab Pakistan" by Ghulam Zakir-Hassan, Pakistan
16:35-16:42	Presentation on "Improving inundation forecasting model accuracy through deep learning based on an optimization algorithm" by Bing-Chen Jhong, Feng-Wen Chen, Hsiang-Kuan Chang and Jung-Lien Chu, Chinese Taipei
16:42-16:49	Presentation on "Development of an affordable IoT lysimeter for precision water management" by Mohd Fazly Mail, Jose Payero1, Bulent Koc, Aaron Turner and William Bridges, USA
16:49-16:56	Presentation on "Developing a new drought index by wavelet analysis and assessing risk under climate change" by Hsin-Wen Pai and Yuan-Chien Lin, Chinese Taipei
16:56-17:03	Presentation on "Optimising irrigation and water management in the Narmada River Basin using a fully distributed hydrological model" by M.Kavya, Sanjeev Kumar Jha and Pushpendra Singh, India
17:03-17:10	Presentation on "Irrigation water sustainability and food security under climate change: A case study of Punjab Province, Pakistan" by Shuaib Aslam and Muhammad Azam Joya, Pakistan

17:10-17:17	Presentation on "Sorjan integrated farming system – An improved agronomic practice in Sri Lanka for water sustainability and food security under climate change" by M.D.J.P. Wickramasooriya and Y.A.C.R. Kumara, Sri Lanka
17:17-17:24	Presentation on "Analysis of the Trends of Rice Cultivation through Rasterisation Data" by Hue-Yuan Chang, Yuan-Yu Li and Shin-Han Wang, Chinese Taipei
17:24-17:30	**Discussions and Wrap-up**

Workshop Conveners:
Prof. Dr. Ray-Shyan Wu, CTCID
Prof. Dr. Ming-Che Hu, CTCID
Prof. Dr. Sheng-Wei Wang, CTCID
Prof. Dr. Fuqiang Tian, CNCID
Prof. Dr. Takanori Nagano, JNC-ICID
Ir. Wan Noorul Hafilah Binti Wan Ariffin, MANCID

CHAPTER VI
Impacts of Climate Change on Agricultural Water Management and Adaptation- Case Studies in Pakistan

Fiaz Hussain[10], and Ray-Shyan Wu[11]

ABSTRACT

Climate change is now an undeniable reality. It is vital for all of us to work together to tackle this issue. The analysis of meteorological data presented in this study indicates clearly that the climate of Pakistan is getting warmer, with some regions facing a faster increase in average annual temperature. The rate of change is 0.74°C for the period 1961–2018 with highest increase in southern part (+0.32°C to +0.50°C per decade) than northern part (+0.02°C to + 0.10°C per decade). Since 1961, average annual rainfall has increased (19%); but for the most part, that increase occurred in 1961–89, while the years after 1990 generally showed a decline in rainfall. There is a decreasing trend (-0.54 mm/day) in annual precipitation under RCP4.5 while increasing trend (0.9 mm/day) in precipitation under RCP8.5 for 2011 to 2100. A 1°C average increase in temperature increases agricultural water requirements by about 5% by 2050, while a 3+°C change in temperature increases crop demand by 6% by 2025 and 12–15% by 2050. It is important to note that central and southwest region (Punjab Balochistan) showed decreasing trend in evapotranspiration. The research findings emphasis that the scope of policy related to climate change adaptation should focus on the strategies at community and farm level for significant development outcomes. While analysis has identified some of the broad changes underway in Pakistan's climate, the findings also point to the critical need to take into account regional and local trends.

Keywords: Observed Climate Changes, Future Projections, Temperature, Rainfall, Flow, ET, Adaptation

6.1. Introduction

Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate (IPCC, 2018) and the outlook for Asia is particularly troubling. Pakistan is a "water-stressed" country and its water resources are considerably vulnerable to climate change. Precipitation trends over the country have increased significantly (25 percent, or 63 mm) over the country during the 20th century while temperature trends also showed pattern of warming (+0.6°C) (Sheikh et al. 2009). Annual historical inflows on the Indus have been declining over the period of 1937-2011 (Yu et al., 2013). Studies show that crop yield declines with the rise in temperature. For example, a 1°C rise in temperature would result in wheat yield declines of 5%-7% (Aggarwal and Sivakumar 2011). In semi-arid regions of Pakistan, the rice yield could decline by 15% from 2012 to 2039, 25% from 2040 to 2069 and 36% from 2070 to 2099 if the rise in temperature continues (Ahmad et al. 2013). The increase in temperature along with decreasing rainfall affects crop production. If rainfall decreases by 6%, net irrigation water requirements in Pakistan could increase by almost 29% (Spijkers, 2010).

The climate scenario assessment approach can be used for climate impact assessment. A modest amount of climate modelling using multiple model ensembles under different scenarios has been undertaken at the regional level to inform analysis of how Pakistan's climate will change in the future; subnational-level projections are largely absent (Salik et al., 2015). Generally, the model outcomes suggest that the observed trend of rising temperatures will continue over the remainder of this century. Pakistan's mean annual temperature is projected to rise by 3.8°C

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(within a range of 2.1°C to 5.1°C) by 2100 (Climate Service Center, 2013). Other studies suggest an increase of 1.4°C to 3.7°C by the 2060s, and a potential increase to 6.0°C by the 2090s (GFDRR, 2014). This increase will not occur uniformly across the country or on a seasonal basis, with greater warming expected in northern regions and during the winter (GFDRR 2011; World Bank, 2015).

Therefore, to minimize adverse impacts of climate change on water resources of Pakistan, it is imperative to implement two approaches of adaptation and mitigation, simultaneously. Salient features are integrated management water resources management, watershed management, water conservation, efficient design of water storage and distributions & supply system. This study overviews recent advances in understanding the impact of climate change on agricultural water management and water resources of Pakistan, and presents certain agricultural adaptation strategies that are determined in the literature studies.

6.2. Methodology

6.2.1 Study area

Pakistan is situated on the western edge of the monsoon region in South Asia. Its major topographical regions include (a) the western offshoots of the Himalayas, which cover its northern and northwestern parts and in which the highest peak, K-2, rises to 8,611 meters above sea level; (b) the Balochistan plateau in the southwest of the country; (c) the Indus Plain, stretching across most of the eastern and central part of the country; and (d) the Potohar Plateau and Salt Range, situated between the Indus and Jhelum rivers in northern Punjab. The climate varies from arid to semiarid. Rainfall occurrence is due to monsoon disturbance in July to September and western disturbances system in January to March that shows large temporal and spatial variability. In most parts of the country, normal annual rainfall is less than 400 millimeters (mm). However, the southern slopes of the Himalayas, sub-mountainous northern region of AJK, northern Punjab, and parts of northern KP typically receive 800–1,800 mm of rainfall every year. The annual normal mean temperature ranges from 8°C in the north of the country to 28°C in the southernmost areas.

6.2.2 Data acquisition and methods

In this study, we have utilized long-term data generated at 55 observing stations in Pakistan for multiple climate parameters to assess changes in the country's climate over the period 1961–2018. The yearly data of rainfall and mean temperature was acquired from Pakistan Meteorological Department (PMD). Key climate change trends (temporal and spatial) are identified at the national level. The spatial patterns were plotted using IDW interpolation method in GIS environment. We use 30-year averages, computed for the period 1961–90, termed "reference normal," as the benchmark for observed climate change assessment (WMO 2017). The river inflows data of five major rivers (Indus, Jhelum, Chenab, Ravi and Sutlej) was acquired from Surface Water Hydrology Project-Water and Power Development Authority (SWHP- WAPDA) for 1961-2016 on yearly basis. The linear trend analysis was adopted to identify the increasing or decreasing trends of river inflows. The spatial patterns and trend analysis of potential evapotranspiration (ETp) over Pakistan was done using the gauge-based gridded ETp data of Climatic Research Unit (CRU). The spatial patterns of the changes in ETp on annual basis are investigated for the period 1967–2016. The CRU data was used because it offer longer temporal span that can be used easily to find change in ETp. Previous studies testified performance of CRU data compared with other gridded data over Pakistan (Iqbal et al., 2019; Khan et al., 2018). Afzaal et al. (2009) showed correlation coefficients above 0.9 between PMD and CRU data for the period 1960–2000.

For the future projections of temperature, rainfall, river flows and evapotranspiration, this paper is primarily based on literature studies (Bokhari et al., 2017; Chaudhry, 2017; GOP, 2013; Parry, 2016; Amir and Habib, 2015; Yu et al., 2013; Khan, 2011). Due to the nature of research, the emphasis and reliance was given to the secondary sources. The documents and reports were obtained from Ministry of Environment and Climate Change; PMD (Pakistan Meteorological

Department); WAPDA (Water and Power Development Authority) and Pakistan Agriculture Research Council. In addition, the reports, documents, policy briefs obtained different NGOs working in Pakistan. The literature cited was selected based on a critical review of publications of greatest relevance to Pakistan using Google Scholar, Web of Science, Scopus, and Science Direct (Hussain et al., 2020).

6.3. Results and Discussion

6.3.1 Present Climate and Observed Changes

a. Spatio-temporal trends of temperature

Figure 1 indicating warming trends since 1960s. The rate of change is 0.74°C for the period 1961–2018. The rise in the latter half of this period is very prominent (0.67°C). The highest increase is seen in the southern cities of Quetta (in Balochistan), at +0.50°C per decade, followed by Karachi (in Sindh), where the annual mean temperature has risen by +0.32°C per decade. The northernmost cities, Muzaffarabad (in AJK) and Gilgit (in GB), have experienced the least increase at +0.02°C per decade and+ 0.10°C per decade, respectively. Figure 6.1-2 shows the spatial pattern of mean annual temperature changes. Warming is apparent over almost the entire country, and it is greater over major parts of Balochistan, in southeastern and southwestern Sindh, and in eastern parts of Punjab.

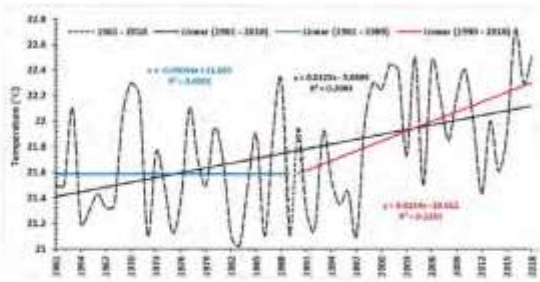


Figure 6.1. Annual temperature trends in Pakistan, 1961–2018, 1961–89, and 1990–2018

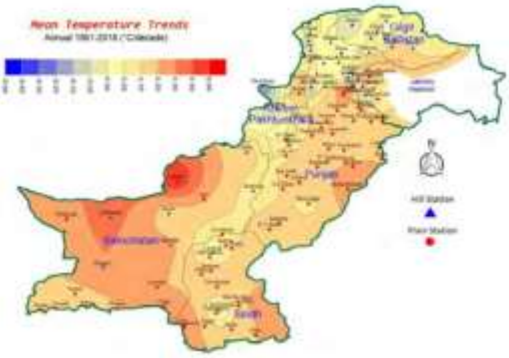


Figure 6.2. Spatial distribution of mean annual temperature trends, 1961 to 2018 (°C/decade)

b. Spatial-temporal trend of rainfall

For the country as a whole, average annual rainfall shows an increase of 19% over the period 1961–2018. Average annual rainfall increased in the earlier period but shows a decreasing trend in the latter half (Figure 6.3). The tendency of rainfall on regional level is somewhat mixed. Annual total rainfall has increased the most in Peshawar (+39 mm/decade), followed by Islamabad (+37 mm/decade) and Lahore (+26 mm/decade), while it has decreased in Muzaffarabad (–19 mm/decade) and Karachi (–17 mm/decade). Figure 6.4 illustrates the spatial distribution of annual rainfall trends and shows that in most parts of the country, there is either no change in average annual rainfall or a slight increase. However, a decrease in annual rainfall is evident in the southernmost parts of the country and also in the northeastern region of AJK and adjoining areas.

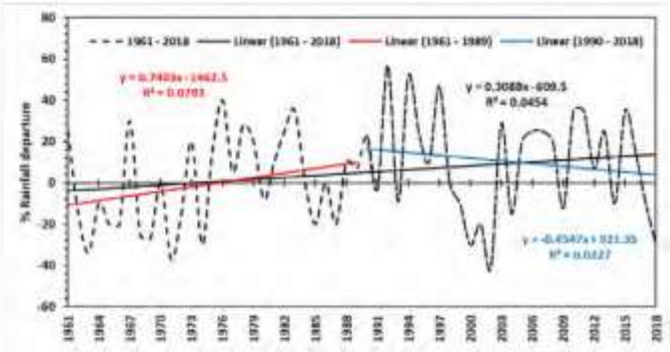


Figure 6.3. Annual precipitation trends in Pakistan, 1961–2018, 1961–89, and 1990–2018

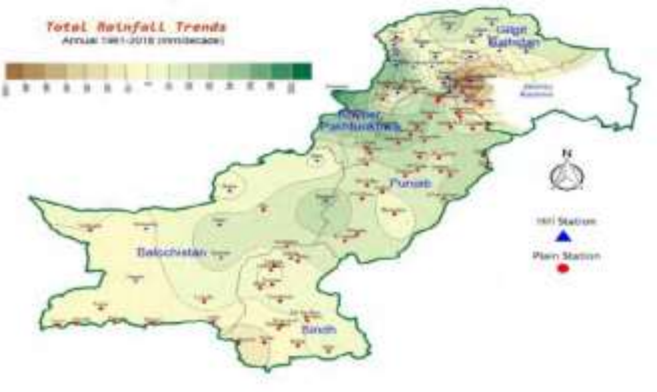


Figure 6.4. Spatial distribution of mean annual rainfall trends, 1961 to 2018 (mm/decade)

c. Temporal trends of major river flows

Stream flow is the major source of irrigation. A plot of annual inflows from the Indus main stem indicates a significant decline over the period of record (Figure 6.5). The Jhelum yields an average of about 23 MAF per year while Chenab delivers about 25 MAF per year at the Marala Headworks. Figure 6.6 indicates the rapidly declining rate of discharge on the Ravi and Sutlej. Ravi inflows at Balloki Barrage display a step function beginning at roughly eight MAF per year in the 1970s, dropping to four or five MAF until 1999, and less than two MAF thereafter. Sutlej River inflows at Sulemanki Barrage also declined dramatically in the 1970s, though with a different pattern than occurred on the Ravi. The Sutlej displays much higher variability than the Ravi. Overall, annual inflows appear relatively stable over the period of record. In contrast with the other two rivers, the Chenab's recent decade of flows are most often below the mean, which raises water concerns downstream.

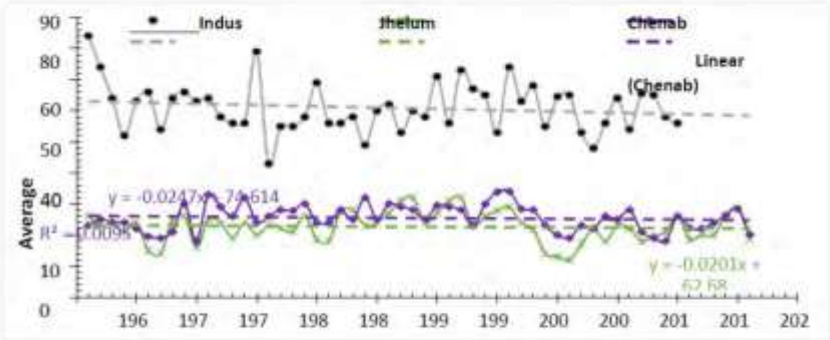


Figure 6.5. Annual inflows: Indus, Jhelum, and Chenab Rivers. Plotted from WAPDA data.

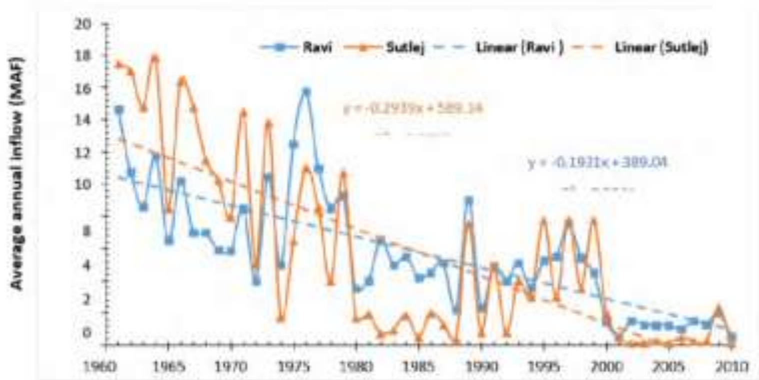


Figure 6.6. Annual inflows: Ravi and Sutlej Rivers. Plotted from WAPDA data.

d. Potential Evapotranspiration (ETp)

The spatial patterns of mean annual ETp from 1967 to 2016 indicating 657 mm in the north to 2540 mm in the southwest (Figure 6.7). The southern region has ETp between 1610 and 1910 mm while central region of the country has ETp between 1290 and 1600 mm. The southwest and the southeast has ETp between 1920 and 2230 mm, respectively. Southwest corner showed highest ETp (2240 – 2540 mm), while lowest (657-971 mm) in north. The spatial patterns in trends of ETp show changes between 1.65 and − 1.59 mm/year (Figure 6.8). The southern, southwest and southeast and extreme north regions showed increasing trend ranging from 0.01 to 1.65 mm/year while most of the area (central and extreme southwest region) has negative values ranging from − 0.19 to − 1.59 mm/year. It is important to note that ETp of central and southwest region (Punjab, Balochistan) showed is decreasing.

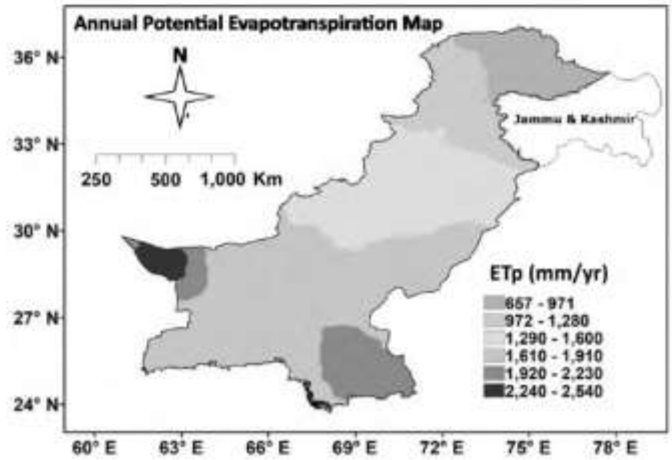


Figure 6.7. Spatial patterns of mean annual potential evapotranspiration of Pakistan during 1967 to 2016

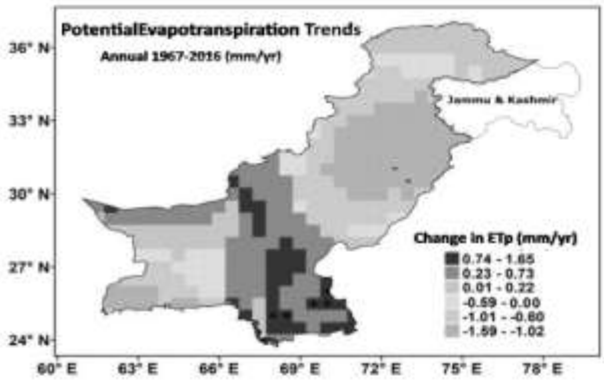


Figure 6.8. Spatial patterns of the changes in annual ETp of Pakistan

6.3.2 Future Climate Projections in Pakistan

a. Future Trends of Temperature and Precipitation under RCPs Scenarios

According to Pakistan Meteorological Department (PMD) data for the four different General Circulation Models, using the World Climate Research Program-Coupled Model Inter Comparison Project Phase-5 (CMIP5), there is a significant positive trend in annual mean temperature of 3°C to 3.5°C for the period 2011-2100 under RCP4.5 while under the RCP8.5 scenario, the increase in annual mean temperature is 8.3°C. There is a decreasing trend (-0.54 mm/day) in annual precipitation under RCP4.5 while increasing trend (0.9 mm/day) in precipitation under RCP8.5 (Figure 6.9). The rainfall is highly variable in both spatial and temporal domains.

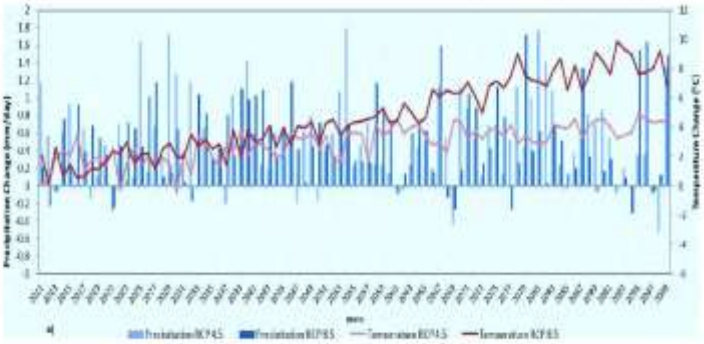
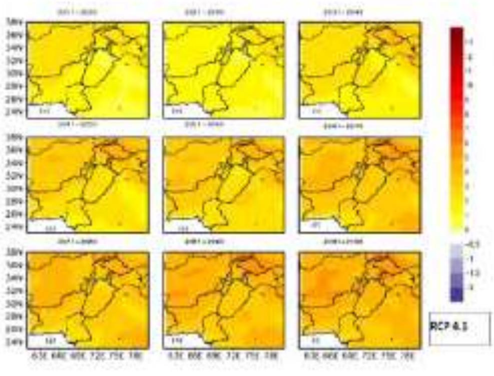


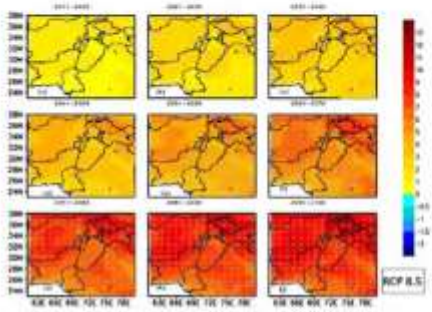
Figure 6.9. Pakistan's Mean Annual Temperature and Precipitation Deviation Projections during the 21st Century Using Two Different Emission Scenarios

According to the model, spatial patterns of temperature and precipitation have similar behavior. RCP 4.5 shows an overall effect of higher warming ranging 3°C to 4°C over the northern areas including GB, Kashmir and Northern part of KPK as compared to southern parts of the county. The southern parts show warming of 2°C to 3°C with a slightly higher rate over Balochistan (Figure 6.10a). In RCP 8.5 however, the warming effects are more enhanced with an increase of 3°C to 8°C over the northern areas during the first half of the 21st century and up to 11°C by the end of the 21st century. Southern parts of the country also show higher rates of warming under this scenario ranging 5°C to 7°C by the end of the century (Figure 6.10b)

The changes in annual mean precipitation under both RCP scenarios show an overall increase in precipitation of 2 mm/day to 3 mm/day over the domain. Regions showing a greater change in temperature also show an increase in precipitation. RCP4.5 shows an increase of 4 mm/day in annual mean precipitation with a shift in maxima toward the northeastern part of the country until 2050. After 2050, the precipitation pattern shifts toward northwest until the end of the 21st century with the same magnitude and wet situation in the southern region. A similar pattern is seen in the RCP8.5 scenario but with less magnitude of up to 2– 3 mm/day and more spatial spread (Figure 6.11a and 6.11b).

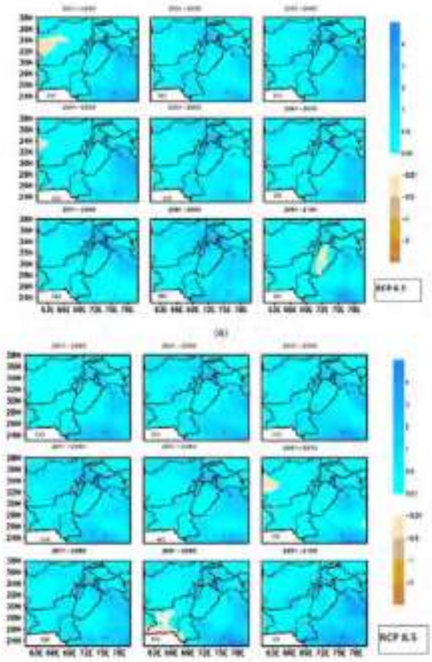


(a)



(b)

Figure 6.10. Coupled Model Intercomparison Project Phase-5 Projections of Annual Average Temperature Changes (°C) for 2011–2100 under Representative Concentration Pathways 4.5 (a), and 8.5 Relative to 1975– 2005 APHRODITE Baseline (b)



(a)

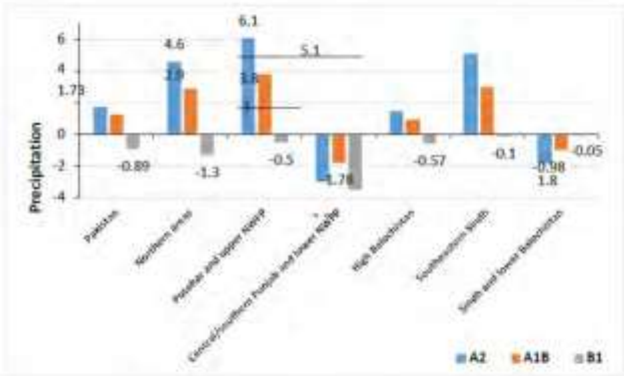
(b)

Figure 6.11. CMIP5 Projections of Changes in Annual Mean Precipitation (mm/day) for 2011-2100 Under RCP4.5 (a), and RCP8.5 Relative to 1975–2005 APHRODITE Baseline (b)

Notes: RCP4.5 is a stabilization scenario where greenhouse gas emissions stabilize by 2100. In RCP 8.5, radiative forcing does not peak by year 2100. APHRODITE – a climate model. Hatching show changes exceeding 90% significance level. Source: Pakistan Meteorological Department. 2015. High Resolution Climate Scenarios. http://www.pmd.gov.pk/rnd/rndweb/rnd_new/climchange_ar5.php

b. Future Trends of Temperature and Precipitation under SRES scenarios

The PMD conducted another significant study that computed temperature and precipitation change for different regions of Pakistan from 2011 to 2050 under climate change scenarios (A2, A1B and B1) based on IPCC Special Report Emission Scenarios (SRES). The climate models show a maximum rise in the northern areas of Pakistan (0.39 to 0.76 °C/decade), central and south Punjab and lower parts of Khyber Pakhtunkhwa Province (0.63 to 0.71 °C/decade). However, mixed trends are projected for precipitation over different regions of Pakistan (Figure 6.12).



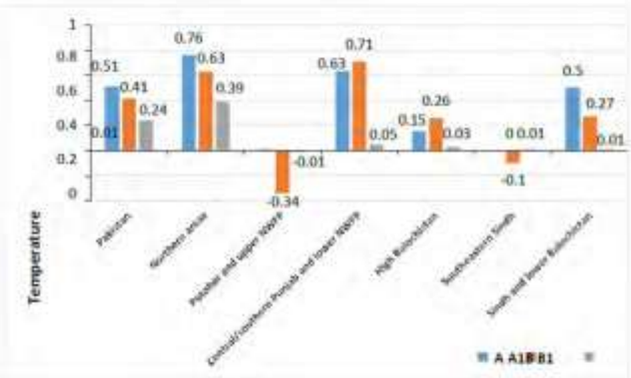


Figure 6.12. Region wise Climate Projections for Pakistan for Alternative Scenarios, 2011–2050. Projected regional precipitation and temperature change in Pakistan with three prospective scenarios (2011–2050). Source: (ADB 2017; Chaudhry et al. 2009). A2 signifies business as usual scenario; A1B signifies balanced scenario; B1 signifies ideal world scenario (SRES Report IPCC 2001). NWFP = Northwest Frontier Province and current Khyber Pakhtunkhwa.

According to Iqbal and Zahid, (2014) the temperature rise in the northern areas by 2020 is projected to be 1.4+/-; it is projected to be 2.7+/- by 2050. Likewise, for southern areas the temperature rise is projected to be 2.7 +/- degrees by 2020 and 2.4 degrees by 2050 (Table 6.1). Similarly, precipitation increases in northern areas and rising temperature trends will affect all sectors: in particular, agriculture.

Table 6.1. Ensemble mean of climate change projections based on IPCC AR4 using 17 GCMs and the A2 SRES and the A1B SRES (Amir and Habib, 2015)

	A2			A1B		
Scenario/area	2020s	2050s	2080s	2020s	2050s	2080s
Temperature change (°C)						
Northern Pakistan	1.4 ± 0.1	2.7 ± 0.2	4.7 ± 0.2	1.6 ± 0.1	3.0 ± 0.2	4.1 ± 0.2
Southern Pakistan	1.3 ± 0.1	2.4 ± 0.1	4.2 ± 0.2	1.4 ± 0.1	2.6 ± 0.1	3.7 ± 0.2
Precipitation changes (%)						
Northern Pakistan	2.2 ± 2.3	3.6 ± 3.2	1.1 ± 4.0	-0.7 ± 1.5	-1.8 ± 2.2	-0.7 ± 3.1
Southern Pakistan	3.1 ± 5.1	6.4 ± 7.5	4.3 ± 9.4	-3.2 ± 4.3	-0.3 ± 5.5	-0.9 ± 7.9

c. *Runoff and river flows*

The impact of climate change on river flows was assessed from previous research studies published during 2015 to 2020. Most of these studies were conducted in the sub catchments of Upper Indus Basin (UIB) and future climate impact were assessed using hydrological models (SWAT, SRM, UBC model and HBV) under RCP 4.5 and RCP8.5 scenarios for 2011-2040, 2041-2070 and 2071-2100 periods (Shah et al., 2020; Haider et al., 2020; Anjum et al, 2019; Nauman et al., 2019; Hayat et al., 2019; Ali et al., 2018; Adnan et al., 2017; Garee et al., 2017; Lutz et al., 2016; Ali et al., 2015). The brief analysis and findings of these studies is summarized in Figure 6.13. According to literature studies, it is anticipated that total water flows in the Indus Basin in the near-term (i.e. before 2050) will remain relatively stable, although there could be an increase in flows due to higher run-off as temperatures warm and a shift in the timing of peak water flow to earlier in the year (Immerzeel et al., 2009). Results depicted an overall increase in average annual flows under RCP 4.5 and RCP 8.5 up until 2100. Mean annual discharge was projected to increase 30.43% (RCP 4.5) and 41.87% (RCP 8.5) and 35.79% (RCP 4.5) and 50.15% (RCP 8.5) for (2011-2040) and (2041-2070), respectively. For 2071-2100 period, the increase in flow is 42.03% and 66.47% during RCP4.5 and RCP 8.5, respectively. Likewise, the anticipated changes in precipitation ranges from 1.2% to 2.5% for RCP4.5 and 3.1% to 6% under RCP8.5 (from mid-century to late century).

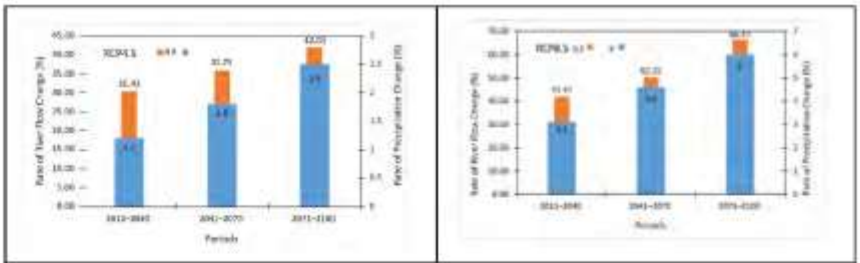


Figure 6.13. Changes in precipitation (P) and river flow (R.F) in the Upper Indus Basin of Pakistan under RCP scenarios

d. *ET and Groundwater*

Agricultural water demand estimates for Pakistan have been summarized in several documents; most projections are based on linear trends. A recent report (Engro Polymer and Chemicals, 2015) summarizes and documents demand for agriculture in 2015 as 111 MAF; in 2020 as 115 MAF;

and in 2025 as 119 MAF. Thus by 2025, 8 MAF more than current 2015 estimates is required. In the case of environmental requirements, the 2015 water demand is estimated at 1.54 MAF; this will rise to 1.62 by 2020, and to 1.70 by 2025 – with an additional requirement of 0.16 MAF from the base year of 2015. This study also notes that due to the expanding population in Pakistan per capita water availability, which was 1,500 cubic meter per annum in 2010, will decline to 1,000 cubic meters per annum in 2025 and to 900 cubic meters in 2050. This clearly shows the water challenge Pakistan faces. Rasul et al. (2011) note that for every 1, 2 and 3 degree rise in temperature crop water requirements will increase by 11%, 19% and 29%, respectively, implying that at 2 degree rise, crop water requirements will almost double water needs in the northern areas. Water demand for 1 and 3 degree Celsius increases under A2 in temperature are estimated in Figure 6.14. A 1 degree average increase in temperature increases agricultural water requirements (crops and livestock) by about 5% by 2050, while a 3+ degrees change in temperature increases crop demand by 6% by 2025 and 12–15% by 2050.

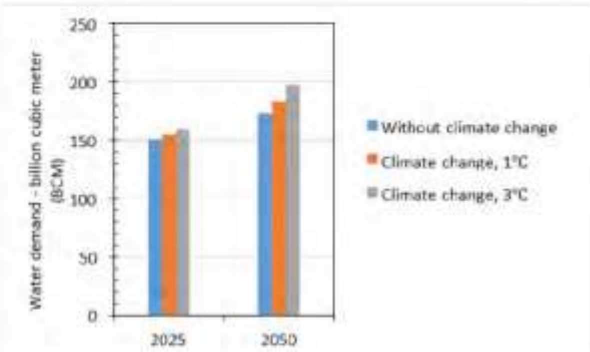


Figure 6.14. Climate change impact on agriculture water demand – years 2025 and 2050 (Amir and Habib, 2015)

Rising temperature and changing precipitation pattern will directly affect groundwater recharge, discharge, level and storage. Groundwater plays a major role in irrigated agriculture in Pakistan (Qureshi et al 2004). With increasing trend of irrigated cropping area and crop yield to provide food to increasing population implies that more water will be required and without careful planning and building of new dams, this will inevitably mean using more groundwater. Globally, Pakistan is the fourth biggest user of the groundwater, according to a recent report by the National Groundwater Association of United States of America (Amir and Habib, 2015). Irrigation is the largest consumer of water in the Indus basin that is using both surface (113 km^3 or 434mm) and groundwater (68 km^3 or 262 mm) to meet the crop water requirements (Cheema et al., 2013). The few estimates of the total volume of usable groundwater suggest that the increased rate of groundwater use could exhaust the best quality groundwater in as little as 50 years (Figure 6.15). The groundwater requirement shows the probable increasing requirement in the absence of alternative policies and adaptations.

e. *Agriculture Yield*

Climate change will disproportionally affect agricultural production across the country. It has been projected that a 4°C increase in temperatures and 3 percent rise in precipitation by 2080 could result in a loss in agricultural productivity of up to 13 percent in Punjab and Sindh provinces (Dehlavi et al., 2014). More positively, in Pakistan's northern foothills, wheat, maize and rice yields could increase due to longer and hotter summer seasons (Rasul & Ahmed, 2012). It has been projected that a 1°C rise in temperature during the vegetative and flowering stages of cotton growth would reduce yield by 24.14 percent and 8 percent, respectively in Sindh (Raza & Ahmed, 2015). According to data of World Bank on projected changes in wheat, rice and maize yield (2030-2080) under A2 scenario, the wheat yield may decrease 3.2 to 27 %, the rice yield may decrease 0.8-1.9% and maize yield may reduce 2.4 to 4.3 % (Figure 6.16). With these facts, there is more stress on wheat crop, so the population should have to reduce dependence on wheat and shift to use coarse grains such as barley, sorghum, millet, oat and coarse rice. The decline in water availability also suggests the shifts in crop rotations and alter sowing and harvesting patterns in coming two or three decades.

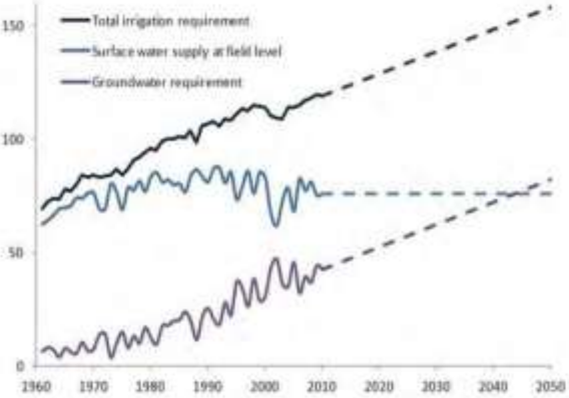


Figure 6. 15. Historical (to 2013) and projected (2013 to 2050) total irrigation requirement, surface water supply to the field, and groundwater requirement, in billion cubic meters (BCM). (Source: CSIRO, 2019)

Overall, available research suggests the potential for water-intensive crops to be most affected by climate change, resulting in significant reductions in crop yields. Current climate-induced changes are affecting the cropping system of Pakistan in diverse ways:

- A change in temperature has increased the annual evapotranspiration, which is not uniform over the critical crop growth periods and across various agro-climatic zones.
- A weather shift (still not fully understood) impacts the water stress periods and gross crop yields.
- Extreme events can cause large-scale crop damage.

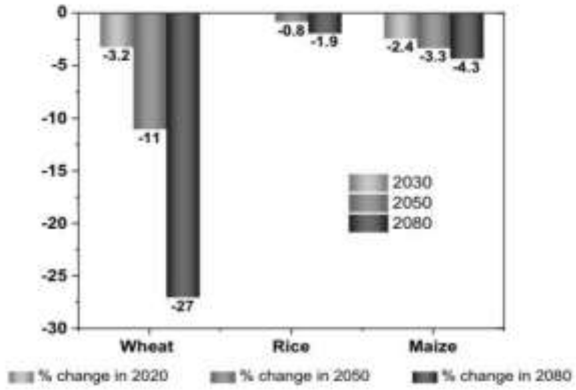


Figure 6.16. Comparison of estimated change in crop yield (2020–2080) with standard crop yield (1961–1990) by A2 Scenario. Source: (World Bank, climate change portal).

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6.4. Pakistan's options for climate change mitigation and adaptation

The present share of water use for agriculture (the most dominant sector) is 111.21 MAF; this accounts for around 92% of total water use. This share is likely to decline as water availability is reduced due to climate change. Based on current temperature and precipitation projections Pakistan must face water shortages and increased demand for water to grow crops and to sustain its agriculture. The projected demand for agricultural water in 2025 is 119.85 MAF; for 2050 it is 135.76 MAF. The gap between present water availability and future availability has clear implications for agriculture in terms of cropping patterns, rotations and water needs under different systems of irrigation like drip, bubbler, and sprinkler and raised bed farming. Without marked investment in irrigation efficiency improvement and water conservation technologies, continuing with the present-day level of agriculture will be difficult (Ali, 2009).

There are two approaches available to for tackling climate change: (upstream) mitigation or abatement, and (downstream) adaptation. Farmers in Pakistan are using a variety of adaptation practices to counter the adverse impacts of climate change. Ali and Erenstein, (2016) conducted a study related to farmer use of climate change adaptation practices in Pakistan using regression models based on structured questionnaire. The data relating to the farmers' experience of climate changes, various adaptation practices adopted and their impact on crop yields was collected. Most (87%) of the respondents reported observing changes in climatic conditions, which suggests that climate change has been experienced by most of the surveyed rural society. Similarly, majority noted a change in rainfall (timing and amount), monsoon onset and temperature during last ten years. Farmers typically adjusted the sowing time of their crops (22%) to the changing conditions, while 15% of the farmers adopted heat/stress tolerant varieties. A quarter shifted to new crops due to changing weather conditions. Adjustment in sowing time (22% households), use of drought tolerant varieties (15%) and shifting to new crops (25%) were the three major adaptation practices used by farmers in the study area. Farmers adopting more adaptation practices had higher food security levels (8-13%) than those who did not, and experienced lower levels of poverty (3-6%).

The research studies emphasis that the scope of policy related to climate change adaptation should focus on the strategies at community and farm level for significant development outcomes. An integrated approach is required to optimally use the available water resources because water availability shortage that was 11% in 2004 will increase to 31% by 2025. There are two options to overcome this shortage, (1) hard path i.e. construct small and large dams where possible, improve the surface water governance with proper pricing, legislate and restrict indiscriminate groundwater abstraction, control increase in population. This path involves huge investment, requires appropriate sites, requires considerable time for (feasibility study, completion of the project, re-settlement issues, and environmental issues) and needs national consensus. The other path is called soft path i.e. improving conveyance and application efficiencies (canal and watercourse improvement/maintenance, improving farm layout, leveling of fields), using high efficiency irrigation systems (bed and furrow methods of irrigation, sprinkler/drip irrigation system), changing the existing cropping patterns (adopting low delta crops), adopting proper irrigation scheduling (when to apply and how much to apply water?), using saline groundwater, in conjunction with canal water, or independently with salt tolerant crops and use of improved agronomic practices. The adaptation of soft path at farm level is an integrated approach, some case studies have been conducted in University of Agriculture Faisalabad and Pakistan Council for Research in Water Resources (PCRWR), and results are shown in Table 6.2.

Intercropping is also a well-known technique to improve water productivity for example the case study results of intercropping of sugarcane in wheat indicated is equivalent to 3 irrigations compared to sowing of sugarcane with traditional method. Another potential option is rainwater harvesting and according to PCRWR study, there is a great rainwater harvesting potential in Pakistan such as from rainfed areas (6.0MAF), deserts areas (0.34 MAF), coastal areas (0.53 MAF) and hill torrents (18.0 MAF).

Table 6.2. Potential of adopting Bed Plating technology at national level

Description	Wheat	Cotton	Maize	Rice
Area under crop (Mha)	8.41	3.05	1.02	2.52
Average production (000 bales/000 tons)	21749	11655	3313	5563
Average yield increase (%)	17	12	27	25
Increase in national production (000 bales/000 tons)	3654	1364	885	1396
Average water saving (%)	46	43	42	30
Potential of increasing area under crop (Mha)	3.83	1.31	0.43	0.76

Agriculture has a significant role to play in adapting and mitigating the impacts of climate change. There are some recommendations for protecting water resources and improving agricultural yield for climate change adaptation (Alvi and Khayyam, 2020; Iqbal and Khan, 2018; CIAT, 2017; Abbass, 2009; Khan, 2008).

- Assess the vulnerability of water sector and estimate the changes in the water availability due to climate change.
- Re-model and up-grade irrigation infrastructures to the projected range of expected extreme weather events.
- Introduce water harvesting and conservation schemes in rural and urban areas
- Improve irrigation technology and promote compost organic fertilizers to reduce water requirements in agriculture
- Construct small and medium-sized reservoir dams to capture water from flash floods
- Promote forestation and reforestation programs to increase water catchments
- Promote judicious use of water by increasing consumer awareness and by applying water metering and budgeting systems
- Establish systems to monitor ground and surface water resources
- Bring crop patterns (planting) in line with shifting weather patterns and adopt farming practices suited to the climate
- Introduce drought and heat resistant crop varieties and reduce dependency on traditional agricultural staples
- Introduce new varieties of crops which are high yielding and less water intensive
- Employ integrated nutrient management techniques to reduce emissions on-site by reducing leaching and volatile losses
- Improve agro-forestry systems by establishing shelter belts and riparian zones/ buffer strips with woody species
- Up-scale land leveling, which enables 30 percent water saving with corresponding increases in productivity
- Modify the local market to absorb the change in cropping patterns in rainfed areas due to climate change
- Establish climate change units or centers at agriculture research organizations to setup agricultural production surveillance system in vulnerable areas to categorize according to extreme climate events and vulnerability
- Awareness raising and capacity building of local level organizations in using sustainable farming techniques, water efficiency and climate

- Enhance capacity of academia and private sector to develop indigenously low cost agricultural water management techniques
- Undertake extensive review of existing research about mitigation options and prepare digital simulation models of climate change impacts on agricultural water to assess the value of investment in this program.

6.5. Conclusions

The analysis of meteorological data presented in this study indicates clearly that the climate of Pakistan is getting warmer, with some regions facing a faster increase in average annual temperature. The rate of change is 0.74°C for the period 1961–2018 with highest increase in southern part (+0.32°C to +0.50°C per decade) than northern part (+0.02°C to + 0.10°C per decade). Since 1961, average annual rainfall has increased (19%); but for the most part, that increase occurred in 1961–89, while the years after 1990 generally show a decline in rainfall. The tendency of rainfall on regional level is somewhat mixed. Annual total rainfall has increased the most in Peshawar (+39 mm/decade), followed by Islamabad (+37 mm/decade) and Lahore (+26 mm/decade), while it has declined in Muzaffarabad (–19 mm/decade) and Karachi (–17 mm/decade). The plotting of river inflows indicating declining rate of discharge on Indus, Jhelum, Chennab, Ravi, and Sutlej over the period 1961-2016. The spatial patterns in trends of mean annual ETp show changes between 1.65 and – 1.59 mm/year from southern to central region of Pakistan. It is important to note that ETp of central and southwest region (Punjab Balochistan) showed evapotranspiration paradoxical behavior i.e. the temperature is increasing while the ETp is decreasing. According to CMIP5 model, there is a significant positive trend in annual mean temperature of 3°C to 3.5°C for the period 2011-2100 under RCP4.5 while under the RCP8.5 scenario, the increase in annual mean temperature is 8.3°C. There is a decreasing trend (-0.54 mm/day) in annual precipitation under RCP4.5 while increasing trend (0.9 mm/day) in precipitation under RCP8.5. RCP 4.5 shows an overall effect of higher warming ranging 3°C to 4°C over the northern areas including GB, Kashmir and Northern part of KPK as compared to southern parts of the county. The southern parts show warming of 2°C to 3°C with a slightly higher rate over Balochistan. The changes in annual mean precipitation under both RCPs scenarios show an overall increase in precipitation of 2 mm/day to 3 mm/day over the domain. Regions showing a greater change in temperature also show an increase in precipitation. Results depicted an overall increase in average annual flows under RCP 4.5 and RCP 8.5 up until 2100. Mean annual discharge was projected to increase 30.43% (RCP 4.5) and 41.87% (RCP 8.5) and 35.79% (RCP 4.5) and 50.15% (RCP 8.5) for (2011-2040) and (2041-2070), respectively. A 1°C average increase in temperature increases agricultural water requirements by about 5% by 2050, while a 3+ °C change in temperature increases crop demand by 6% by 2025 and 12–15% by 2050. The groundwater requirement shows the probable increasing requirement in the absence of alternative policies and adaptations. According to data of World Bank on projected changes in wheat, rice and maize yield (2030-2080) under A2 scenario, the wheat yield may decrease 3.2 to 27 %, the rice yield may decrease 0.8- 1.9% and maize yield may reduce 2.4 to 4.3 %. The research studies emphasis that the scope of policy related to climate change adaptation should focus on the strategies at community and farm level for significant development outcomes. While this analysis has identified some of the broad changes underway in Pakistan's climate, its findings also point to the critical need to take into account regional and local trends, which may diverge greatly from country-level trends. Pakistan needs to develop policies and programs that promote an economy and society resilient to a range of shocks and stresses, including those induced directly and indirectly by climate change.

References

Abbass, Z. 2009. Climate change, poverty and environmental crisis in the disaster-prone areas of Pakistan. Oxfam GB, Pakistan Programme Office, Islamabad - Pakistan

ADB, 2017. Climate change profile of Pakistan.

Adnan, M., Nabi, G., Poomee, M.S. and Ashraf, A. 2017. Snowmelt runoff prediction under changing climate in the Himalayan cryosphere: A case of Gilgit River Basin. *Geoscience Frontiers*, 8(5): 941-949. Afzaal M, Haroon MA, ul Zaman Q. 2009. Interdecadal oscillations and the warming trend in the area- weighted annual mean temperature of Pakistan. *Pakistan Journal of Meteorology* 6:13–19

Aggarwal, P., and Sivakumar, M.V. 2011. Global climate change and food security in South Asia: An adaptation and mitigation framework. Pages 253-275. Climate change and food security in South Asia. Springer.

Ahmad, M.,Iqbal, M. and Khan, M. 2013. Climate Change, Agriculture and Food Security in Pakistan: Adaptation Options and Strategies. Pakistan Institute of Development Economics, Islamabad. (Climate Change Brief).

Ali, A. and Erenstein, O. 2017. Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Climate Risk Management.* 2017(16): 183-194. doi: http://dx.doi.org/10.1016/j.crm.2016.12.001

Ali, A.F., Xiao, C., Zhang, X., Adnan, M., Iqbal, M., and Khan, G. 2018. Projection of future streamflow of the Hunza River Basin, Karakoram Range (Pakistan) using HBV hydrological model. J. Mt. Sci. 15, 2218–2235. https://doi.org/10.1007/s11629-018-4907-4.

Ali, G., Hasson, S. Khan, A.M. 2009. Climate Change: Implications and Adaptation of Water Resources in Pakistan. Research report, GCISC RR-13. Global Change Impact Studies Centre, National Centre for Physics (NCP) Complex, Islamabad, Pakistan.

Ali, S., Li, D., Congbin, F. and Khan, F. 2015. Twenty first century climatic and hydrological changes over Upper Indus Basin of Himalayan region of Pakistan. *Environ. Res. Lett.* 10 (1): 014007, http://dx.doi.org/10.1088/1748-9326/10/1/014007

Alvi, S. and Khayyam, U. 2020. Mitigating and adapting to climate change: attitudinal and behavioural challenges in South Asia, International Journal of Climate Change Strategies and Management, 12(4): 477- 493.

Amir, P., Habib, Z. 2015. Estimating the impacts of climate change on sectoral water demand in Pakistan. Action on Climate Today (ACT) Report, www.actiononclimate.today

Anjum, M.N., Ding, Y. and Shangguan, D. 2019. Simulation of the projected climate change impacts on the river flow regimes under CMIP5 RCP scenarios in the westerlies dominated belt, northern Pakistan. *Atmospheric Research*, 27(1): 233-248

Bokhari, S.A.A., Rasul, G., Ruane, A.C., Hoogenboom, G., Ahmad, A. 2017. The Past and Future Changes in Climate of the Rice-Wheat Cropping Zone in Punjab, Pakistan. *Pakistan Journal of Meteorology*, 13(26): 9-23

Chaudhry Q.Z. 2017. Climate Change Profile of Pakistan. Manila: Asian Development Bank.

Chaudhry, Q.-Z., Mahmood, A., Rasul, G., and Afzaal, M. 2009. Climate change indicators of Pakistan. Tehcnical Report no. PMD-22/2009 42.

Cheema M.J.M., Immerzeel, W.W. Bastiaanssen, W.G.M. 2013. Spatial Quantification of Groundwater Abstraction in the Irrigated Indus Basin. *Groundwater*, 52, 25-36. https:doi.org/10.1111/gwat.12027 CIAT; World Bank. 2017. Climate-Smart Agriculture in Pakistan. CSA Country Profiles for Asia Series. International Center for Tropical Agriculture (CIAT); The World Bank. Washington, D.C. 28 p.

Climate Service Center. 2013. Climate fact sheet: Pakistan. Retrieved from Hamburg, Germany: Climate Service Center.

CSIRO, 2019. Future food security and water in Pakistan. In: Indus Technical Fact Sheet Series, March 2019. https://research.csiro.au/sdip/projects/indus/

Dehlavi, A., Groom, B. and Gorst, A. 2014. The Determinants, Impact and Cost Effectiveness of Climate Change Adaptation in the Indus Ecoregion: Micro Econometric Study. Lahore University of Management Studies. World Wide Fund for Nature – Pakistan and London School of Economics. Retrieved from: http://www.pide.org.pk/psde/pdf/AGM30/papers/The%20Determinants_Impact%20and%20Cost%20Effectiveness.pdf

Engro Polymer and Chemicals. 2015. Water Scenario of Pakistan, Karachi: s.n.

Garee K, Chen X, Bao A,. 2017. Hydrological Modeling of the Upper Indus Basin: A Case Study from a High-Altitude Glacierized Catchment Hunza. *Water*, 9(1): https://doi.org/10.3390/w9010017 Global Facility for Disaster Reduction and Recovery (GFDRR). (2014). Pakistan. Country program update series. Retrieved from https://www.gfdrr.org/sites/gfdrr/files/region/PK.pdf

Global Facility for Disaster Reduction and Recovery (GFDRR). 2011. Vulnerability, risk reduction and adaptation to climate change: Pakistan. Climate risk and adaptation country profile series. Washington, DC: The World Bank.

Government of Pakistan (GOP),. 2013. Framework for Implementation of Climate Change Policy (2014

– 2030). Government of Pakistan, Climate Change Division, Islamabad, Pakistan.

Haider, H., Zaman, M., Liu, S., Saifullah, M., Usman, M., Chauhdary, J.W., Anjum, M.N. and Waseem,

M. 2020. Appraisal of Climate Change and Its Impact on Water Resources of Pakistan: A Case Study of Mangla Watershed. *Atmosphere* 2020, 11, 1071; doi:10.3390/atmos11101071

Hayat, H., Akbar, T.A., Tahir, A.A., Hassan, Q.K., Dewan, A. and Irshad, M. 2019. Simulating Current and Future River-Flows in the Karakoram and Himalayan Regions of Pakistan Using Snowmelt-Runoff Model and RCP Scenarios. *Water* 2019, 11, 761; doi:10.3390/w11040761

Hussain, M., Butt, A.R., Uzma, F., Ahmed, R., Irshad, S., Rehman, A. Yousaf, B. 2020. A comprehensive review of climate change impacts, adaptation, and mitigation on environmental and natural calamities in Pakistan. *Environ Monit Assess*. 192(48): 1-20. https://doi.org/10.1007/s10661-019-7956-4

Immerzeel, W.W., Droogers, P., de Jong, S.M. and Bierkens, M.F.P. 2009. Large-scale monitoring of snow cover and runoff simulations in Himalayan River basins using remote sensing. *Remote Sensing of Environment*, 113 (2009): 40-49.

IPCC. 2018. "Summary for policymakers." In Masson-Delmotte, V. et al. (eds.), pp. 3–24. Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Geneva: World Meteorological Organization, Switzerland, 32 pp.

Iqbal, K.M.J. and Khan, M.I. 2018. Climate Governance: Implementing Water Sector Adaptation Strategies in Pakistan. *Policy Perspectives*. 15(3): 139-155

Iqbal, W. and Zahid, M. 2014. Historical and Future Trends of Summer Mean Air Temperature over South Asia. *Pakistan Journal of Meteorology*, 10(20): 67-74

Iqbal Z, Shahid S, Ahmed K, Ismail T, Nawaz N. 2019. Spatial distribution of the trends in precipitation and precipitation extremes in the sub-Himalayan region of Pakistan. *Theor Appl Climatol*. https://doi.org/10.1007/s00704-019-02773-4

Khan, D. 2008. Pakistan's Options for Climate Change Mitigation & Adaptation. Scoping Study, Occasional Paper 2, Leadership for Environment and Development (LEAD), Pakistan

Khan, M.A.A., Amir, P. Ramay, S.A., Munawar, Z. and Ahmad, V. 2011. National Economic & Environmental Development Study (NEEDS) Pakistan. The Ministry of Environment of Pakistan, United Nations Framework Convention on Climate Change (UNFCCC).

Khan N, Shahid S, Ismail T, Wang X-J. 2018. Spatial distribution of unidirectional trends in temperature and temperature extremes in Pakistan. *Theor Appl Climatol*. https://doi.org/10.1007/s00704-018-2520-7 Lutz, A.F., Immerzeel, W.W., Kraaijenbrink, P.D.A., Shrestha, A.B., Bierkens, M.F.P. (2016). Climate Change Impacts on the Upper Indus Hydrology: Sources, Shifts and Extremes. *PLoS ONE* 11(11): e0165630. https://doi.org/10.1371/journal.pone.0165630

Nauman, S., Zulkafli, Z., Ghazali, A.H.B. and Yusuf, B. 2019. Impact Assessment of Future Climate change on Streamflows Upstream of Khanpur Dam, Pakistan using Soil and Water Assessment Tool. *Water* 2019, 11, 1090; doi:10.3390/w11051090

Pakistan Meteorological Department. 2015. High Resolution Climate Scenarios. http://www.pmd.gov.pk/rnd/rndweb/rnd_new/climchange_ar5.php

Parry, J-E. 2016. Review of current and planned adaptation action in Pakistan. CARIAA Working Paper no. 15. International Development Research Centre, Ottawa, Canada and UK Aid, London, United Kingdom. Available online at: www.idrc.ca/cariaa

Parry, J-E., Osman, H., Terton, A., Asad, S.A. and Ahmad, T. 2017. The Vulnerability of Pakistan's Water Sector to the Impacts of Climate Change: Identification of gaps and recommendations for action. https://www.iisd.org/publications/vulnerability-pakistans-water-sector-impacts-climate-change- identification-gaps-and

Qureshi, A.S., Akhtar, M., Shah, T. 2004. Role of changing energy pricing policies on groundwater development in Pakistan. *Journal of Applied Irrigation Science* 39(2):329–342.

Rasul, G. and Ahmed, B. 2012. Climate change in Pakistan. Pakistan Meteorological Department. Rasul, G., Chaudhry, Q.Z., Mahmood, A. and Hyder, K.W. (2011). Effect of Temperature Rise on Crop Growth and Productivity. *Pakistan Journal of Meteorology*. 8(15): 53-62

Raza, A. and Ahmad, M. 2015. Analyzing the impact of climate change on cotton productivity in Punjab and Sindh, Pakistan. Climate change Working Paper Series (no.9). Retrieved from http://www.pide.org.pk/pdf/Climate_Change_9.pdf

Salik, K., Ishfaq, S., Saeed, F., Noel, E., and Syed, Q. 2015. Pakistan: Country situation assessment [Working paper]. Sustainable Development Policy Institute. Retrieved from https://sdpi.org/publications/files/Pakistan-Country-Situation-Assessment.pdf

Shah, M.I., Khan, A., Akbar, T.A., Hassan, Q.K., Khan, A.J. and Dewan, A. 2020. Predicting hydrologic responses to climate changes in highly glacierized and mountainous region Upper Indus Basin. *Royal Society Open Science*, 7(8): 191957. https://doi.org/10.1098/rsos.191957

Sheikh, M.M., Manzoor, N., Adnan, M., Ashraf, J., and Khan, A. M. 2009. Climate profiles and past climate changes in Pakistan. GCISC-RR-01. Islamabad, Pakistan: Global Change Impact Studies Centre (GCISC).

Spijkers M.A. 2010. Implications of Climate Change on Agriculture and Food Security in South Asia. In: Lal R., Sivakumar M., Faiz S., Mustafizur Rahman A., Islam K. (eds) Climate Change and Food Security in South Asia. *Springer, Dordrecht*. https://doi.org/10.1007/978-90-481-9516-9_14

World Bank. 2013. World Bank climate change knowledge portal: agriculture model by IIASA. [WWW document]. URL http://sdwebx.worldbank.org/Accessed 3.24.16

World Bank. 2015. Pakistan dashboard. Climate change knowledge portal. Retrieved from http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=PAK&ThisTab=Dashboard

World Bank. 2019. World Bank Group. Climate Chang Knowledge portal Dev0 Pract policy Mak. https://climateknowledgeportal.worldbank.org/country/pakistan/climate-sector-health Accessed 10 Apr 2019.

World Meteorological Organization (WMO). 2017. WMO Guidelines on the Calculation of Climate Normals. Geneva: World Meteorological Organization (WMO)

Yu, W., Yang, Y.-C., Savitsky, A., Alford, D., Brown, C., Wescoat, J., Debowicz, D. and Robinson, S. 2013. The Indus basin of Pakistan: The impacts of climate risks on water and agriculture. Washington, DC: World Bank. http://dx.doi.org/10.1596/978-0-8213-9874-6