Water Security Issues of Agriculture in Pakistan

Riaz Hussain Qureshi
Muhammad Ashraf

Pakistan Academy of Sciences, Islamabad
2019

PAKISTAN ACADEMY OF SCIENCES

MDCCCCLIII

Water Security Issues of Agriculture in Pakistan

وَجَعَلْنَا مِنَ الْمَآءِ كُلَّ شَيْءٍ حَيٍّ ۗ أَفَلَا يُؤْمِنُونَ

(Al Quran)

"And we made every living thing from water. So will they not accept faith?"

Pakistan Academy of Sciences
Islamabad
2019

Citation:

Qureshi, R.H. and M. Ashraf (2019), Water Security Issues of Agriculture in Pakistan. Pakistan Academy of Sciences (PAS), Islamabad, Pakistan, pp. 41.

ISBN:	978-969-8223-27-4
Copyright:	**Pakistan Academy of Sciences**
Composed & Edited by:	Dr. Riffat Mahmood Qureshi (Pakistan Academy of Sciences)
Printed by:	PanGraphics (Pvt) Ltd., Islamabad

Disclaimer:

FOREWORD

One of the prime objectives of the Pakistan Academy of Sciences (PAS) is to prepare policy documents and provide advice to the Government of Pakistan on matters of national importance. This manuscript, **Water Security Issues of Agriculture in Pakistan**, jointly compiled by Professor Dr. Riaz Hussain Qureshi and Dr. Muhammad Ashraf, is one of a series of documents prepared by the PAS under this objective. Pakistan, like the rest of the world, is confronted by several serious threats, such as climate change, energy crisis, food security, natural hazards, and water shortage. The latter, quite obviously, is of the highest concern for sustainable agriculture (which consumes over 90% of the surface water), domestic- and industrial use. Much of the surface water in Pakistan is also contaminated and hazardous to health. Dr. Qureshi and Dr. Ashraf deserve special thanks and appreciation for compiling this document which deals with the supply of water for sustainable agriculture and food security of our unfortunately rapidly growing population. It has primarily been prepared for the perusal of the relevant professionals, policy makers and water managers. However, its simple format also allows easy access to information and education of the public at large.

Pakistan is a semi-arid region and primarily an agricultural economy. Its water resources (essentially comprising monsoon and westerly rains, melting of Himalaya-Karakoram-Hindu Kush ice/glaciers, and excessively extracted groundwater) are not only finite but also exhaustible. Pakistan has the world largest contiguous irrigation network in the form of canals, distributaries and water courses, with its own inherent benefits as well as operational and management problems. Pakistan’s agriculture depends heavily on irrigation and 90% of its agricultural output comes from irrigated lands. The Indus Basin irrigation system is the principal agriculture base of the country. It is facing serious constraints and issues of environmental (climate change, drought), financial, political (Indus Water Treaty, etc.), policy-management, governance, and technical nature, and many others. Such issues are posing water security concerns and require utmost and urgent attention. There is a need to secure the available water potentials and develop additional potentials to improve water availability and storage for agricultural sustainability in the country.

The 21st Century has brought its own challenges and new dimensions in several environmental, and socio-economic sectors in Pakistan, particularly in the water sector arising from increased demand of water supply for growing agricultural and domestic needs. Pakistan’s water profile has changed drastically from being a water abundant country to one experiencing water stress. Population growth, rapid urbanization, industrialization, as well as water-intensive obsolete farming practices, all contribute to Pakistan’s increasing demand for water. Flood irrigation, the prevailing system in the hot and semi-arid Pakistan, leads to heavy losses of water through evaporation. Simultaneously, the supply is hampered by its small water storage capacity and climatic changes that have made rainfall more erratic, leading to floods in some years and droughts in the others. Excessive pumping of aquifers (potential groundwater reservoirs) has raised major concerns over its sustainability. Poor water infrastructure and inadequate lining of canals, along with breaching (sometime illegal) of water courses, further exacerbates the situation of water availability and supply. Pollution of available surface and groundwater resources, mainly due to inputs from agricultural wastes/run-offs and dumping of untreated industrial and domestic sewage on to land and in water courses, is another factor hampering the supply of freshwater.

Agriculture in Pakistan (indeed in the entire sub-continent) is by far the largest user of raw water, but it is also the backbone of its economy. Therefore, it is the main concern of this document. The irrigated areas in Pakistan have increased dramatically during the early and middle parts of the 20th Century, driven by rapid population growth and the consequential demand for food. To meet the challenge of growing demands for water supply, and to address the twin menace of water logging and salinity, groundwater has been excessively exploited in the inter-fluvial areas of the Indus basin, causing its depletion both for irrigation and domestic purposes. In the wake of this issue, agricultural livelihoods have gained importance in development planning. Proper knowledge, regarding water availability and water security for agriculture, its demands and allocation mechanisms, is critical to understanding national management challenges and security threats. This necessitates critical examination of the past programs related to water resources sector to shape its future for most optimum development and utilization of water resources for the benefit of the country.

The compilation of this document is timely, given the increasing influence of global climate change, as well as new changes and constrains on access to water in Pakistan and the surrounding region. It provides a comprehensive overview of the status of water security issue in Pakistan and summarizes information on anticipated environmental, social and political impacts on water resources for agricultural activities in the country. The document deals with water availability indicators, water quality, statistics of land and water use in Pakistan, water wastage at the field level, causes of water shortage and the way forward, misuse of water, key forces of climate change affecting the future of water security in the country, water storage situation and misconceptions about dams, dry-land agriculture, implementation of national water policy-2018, solutions for a way forward to secure water for agriculture in Pakistan. Implications of water security at national and local levels have been dealt with in detail.

This manuscript, **Water Security Issues of Agriculture in Pakistan**, lays emphasis on the fundamental importance of close connection between strategic planning, adaptation of sound policy, and quick and effective implementation. It is hoped that the concerned departments and policy makers will find the information and guidelines herein useful in evolving a strategy of effective water management that would ensure a secure and resilient supply system to meet the agriculture, domestic and industrial water needs of Pakistan in a globally changing climate, growing population, and external constraints.

Professor M. Qasim Jan *(PhD, DSc, HI, SI, TI)*
President
Pakistan Academy of Sciences
Islamabad

ABOUT THE AUTHORS

Prof. Dr. Riaz Hussain Qureshi

Professor Qureshi is a Fellow of the Pakistan Academy of Sciences, Professor Emeritus and former Vice Chancellor of the University of Agriculture Faisalabad, and former Advisor (Quality Assurance and Learning Innovation/HRD) of the Higher Education Commission of Pakistan. He obtained PhD from the University of Wales, and MSc and BSc with distinction from the University of Agriculture, Faisalabad.

Prof. Qureshi has been President Soil Science Society of Pakistan, Member of the Steering Committee of International Irrigation Management Institute (IWMI), Member Research Advisory Committees of PARC and NIBGE, National Coordinator of Saline Agri. Project for 8 years. He supervised 13 Ph.D. and 74 M.Sc. (Hons) students, and authored over 200 research papers (including one in Nature) and reports. He was the Chief Editor Pak. J. of Agriculture Sciences for eight years, and was In-charge of many international projects from U.K., Australia, USA, Philippines and Japan. He is pioneer of introducing Saline Agriculture Technology in Pakistan. His Co-authored book on Saline Agri. for Irrigated Land in Pakistan has been published by the Australian Centre for International Agri. Research.

Prof. Qureshi received many honors and awards, including Sir William Roberts shield and scholarships for M.Sc. and Ph.D. studies, Borlaug award, Pak Academy of Sciences Best Scientist of the Year award, and Pakistan Civil award Pride of Performance.

Dr. Muhammad Ashraf

Dr. Ashraf is basically an Agricultural Engineer. He graduated from the University of Agriculture, Faisalabad and earned his Ph.D. from the University of Newcastle, UK. He has more than 22 years research and development experience in water resources development and management and more than 80 national and international research publications to his credit. During his professional career, he has worked for integrated management of water resources in irrigated as well as in dry areas. His areas of expertise are: rainwater harvesting, irrigation system design and improvement, supplemental irrigation, irrigation scheduling, groundwater recharge, watershed management, and wastewater management. He has been working for provincial and national organizations such as On Farm Water Management, Punjab and Pakistan Council of Research in Water Resources (PCRWR).

Dr. Ashraf also had the opportunity of working for international organizations such as International Water Management Institute (IWMI), International Center for Agricultural Research in the Dry Areas (ICARDA). He has been Chairman, PCRWR from June, 2014 to May 2018 and member of Pakistan Engineering Council's Governing Body from 2015 to 2018. He is the Editor of the Journal "Paddy and Water Environment" published by Springer.

ACKNOWLEDGEMENTS

This report is largely focused on water issues of agriculture sector and related factors. It is based on initial discussion with the senior management of the Pakistan Academy of Sciences (PAS) and agricultural scientists. The authors have benefitted from the published literature and personal communications with many experts and farmers while compiling this report. It was circulated among the selected stakeholders for their input before publication by the PAS. The authors would like to thank the members of PAS Committee: Dr. Amir Muhammad, Dr. M. Qasim Jan, Dr. M. Aslam Baig and Dr. Riffat Mahmood Qureshi for their contribution in improving the report. Furthermore, thanks are due to the PAS for entrusting this important task to the authors, and for editing, composing and finally printing it.

WHAT'S INSIDE

CONTENTS

Contents	Page

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS AND ACRONYMS

CCI	Council of Common Interest
CDA	Cholistan Development Authority
CPP	Changa Pani Program
DE	Dam Equivalent
FAO	Food and Agriculture Organization
FPCCI	Federation of Pakistan Chambers of Commerce and Industry
GCRI	Global Climate Risk Index
GDP	Gross Domestic Products
GoP	Government of Pakistan
ITS	Indus Telemetry System
IWMI	International Water Management Institute
IRSA	Indus River System Authority
kg/m^3	Kilogram per Cubic Meter
kg/ha	Kilogram per Hectare
LBDC	Lower Bari Doab Canal
MA	Million Acre
m^3	Cubic Meters
MAF	Million Acre Foot
MoWR	Ministry of Water Resources
MTDF	Mid-Term Development Framework
Mha	Million Hectares
mm	Milli Meter
NWC	National Water Council
PCRWR	Pakistan Council of Research in Water Resources
POPs	Persistent Organic Pollutants
PMD	Pakistan Meteorological Department
SC	Steering Committee
t/ha	Tons per Hectare
TMA	Tehsil Municipal Administration
UAF	University of Agriculture Faisalabad
WUE	Water Use Efficiency
WRVI	Water Resources Vulnerability Index

1. INTRODUCTION

Agriculture contributes about 19.5% to Pakistan's GDP, employs 42% of the labour force, constitutes 64% of export earnings and provides livelihoods to 62% of the population of the country (Economic Survey, 2016-17). The agriculture sector is also the biggest user (more than 90%) of water in Pakistan. The water availability in Pakistan is already below the scarcity level of 1000 m^3/person and climatic changes in the region may further worsen the situation.

The minimum per capita domestic water requirement is 50 liters whereas it requires 2600 to 5300 liters to grow food for one person per day (Rijsberman, 2006). Therefore, food security is directly related to the water security as 50 to 70 time more water is required to grow food than the water used for domestic purposes.

About 90% food production in Pakistan comes from irrigated agriculture, whereas dry-land (rain-fed) agriculture contributes only 10% due to scanty and low rainfall. The total benefits derived from irrigation are also 12 times the direct, onsite benefits when all quantifiable economic and social benefits are accounted for (World Bank, 2006).

The Government and people of Pakistan are showing their great resolve to address the immediate and future impact of water scarcity on their lives and livelihood. The issue is extremely sensitive and extensive in dimension, requiring multiple and long-term actions to deal effectively with water shortages confronting different regions and various segments of the society.

In the context of increasing water scarcity, the issues that need to be addressed immediately include:

(i) increase in water storage capacity,
(ii) minimizing water wastages at various levels,
(iii) increasing water productivity,
(iv) development of appropriate regulatory framework for surface and groundwater management,
(v) devising and implementing appropriate crop zoning and cropping pattern, and
(vi) rationalizing pricing structure for water usage in all sectors.

The approved National Water Policy-2018 is an important document and can be used as guiding principles to address the water scarcity issues.

2. WATER AVAILABILITY IN PAKISTAN

2.1 Water Availability Indicators

Water availability status of a country can be assessed by four Indicators as given in the following:

Falkenmark Indicator (Falkenmark *et al*., 1989) provides relationship between available water and the human population. A country whose per capita water resources are less than 1700 m^3 is said to be a water-stressed country. When per capita water availability falls below 1000 m^3, the country is water scarce, and when it falls below 500 m^3/person, the country experiences an absolute-water scarcity. According to this indicator, Pakistan crossed the water scarcity line during 2005 and, if the situation continues, the country will touch the absolute water scarcity line by 2025 (Ashraf, 2016).

Water Resources Vulnerability Index (WRVI) (Raskin *et al*., 1997) compares annual water availability with the total annual withdrawals (in percent). If annual withdrawals are 20-40% of the annual water supply, the country is water scarce. If it exceeds 40%, the country is said to be severely water scarce. As reported by Ashraf (2016), the current WRVI Index for Pakistan is 77%, reflecting a severe water scarcity condition. Pakistan is among the top ten countries with largest water withdrawal for agriculture. India is by far the leading country (90%), followed by China, the USA and Pakistan (Scheierling and Treguer, 2018).

IWMI's Physical and Economic Water Scarcity Indicators (Seckler *et al.,* 1998): According to these indicators, the countries that will not be able to meet the estimated water demands in 2025, even after accounting for the future adaptive capacity, are called 'physically water scarce', while the countries that have sufficient renewable water resources but would have to make very significant investment in water infrastructure to make these resources available to people are called 'economically water scarce'.

In Pakistan, the shortfall, which was 11% in 2004, is estimated to reach 31% by 2025 (GoP, 2001). Pakistan has sufficient water resources (2010, 2012 and 2014 floods are recent examples), however, it is struggling for funding two already approved dam sites, i.e. Mohmand and Diamer-Bhasha. Therefore, under the present conditions, Pakistan is both physically and economically a water scare country.

Water Poverty Index (Sullivan *et al*., 2003) has five components: (i) access to water, (ii) water quantity, quality and variability, (iii) water uses for domestic, food and productive purpose, (iv) capacity for water management, and (v) environmental aspects. According to this indicator, if water is available but is of poor quality, it is still a water scarce country. The survey conducted by Pakistan Council of Research in Water Resources (Ashraf, 2016), found more than 80% samples of drinking water from 24 major cities of Pakistan unsafe for human consumption (Tables 1 and 2). Therefore, according to all four indicators discussed above, Pakistan is now a water-scarce country.

According to the four water availability indicators used widely, Pakistan is now a water scarce country and is fast approaching the absolute water scarcity.

Table 1: Drinking Water Quality Profile of Rural Areas (2004-2011)

Sr No.	Province	Districts surveyed	Tehsils	Union Councils	Villages	Samples collected	No. of Water Samples			
							Safe		Unsafe	
							No.	%	No.	%
1	Punjab	12	49	1227	2090	10440	2183	21	8257	79
2	Sindh	3	12	54	149	745	212	28	533	72
3	KP	4	6	211	240	1200	89	7	1111	93
4	Baluchistan	4	12	54	298	1465	05	0.3	1460	99
5	Federal	1	1	21	30	150	61	41	89	59
	Total	24	80	1567	2807	14000	2550	18	11450	82

Source: Ashraf (2016)

Table 2: Water Quality Assessment of Water Supply Schemes (2006-2012)

Province	Districts surveyed	Water supply schemes	Surveyed water supply schemes			Functional	Samples safe for drinking (%)	
			Total	Urban	Rural		Urban	Rural
Punjab	33	4100	3883	746	3137	2725	17	23
Sindh	22	1300	1247	123	1124	529	5	5
KP	16	3000	2203	474	1729	1710	63	26
Baluchistan	14	1600	1034	480	554	968	20	13
GB/AJK/FATA	10	2000	1794	18	1776	1379	8	2
Total	95	12000	10161	1841	8320	7311	23	14

Source: Ashraf (2016)

2.2 Basic Statistics of Land and Water Use in Pakistan

Basic statistics about land and water use in Pakistan are given in Tables 3 and 4, respectively. The rainfall pattern in various regions of Pakistan is shown in Figure 1.

Table 3: Land Resources of Agriculture[1]

Land category	Area (MA)	Area (Mha)
Geographical area	196.64	79.61
Culturable land	83.61	33.85
i) Forest area	6.94	2.81
ii) Culturable waste	26.97	10.92
iii) Culturable area	49.70	20.12
a) Barani	14.23	5.76
a.i. Rainfed	12.50	5.06
a.ii. Riverain	1.73	0.70
b) Irrigated	35.47	14.36
b.i. Canal	27.05	10.95
b.ii. Tubewells	7.01	2.84
b.iii. Others	1.41	0.57
Annual cropped area	47.33	19.16
a) Barani	10.13	4.10
b) Irrigated	37.20	15.06
Cropping intensity	-	95%
a) Barani	-	71%
b) Irrigated	-	105%

Source: GoP (2017). MA = million acre; Mha = million hectare

Table 4: Area Irrigated by Source (Mha)

Province	Canals	Tube wells/wells	Canal plus tube wells	Others	Total
Punjab	3.35	2.97	8.44	0.12	14.88
Sindh	1.36	0.364	0	0	1.724
KP	0.72	0.17	0	0.07	0.96
Baluchistan	0.54	0.46	0.05	0.04	1.09
Total	5.97	3.964	8.49	0.23	18.654

Source: GoP (2017).

[1] For the ease of the local readers, both metric and non-metric units have been used. Important conversion factors have been given as Annexure 1.

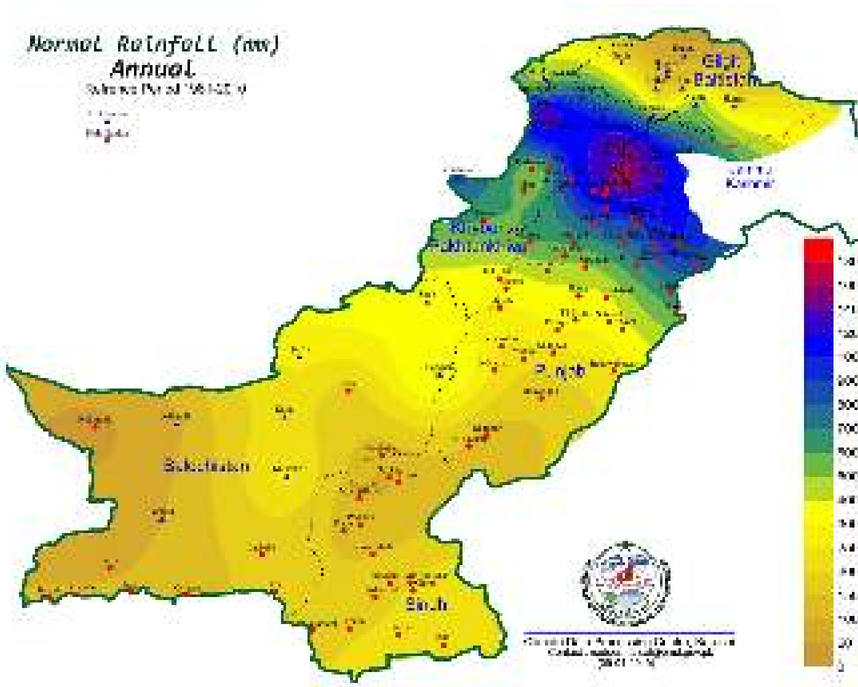


Figure 1: Average distribution of rainfall in Pakistan

2.3 Province-wise Area and Water Allocations

Pakistan has one of the largest contiguous irrigation systems in the world. The distribution of water has been an issue among the provinces even before 1947. The Water Apportionment Accord was signed by the provinces on March 16, 1991, and approved by the Council of the Common Interest (CCI) on March 21, 1991. The Indus River System Authority (IRSA) distributes the water among the provinces according to the Accord (Table 5). However, there is some mistrust among the provinces on the distribution of water. One of the major reasons is the lack of accurate and real-time measurement of water at the strategic locations.

Pakistan Council of Research in Water Resources in collaboration with the International Water Management Institute (IWMI) has installed Indus Telemetry System (ITS) at four canals, one in each province, which provides real-time and accurate discharge without human involvement. Such systems need to be installed at all strategic points/canals. This will not only help trust building among the provinces, but will also help to address the issue of unaccounted for water that has now increased to over 20% (Anwar *et al*., 2018).

Table 5: Water Shares of Provinces According to Water Accord 1991

Province	Water Shares (MAF)		Total (MAF)
	Kharif	Rabi	
Punjab	37.07	18.87	55.94
Sindh*	33.94	14.82	48.76
KP	3.48	2.30	5.78
Civil Canals**	1.80	1.20	3.00
Baluchistan	2.85	1.02	3.87
Total	77.34 + 1.80	37.01 + 1.20	114.35 + 3.00

*Including flood flows & future storage** Ungauged civil canals above the rim stations
Source: Anwar *et al*., (2018).

The apportionment of water was mainly based on the population and the cultivated area. Table 6 shows that Sindh had the highest per acre allocation (2.87 acre ft) for the cultivated and cultivable area followed by Punjab (1.59 acre ft), KP (0.74 acre ft) and Baluchistan (0.24 acre ft). The high water allocation for Sindh may be due to high evaporative demands of the crops and the more leaching fraction.

Table 6: Province-wise Area Cultivated and Water Allocation

Province	Cultivated Area (Mha)	Cultivable Area (Mha)	Total Area (Cultivated + Cultivable) (Mha)	Total (Cultivated + Cultivable) (MA)	Water Allocation MAF	Allocation per acre Foot
Punjab	12.52	1.52	14.04	35.100	55.94	1.59
Sindh	5.18	1.60	6.78	16.950	48.76	2.87
KP	1.88	1.25	3.13	7.825	5.78	0.74
Baluchistan	2.49	3.90	6.39	15.975	3.87	0.24
Total	22.07	8.27	30.34	75.850	111.35	1.46

2.4 Water Storage Situation

One of the major reasons of water scarcity is inadequate storage. The per capita water storage of Pakistan is far less than most other countries. The per capita storage of Australia and USA is over 5000 m^3, China 2200 m^3, Egypt 2362 m^3, Turkey 1402 m^3, Iran 492 m^3 while in Pakistan it is only 159 m^3. Aswan High dam on Nile River has a storage of about 1000 days, Colorado and Murray-Darling Rivers of 900 days, South

Africa Orange River 500 days, India 320 days and Pakistan only 30 days (Qureshi, 2011). Due to inadequate storage facilities, Pakistan lost more than 89 MAF of water during the floods of 2010, 2012 and 2014, besides having devastating effects on infrastructure, crops, livestock and people (Ashraf, 2016).

The present water storage capacity of three major reservoirs is less than 10% of the average annual inflow, against the world average of 40%. Due to sedimentation in the reservoirs, the existing capacity is being lost at a rate of 0.2 MAF per year. By 2010, the reservoirs had already lost 35% of their storage capacity (Table 7, Figure 2) (Iqbal *et al*., 2012).

Table 7: Water Storage Capacity (MAF)

Reservoir	Live Storage Capacity		Storage Loss	
	Original	Year 2013	Year 2013	Year 2025
Tarbela	9.69 (1974)	6.58 (68%)	3.11 (32%)	4.16 (43%)
Mangla (post raising)	8.24 (2012)	7.39 (90%)	0.85 (10%)	1.16 (20%)
Chashma	0.72 (1971)	0.26 (36%)	0.46 (64%)	0.64 (78%)
Total	18.65	14.23 (76%)	4.42 (24%)	5.96 (37%)

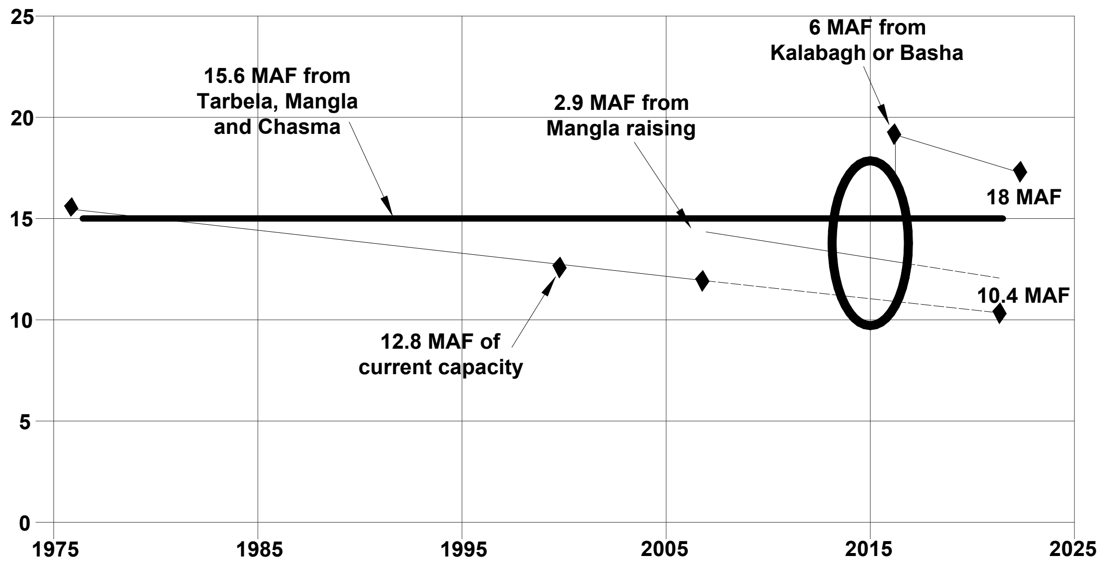


Figure 2: Water storage situation in Pakistan with time (Source: Briscoe and Qamar, 2005)

3. CAUSES OF WATER SHORTAGE AND THE WAY FORWARD

3.1 Lack of Population Control

The increase in population is one of the most important factors in the reduction of per capita water availability (Table 8). At the same time, population control has been a neglected subject both at the public and private levels. There is an urgent need to take some stern steps to control the ever-increasing population by involving all the stakeholders. Figure 3 shows a trend in water availability and population growth in Pakistan.

Table 8: Population v/s Water Availability in Pakistan

Year	Population (million)	Per capita water availability (m^3)
1951	34	5650
2003	146	1200
2010	168	1000
2025	221	800

Source: MTDF (2005-10).

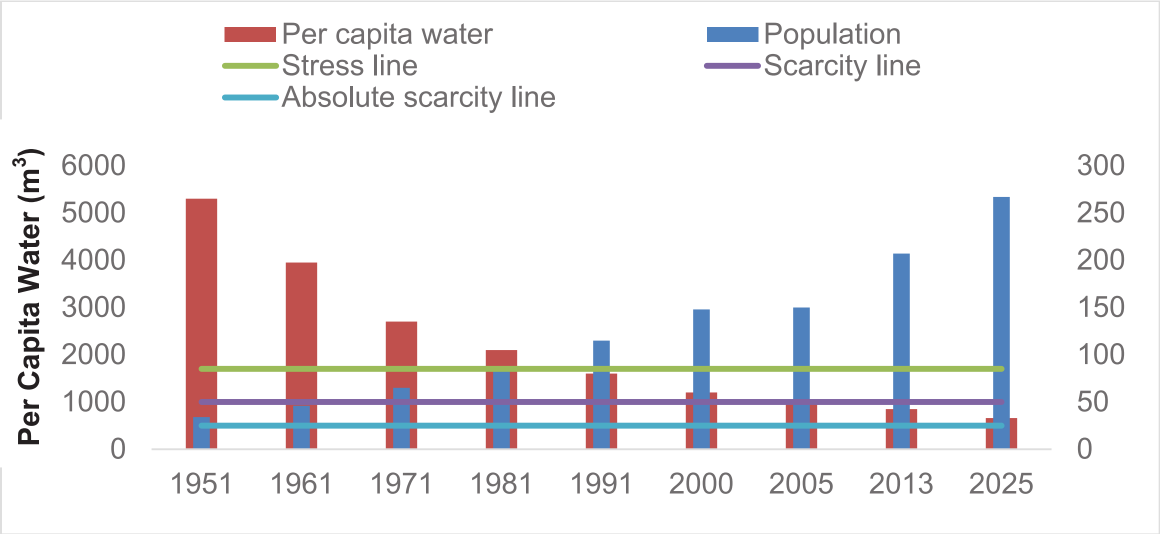


Figure 3: Trend of population v/s per capita water availability

3.2 Low Water Productivity

Water productivity is defined as the physical or economic output per unit of water application (Cai and Rosegrant, 2003). The average yield of crops (and animals) per unit water is also much lower than the international levels, and the yields obtained at the research farms and by the progressive farmers within the country (Tables 9, 10 and Figure 4). For example, for wheat it is 0.5 kg/m^3 compared with 1.0 kg/m^3 in India and 1.5 kg/m^3 in California (IWMI, 2000). In Egypt, the average wheat yield was 6.5 tons/ha as against 2.5 tons/ha in Pakistan (Wyn Jones *et al*., 2006). Similarly, the water productivity of maize is also low (0.3 kg/m^3) compared with Argentina (2.7 kg/m^3).

Table 9: Yield Gap for Major Crops

Crop	Progressive Farmers' Yield (t/ha)	National Average Yield (Avg. of last 3 years) (t/ha)	Yield Gap (%)
Wheat	4.6	2.6	43.5
Cotton	2.6	1.8	30.8
Sugarcane Sindh	200	54.5	72.8
Sugarcane Punjab	130	49.9	61.6
Maize	6.9	2.9	58.5
Rice	3.8	2.1	45.6

Source: MTDF (2005-10)

Table 10: Water Productivity of Cereal Production in Selected Countries

Name of country	Cereal Production (kg)/m^3 of Irrigation Water
Canada	8.72
USA	1.56
China	0.82
India	0.39
Pakistan	0.13

Source: Food Security and Sustainable Agriculture in India, IWMI Publication No. 60, Quoted in MTDF (2005-10), Planning Commission of Pakistan.

The gap in the water productivity for various crops shows that there is a tremendous scope for the improvement in water productivity that can help increase both horizontal and vertical expansion of agriculture (Ashraf *et al.,* 2010; Qureshi, 2011). The water productivity can be improved by increasing the yield per unit of used water or by reducing the amount of water used for the same yield. However, in Pakistan, there is potential for both increasing crop yield and reducing the depth of water applied (delta of water) using appropriate methods and techniques.

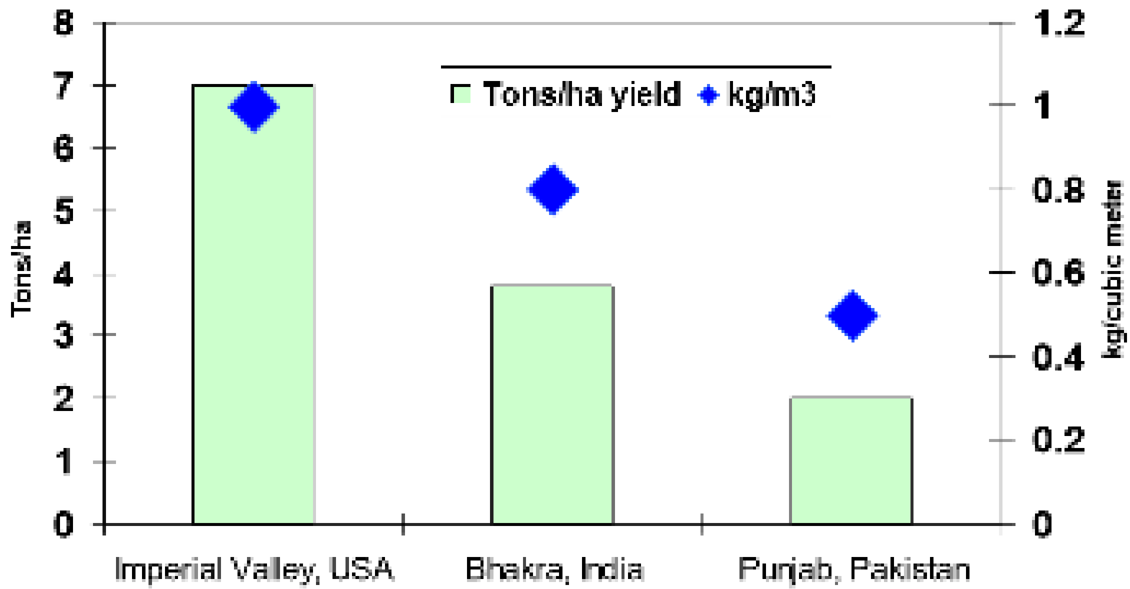


Figure 4: Land and water productivity of wheat (Source: Briscoe and Qamar, 2005)

The yield can be improved by using high yielding varieties, appropriate seed rate, time of sowing and use of fertilizers (Mahmood *et al*., 2015). The amount of water applied can be reduced through (i) precision land leveling, (ii) proper layout of the field, (iii) appropriate irrigation methods such as bed planting, and (iv) by adopting proper irrigation scheduling (Ashraf, 2016). These are simple methods and techniques that can help increase the water productivity manifold. However, the small farmers cannot purchase equipment such as laser leveler and bed planters. Therefore, the role of Agricultural Service Providers (ASPs), who are a link between professionals and the farmers, becomes crucial. They own machinery and equipment and can provide services to the farmers on rental basis (Ashraf, 2016).

3.3 Water Wastages at the Field Level

Pakistan has one of the largest contiguous irrigation systems in the world, covering about 17 Mha of land. However, at the same time, it is one of the most inefficient irrigation systems where more than 60% water is lost during conveyance in the channels and application in the field. Table 11 shows that maximum irrigation water losses occur essentially at water course level (30%) due to leakage and seepage, and at the field level (29%) due to poor irrigation methods.

Plate 1: The conventional planting of rice is water and energy extensive

Table 11: Water Losses in the Irrigation System

Location	Delivery at Head (MAF)	Losses (MAF)	Losses (%)
Canals	106	16	15
Distributary & minor	90	6	7
Watercourses	84	26	31
Fields	58	17	29
Crop use	41		
Total		65	61

Source: (GoP, 2001).

The following measures can help reduce the water losses at the tertiary level.

i. Ensuring laser levelling and ridge/bed sowing at field level and improving water courses. Improvement of Nakkas (farm outlets) can greatly reduce losses from water channels.
ii. Where feasible, use of rain gun, drip irrigation and sprinkle irrigation may be encouraged, especially in the hilly areas, sandy soils, and for high value crops.
iii. Direct seeding of rice should be encouraged which can reduce water use by 15%.
iv. Growing rice on ridges/beds can save up to 50% water and 20% increase in yield besides having a number of environmental benefits (Soomro *et al.*, 2015; Farooq *et al.*, 2009). It would also reduce methane emission from the rice fields.
v. Applying irrigation according to crop water requirements, i.e., adopting proper irrigation scheduling.

Plate 2: Growing rice on beds can help save up to 50% water as compared to the conventional irrigation system

3.3.1 Wastage of Water through Pancho System of Irrigation for Rice Crop

In the 21st century, when water has become a scarce resource and the world is trying its best to use it efficiently, it is still being used lavishly in Pakistan. One of such glaring examples is the use of Pancho irrigation system in Sindh province and major part of the rice growing area of Naseerabad and Jafferabad districts of Baluchistan. This system involves draining standing water from the field at regular interval (4-5 days) to the adjoining low-lying areas and its replacement with fresh water with the misconception that this system reduces water temperature and salinity level in the field. However, Ashraf *et al*. (2014), through a three years study, proved these misconceptions to be wrong. They reported that about 785 mm (59%) more water was applied under Pancho as compared to non Pancho system. It results in decrease in yield and increase in waterlogging and salinity besides the use of additional labor (Tables 12 and 13).

Rice is cultivated on 0.54 M ha in Sindh and there is about 50% water saving in non pancho system (though it is also highly inefficient system). About 3 MAF can be saved in Kharif season simply by avoiding the Pancho system. The saved water can be used for horizontal and vertical expansion of crop production, and will also help to address the issue of waterlogging and salinity in the rice growing areas of Sindh and Baluchistan.

Table 12: Gross Irrigation Water Applied, Water Drained and Net Water Applied

Year	Gross irrigation water applied (mm)			Water drained (mm)		
	Pancho	Partial Pancho	Non Pancho	Pancho	Partial Pancho	Non Pancho
2006	2135	1574	1338	535	224	0
2007	2273	1856	1371	676	483	0
2008	1957	1712	1252	465	379	0
Average	2122	1714	1337	559	362	0

Source: Ashraf *et al*. (2014)

Table 13: Yield and Water Productivity under Three Treatments

Year	Yield (kg/ha)			Water productivity (kg/m)		
	Pancho	Partial Pancho	Non Pancho	Pancho	Partial Pancho	Non Pancho
2006	5060	4405	7080	0.32	0.33	0.51
2007	5499	5682	6488	0.34	0.42	0.48
2008	8925	8562	8562	0.60	0.65	0.68
Average	6495	6216	7377	0.42	0.46	0.56

Source: Ashraf *et al*. (2014)

Misconceptions of the rice farmers in Sindh results in about 50% (≈ 3 MAF) loss of canal irrigation water. These misconceptions have been proved to be wrong and, therefore, the practice of Pancho irrigation should be stopped immediately.

3.3.2 Wastage as 'Awara Pani' (Un-attended Water)

In the plains of Punjab, KP and Sindh, sometime the farmers do not need water, particularly during winter and monsoon rains. Farmers generally stop the canal water entry into their cropped fields. The excess water flows downstream through the watercourses and is called 'Awara Pani' or un-attended water. Quantitative estimates of this precious water resource are not available. However, this water can easily be saved in small ponds that can be constructed at suitable places at the farm. This water can also be stored in community ponds near the villages which will help in recharging the groundwater.

3.4 Low Water Prices

Low water price is an important reason for wastage and overuse of water. Canal irrigation water is being supplied to the farmers almost free, i.e., Rs.135 per acre (Rs. 50 for Rabi crops and Rs. 85/- for Kharif crops) in terms of Abiana rates. This rate is equal to the price of about 4 kg of wheat grain in the market. Thus, practically, the irrigation water has only a nominal price and is almost free compared with the diesel tube well water which costs about Rs. 6000/acre for wheat. Abiana rates have not been revised since many decades. As a matter of fact, the cost of collecting Abiana from the farmers is higher than the Abiana collected. This has resulted in the deferred maintenance of the irrigation system further aggravating the situation. Therefore, a rational system of water pricing needs to be introduced.

3.5 Inappropriate Crop Zoning and Cropping Pattern

One of the most important examples of the poor management at the farm level is the inappropriate cropping pattern and lack of crop zoning. High delta crops such as rice and sugarcane are grown even in areas where surface water is insufficient and groundwater is deep and saline. Cultivation of these crops in such areas has huge pressure on groundwater, resulting into its depletion and secondary salinization.

Logically, rice should be restricted to those areas where sufficient water is available and there is minimum dependence on stored water reserves. Moreover, crops like sugarcane should only be grown to fulfil country's needs and their export should be banned as the export of sugar and rice means export of huge amount of fresh water.

For example, during 2015-16, 8.6 million tons of rice was produced in the country, out of which 4.2 million tons worth Rs. 194 billion (≈ US$ = 2.0 billion) was exported. If we assume a water use efficiency (WUE) of 0.5 kg/m^3 (though WUE of Basmati rice in Pakistan is much lower) and the price of water as Rs 1.0 per m^3 or Rs. 1233 per acre foot (Ashraf and Saeed, 2006), it means around 6.8 MAF of freshwater worth Rs. 8.4 billion was exported virtually during the year. In the same year, the import of edible oil was 2.96 million tons with an import bill of Rs. 201 billion (≈ US$ = 2.0 billion).

Edible oil crops should be introduced in the system which has much less water requirement (1/10th of rice and sugarcane). This will not affect the foreign exchange earnings as we are spending almost the same size of foreign exchange on the import of edible oil as is being earned from the export of rice. Sugar should never be produced for export purpose as it is always a loss to nation, both in terms of water used and subsidy given to the industry.

The crop zoning of Punjab developed by Food and Agriculture Organization (FAO) with the help of University of Agriculture Faisalabad (personal communication with Dr. Iqrar A. Khan former Vice Chancellor, UAF) should be approved and notified on priority basis.

3.6 Mismatch between Irrigation Water Supplies and Crop Needs

Warabandi is a fixed system of canal water supplies while each crop has a critical physiological stage of development (e.g. tillering and booting stage of wheat) at which water shortage will drastically reduce the yield. Warabandi system results in water wastage when water is applied at the inappropriate growth stage. Though difficult to replace immediately, there is urgent need to develop system that will allow enough flexibility to provide water according to the crop needs without disturbing the existing irrigation infrastructure in a major way.

3.7 *Misuse and Pollution of Water in Domestic and Industrial Sectors*

There is a perception that as water use in domestic and industrial sectors is small (about 5%) and maximum water is used in agriculture (more than 93%), therefore, we should be more concerned about the agriculture sector to improve water management. No doubt water use in domestic and industrial sectors is small as compared to agriculture sector, but it has much more implications for the society and the ecosystem.

As more than 90% domestic and almost 100% industrial water comes from groundwater, the over use of water results in lowering of water table beyond its sustainable level as recharge in these areas has already been reduced due to urbanization. This phenomenon is occurring in almost all the urban settlements and will have great impact on people health and wellbeing.

Secondly, only a fraction (about 5%) of the water used in domestic sector is consumed (Jan and Batool, 2016) and the rest is returned back to the system as a wastewater which is disposed off into the surface water bodies. The waste water generated annually from 16 major cities exceeds 4 MAF, while there is a potential of use of drainage water to the extent of about 10 MAF (Ashraf, 2016). This water may percolate to pollute the aquifer further.

The disposal of untreated wastewater into the surface water bodies has great impact on the whole ecosystem (surface and groundwater, soils, crops, livestock, aquaculture and the human). Many studies show that the surface water bodies are contaminated with microbiological, chemicals, heavy metals and even with the Persistent Organic Pollutants (POPs) (Imran *et al*., 2018). The sectors responsible for causing water pollution should be charged for the treatment of the polluted water.

The major reasons for the over use are: (i) water is considered a free commodity, (ii) lack of awareness about the importance of water, (iii) lack of any legislation on groundwater use, (iv) inefficient sanitary utensils, and (v) highly water intensive and inefficient industry.

One of the authors of this report recently visited Canada (country with the largest freshwater resources in the world) and collected bills of electricity, gas and water from some households. The domestic water is being provided on volumetric basis and a meter has been installed for each household to measure the amount of water used. Interestingly, the water charges were found almost the same as those of electricity or gas.

A two-pronged strategy is required to address the issue of misuse of water in domestic and industrial sectors, (i) reduce the groundwater abstraction by providing water on volumetric basis and imposing the water tariff accordingly. For this purpose, meters should be installed at the household level and for each industrial unit. This is also in line with the approved National Water Policy. (ii) Groundwater recharge should be an integral component of any water development scheme. Rainwater collected from rooftops, public parks and play grounds may be diverted to aquifer through recharge wells. Pakistan Council of Research in Water Resources (PCRWR) has developed technologies for groundwater recharge (Ashraf and Sheikh, 2017).

It is also argued that metering and groundwater regulations are not possible in Pakistan. Here are two recent examples. The first example is the Changa Pani Program (CPP) in Bhalwal, district Sargodha. The CPP is providing water to the community on volumetric basis by installing water meters. This is a classic example of public-private partnership and community involvement. The government provided the external component, i.e., laying the pipelines up till the streets whereas the CPP provided water supply line and water meters at the household level. Collection of revenue, operation and maintenance is the responsibility of the CPP.

The CPP, started in 2013, provided connections to 2100 households. The cost of installation of water supply lines inside the house and the water meter was Rs. 4500 per household. Water charges are Rs. 70 per 1000 gallon and Rs. 100 per 1000 gallon if it is used above 2000 gallons. Water supply is almost 24 hours and the average water use has reduced from 15 gallon per person in 2013 to less than 10 gallon per person in 2019. Average water charges vary from Rs 50 to Rs. 450 per household, depending on the quantity of water use. For the last eight years, there is no cost of O&M at the part of Tehsil Municipal Administration (TMA). Before 2013, it was Rs. 3.0 million per year.

The second example is the ban on drilling of bores/tube wells by the individuals in Bahria Town and River Gardens, Islamabad. These societies have taken responsibility to provide water to their inhabitants. This practice has helped overcoming the water wastage and groundwater mining.

4. LACK OF COORDINATION

Over the time, many promising land and water management technologies/practices have been developed. However, these technologies could not reach the stakeholders, mainly due to (i) lack of coordination between research and development agencies, (ii) low or no priorities of the Agriculture Extension Departments on irrigation management, and (iii) low professional capacity of the Extension workers. In the Provincial Agriculture Extension Departments, a cadre of Irrigation Extension Experts may be created who have the knowledge of contemporary irrigation management technologies to be transferred to the farmers. Similarly, there is need to increase coordination at the highest level among water storage, water distribution and water management agencies.

5. GROUNDWATER DEPLETION

Pakistan has one of the world's largest groundwater aquifer (4th after China, India and the USA). It provides more than 60% irrigation water supplies and over 90% drinking water.

Almost 100% water used in industry comes from groundwater and the number of tube wells has increased from 0.2 million to over 1.2 million over the last two and a half decades (Figure 5).

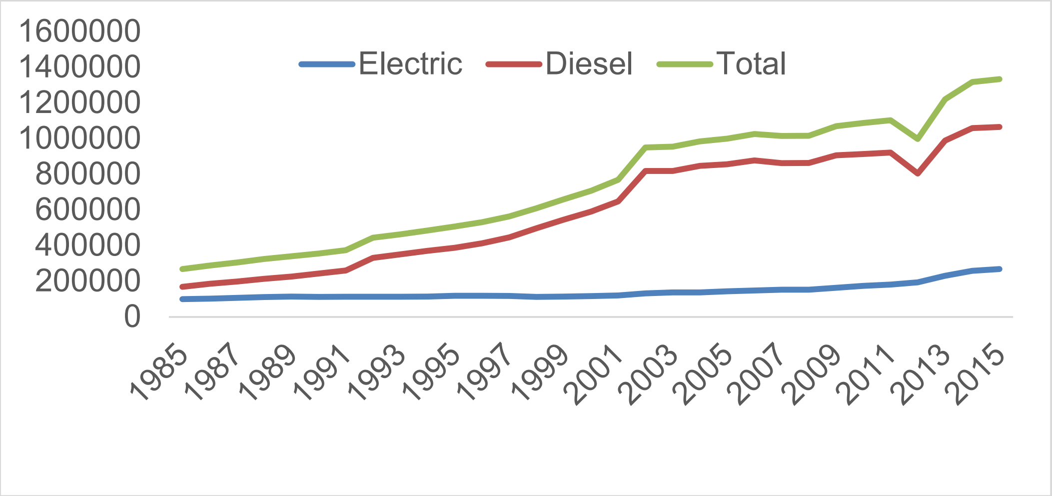


Figure 5: Growth of tube wells in Pakistan (Source: GoP, 2016-17)

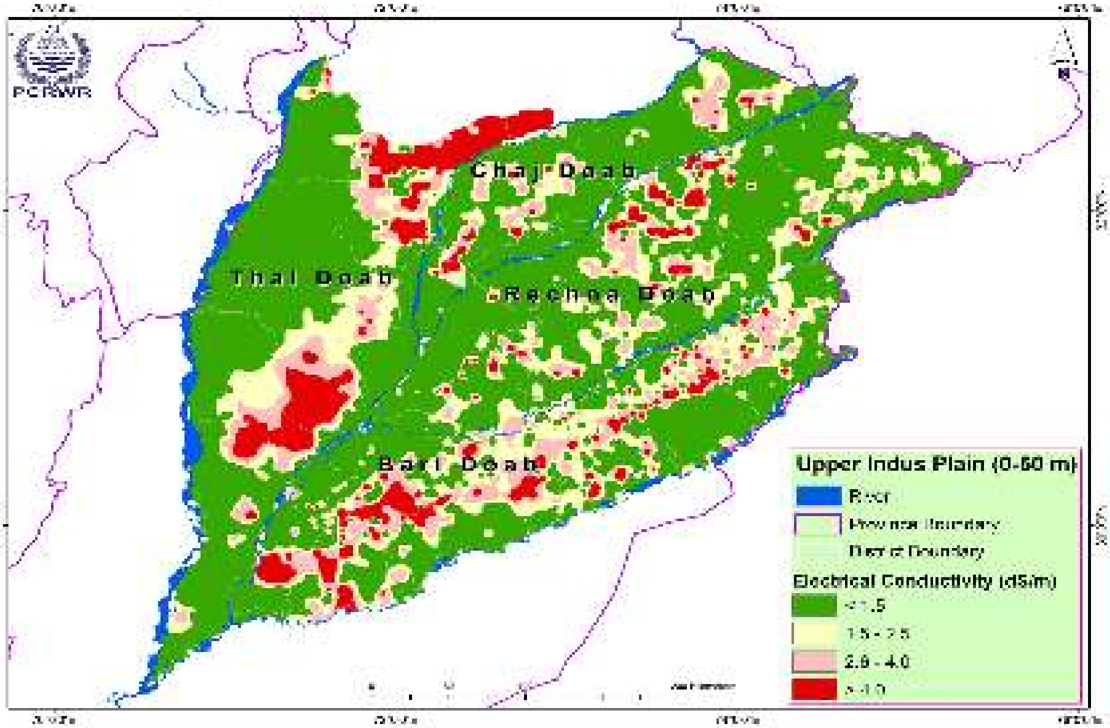
The groundwater has played a major role in increasing the overall cropping intensity in Pakistan from about 63% in 1947 to over 120% in 2018 (Khan *et al*., 2016). It is the only reliable resource that provides resilience against droughts and climate change impacts. However, this resource is freely accessible. In the absence of any regulatory framework, anyone can install any number of tube wells, of any capacity, anywhere and can pump any amount of water anytime and even can sell it to others (Ashraf *et al*., 2012). This indiscriminate drilling and operation of tube wells has resulted in groundwater depletion and secondary salinization (Qureshi and Barrett-Lennard, 1998). This phenomenon is more common in the central and lower parts of the doabs (the area between two rivers) and towards tail ends of all the canal commands. Due to availability of less water and use of low quality water towards tail end, the crop yields are less. For example, in 10 irrigation areas of Pakistan, the average wheat yields were found to be 1.7-3.4 tons/ha at the head but 1.2-2.9 tons/ha at the tail end (Hussain and Hanjra, 2004).

Plate 3: Three tube wells installed about 15 m apart in the LBDC (Lower Bari Doab Canal) command area

With groundwater depletion, tube well installation and operational costs increase manifold. Shah *et al*. (2008) reported that, in India, per hectare cost of groundwater irrigation ranged from 1.5 to 8 times the cost of irrigating with surface water. In the extreme cases, the cost of supplemental irrigation with gensets could reach 100 times the cost of gravity supply. The farmers are spending about 4 billion rupees per year on maintenance and repair of private tube wells (Qureshi *et al*., 2003). The benefit cost ratio of the groundwater irrigation declines with an increase in the cost of irrigation, as the incremental income generated by investing in groundwater is eventually offset by the incremental cost of water (Khan *et al*., 2008).

Unlike surface water supplies, groundwater requires much more attention and knowledge for its management. Once depleted (quantitatively and qualitatively), it becomes very difficult to replenish it. Therefore, its regular monitoring, in time and space, is very important. PCRWR has investigated and mapped the upper (Figure 6) and lower Indus plains (Khan *et al*., 2016) which could be used as a starting point for the development of any groundwater regulatory framework. Such laws were implemented in Japan in 1962 to restrict groundwater pumping in the designated area.

Figure 6: Groundwater quality from 0 to 50m depth in the Upper Indus Plain



(Source: Khan *et al.*, 2016)

6. CLIMATE CHANGE AND FUTURE WATER SCENARIO OF PAKISTAN

Climate change has become a reality and Pakistan is highly vulnerable to it. According to the Global Climate Risk Index. Pakistan is the world's 7th most vulnerable country negatively affected by climate change during the period 1996-2015 and it faces an average annual loss of 3.8 Billion US $ (Jan *et al*., 2017). At the same time, Pakistan is among the top five countries that have the least clean air (Krepon, 2015). According to Pakistan Meteorological Department (Rasul, 2016), there are 7259 glaciers in northern Pakistan, covering 11780 km^2 with ice volume of 2066 km^3. The snow maxima seem to have shifted from January to February between the years 2010 and 2015.

According to the Ministry of Climate Changes (Ali, 2016), water from melted glaciers contributes to more than 60% of the flows from the Upper Indus Basin. It has been reported that the water availability is likely to be increased in the 21st century. Jan *et al*. (2018) stated that various challenges of climate change for agriculture included increase in temperature, uncertainty in availability of irrigation water, increased variability of monsoon, severe water stress conditions in arid and semi-arid areas and events as floods, drought, heat waves, cold waves and cyclones which will affect crop and animal production. All these impacts will negatively affect the human health and social life in the region. Changes in climate are considered to increase occurrence of floods and new reservoirs need to be developed to store this water for its subsequent uses.

Ali (2016) concluded that the available climate models are not able to simulate seasonal changes over northern parts of Pakistan. However, there was consistent increase in temperature and precipitation with greater increase in minimum temperature. Two major challenges ahead due to climatic changes are (i) frequent floods and droughts and (ii) inadequate capacity of reservoirs to store the excess water that can be transferred to the dry seasons and dry years (Rasul, 2016). According to Karki *et al.*, (2011), climate change impacts are likely to be severe in the cryo-sphere and on the dependent water supply. Various studies have shown different temperature trends in the region and the Basin. There was a non-significant increasing trend of mean temperature in mountain areas of the Upper Indus Basin. However, it was significant in Baluchistan (+1.5°C), Punjab (+0.56 °C) and Sindh (+0.44 °C) for the period 1960-2007 (Chaudhry and Rasul, 2007).

In general, scientists disagree about whether glaciers of the Himalaya-Karakoram-Hindukush region are retreating. According to Bhutiyani *et al.,* (2009), there was a significant increasing annual temperature trend in all the three stations in north western Himalayas region. On the contrary, Fowler and Archer (2006) reported reduction in summer temperature from the year 1961 to 2000, and a positive trend in accumulation of Karakoram glaciers. However, more detailed studies are required to clarify the situation because the glacier environment of the great Himalaya region in still a “black box” (Karki *et al.,* 2011).

An International Expert Consultation on Water Management of Indus Basin was organized in 2010 (Karki *et al.,* 2011). The group identified the following key priority areas of research:

i. Intensification in the use of remote sensing tools for collecting data;
ii. Reducing the scale issue in building climate scenarios using down-scaling techniques;
iii. Understanding glacier behavior using a combination of *in-situ* and remote sensing observations, paleoclimatic analysis, and modeling;
iv. Understanding other factors influencing hydrology, including the role of avalanches, debris cover, and dirt cover, including black carbon deposit;
v. Understanding water balance using state-of-the-art tools, including improved hydro-meteorological observation networks;
vi. Understanding the roles of socio-economic, institutional, and policy-related factors; and,
vii. Involving stakeholders to develop adaptive water management strategies.

Crop varieties that can tolerate high temperatures and drought at the critical growth stages need to be developed. Azeem (Personal communication, 2018) reports wheat yield of 4.8 tons/ha for the variety Galaxy and Advance lines 14154 and 12304 compared with Anaj which gave 3.5 tons/ha under the similar conditions. It shows that impact of high temperature due to climate change can be offset through development of suitable crop varieties. [Dr. Azeem is a Plant Breeder and Progressive Farmer from Jhang, central Punjab]

7. SOME MISCONCEPTIONS ABOUT DAMS

The establishment of a fund for the construction of Diamer Bhasha and Mohmand dams by the former Chief Justice of Pakistan, Mian Saqib Nisar, has triggered some debate on the issue. Some of the frequently asked questions and proposed solutions are: (1) Whether there is real water scarcity as Pakistan is perceived to be a water-rich country?, (2) Is there enough water to fill the proposed dams?, (3) There should be focus on small dams instead of large dams, and (4) There should be more focus on water management such as watercourse improvements (FPCCI, 2018) as it can save water to the tune of Bhasha dam. There is also apprehension that with the construction of large dams, the flow to Indus delta will be further reduced.

In the above context, a term “Dam Equivalent (DE)” has been used to highlight that water saving equivalent to a large dam is possible through adoption of modern techniques in agriculture, industry and municipalities while dams cannot address issues of water wastage, pollution, mismanagement and corruption which are the main contributing factors to water shortage and inequitable distribution. In the following section, these questions are analyzed based on facts and figures.

It has been explained in the Section 2.1 that Pakistan is now a water scarce country and if the situation continues, i.e., population keeps on increasing at the same rate and the water resources remain constant, Pakistan will be touching the absolute water scarcity line by 2025, which is not far away from now.

Pakistan is dependent on a single source of Indus River and its tributaries where about 84% of the total inflow is received in three monsoonal months and the rest 16% during the remaining nine months. With the increased climate variability, the wet years/seasons are becoming more wet and dry years/seasons drier (Ashraf, 2016). Moreover, the capacity of the existing reservoirs is depleting at a rate of about 0.2 MAF/year. Only in Terbela reservoir, 500,000 tons of sediment is being deposited every day. Therefore, new reservoirs would also be needed to replenish the depleting capacity and to transfer water from the wet seasons to the dry seasons and from the wet years to the dry years.

Due to inadequate storage, Pakistan has lost more than 90 MAF of water during the floods of 2010, 2012 and 2014, besides their devastating effects on infrastructure, crops, livestock and human. This shows the amount of water available in the system. Nevertheless, as large dams store huge amount of water, they are filled during the wet years to provide water to the subsequent years.

Besides providing irrigation water, small dams have several advantages. They recharge the groundwater, provide water for domestic and municipal purposes, control erosion, are close to the point of use, help develop aquaculture and also provide recreational activities. However, these also have certain limitations, such as they lose 50% of their impoundments to evaporation due to high surface area to volume ratio. The seepage and percolation losses in these reservoirs are about 20% of their volume against 5% in large dams. Their small storage volume does not allow seasonal or annual carryover, and there are safety problems of handling the overflow during extreme storm events. The unit cost of water in small dams is 4-7 times higher as compared to large dams

(Ashraf, 2016, Keller, 2000; Sakthivadivel, 1997). Moreover, small dams cannot be constructed on large rivers and large dams cannot be constructed on small rivers.

The large dams store a huge amount of water that can be used for irrigation, hydropower generation (the cheapest source of energy), and to meet the environmental flow requirements of the river. These dams control floods, provide water throughout the year, act as buffer during dry season and dry years, and can be sites for fisheries, water sports and tourism. Therefore, small dams should be constructed wherever possible however, these cannot be alternative to the large dams (Ashraf, 2016).

The improvement of watercourses is very important as more than 60% of water is lost within the system *i.e.* from canal head to the fields. These losses further aggravate the problem of water scarcity, particularly towards the tail end. It also affects the equity in the distribution of water *i.e.* irrationally high-water withdrawals at the canal head at the cost of water allocation for the tail enders (Ashraf, 2016). The watercourse improvement increases the conveyance efficiency with equitable distribution of water among the head, middle and tail end farmers. Therefore, watercourse improvement will help manage the available water within the watercourse commands and no additional water will be available to inject into the system.

There is apprehension that decrease in river water inflow into the Arabian sea will lead to sea water intrusion into the coastal area and thus will have an adverse impact on the coastal ecosystem, especially the mangrove ecosystem. It is generally quoted that about 2 million hectares of land in districts of Thatta, Badin and Sujawal has been salinized due to sea water intrusion (National Water Policy, 2018). The phenomenon of seawater intrusion needs to be closely monitored so that the extent and causes of sea water intrusion are thoroughly explored in long term studies.

Some studies suggest that saline water intrusion in coastal area is also connected to rise in the sea level. Moreover, international experience in controlling the seawater intrusion, particularly in the closed basins, needs to be studied. The Indus delta would need water throughout the year - not only during 2 to 3 monsoon months. This is only possible if large storages are built to regulate water from the high-flow period to the low-flow periods.

There is no second opinion that water conservation and management is crucial and it must be done at all levels – domestic, industrial and agriculture. However, water management and DEs can never be alternative to large dams, which control floods and provide water security during drought in addition to provision of cheap and green energy.

Management of water in the field helps improve conveyance efficiency, and improved land and water productivity; it may also reduce pressure on the dwindling groundwater resources. However, it cannot help to fill the gap between water supply and demand as no water can be injected into the system. The only way to inject water into the system is the construction of large storage reservoirs.

8. DRYLAND AGRICULTURE

Dryland (rainfed) area constitutes about 40% (12 Mha) of the total culturable area of Pakistan. However, it contributes only 10% to the total crop production (Mahmood *et al*., 2015). The main reason for this low production is the neglect of these areas. The maximum investment in agriculture sector in Pakistan has been in the irrigated areas, whereas the rainfed areas have almost been neglected.

It has been estimated that there is a potential of about 18 MAF of water from hill torrents. The potential area under the *Sailaba* system in Pakistan is around 7 Mha, out of which around 1.0 Mha are commanded in an average year. The largest area under the *Sailaba* irrigation system is in Baluchistan, followed by Khyber Pakhtunkhwa, Punjab and Sindh. The water is available during a short period of two to three months, proper management of which could help boost the socio-economic conditions of the local communities.

There are two dry land farming systems – *Sailaba,* hill-torrents irrigation or spate irrigation and *Khushkaba, which is* exclusively rainfed. *Sailaba* irrigation system (spate irrigation) constitutes the major portion of the country's dry-land farming system and exists in the four provinces with varying magnitude. The run-off from hill-torrents is directed through a network of indigenously managed system to provide deep watering to the bunded fields. The water availability in the spate system depends on the occurrence and distribution of rainfall in the catchment areas along with the hydrological aspects of watersheds responsible for run-off process. This indigenous system is a source of livelihood for millions of people - mostly poorer of the poor. Under this system, the major crops include wheat, pulses, gram, and fodder crops (millet, sorghum etc.).

The *Khushkaba* system is exclusively dependent on the incident rainfall and localized runoff. This is the second largest water harvesting system in the dry lands. It also exists in the four provinces. Nevertheless, risk of crop failure under this system is relatively high due to inadequate soil-moisture conditions. This system is more vulnerable to drought conditions as compared to *Sailaba*. Productivity of this farming is low, resulting in food insecurity of the poor community. However, livestock is an integral part of these systems, income from which is a major source for many of the poor farming communities.

A number of technologies have been developed for dry land agriculture. By adopting these technologies, the land and water productivities of these areas can be increased manifold as there is a wide gap between current level of agricultural productivity and its potential. This land is largely owned by poor communities and large area is available for up-scaling and out-scaling of promising interventions (Ashraf, 2016).

Many examples exist within and outside Pakistan. For example, PCRWR developed 110 rainwater harvesting ponds in the Cholistan desert, each with a storage capacity of about 4 million gallons. Following PCRWR, the Cholistan Development Authority (CDA) also developed about the same number of ponds in the areas. Now, after about every 20 km, a pond can be found. These ponds provide drinking water to the local community, water for the livestock which is the main livelihood of the desert community (there are about 0.1 million human and 2.0 million livestock heads in Cholistan).

Mainly nomads are living in these areas. They settle near the ponds, get water for themselves, for their livestock, and graze the nearby land. Once the water in the pond(s) is near to finish, they move to new pond(s) and fresh grazing lands. In this way, the livestock productivity increases as they have to travel less distance to get water and the fodder. Besides providing water to human and livestock, these ponds provide a number of other benefits such as change in the micro-climate, attracts the biological life and act as buffer against drought (Ashraf and Faizan, 2018).

Cholistan and Thar are part of the Greater Rajasthan desert. During the recent drought in Thar, human, livestock, flora and fauna were badly affected. However, there was no such cry from the Cholistan mainly due to these ponds. Therefore, these models should be replicated in other deserts. Moreover, the stored water can be used as supplemental irrigation to grow crops.

Data gathered from a number of regions (Wyn Jones *et al*., 2006) show that wheat yields of 4 to 5 tons per hectare can be achieved with the use of 300-400 mm water in rainfed conditions. Wheat yields obtained at 300 mm evapotranspiration vary between ½ ton per ha and 4.5 ton per ha (Figure 7).

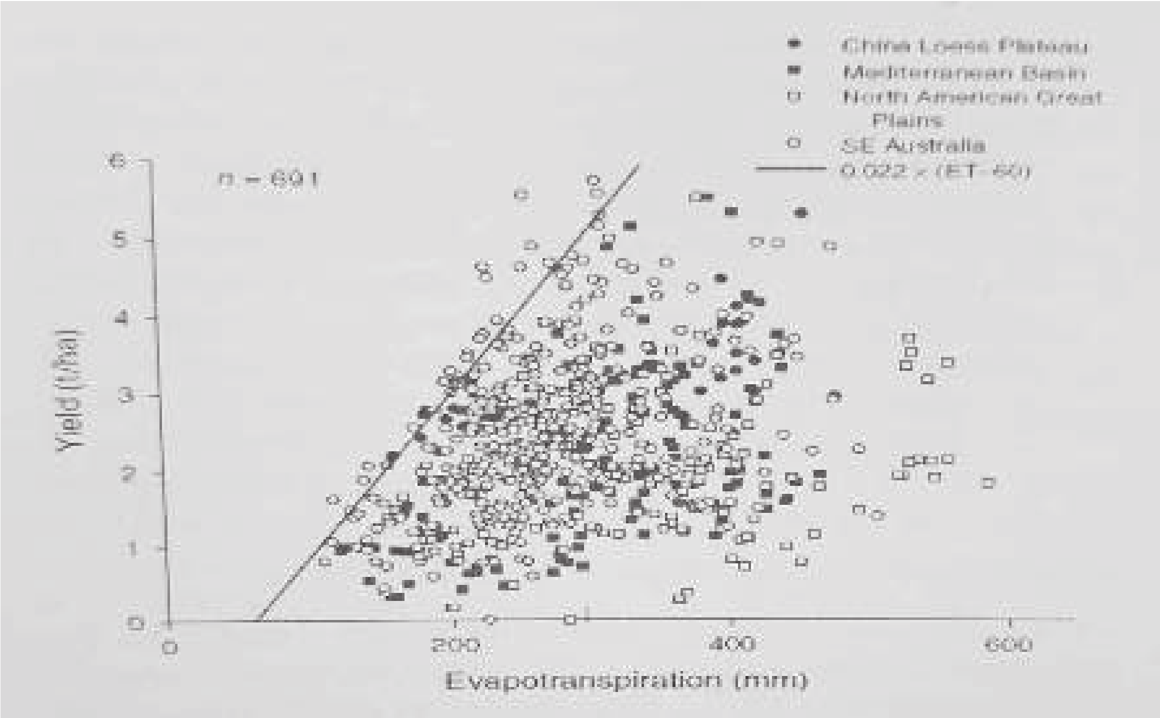


Figure 7: Grain yield and seasonal evapotranspiration in 4 different environments (Source: Wyn Jones *et al*., 2006)

9. IMPLEMENTATION OF NATIONAL WATER POLICY 2018

The Council of Common Interest (CCI) approved long awaited National Water Policy in April 2018 along with a Water Charter signed by the Prime Minister and the Chief Ministers of the four provinces. In the Water Charter, the Federal and Provincial leaders have shown their commitment in the following words:

"The Charter is a Call to Action and the declaration of a water emergency. We must look beyond our differences and come together as a nation to rise to the challenge that is before us. We have done so before, and we can do it again. We will seize the day and secure our collective future. This is our promise to the coming generations."

Though there is some criticism on the National Water Policy, yet it is a national consensus document which can be used as a guiding principle. There are 33 objectives covering almost all aspects of water, including water resources development and management (both surface and groundwater), development of regulatory framework, urban water management, hydropower development, flood and drought management, rainwater harvesting, capacity building and institutional arrangements. Besides policy statements, it has set targets and timelines for some of the important tasks, such as development of new water reservoirs (up to 10 MAF), reduction in conveyance losses by 33%, enhancing water use efficiency by 30%, real-time river/canal flow monitoring to develop transparent water accounting system by 2021 and so on.

However, implementation of the NWP in true letter and spirit will be a great challenge. A mechanism has been proposed in the NWP for its implementation that consists of a National Water Council (NWC) to be chaired by the Prime Minister and a Steering Committee (SC) with Secretariat at the Ministry of Water Resources (MoWR) to be chaired by the Federal Minister.

The current NWC and SC, as given in the NWP, are skewed towards engineering profession. It is proposed that NWC and SC should include members from Ministry of Food Security and Research Division (dealing with the agriculture sector which is the largest water user), Ministry of Climate Change, relevant research organizations such as PCRWR, IWMI who can assist the SC on emerging issues. One of the important tasks for the MoWR would be to develop a strong coordination among the research and development agencies working in water sector. For this purpose, all water-related organizations working at federal level may be placed under the umbrella of Ministry of Water Resources. Moreover, there should be a strong monitoring system placed at the federal and provincial levels responsible for monitoring the implementation of the NWP and reporting to the NWC and the CCI.

10. CONCLUSIONS AND THE WAY FORWARD

1. Development and management of water resources should be given top priority to address the water and food security issues. Building multipurpose large dams is extremely important to store excess water from melting glaciers and runoff from Monsoon rainfall. These dams will also provide relatively cheap hydropower while controlling floods and droughts caused by climate changes.
2. Building small and medium size dams and ponds is equally important to store runoff and any excess water. These dams and ponds can also contribute in recharging aquifer at local level.
3. Immediate measures should be taken to minimize water losses from water courses and wastage of water at field level. This can be done by properly improving the water courses to minimize seepage and leakage, while wastage in the field should be minimized by adopting laser leveling and appropriate sowing methods such as bed planting etc.
4. There is urgent need to replace the current Pancho system and flood irrigation of rice with recommended methods.
5. Pricing system of water use for agriculture, industrial and domestic purposes needs to be developed and effectively implemented.
6. Pollution of the surface water bodies and groundwater aquifers affect the whole ecosystem in general and the human health in particular. Therefore, the industry and other sectors polluting the water bodies should be charged by imposing Pollution Tax using the “polluter pays” principle.
7. Research efforts in crop and the related sectors should be enhanced to produce varieties having flexibility and tolerance to drought, heat and salinity. An alternate cropping system needs to be developed to reduce irrigation requirements during the dry period.
8. Long term studies should be initiated to assess causes of sea water intrusion and extent of damage caused to the coastal ecosystem, especially to the mangroves, aquatic life and land in the coastal area.
9. Studies should be undertaken for developing innovative technologies to create flexibility in the existing rigid Warabandi system so as to provide water at the critical stages of crop growth in various parts of the Indus Basin.
10. A regulatory framework should be devised and strictly implemented for the installation and operation of tube wells to reduce and control the over extraction of groundwater. Subsidy given to users of groundwater should be withdrawn.

11. Accurate and real-time discharge measurements at the strategic locations are critical and telemetry system should be installed immediately to address concerns of the provinces.
12. Appropriate crop zoning and cropping pattern should be adopted and implemented. For example, sowing of rice and sugarcane should be restricted to only those areas where sufficient water is available. The export of these commodities should be stopped. Considering high value of water used per kg of sugar/rice, these crops do not have a comparative and competitive advantage in the international market. Instead, edible oil crops should be introduced to reduce pressure on water and the import bills.
13. Further development of culturable area should be restricted only to less water intensive sectors such as forestry, wildlife and grazing area for livestock instead of crop sector, while the available water should be used for increasing per acre yield for high production.
14. There is lack of coordination between the water related research and development departments. All such departments should be placed under the umbrella of Ministry of Water Resources to implement the National Water Policy in its true letter and spirit.
15. There is need to improve coordination at the policy and planning levels between the agencies responsible for water storage, water distribution and water management on the one hand and water users on the other. Currently, the representation on the NWC and SC is skewed in favor of Engineering professionals. Members from Ministry of Food Security and Research Division, Ministry of Climate Change, and the relevant research organizations such as PCRWR and IWMI should be included in the NWC and the Steering Committee for development and implementation of the strategy to deal with water security issues.
16. An effective Public Awareness Program needs to be pursued through media and the extension wing of the Provincial Departments for Agriculture. Media can also play an important role in creating awareness about saving water during domestic and other uses.

REFERENCES

Ali, S. 2016. 21st century climatic and hydrological changes over Upper Indus Basin of Himalayan Region of Pakistan. Proceedings of AASSA-PAS Regional Workshop on Challenges in Water Security to Meet the Growing Food Requirement. Pakistan Academy of Sciences, Islamabad. pp. 228-260.

Anwar, A. A., M. Ashraf, and T. Bhatti. 2018. Pakistan Inter Provincial Water Accord, Perception and Opinion. Pakistan Council of Research in Water Resources, Islamabad, Pakistan (PCRWR). pp. 54.

Ashraf M., Faizan ul H. 2018. Pakistan's Deserts: Land and Water Resources Development. Higher Education Commission, Islamabad, Pakistan. pp. 38.

Ashraf, M. 2016. Managing Water Scarcity in Pakistan: Moving Beyond Rhetoric. Proceedings of AASSA-PAS Regional Workshop on Challenges in Water Security to Meet the Growing Food Requirement. Pakistan Academy of Sciences, Islamabad. pp. 3-14.

Ashraf, M. and A.A. Sheikh. 2017. Sustainable groundwater management in Balochistan. Pakistan Council of Research in Water Resources (PCRWR). pp. 34.

Ashraf, M. and M.M. Saeed. 2006. Effect of improved cultural practices on crop yield and soil salinity under relatively saline groundwater applications. Irrigation and Drainage Systems. 20: 111-124.

Ashraf, M., A. Nasir, and M.M. Saeed. 2010. Evaluation of the existing water productivity in the Lower Bari Doab Canal (LBDC) Command–A Case study. Pakistan Journal of Agricultural Sciences. 47(4): 389-396.

Ashraf, M., A.Z. Bhatti, and Zakaullah. 2012. Diagnostic analysis and fine tuning of skimming well design and operational strategies for sustainable groundwater management - Indus basin of Pakistan. International Journal of Irrigation and Drainage. 61: 270-282.

Ashraf, M., M.K. Marri, I. Rao, A. Salam, and M.A. Khan .2014. Pancho-irrigation system – a wasteful practice of irrigation rice fields in the Lower Indus Basin of Pakistan. Pakistan Journal of Agricultural Sciences. 51 (4): 867-873.

Bhutiyani, M.R., V.S. Kale, and N.J .Pawari. 2009. Climate change and the precipitation variations in the north western Himalaya. International Journal of Climatology. 30(4): 535-548.

Briscoe, J. and U. Qamar. 2005. Pakistan's water economy running dry. The World Bank. Oxford University Press, Karachi.

Cai, X. and M. Rosegrant. 2003. World water productivity: current situation and future options. In: J.W. Kijne, R. Barker and D. Molden (eds.), Water productivity in agriculture: limits and opportunities for improvement. CABI, Oxford. pp.163-178.

Chaudhry, Q.Z. and G. Rasul. 2007. Development of a meso-scale connective system over the foothills of Himalaya into a severe storm. Developments in Earth Surface Processes. 10: 301-311.

http://dx.doi.org/10.1016/SO928-2025(06)10033-4.

Economic Survey 2016-17. Economic Survey of Pakistan 2016-17. Government of Pakistan

Farooq, M., N., Kobayashi, A. Wahid, O. Ito, and S.M.A. Basra. 2009. Strategies for producing more rice with less water. Advances in Agronomy. 101: 351-388.

Flakenmark, M., J. Lundquist, and C. Widstrand. 1989. Macro-scale water scarcity requires micro scale approaches: aspects of vulnerability in semi-arid development. Natural Resources Forum. 13: 258-267.

Fowler, H.J. and D.R. Archer. 2006. Conflicting signals of climate change in the Upper Indus Basin. Journal of Climate. 19:4276-4293.

FPCCI 2018. Report of the Committee on Water Management, Floods, Transport & Aquatic Tourism. Federation of Pakistan Chambers of Commerce and Industry. pp. 76.

GoP. 2001. Ten years Perspective Development Plan 2001-2011 and three year development program 2001-2004. Planning Commission, Government of Pakistan. 53 (1): 1–15.

GoP. 2017. Agriculture Statistics of Pakistan (2016-17). Government of Pakistan

http://www.armscontrolwonk.com/archive/1200664/global-warming-up-arms-control-down/

Hussain, I. and M. A. Hanjra. 2004. Irrigation and Poverty Alleviation: Review of the Empirical Evidence. Irrigation and Drainage. 53 (1): 1–15.

Imran S., L.N. Bukhari., and M. Ashraf. 2018. Spatial and temporal trends in river water quality of Pakistan (Sutlej and Ravi) 2018. Pakistan Council of Research in Water Resources (PCRWR). pp. 45

Iqbal, M.N., T. Oweis, M. Ashraf, B. Hussain, A. Ali, A. Majid, and G. Nabi. 2012. Natural resources degradation: assessment and options for improvement. In: T. Oweis and M. Ashraf (eds.), Assessment and Options for improved productivity and sustainability of natural resources in Dhrabi watershed Pakistan, International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria. pp. 205.

IWMI. 2000. Water Issues for 2025. A Research Perspective. International Water Management Institute, Colombo, Sri Lanka.

Jan, M.Q. and S. Batool. 2016. Water scenario in Pakistan. Proceedings of AASSA-PAS Regional Workshop on Challenges in Water Security to meet the Growing Food Requirement, Islamabad, 19-21 January, 2016, pp. 187–194.

Jan, M.Q., K. Muazim and A. Ashraf. 2018. Global warming, climate change and threats to sustainable agriculture. In: Climate Change and Sustainable agriculture. Региональные проблемы. 2018. Т. 21, № 3(1). С. pp. 37–40. DOI: 10.31433/1605-220X-2018-21-3(1)-37-40.

Jan, M.Q., S. Kakakhel, S. Batool, K. Muazim, and I.A. Chata. 2017. Global warming: evidence, causes and consequences and mitigation. Journal of Development Policy, Research and Practice. 1: 61-81.

Karki, M.B., A.B. Shrestha, and M. Winiger. 2011. Enhancing Knowledge Management and Adaptation Capacity for Integrated Management of Water Resources in the Indus River Basin. Mountain Research and Development (MRD). 31(3): 242-251.

Keller, A., R. Sakthivadivel, and R.D. Seckler. 2000. Water scarcity and the role of storage in development. International Water Management Institute Research Report No. 39, Colombo, Sri Lanka.

Khan, A.D., N. Iqbal, M. Ashraf, and A.A. Sheikh. 2016. Groundwater investigation and mapping in the Upper Indus Plain. Pakistan Council of Research in Water Resources (PCRWR). pp. 72.

Khan, S., R. Tariq, and M.A. Hanjra. 2008. A cross disciplinary framework for linking farms with regional groundwater and salinity management targets. Agricultural Water Management. 95: 35-47.

Krepon, M. 2015. Global warming up; Arms control down, the Stimson Centre's South Asia Programme, USA.

Mahmood, A., T. Oweis, M. Ashraf, A. Majid, M. Aftab, N.K. Aadala, and I. Ahmad. 2015. Performance of improved practices in farmers' fields under rainfed and supplemental irrigation systems in a semi-arid area of Pakistan. Agricultural Water Management. 155, 1-10.

MTDF. 2005-10. Mid-Term Development Framework, Planning Commission, Government of Pakistan.

National Water Policy, 2018. Ministry of Water Resources, Government of Pakistan, pp. 41

Qureshi, A.S. 2011. Water management in the Indus Basin in Pakistan: Challenges and opportunities. Mountain Research and Development. 31(3): 252-260.

Qureshi, A.S., T. Shah, and M. Akhtar. 2003. The groundwater economy of Pakistan. Working Paper 64, International Water Management Institute, Lahore, Pakistan.

Qureshi, R.H. and E.G. Barrett-Lennard. 1998. Saline Agriculture for Irrigated Land in Pakistan: a Hand Book. Australian Centre for International Agriculture Research, Canberra, Australia.

Raskin, P., P. Gleick, P. Krishen, G. Pontius, and K. Strezepek. 1997. Water Future: Assessment of long-range pattern and prospects, Stockholm Environment Institute, Stockholm, Sweden.

Rasul, G. 2016. Implications of climate change for Pakistan. Proceedings of AASSA-PAS Regional Workshop on Challenges in Water Security to Meet the Growing Food Requirement. Pakistan Academy of Sciences, Islamabad. pp. 133-139

Rijsberman, F. R. 2006. Water scarcity: fact or fiction? Agricultural Water Management. 80: 5-22.

Sakthivadivel, R., N. Fernando, and J. Brewer. 1997. Rehabilitation planning for small tanks in cascades: A methodology based on rapid assessment. International Water Management Institute Research Report 13. Colombo, Sri Lanka.

Scheierling S.M., and D.O. Treguer. 2018. Beyond crop per drop: assessing agricultural water productivity and efficiency in a maturing water economy. The World Bank, Washington DC.

Seckler, D., U. Amarasinghe, D.J. Molden, R. De Silva, and R. Barker. 1998. World Water Demand and Supply, 1990-2025. Scenarios and issues IWMI Research Report 19. IWMI, Colombo, Sri Lanka.

Shah T., M.U. Hussain, M.Z. Khattak, P.S. Bannerjee, O.P. Sigh, and S.U. Rehman. 2008. Irrigation water free? A reality check in the Indo-Gangetic Basin. World Development. 37(2): 422-434

Soomro Z.A., M.D. Arshad, K. Ejaz, A.Z. Bhatti, and M. Ashraf. 2015. Rice cultivation on beds: an efficient and viable irrigation practice. Pakistan Council of Research in Water Resources (PCRWR). Islamabad, pp. 24.

Sullivan, C.A., J.R. Meigh, A.M. Giacomello, T. Fediw, P. Lawrence., M. Samad, S. Mlote, C. Hutton, J.A. Allan, R.E. Schulze, and D.J.M. Dlamini 2003. The water poverty index: development and application at the community scale. Natural Resources Forum. 27: 189-199.

World Bank. 2006. Reengaging in Agricultural Water Management: Challenges and Options. The World Bank Washington DC. pp. 218.

Wyn Jones, R.G., J. Gorham, and P.A. Hollington. 2006. Proceedings of International Conference on Sustainable Crop Production on Salt-affected Soils. University of Agriculture, Faisalabad. pp 9-16.

SUBJECT INDEX

ANNEXURE-1

SOME IMPORTANT CONVERSION UNITS

Area	1 ha	2.47 acres	
	1 km^2	100 ha	
Length	1 mile	1.609 km	
	1 m	3.28 feet	100 cm
	1 inch	2.54 cm	
Volume	1 m^3	35.28 ft^3	1000 liters
	1 m^3	264 US gallons	
	1 m^3	220 Imp gallons	
	1 m^3	0.0008 acre foot	1 acre foot = 1233 m^3
	1 billion cubic meter (BCM)	0.81 million acre foot (MAF)	1 MAF = 1.234 BCM
Discharge	1 m^3/s	35.32 ft^3/s (cusecs)	28.32 l/s
Weight	1 metric ton	1000 kg	

Pakistan Academy of Sciences
3-Constitution Avenue, G-5/2, Islamabad, Pakistan
Email: sec.gen@paspk.org, editor@paspk.org
Tel:(+92 51) 920-4843 , 920-7140 , 921-5478
Web: www.paspk.org

ISBN 978-969-8223-27-4