Improving Salinity and Agricultural Water Management in the Indus Basin, Pakistan

Issues, Management and Opportunities

(A Synthesis from Desk-Top Literature Review)

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Abbreviations

ACIAR	–	Australian Center for International Agricultural Research
CCI	–	Council of Common Interest
CSU	–	Charles Sturt University
DRIP	–	Drainage and Reclamation Institute of Pakistan
GNP	–	Gross National Product
GRF	–	Groundwater Regulatory Framework
IBDP	–	Indus Basin Drainage Plan
IBIS	–	Indus Basin Irrigation System
IRS	–	Integrated research sites
IRSA	–	Indus River System Authority
ISMF	–	Integrated salinity management framework
IWASRI	–	International Water Logging and Salinity Research Institute
IWRM	–	Integrated Water Resource Management
LBOD	–	Left Bank Outfall Drain
Mha	–	Million hectare
MOM	–	Maintenance and Operational Management
NFDC	–	National Fertilizer Development Center
NDP	–	National Drainage Program
NWP	–	National Water Policy
PCRWR	–	Pakistan Council of Research in Water Resources
PIDA	–	Punjab Irrigation and Drainage Authority
RBS	–	River Basin Scale
SAWM	–	Salinity and Agricultural Water Management
SCARP	–	Salinity Control and Reclamation Project
SIDA	–	Sindh Irrigation and Drainage Authority
SRDP	–	Strategic research and development plan
SSRI	–	Soil Salinity Research Institute
STPP	–	SCARP Transition Pilot Project
TIPOs	–	technical, institutional and policy options
WAPDA	–	Water and Power Development Authority
WRRI	–	Water Resource Research Institute

Note: “$” sign in this report refers to US Dollar.

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1. INTRODUCTION

1. Since soil survey of the Indus Basin under Colombo Plan in 1953, Pakistan made several efforts to manage the problem of water logging and salt-affected soils and address its biophysical and socio-economic consequences. This included assessing the prevailing conditions, launching the mega projects and initiating research and creating institutions. The main focus has been on lowering the groundwater levels through deep pumping, leaching the salts by excess irrigation, application of chemical amendments (e.g. gypsum, acids, organic matter), with international cooperation and billions of US Dollars investment in water logging and salinity control. The efforts resulted in modest benefits—the impacts have been low, salinity continues to persist over a large area of about 6.2 million ha (38% of total irrigated land) and agricultural water productivity remains much lower than expectation. On-farm approaches showed limited success and early success of basin-wide interventions could not sustained. The low success rate was attributed to unsustainable interventions, weak research, and lacking in participatory management approaches and very low uptake of the methodologies and technologies by the farmers. The problem consistently persisted and continued to affect livelihood and the environment and slowing down the economic development. The map of Indus Basin, Pakistan is in Figure 1.

2. Australian Center for International Agricultural Research (ACIAR), Charles Sturt University (CSU) Australia and Pakistan Council of Research in Water Resources (PCRWR) and partners initiated a short research and development activity (SRA) in March 2017 for improving salinity and agricultural water management (SAWM) in the Indus Basin. The SRA requires establishing the case for a holistic approach to salinity and water management, and a network of researchers and intended research beneficiaries able to co-design an integrated salinity research project for ACIAR funding. The SRA objectives are to: (i) develop a holistic understanding of the underlying causes of salinity, and the difficulties that result for farming and coastal communities affected, through review of existing technical, economic and social assessments of salinity; (ii) develop a case for incorporating the broad concept of ecosystem services into an integrated salinity management framework (ISMF) for Pakistan, by exploring its potential to (a) enhance appreciation of salinity as a systemic issue, and (b) help identify opportunities for amelioration of those impacts and/or improve livelihoods of those living with salinity; and (iii) establish a network of researchers and intended research beneficiaries with whom the case for a more holistic approach to salinity management can be discussed, and who can then take a leading role in designing an ACIAR funded research project through which an ISMF for Pakistan can be developed and applied.

3. This report is prepared for the organizers of the SRA and is based on a desk-top literature review of technical, economic and social aspects of the SAWM in the Indus Basin. The review covered the Government's policy documents, published articles and unpublished reports as available and is expected to help better understand the water and salinity management issue in the Indus Basin (TOR in Appendix 1). Some conflicting information on the extent of salt-affected land and salt inflows may be attributed to the seasonal variation of the water logging as well as the researcher's judgment. The report is divided into three main sections. The first section presents the historical perspective, issue and causes of water logging and salinity in the Indus Basin. The second section discusses the salinity and water management approach and practices; reviews technical, institutional and policy options; and analyses outcome and impacts of the mega projects. This section converges on scale, participation and sustainability issues. The third and last section suggests developing Indus Basin's SAWM plan setting direction and domain for sound research and sustainable development. The earlier draft of this report was reviewed. The

comments and response matrix is in Appendix 2

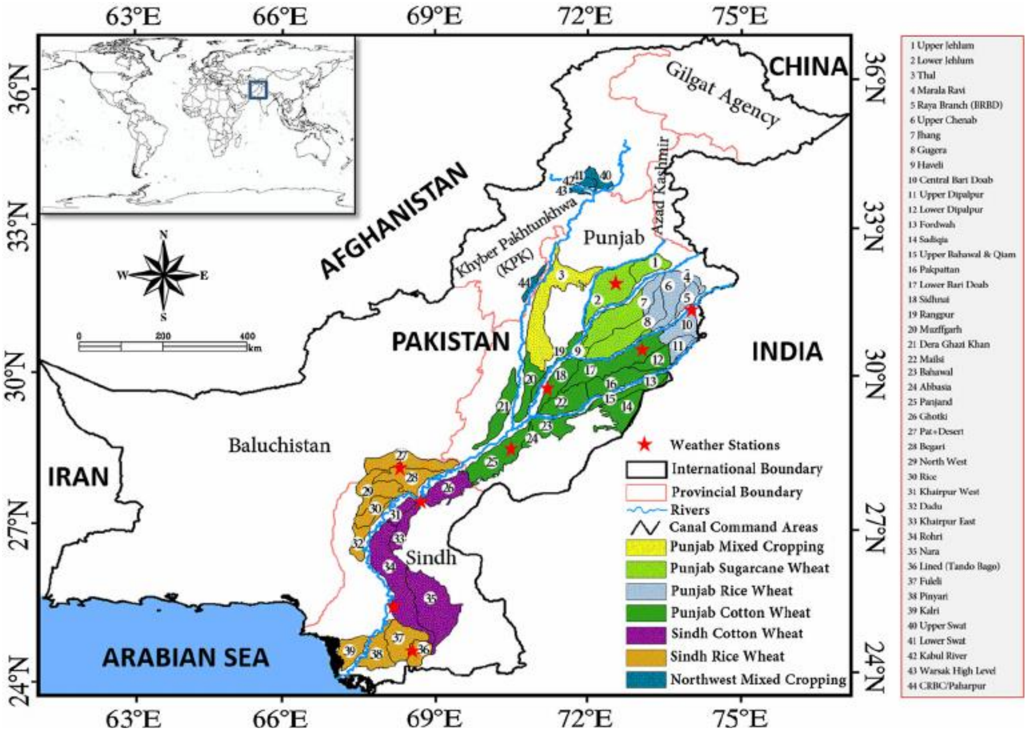


Figure 1. Map of Indus Basin Pakistan

2. THE SALINITY ISSUE, CAUSES AND HISTORICAL PERSPECTIVE

2.1 The Salinity Issue

4. Globally, salinity affected twenty percent (20%) of the irrigated land, reducing cultivable area and undermining agriculture production and world food supply (Shehzad *et al.*, 2017). In Pakistan, salinity affects 6.2 million hectares which is 40% of the 16 million ha irrigated land and 29% of the 22 million ha of total cultivable area in the country. Of the 6.2 million ha, 4.3 million ha are severely affected (70%) and 3.4 million ha was not cultivated (Government of Pakistan, 1997). In 2010, the water table was reported 1.5 meters from the ground surface over 5.25 million ha area and 3 meters from the ground surface over 9.37 million ha. Seasonal fluctuations indicates that the area with water table between zero and 1.5 meters (5 feet) was 2.0 million ha in June and 5.2 million ha in October. Shallow and saline groundwater induces secondary salinization abandoning about 40,000 ha land annually in the Indus Basin (WAPDA, 1989). In 2010, the annual loss of cultivated land reported to be varied between 20,000 ha and 40,000 ha (Anjum *et al.*, 2010).

5. Salinity is agriculture, environmental and social and economic development problem as 75% of the population and about half of the gross national product (GNP) directly or indirectly are linked with agriculture (NESPAK and MMI, 1997). Salinity affects the agricultural production by reducing the crop yield and available area for cultivation. Shallow groundwater by restricting plant growth and adding salts also causes land degradation. Water logging and salinity have adverse social and economic impact on the communities, causing poor living standard and health problem to the human and animals. Declined livelihood opportunities and degrading infrastructure force people's migration and cause administrative and political problems. Pakistan suffered from high cost of land degradation: water erosion US$5.4 billion; wind erosion US$1.8 billion; fertility decline US$0.6-1.2 billion; water-logging US$0.5 billion and salinity US$1.5 billion (Anjum *et al.* 2010). Land degradation reduced the production potential of major crops by 25% with an estimated loss of $250 million per year (Haider et al 1999).[1] Ahmad (1968) showed a gap between yields from saline soils and normal soils varying from 250% to 400%.

2.2 Main Causes of the Salinity

The Mechanisms that Cause Salinity

6. There are two main causes of soil salinity: inherited saline or sodic soils and water induced salinity. Most of soil salinity is inherited. The Indus river and its tributaries transported salts from the upper catchment to the plains during soil formation process. The inherited salt in the soil are generally deep and are only comes on the surface through pumping of saline water. The water induced salts take two forms. First on an average annual salt inflow of 33 million ton to the Indus Basin, which are routed through irrigation system in the command area. Around 16.4 million ton is washed to sea and remainder 16.6 million ton remains within the system. Only 2.2 million ton is deposited in series of evaporation ponds. A balance of about 14. 4 million ton of salt accumulates in the soil profile, underlying strata and the aquifer (NESPAK and MMI, 1993). This implies that on an average one ton of salt is added to one hectare of irrigated land annually. An indicative salt balance of the Indus Basin is in Figure 2. Secondly, use of marginal quality groundwater and deep pumping add salt to the surface or shallow soil layers.

[1] "$" sign in this report represents US Dollar or otherwise mentioned.

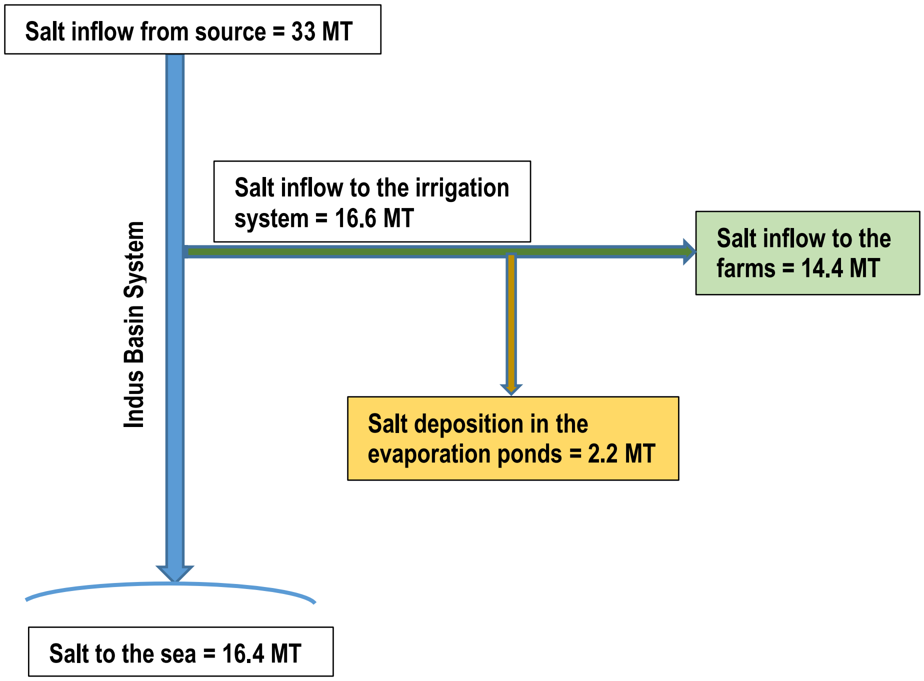


Figure 2. Indicative Salt Balance in the Indus Basin

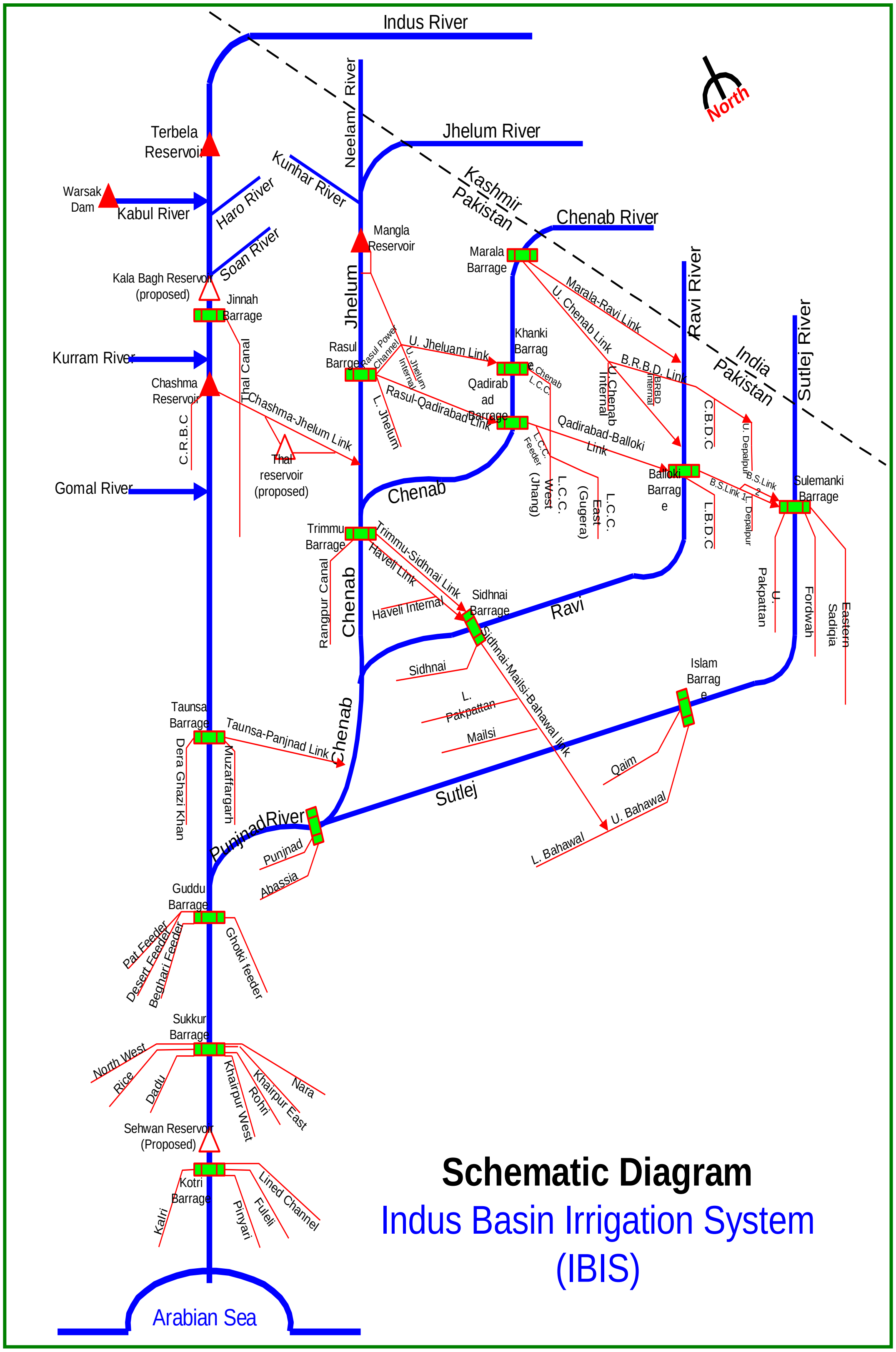
7. In Indus plain, the upper 100 meters' groundwater reservoir has an estimated 7,500 million tons of salts (ICID, 1991). Marginal quality groundwater use adds 100 million ton of salts to the soil surface every year (ICID, 1991). The surface water through canals adds an additional 50 million ton of salts to the system every year (Qureshi, 1993).

8. In Indus Basin, salts are transported by water over a large catchment area. More erosion and salts are expected if the catchment area is degraded. Exploitation of catchment area for livelihood opportunities and meeting the energy needs in harsh winter cause degradation. In irrigated area, farmers use more irrigation water to leach the soil, which brings more salts. Vicious degradation cycle for livelihood opportunities accelerates salt transport in the Indus Basin. Complex links between natural and social processes, weak institutions and farmers lacking in appropriate and practical options constrained SAWM.

9. An estimated 6 million ha land was affected by salinity including 2 million ha which was abandoned due to severely saline (Wolters and Bhutta, 1997). The available empirical evidence shows that the decline in productivity because of salinization ranges from 25 to 70 percent on moderately salt affected soils and it approaches 100 percent in areas where the problem of salinization is severe.

Water Mismanagement is Linked with the Salinity

10. Pakistan's large network of irrigation canals (about 57,000 km of the primary, secondary and tertiary canals, 88,600 irrigation canal outlets and 1.6 million km long water courses downstream the outlets) is one of the causes of the water induced salinity (Bhatti and Kijne, 1992). Irrigation without drainage caused groundwater rise and resulted into waterlogging. Water logging through capillary rise brought salts to the soil surface or to the plant root zone constraining the plant growth. Schematic diagram of Indus Basin Irrigation System (IBIS) is in Figure 3.



Schematic Diagram
Indus Basin Irrigation System (IBIS)

Figure 3. Line Diagram of Indus Basin Irrigation System

11. Groundwater pumping for irrigation has two effects. In shallow and fresh groundwater zones, it can help lowering groundwater table, reducing water logging and salinity and increase agricultural production by supplementing irrigation supplies for crop intensification. Pumping deep groundwater has an economic cost as well as danger of mixing of underlain poor quality water by up-conning phenomenon. Pumping marginal quality groundwater for lowering the groundwater table and reducing water logging and salinity may be desirable. But irrigation with the marginal quality groundwater can lead accumulation of salts in the soil profile and plant root zone, causing secondary salinization and land degradation and reducing agricultural production.[2]. Khan *et al*. (2004) comparing three irrigated environments of Australia, China and Pakistan conclude that in Rachna Doab Pakistan, where groundwater meets about 50% of the irrigation requirement, continued and unchecked pumping may result in soil salinity, if adequate leaching of root zone is not exercised.

12. In Punjab, where the groundwater use in agriculture is the highest, about 25 percent of the tubewell's water has marginal quality and an approximated 50 percent of the water is not safe for irrigation. In Sindh, the groundwater quality is rather worse but groundwater uses for irrigation are lower than Punjab (Ahmad *et al.* 1998). Qureshi *et. al.* (2011) estimated spatial and temporal variations of hydro-salinity behavior of shallow groundwater aquifer underlain by saline groundwater for a skimming well in command area of Kunnar-II distributary in Sindh. They modelled pumping test using MT3D model (MODFLOW for Windows) and showed that groundwater quality deteriorates at a faster rate with pumping time more than 12 hours and with depth (well strainer depth and below).

13. During the extreme drought conditions from 1996 to 2001, the surface water availability in Punjab was reduced by 46%. This led to a 59% increase in the number of private tubewells over the same period (Qureshi et al., 2003). An estimated 800,000 small capacities private tubewells were functional in Pakistan at that time. The total groundwater abstraction from these tubewells was estimated at 45 km^3 against a recharge of 40– 60 km^3 (Shah et al., 2003).[3] Out of this, about 33 km^3 was extracted through private small capacity tubewells, which were mostly located in fresh groundwater areas. The remaining 12 km^3 is extracted by large capacity public tubewells mainly to provide domestic water supplies to urban areas. Inadequate leaching and consequently the accumulation of salts in the plant root zone is attributed to the high evapotranspiration and low rainfall. Lacking in an effective drainage system caused water logging and salinity. Irrigation without drainage, over irrigation, use of poor quality groundwater are the main causes of this problem.

14. Due to an overall shortage of good-quality water, the use of poor-quality groundwater as a supplemental source of irrigation has become routine practice. The large scale exploitation of poor quality groundwater is another substantial source of salt inflow adding salinity. Fig. 4 shows an indicative representation of groundwater quality in the Indus Basin, which ranges between marginal to hazardous in the major irrigated areas of the Sind Province (Qureshi *et al*., 2004). Groundwater pumping brings 28.2 million ton of salt to the soil surface, annually. This includes 24.7 million ton in Punjab and 3.5 million ton in Sindh. Low groundwater pumping in Sindh is responsible for low salt accumulation.

[2] A cautious conjunctive use of such groundwater and canal water may help meeting irrigation water shortages and maintaining agricultural production.
[3] The broad recharge range shows effect of drought and flood years

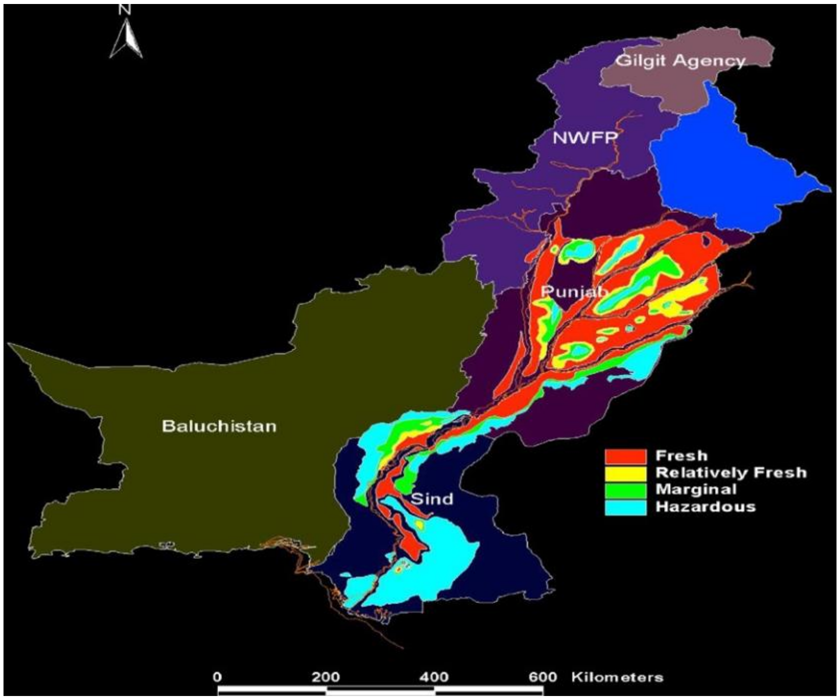


Figure 4. Spatial Variation of Groundwater Quality in the Indus Basin of Pakistan (Qureshi *et al.*, 2004).

Climate Change Impact will Further Aggravate the Situation

15. The impact of climate change in the coastal area will cause rise in sea level resulting into an increased risk of coastal flooding, inundation of wetland and other ecosystems, salinization of the land and negatively impacting the land and livelihood of the people depending on that land and water. Sea level rise may also cause saltwater to ingress farther inland. In plains in Punjab and Sindh, high evapotranspiration demand due to temperature rise, the crops may require additional irrigation, which means increased water requirement and as a result accumulation of more salts in the soil.

2.3 A Walk Through the History

16. In 1953 and 1954, the land survey of the Indus Basin under Colombo Plan showed that almost 30% of the 8.0 million hectares in northern zone was either water logged or severely saline and of limited use for agriculture production (GOC and GOP, 1958). In southern zone, 53% of the 5.0 million ha were water logged or poorly drained and 25% was predominantly severely saline.

17. In 1962, the Roger's report to President of Pakistan indicated an average rise of groundwater table at two feet a year. This rise in water table was linked to 45 to 54% water loss during water conveyance and application. It was reported that out of an average annual water diversions of 92.5 cubic kilometers (km^3) to canals, only 42 to 50 km^3 was available for crops (Mohammad and Bering, 1962).

18. In 2003, according to the Soil- survey of Pakistan, the total waterlogged summer-rain area in the country is 4.11 mha and the waterlogged area is doubled during the post-monsoon season. In Pakistan, approximately 5.7 mha of irrigated land is affected by salinization. Out of this, 44.1%

is saline, 55.4% is saline-sodic and 0.5% sodic. Maximum salt- affected areas are in the Punjab (2.6 mha), followed by Sindh (2.3 mha) (Zia *et al*., 2003).

19. In 2006, 43% of the 16.7 million ha was water logged including 4.01 million ha severely water logged with water table between zero to 1.5 meters and 3.1 million ha was moderately water logged with water depth from 1.5 to 3.0 meters (WAPDA, 2006).

20. Sumia and Shahid (2009) presented temporal variation of water logged area in Pakistan (Table 1).

Table 1. Variation of Water Logged Area with Time (Modified from Sumia and Shahid, 2009)

Year	1979	1989	1992	1993	1994	1997	1998	1999	2000	2001	2002	2006	2010
Waterlogged area (Mha)	7.0	14.0	15.2	14.0	14.5	15.0	14.0	12.5	9.0	8.5	7.8	7.0	6.3

Note: The waterlogged area is presented in million ha and the values are rounded.

21. Anjum *et al*., (2010) reported around 6.3 million ha salt affected land in 2010 in Pakistan. Government of Pakistan (1997) statistics showed salt affected area as 6.2 million ha. Province and category wide salinity affected area is in Table 2.

22. In 2017, Pakistan's national policy dialogue on salt-affected soils indicated over 7 million hectares are affected by soil salinity and sodicity in the country. Also, the secondary salinization was accelerated on about 2.0 million hectares due to use of poor quality groundwater, which warrants reassessment (Government of Pakistan, 2017). FAO, USDA, National Fertilizer Development Center (NFDC), International Peace Institute (IPI), PARC, NARC, ILRI, CIMMYT, ICARDA participated in the dialogue. ICBA attended through video links.

Bhutta and Smedema (2007) indicates that reducing waterlogging and salinity in last decade of nineteenth century is mainly attributed to the fresh groundwater use in irrigation. Reduced fresh groundwater availability in future can bring the problem back and raises questions on the sustainability of water logging and salinity in the Indus Basin.[4]

[4] Cross-sectoral competition and water reallocation for other uses (households, industry, environment) may reduce the freshwater availability for irrigation.

Table 2. Salinity Affected Soils in Pakistan (Adapted from Government of Pakistan 1997)

Area in 000 ha

Description	Balochistan			KPK and FATA			Punjab			Sindh			Pakistan		
	Total	Cultivated	Uncultivated	Total	Cultivated	Uncultivated	Total	Cultivated	Uncultivated	Total	Cultivated	Uncultivated	Total	Cultivated	Uncultivated
Slightly affected	3.0	3.0	0.0	5.2	5.2	0.0	472.4	472.4	0.0	118.1	118.1	0.0	598.7	598.7	0.0
Moderately affected	74.6	74.6	0.0	25.7	25.7	0.0	804.8	804.8	0.0	324.7	324.7	0.0	1229.8	1229.8	0.0
Severely affected	1270.3	31.4	1238.9	17.6	0.9	16.7	1390.3	235.5	1155.5	1666.8	708.2	958.6	4345.0	976.0	3369.7
Total	1347.9	109.0	1238.9	48.5	31.8	16.7	2667.5	1512.0	1155.5	2109.6	1151.0	958.6	6173.5	2803.8	3369.7
Percentage of the Country (%)	22	4	37	1	1	0	43	54	34	34	41	28	100	100	100

3. SALINITY AND WATER MANAGEMENT

3.1 The Approach

23. The literature suggests that in Pakistan, the water and salinity problem was approached through technical, institutional, policy instruments. In 1950's, the Government showed a highest level of commitment. A country-wide land survey was carried out in 1953-54 under Colombo Plan. The Water and Power Development Authority (WAPDA) was established through an act of the Parliament in 1958 to develop water and energy resources in the country. Water logging and salinity was assessed in 1962 by the international experts and the assessment report was presented to the President of Pakistan (Roger report to President of Pakistan). The Government arranged the required investment and implemented several mega projects including five barrages and eight inter-river Link Canals (1965-1970), two major reservoirs (Mangla in 1967 and Tarbela in 1976), six salinity control and reclamation projects (SCARP) and Left- and Right- Bank Outfall Drains projects.[5] International Waterlogging and Salinity Research Institute (IWASRI) was created in 1986 under WAPDA to mainly conduct research and gather scientific information on water logging and salinity, surface and groundwater, and environment. The Government enacted several laws including WAPDA Act 1958, provincial irrigation and drainage authorities Act 1997 and Pakistan Environment Protection Act 1997. Until the late nineties, the approach worked well and showed good results including a major relief to waterlogging and salinity by the SCARP. After NDP failure in 2002, the SAWM priority was demoted and the issue was almost shelved. Except for some fragmented research, a well-planned work remained missing. An approach blending the lesson learned, innovations and integrating the fragmented work may help better address the problem. A spiral representation of the past development and future direction is in Figure 5.

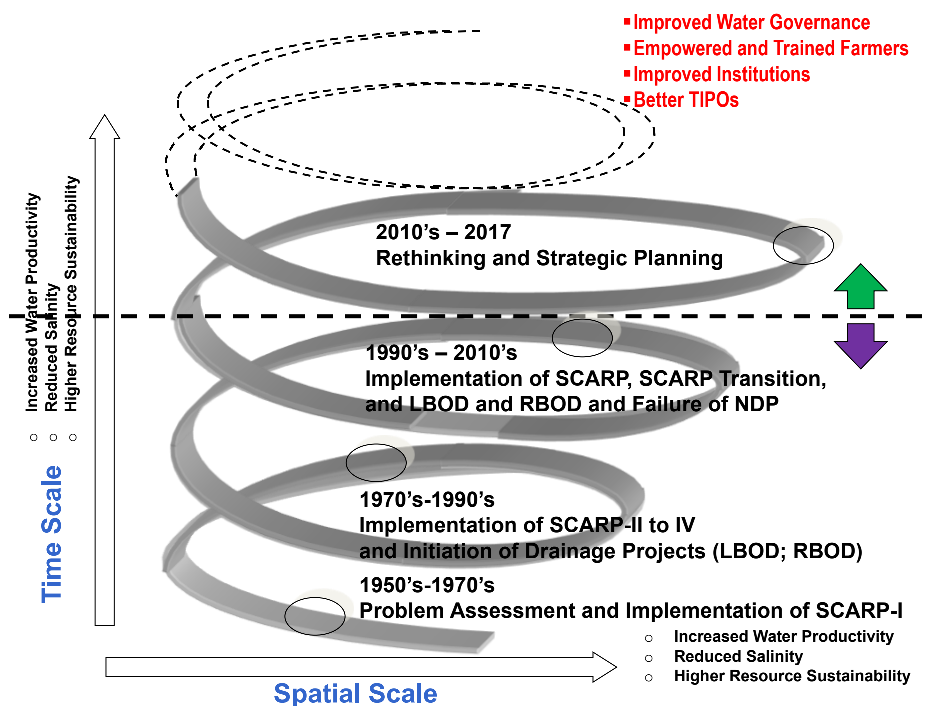


Figure 5. Spiral Representation of Salinity and Agricultural Water Management in the Indus Basin

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[5] The two reservoirs, barrages and inter-river Link Canals were constructed under Indus Basin replacement work.

3.2 National Water Policy and Strategy

24. Ministry of Water and Power, Pakistan drafted a National Water Policy (NWP) in 2002. Drainage, water logging and salinity are a part of the NWP. The revised NWP in 2012 recognizes the salt build up in irrigated agriculture, increased intrusion of saline water in Indus delta, groundwater management planning and regulatory zones, secondary salinization, water logging, and relevant adaptive research as main thrust areas. However, NWP remains draft since 2002 and was not approved and implemented. Further, it has to harmonize with the provincial water policies, which so far are not available. Therefore, policy intention could not be sufficiently translated into action. A cohesive and approved water policy is needed.

25. Pakistan water sector strategy, 2002, identifies increasing water demand, deteriorating water quality, deteriorating irrigation and drainage infrastructure, waterlogging and salinity on irrigated land and disposal of saline drainage effluent as the main issues. It emphasizes integrated water resource management (IWRM), promoting water conservation, regulating groundwater, improving water quality, reducing water logging on 2.8 million ha and providing long-term and safe solution of saline drainage effluent as main objectives (Government of Pakistan, 2002).

26. The strategy developed short (2003-2004), medium (2005-2011) and long term (2012-2025) actions for estimated US$33.6 billion for water sector including US$11 billion exclusively for irrigation and drainage.[6] The drainage related main short term actions were identified as (i) assessment of benefits for lining of canals in saline areas, (ii) restructuring National Drainage Program(NDP), (iii) completion of feasibility study for spinal drain, and (iv) groundwater regulation. The medium term action included (a) line distributaries in saline groundwater area; (b) complete revised NDP I; and (c) prepare NDP II, III and complete NDP II including spinal drain. The long term plan included continue lining of distributaries in the saline groundwater area and carry out NDP III including spinal drain. The strategy identified sectoral constraints to irrigation and drainage as: (1) poor project implementation, (2) water scarcity, (3) lack of consensus and cooperation, (4) over use of water lacking in conservation, (5) inequitable distribution of water, (6) low cost recovery and poor maintenance, (7) institutions weakness, and (8) lack of stakeholders' participation.

27. Reviewing the implementation of short, medium and long term strategy actions reveals that implementation of drainage component was weak. NDP's restructuring and groundwater regulation under short term actions were not completed. So far, progress on these two aspects remain sketchy. The progress on implementation of midterm actions was even worse. With this progress, implementation of long term plan by 2025 appears to be challenging. The identified sectoral constraints are of serious nature. In particularly, poor project implementation, lack of consensus and cooperation, institutional weakness and stakeholders' non-participation can ruin a good plan anytime. Unfortunately, serious work to remove the sectoral constraints is not known. In post-strategy era, groundwater and drainage remain almost neglected areas.

3.3 Legislation

28. The Government enacted several related laws including WAPDA Act 1958, provincial irrigation and drainage authorities Act 1997 (PIDA/SIDA Act 1997; amendments to Canal and

[6] The total for water sector including water resource, urban and rural water supply, industrial and irrigation and drainage was US$33.6 billion.

Drainage Act 2006 and 2016; Sindh Water Management Ordinance 2002) and Pakistan Environment Protection Act 1997. The laws were enacted on need basis, which largely remained fragmented (Box 1). For example; river channel, land use, groundwater regulatory laws are non-existent or weak. Scheumann and Memon (2003) indicated the first legislation on groundwater was enacted as the Punjab Soil Reclamation Act of 1952. The act created the basis for the Soil Reclamation Board, later suspended (1964–65); its executive powers for operation and maintenance of the public SCARPs were transferred to Superintending Engineer (SE) SCARP, established within the provincial irrigation department. However, the SE SCARPs did not become responsible for groundwater development. WAPDA's establishment act stipulated that it would be in charge of the development of groundwater resources and would issue official area-specific rules—which have never been formulated. More confusion was added by the Local Government Ordinance of 1979, which proposed that all groundwater falling within the local area of a union council comes under the control of that local government body. All acts are still in place, which leaves three authorities in charge of groundwater development, the federal WAPDA, the provincial irrigation departments, and the local governments. In fact, all has free access to extract groundwater without any limitations. Neither rights to groundwater nor obligations for its use have been specified.

Box 1 Major Water-and Salinity Related Legislation in Pakistan	
• Water and Power Development Authority Act, 1958 • Water Apportionment Accord 1991 • Indus River System Authority Act, 1992 • Environmental Protection Act, 1997 • Provincial Water Accord, 1991 • Territorial Waters and Maritime Zones Act, 1976 • West Pakistan Land and Water Development Board (Control over Underground Waters) Rules, 1965 • West Pakistan Amendment Ordinance V of 1964 • West Pakistan Amendment Act1956,1968,and Ordinances of 1970. • Soil Reclamation (Punjab Amendment) Ordinance VI of 1970 • Punjab Minor Canals Act, 1905 • Punjab Canal and Drainage Act, 1873 • Punjab Soil Reclamation (Amendment) Act. IX of 1977 • Punjab Water User Punjab Soil Reclamation Act, 1952 • Punjab Amendment Act 1952. Extension Act 1964 • Punjab Amendment Ordinance 1971 and Amendment Act 1975 • Punjab Water Users Association Ordinance, 1981 • Punjab Irrigation and Drainage Authority Act, 1997	• NWFP Canal and Drainage Act, 1873 • NWFP Amendment Act, 1948 • NWFP Irrigation and Drainage Authority Act, 1997 • NWFP Water User's Association Ordinance, 1981 • Balochistan Ordinance 1980 • Balochistan Groundwater Rights Administration Ordinance, 1978 • Balochistan Water Supply Regulation 1941 • Balochistan Pat Feeder Canal Regulation ,1972 • Balochistan Canal and Drainage Ordinance, 1980 • Balochistan Coastal Development Authority Act, 1998 • Balochistan Irrigation and Drainage Authority Act, • Balochistan Groundwater Rights Administration Ordinance, 1978 • Balochistan Water User's Association Ordinance, 1981 • SindhWaterManagementOrdinance,2002 • Sindh Irrigation Act, 1879 • Sindh Water Users Association Ordinance, 1981 • Sindh Water Users Association Ordinance, 1982 • Sindh Irrigation and Drainage Authority Act, 1997

3.4 The Relevant Institutions

29. Council of Common Interest (CCI) was created in 1973. It comprises the Prime Minister of Pakistan (chairperson), the Chief Ministers of the provinces, and three members from the national government who are nominated by the Prime Minister. The CCI ensure equitable distribution of water among the provinces and formulate and regulates policies and reports to the Parliament.

30. The Water and Power Development Authority (WAPDA) was established through an act of the Parliament in 1958. Before eighth amendment to the Country's Law and devolution of powers to the provinces in 2010, WAPDA was responsible for development of water and energy resources, management and operation of major water infrastructure and address the issues of water logging and salinity, drainage and groundwater. With the formation of WAPDA, the Groundwater Development Organization of Punjab was transferred to WAPDA's Water and Soil Investment Division. The first legislation on groundwater was enacted when vertical drainage projects had started: the Punjab Soil Reclamation Act of 1952 (table 5). The act created the basis for the Soil Reclamation Board, later suspended (1964–65); its executive powers for O&M of the public SCARPs were transferred to SE SCARP, established within the provincial irrigation department. However, the SE SCARPs did not become responsible for groundwater development. The International Waterlogging and Salinity Research Institute (IWASRI), the MONA Experimental Research Station, the SCARP Monitoring Organization, the Reclamation Research Institute – Lower Indus Management, and so on are WAPDA's subsidiary organizations or units established for specific research, monitoring, and evaluation functions (Scheumann and Memon, 2003).

31. The eighth amendment, delegated the responsibility of water and agriculture sectors to the provinces. WAPDA was then envisaged as the national water institution mainly for planning and implementation of only inter-state and transboundary projects. WAPDA continued to be project-based and so far its transformation into basin scale national institution could not be materialized. Further, WAPDA's engineering-based fabric and culture was not much helpful to enhance its capacity to deal with diversified and cross-sectoral issues. This transformation may require resources, time and political will. Nevertheless, WAPDA is capable of implementing mega engineering projects.

32. Pakistan Council of Research in Water Resources (PCRWR) functions at the country level to address the water related issues. PCRWR has undertaken initiatives to deal with the national water and land related issues. The council is effectively using its position for coordination and cooperation among national and international institutions. PCRWR's regional office in Sindh "Drainage and Reclamation Institute of Pakistan (DRIP) conducts research on drainage, salinity control and land reclamation, irrigation and drainage and seawater intrusion. There are also knowledge centers which work on water and salinity aspects including centers of excellence in Lahore and Jamshoro, engineering universities and PCRWR

33. More than one provincial departments are involved in water and land related activities. These includes Irrigation, agriculture, public health, environment and energy departments. One or the other way, these all departments are responsible for water management within their mandate. Irrigation and agricultural departments due to biggest users are frequently involved. In general, salinity management and on-farm water management is the responsibility of the provincial agriculture departments. Irrigation water delivery and off-farm drainage is responsibility of Irrigation Department. Four irrigation departments acquire about 100,000 staff (Punjab over 50,000 and Sindh around 32,000) but maintenance and operational management (MOM) remains inefficient and ineffective (Scheumann and Memon, 2003). Directorate of Land Reclamation in provincial irrigation departments is responsible for land reclamation. Unfortunately, stewardship of groundwater and water quality is missing. Water quality standards differ by the institutes. For example; SCARP monitoring Organization uses different water quality standard the Directorate of Land Reclamation. Other provincial institutions such academic institutions and non-governmental organization also involve whenever opportunities exist and situation requires their involvement.

34. Soil Salinity Research Institute (SSRI) under Punjab's Agricultural Department was established in 1982 to conduct dedicated research on (i) economic utilization of salt affected soils; (ii) causes of salinity and sodicity; (iii) development of reclamation technology for salt affected soils; (iv) development of measures/practices to avoid salinization of soils; (v) standardization, screening and evolution of salt tolerant crops, vegetables and horticultural plants; (vi) development of crop production technology for salt-effected soils; (vii) identification and collection of natural vegetation capable of withstanding high salt concentrations; (viii) promotion of aquaculture, farm forestry in areas less favorable for crop cultivation; (ix) development of cheap drainage system and mechanical devices for better tillage and (x) advisory service to the farmers facing soil salinity problems. The SSRI tested rice and wheat varieties in saline soils and conducted research on safe use of brackish water, reclamation of salt-effected soils and provided farmers advisory services (Hussain and Mehdi, 2008). So far success has been moderate and farmers uptake of the research results was not significant. Unfortunately, the provincial research and knowledge management could not show impact.

35. Most of the institutions were need-based and were created to address the specific problem at the time of their creation (**Table 1**). Some of the longtime task specific organizations such as WAPDA and provincial irrigation and agricultural departments lack in their internal evolution. Largely, these institutions worked uni-directionally. Although there were successes to share but often their work was fragmented, less effective and with low impacts. Their capacity was low and mechanism transforming them into responsive institutions was weak, therefore, their sustainability remained questionable. WAPDA and provincial irrigation and agriculture departments are classical examples of transformation resistive culture. Overall, the institutional role was partially successful, less effective and unlikely to be sustainable. Efficiency was low and dominantly non-responsive. To address the complex and multi-sectoral water and food security, combating land degradation and improved water and land productivity, an effective transformation of provincial irrigation and agricultural departments and WAPDA may be needed. The farmers-based organizations—water users association, drainage beneficiary groups and community tubewell groups, struggled for survival. The World Bank ambitious reform program 1994-2002 failed to bring envisaged changes.

Table 1. Evolution of Water, Drainage and Salinity Related Institutions in Pakistan's Indus Basin
(Adapted from Scheumann and Memon, 2003)

Year	Organization Evolved	Purpose/Result
1917/18	Drainage Board created for Upper Chenab Canal	Investigations for controlling canal seepage.
1920	Drainage Division created in Upper Bari Doab Canal with a drainage engineer	
1925	Waterlogging Inquiry Committee (WIC) created with a superintending engineer	Advisor to government. Waterlogging investigations (1927).
1928	WIC replaced by Waterlogging Board	
1930/31	Irrigation Research Institute established in provincial irrigation department	Research on seepage drains in Upper and Lower Chenab Canal.
1932	Drainage circle created with superintending engineer Reorganization of drainage circle, i.e. two divisions (jurisdiction over Chaj and Rachna)	Organized around natural drainage basins to better tackle construction of seepage and seepage - cum - storm drains. Investigations in deep water table areas (1937).
1939	United with Upper Jhelum Canal Circle and Lower Chenab Canal Circle	
1940	Land Reclamation Board created	Recommended nonstructural measures Salinity and alkalinity

		survey in Punjab (1943)
1944	Northern Drainage Circle created with jurisdiction over Chaj and Rachna	Independent circles better suited to construct and maintain drains.
1945	1945 Directorate of Land Reclamation created To reclaim saline and sodic soils.	
1947	Drainage circles closed; Drainage divisions attached to irrigation circles	Drainage divisions better suited because already in charge with maintenance of canals.
1947	Pakistan Meteorological Department (PMD), Ministry of Defense	weather data and forecasts
1951	Two drainage circles created , separate from irrigation circles	
1952	Soil Reclamation Board created for groundwater management	Established after FAO investigations.
1954	Groundwater Development Organization created Drainage circles abolished	Later transformed into WAPDA with a Water and Soil Investigation Division to economize expenditures.
1958	Drainage circles reestablished Director of drainage appointed in the office of the chief engineer, irrigation (West Pakistan)	To improve land reclamation and drainage.
1959	WAPDA established	For investigation, planning and implementation of control means. Master Plan, Regional Plan (1967). Action Program for Irrigation and Drainage (1965 – 75). Accelerated Program "Waterlogging and Salinity Control" (1974/75 to 1984/85), revised in 1985 f or a 21 - year period.
1960	Pakistan Commissioner for Indus Waters (PCIW)	The Indus Waters Treaty (1960), following the provisions of Article VII(1), created the Permanent Indus Commission. Two commissioners, one appointed by Pakistan and the other by India, comprise the full membership of the commission.
1964/ 65	Soil Reclamation Board suspended	Responsibilities/power transferred to PID, SE SCARPs except groundwater management.
1977	Federal Flood Commission	Approval of flood control schemes; forecasting; evaluation/monitoring of National Flood Protection
1977 Plan.	Drainage Circles in Lahore, Faisalabad, Sargodha; Drainage Divisions in other zones	Functional units (O&M of drains).
1982	Soil Salinity Research Institute (SSRI) in Punjab Agriculture Department	To conduct research on causes and remedial measures, testing salt tolerant plants and developing improved technologies and methodologies for salt-affected soils.
1995	WAPDA takes over O&M responsibility for interprovincial drains	Cost - sharing between federal state and provinces.
1986	International Water Logging and Salinity Research Institute (IWASRI) in WAPDA	Research and planning on water logging and salinity
1964/ 2007	Pakistan Council of Research in Water Resources (PCRWR) in Ministry of Science and Technology. Established in 1964 and corporate in 2007	conduct, organize, coordinate and promote research on all aspects of water, specifically irrigation, drainage and land reclamation, surface & groundwater management, groundwater recharge, watershed management, rainwater harvesting, desertification control, water quality and saline agriculture.
1991	The Water Resources Research Institute (WRRI) in Pakistan Agriculture Research Council	To develop technologies; new knowledge and management strategies for water resources of the rain-fed and irrigated farming systems to enhance the productivity per unit of water.
1997	Provincial Irrigation and Drainage Authorities in all the four provinces.	To take over responsibilities of farmers managed irrigation and drainage systems.

WAPDA = Water and Power Development Authority; O&M = operation and maintenance; FAO = Food and Agriculture Organization; PCRWR = PID = provincial irrigation department; SCARP = Salinity Control and Reclamation project; SE SCARP = superintending engineer SCARP.
Source: Major part of this Table 1 is adapted from Scheumann and Memon, 2003.

3.5 Research and Data Management

36. In the past, water and salinity related research was carried out at two scales: medium to large scale research by IWASRI and field/farm scale research by many including provincial and educational organization. The IWASRI work benefitted the need of the prevailing environment at that time but its impact diminished with the passage of time probably due to discontinuity/scale-down or low priority reasons. Further, the information generated were not significantly transformed in the policy and institutional tools. The small scale research work by many organizations was although voluminous but could not be properly screened and bundled for farmers' uptake. This research work was mostly disconnected, fragmented and localized. Lacking in appropriate planning: searching maximum potential at experiment stations and working on farmers field for actual gain, was missing. At least 50% of the research work by these institutions should have been carried out with the farmers at their farms. This could have benefitted in targeting real need, dissemination through farmers to farmers links and upscaling.

37. Unfortunately, the generated data was inappropriately managed and was not timely available for critical review and use. Therefore, a large chunk of the research work remained underutilized. The bigger picture and integrated research framework was missing. National Drainage Program (NDP; 1997-2004) developed a strategic research agenda, but due to the failure of the overall program, the research component alone could not yield the envisaged results. An assessment of current research (organizations and their work) may help better plan, organize and manage the research work for future.

3.6 The Mega Projects for Salinity Management

38. In 1960's, the Indus Basin experienced a large scale infrastructural transformation. Subsequent to the Indus Water Treaty between India and Pakistan in 1960, the Indus Basin Replacement Works (1960-1980) built two large reservoirs (Mangla and Tarbela), 12 inter-river Link Canals and appurtenant structure. Parallel to this development, the Government implemented six SCARP projects (SCARP I to SCARP VI) for $2 billions from 1964 to 2000 covering 8 million ha. This infrastructure brought several changes to the Indus landscape. Performance of these mega projects varied. Most of the mega projects were not evaluated for impacts and sustainability and so far this information is not available. A summary of the water logging and salinity related projects is in Table 2.

Table 2. Investment Mega Projects at a Glance

Project Name	**Description**	**Performance Indicators and Results**				
		Outcome	**Relevancy**	**Efficiency**	**Effectiveness**	**Sustainability**
SCARP I to SCARP VI	1964-2000 for $2 billion	Successful	Relevant	Satisfactory	Effective	Not sustainable
SCARP Transition	1987-1990 for $21.8/14.9 million	Successful	Relevant	Generally satisfactory	Effective	Partially sustainable
Left Bank Outfall Drain	1986-1997 for $150 million	Partially successful	Relevant	Not satisfactory	modest	Not rated
Private Sector Groundwater Development	Punjab ($33.4 million) (1997-2001)	Partially successful	Relevant but "quality at entry" was poor	Satisfactory	modest	Inadequate data

National Drainage Program	Pakistan ($785/$226 million) (1997-2004)	Unsuccessful	Relevant but complex design and "quality at entry" was poor	Unsatisfactory	Not effective	Not sustainable

Salinity Control and Reclamation Project (SCARP)

39. SCARP aimed to reduce waterlogging and salinity by pumping the groundwater and lowering groundwater levels. Six SCARP projects for $2 billion benefitted 8 million ha irrigated land. The first SCARP project in 1961 installed 2,100 public tubewells to serve 600,000 ha land in Punjab. A list of SCARP is in Appendix 3. Suitable fresh pumped groundwater was transferred to canals for irrigation purposes, moderately saline water was mixed with canal water for irrigation, and saline water was dumped into ponds to evaporate. The SCARP was moderately successful to lower down the groundwater table reducing waterlogging and salinity and providing additional irrigation supply in the fresh underground water zones. The additional water supplies and the associated drainage increased cropping intensities from 84% to 115% in most SCARP areas (although the targeted cropping intensities of 150% were not achieved) (Qureshi and Sarwar, 2009). SCARP reduced salinity but due to costly operation and maintenance, the well operation did not sustain.

40. Lacking in farmers participation, high operating cost, frequent energy failure and regeneration of waterlogging lost farmers confidence in the effectiveness of the SCARP. In 1977, Government launched SCARP VI to mainly encourage farmers for private tubewells through credit facility and subsidy on electricity. This reduce the Government's burden. Horizontal and subsurface pipes were installed in 1980 to 1990. From 1984 to 2000, salt free area increased from 56% to 73%. By 2000, the SCARP well were discontinued due to poor performance, high cost and short life.

SCARP Transition Pilot Project

41. **The project objectives, components and scale.** The $14.9 million SCARP Transition Pilot Project (STPP) was implemented from 1987 to 1990 in SCARP I area of Khanqah Dogran, Punjab.[7] The project **objective** was to develop a replicable approach to implement the Government's policy of transferring the responsibility for fresh groundwater pumping in SCARP area from the public to private sector meeting more effectively the irrigation and drainage requirements. The project covered 46,000 ha area and 11,500 farming families. It mainly tested farmers' willingness and ability to install their own tubewells, when the Government tubewells shutdown.

42. **Project performance**. STTP **successfully** demonstrated the farmers' installation of private tubewells as substitution of the closing public sector tubewells. High cost of electric transmission lines made electric driven tubewells less favorable as compared to diesel operated tubewells, which were largely opted. Necessity and farmers' profitability made the "transition" concept successful and replicable.[8] Small-scale interventions, affordability and personal ownership also played important role in the success.

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[7] SCARP stands for Salinity Control and Reclamation Project. Original project estimate was US$21.8 million. The lower actual cost was due to over estimation of tubewell installation, electrification material and equipment.

[8] About 70% of the irrigation demand was met from groundwater in the project area. Failure of "transition" means high loss of agricultural production.

43. **Project sustainability**. Lacking in adequate data, the project impacts were not assessed. Farmers' full control of the operation of their own tubewells and bearing all the operation of maintenance expenses made the project **sustainable**. However, only additional income from demand driven water availability, efficient use of water and high value crops could ensure the project sustainability in longer term.

44. **Lesson learned**. Following lessons can be learned from the project implementation:

- Low capital cost of diesel-operated pumps favored over high capital cost of the electrify driven tubewells;
- A large Government subsidy is not necessarily needed to convince the farmers;
- Early appointment and assigning the responsibility of design review by the supervisory consultant is important for smooth implementation of the projects;
- A full scale project of this nature may need international competition bidding for procurement of equipment; and
- Monitoring and evaluation should be given more attention.

National Drainage Program

45. **The project objectives, components and scale*.*** The National Drainage Program (NDP) with appraisal cost $785 million and actual cost of $226.5 million covered entire country and was implemented from 1997 to 2004. The program objective was to assist the Borrower and the Provinces in implementing the first phase of the NDP, which was designed to restore environmentally-sound irrigated agriculture, inter alia, through the minimization of saline drainable surplus and the eventual evacuation of all saline drainable surplus to the sea.[9] The program component included institutional reforms, sector planning and research, investment, coordination and supervision.

46. **The Project Performance.** Overall relevance was **Modest** (relevance to objectives "substantial" and relevant to design "Modest"). Achievement of the project objectives was negligible. On institutional reforms, WAPDA reduced staffing and devolved implementation of drainage projects to the provinces, but WAPDA's transformation into a basin-oriented water resources agency was limited. Achievements at provincial levels were disappointing to varying degrees. Initial progress on Area Water Boards and Farmers' organizations in Punjab and Sindh was severely declined and were phased out in less than a decade. Staff from provincial Irrigation and Power Departments were apprehensive about the effect of the farmer organizations on its own future, and capacity building efforts were weak. Unfortunately, due to the vested interests noted above, even the limited progress that was achieved substantially reverted to the pre-project situation. The project has not achieved its first objective—irrigation and drainage system management has remained practically the same as pre-reform, with minimal changes." A more encouraging postscript could be "since project closure (December 2004), there has been an increased commitment to reform in Sindh and Punjab provinces; and that, "in 2005-06, Punjab has moved forward in the reform process through the Irrigation Sector Development Policy Loan."

47. Modest achievements were under strengthening drainage and irrigation research and

[9] The specific objectives were to (i) promote the carrying out of policy and institutional reforms in the water sector; (ii) strengthen drainage and irrigation research and sector planning capabilities; (iii) finance investments in drainage and irrigation infrastructure; (iv) promote the carrying out of policy and institutional reforms in the water sector; (v) strengthen drainage and irrigation research and sector planning capabilities; (vi) financial investments in drainage and irrigation infrastructure.

sector planning capabilities. There were negligible achievements under investing in drainage and irrigation infrastructure. The main sub-components responsible for the shortfall were the off-farm drainage and on-farm drainage also had no investments in new drains. The project has made only limited progress towards its overall objective; far less than planned and project outcome was rated unsatisfactory.

48. **Lessons learned**. The main lessons learned are:

- Over complexity was the main reason for the failure of the program;
- A reform agenda needs to give attention to incentives for change for the different stakeholders, and to the processes and sequential actions of the reform program;
- Commitment to reform needs a broad base, preferably stakeholder led agenda; and
- Reform champions can have major impact, but basing reform on a few champions is a vulnerable strategy.

Punjab Private Sector Groundwater Development

49. **The Project Objectives, Components and Scale.** The US$33.5 million private sector groundwater development project (PGWD) (1997-2001) was aimed to increase the scope and productivity of **Punjab's** irrigation and drainage subsector, and increase farmers' incomes.[10] Specific objectives were to: (i) redefine Government's role in groundwater development and provide assistance to facilitate change; (ii) develop a monitoring program and groundwater regulatory framework (GRF) to ensure sustainable use of the groundwater resources; (iii) develop sustainable farmers' organizations (FOs), which can efficiently operate and maintain groundwater irrigation, improve surface irrigation and establish a base for participation in the management of the canal systems; (iv) Increase beneficiaries' incomes and alleviate poverty; (v) rationalize public expenditure on O&M of the irrigation and drainage systems as well as increase the recovery of public expenditures on irrigation infrastructure; and (vi) avoid environmental hazard of saline water intrusion into fresh groundwater aquifers.

50. The project components were: Tubewell Disinvestment; Development of Groundwater Regulatory Framework (GRF); Improvement of Irrigation Facilities; Prevention of Saline Groundwater Intrusion; Monitoring and Evaluation (M&E); Project Management; and Technical Assistance and Training. The component 1 involved transfer of 4,250 government tubewell (TW) sites to cooperative tubewell (CTW) management. The tubewells provided supplementary supplies to surface water canals, as well as salinity control benefits through reducing the level of the groundwater table. There is not a one to one correspondence of the existing government TW sites with a single community tubewell management group. Sometimes a government tubewell was taken over by several CTW management groups, thus the number of CTWs exceeded the 4,250 disinvested tubewells.

51. **The Project Performance.** Redefinition of the Punjab government's role in groundwater development was largely achieved by the end of the project, with all 4,250 SCARP tubewells. Development of a monitoring and regulatory framework to ensure sustainability of groundwater resources **fell far short** of overambitious targets because the time needed for consultation and building of stakeholder ownership and acceptance was underestimated. Change was facilitated and the numbers of farmers groups established and trained exceeded targets. Over 6,700 community tubewells (CTWs) were set up, and 85%of these judged "successful" through independent monitoring. 2,000 water user associations (WUAs) were established. The subsidies

[10] Actual cost of US$33.5 million was 32% of the planned cost of US$104.8 million.

on private tubewell construction ended. However, the scheme to implement severance packages for 5,000 redundant operators was not implemented and $8 million remains unutilized. Monitoring data are inadequate to determine if saline intrusion was reduced and water quality deteriorated in allegedly affected areas.

52. **Significant outcome**. There were substantial improvements in irrigation management within the long -term policy framework adopted by the Punjab government. Promising new agricultural technologies have been demonstrated, including resource conservation through zero tillage for wheat on 60,000 ha (over 2800 sites), and laser-guided land-leveling on 22,250 ha.

53. **Significant shortfall.** The institutional and technical difficulties of managing surface and groundwater sources conjunctively were underestimated, and the GRF remains to be enacted and operationalized. This project was categorized as a poverty targeted intervention (PTI) but alternative PTIs were not considered. The saline intrusion control component was poorly conceived on inadequate data. The lack of a uniform sector policy for farmers' contributor to civil works capital investment created implementation problems and required significant redesign. The M&E system for agricultural production impact had only 30 control households, which is a small sample. The sustainability of benefits from canal rehabilitation and watercourse improvement were not established.

54. **Project rating**. The project outcome was rated as moderately satisfactory. Although CTW disinvestment targets were met but “quality at entry problem” resulted in failure to meet objectives for GRF and irrigation improvement component. The achievement on institutional development was modest as slow progress in implementing at provincial level reforms and GRF offset the good progress on new management structure at field level. Project sustainability was not evaluable due to non-availability of data at early stage on how likely the ambitious institutional changes will lead to both improved and sustained irrigation management performance.

55. **Lesson learned.** Following lessons were learned.

- ❖ Establishing a groundwater regulatory framework (GRF) requires coordination of a wide range of institutional changes, affecting the equity of water distribution, ownership by both communities and local government, alternative income sources to compensate for decreased reliance on groundwater, and poverty-targeting of "critical areas."
- ❖ A public awareness program and stakeholder participation must precede introduction of groundwater regulation. Users must be involved in groundwater monitoring and voluntary self -regulation.
- ❖ Women's Organizations can contribute to conflict resolution among members of FOs/CTWs and the optimal siting of TWs.
- ❖ To control salinity, non-engineering solutions, for example saline agriculture and biological drainage, may be effective in controlling groundwater induced salinity.

Left Bank Outfall Drain Stage I (Reference ICR)

56. ***The Project Objectives, Components and Scale.*** The IDA credit US$150 million project ran from1986 to1997 to address problems of water logging and salinity along left bank of the River Indus in Sindh Province.[11] Project objectives were to provide surface drainage for about 516,000

[11] Project implementation completed after 4 years of scheduled completion in 1993. The total cost when the IDA credit closed was US$845.1 million, but this was expected to rise to US$ 1,021 million when the project completed in 2002.

ha and subsurface drainage for about 392,000 ha and transport excess water and salts out of the area. The project components were: (i) remodeling and completion of the main outfall drain to the ocean, (b) construction of a surface and subsurface drainage systems over about 970,000 ha; (iii) remodeling and rehabilitation of associated irrigation works; (iv) consulting services and training; and (v) a monitoring and impact evaluation. In 1993, after a mid-term review, the project objectives were expanded including decentralization, beneficiary participation and private sector dimensions. The project has seven financiers (ADB, CIDA, SFD, ODA/DFID, OPEC, IsDB, SDC, M&E Trust Fund (SDC/DFID/CIDA)). The cost overran by 61%, which was caused mainly by security-related problems, substantial additional works not identified at appraisal, design changes and weak contractors.

57. **The project performance*.*** At loan closing date, the physical works were substantially complete. However, some drainage areas were yet to be connected, and irrigation improvements not fully completed including off-stream reservoir was delayed by resettlement problems. Production, social and institutional benefits delayed and were considerable. The project outcome was rated marginally satisfactory, since the process has been long and tortuous, costs have risen greatly, and the project delayed by four years.

58. The main drain was completed to allow discharge of salt and storm water to the sea. Watercourse level works exceeded targets (channel rehabilitation and land leveling). Substantial crop production increases attributable to the project have been identified by impact studies. Some improvement in land tenure patterns have been identified and women's groups are being formed to pursue their concerns.

59. The **shortcomings** included significant delay, neglected social, institutional, fiscal and sustainability aspects in the initial design, prolonged law and order problems in the interior of Sindh, unusually heavy rainfall in three years (1988,1992 and 1994), design changes requested by cofinanciers, and poor performance by the contractors. The closing date was extended by four years and even works did not complete. The original project design exclusively focused only on engineering construction to solve complex technical, environmental, financial and social problems. The M&E component was flawed in design and execution, despite efforts by both borrower agencies and financing partners to resolve its problems.

60. **Lessons learned.** Following lessons were learned:

- A major multi-disciplinary project of this type and complexity require a higher order of preparation and detailed planning than either the donor or borrower were accustomed to at the time;
- Early and determined action was needed for efficiency and cost containment to resolve problems on slow moving projects;
- complex engineering/social programs need careful analysis of institutional capabilities and risks as critical inputs to realistic scheduling, and some contingency time built into the program.
- sustainability, including drainage technology and performance, O&M performance, role of the FOs, and plans for future operation of the system should be fully considered; and
- contracting arrangements, including construction quality and to remedial work being needed for serious problems with the "tidal link".

3.7 Maintenance and Operational Management of Mega Projects—A Chronic Issue

61. Maintenance and operational management (MOM) of irrigation and drainage infrastructure has always been problematic. Scheumann and Memon (2003) showed that maintenance of tile drainage and SCARP tubewells fell sharply after handing over it from WAPDA to provincial irrigation departments. Underfunding and departmental hierarchy in budget allocation have been the main constraints for poor maintenance. The Punjab Drainage Circles' establishment, for example, reaches or exceeds international standards in terms of the number of maintenance personnel employed. However, the large working forces of both units—SE SCARPs and SE Drainage Circles—have been unable to cope with drainage requirements because of low labor productivity, lack of qualified staff, and PID staff indifference to the users' drainage demands.

62. Both inadequate drainage infrastructure and poor irrigation system performance have increased the need for land reclamation. The current rate of land reclamation is lower than the rate of soil deterioration. Reportedly, the land reclamation activities were successful in the areas where farmers committees were established and functional (Scheumann and Memon, 2003). Experience of participatory management of drainage showed modest success. For example; the drainage beneficiary groups (DBGs) in low lying areas and areas where social mobilization was more effective were successful. Transfer of public tubewells in freshwater areas to the community was also successful. However, DBG in tile drainage area due to high maintenance cost and transfer of public SCARP tubewells in saline groundwater areas have been challenging.

3.8 Biological Management of Salinity—Nonstructural Approach

63. Qureshi and Sarwar (2009) reported that plantation of salt tolerant crops was successfully demonstrated in the Indus Basin. For example; sugar beet are more salt tolerant at germination stage, barley at the early seedling stage and rice at the flowering stage. Growing salt-tolerant plants such as kallar grass and jantar has also been successfully tested in saline soils. They further add that agricultural and industrial waste, e.g., farmyard manure and byproducts of the sugar industry, have been used to improve soils affected by high sodicity. A large range of acid materials has also been tested in Pakistan including sulfur, sulfuric acid, and aluminum sulfate.

64. **Biosaline Agriculture.** Salt tolerant grasses, trees and salt bushes were tested, however, success of biosaline agriculture hinges on the socio-economic conditions and level of community participation. In Pakistan, the generally recommended salt-tolerant plant-species include: "Kallar" grass, Artiplex spp, Acacia spp. and Eucalyptus spp. (Zia *et al.*, 1986, Zia and Rashid, 1995). UNDP and AusAid's biosaline project 1997 rehabilitated 630 ha salt-affected soil through Salt-Land Users and Women Interest Groups in Punjab. The project also generated livelihood opportunities for poor including fish farming and livestock. The project was rated most successful (UNDP and Government of Pakistan, 2006).

65. Lashari *et al* (2015) recommend practicing bio-saline agriculture and brackish water ponds for fisheries development in Indus Basin in Sindh, where saline groundwater occurs in 70% of the area and soil salinity affects 20% of land. Bio-saline agriculture can make use of salt-loving halophytes and special varieties - such as Sesbania sesban, an appreciated fodder shrub that can yield as much as 7.5 ton per ha of dry matter or fodder grasses belonging to the family of the Poaceae. Existing varieties of common crops (wheat, sorghum, sugar- beet, potatoes, etc.) should be tested adapting brackish water use on free draining soils. Similarly, testing and adaptation planting on ridges and high value fruit trees such as mango on top of field bunds can also among the options to live with salinity.

3.9 Scale is Important in Salinity and Agricultural Water Management

66. The Indus Basin resources and services are enormous and resource linkages are complex. An action at one place in a specified time could have reaction at same or at different place at different time. Water and salt balance in the basin are dynamic and continue to change with time and in space. Therefore, an appropriate strategy and informed decisions are critical for sustainable improved SAWM in the basin. Secondly, salinity cannot be eliminated in absolute terms, the possible solutions and options should have a room to live with certain level of salinity. Thirdly, a SAWM framework with socio-economic and health indicators may help in better management planning. The SAWM framework may suggest an impact pathway, feedback and monitoring and evaluation mechanism and management planning review and implementation. Determining appropriate planning, management and implementation scales can only ensure cost-effective solutions and sustainable long-term benefits. Being natural hydrological units, farm, canal command or drainage area and basin/sub-basin could be appropriate scales for work.

67. Lashari *et al.* (2015) in the context Indus Basin in Sindh, Pakistan recommend six points action agenda to improve SAWM, which includes (i) rationalize irrigation duties, (ii) increase and intensify irrigated area, (iii) Improve field water use efficiency, (iv) well targeted and selective drainage investment, (v) make use of storm water and (vi) adapt to saline conditions in some areas. For six canal command areas, they suggest priorities for water management, investment and agriculture, which is a good example of working scale (Table 3). Broadly, the water management priorities require policy decisions at canal command or larger scale. The agricultural priorities shall be implemented with farmers at farm scale. The investment priorities will however, be selective depending on the effectivity and connectivity of on-farm, off-farm and terminal drainage.

Table 3: Broad Agenda for the Six Command Areas in Sindh (adopted from Lashari *et al*. 2015)

Area	Water Management Priorities	Investment Priorities	Agricultural Priorities
Guddu Right Command	Rationalize irrigation duties	Restore surface drainage	Introduce more efficient rice irrigation
Guddu Left Command	Rationalize irrigation duties	Restore surface drainage	Use fresh water zones for high value crops
Sukkar Right Command	• Rationalize irrigation duties • Improved field irrigation	Restore surface drainage	Introduce more efficient rice irrigation
Sukkur Left Command	Relocate/increasing supplies to fresh groundwater areas	• Selective rehabilitation of saline drainage wells • Escapes structure • Lining of drainage section that are in fill	
Kotri Right Command		Restore surface drainage	Reconsider cropping pattern to low delta crops
Kotri Left Command	Rationalize irrigation duties	• Flap gates at tail of drains to prevent sea water intrusion • Selected drainage investments	• Reconsider cropping pattern to low delta crops • Introduce biosaline agriculture and aquaculture • Introduce more efficient rice irrigation

Farm and Field Scale

68. Traditionally, three levels of scale have been tested addressing the water logging and salinity management in the Indus Basin. Farm and field scale is suitable for water intensive leaching approach, chemical amelioration of improving soil structure, biological approach of salt loving grasses, physical approach of sub-surfacing and deep plowing, all farmers or community-based interventions. At this scale, the saline-sodic soils have been reclaimed or their productivity increased through use of gypsum, farmyard manure, surface scraping and deep plowing. Barani Village Development project (BVDP; 2003-2006) and Integrated Watershed Development Project in Pothowar region in Punjab successfully tested use of Gypsum to improve farmers' income and profitability from the saline soils.[12] Ali and Kahlown (2001) concluded use of Gypsum for reclamation of saline soils and showed that subsidy on Gypsum increased its use 600 ton in 1972 to 218,000 tons in 1980 and reclaimed area increased from 177 ha to 29,000 ha; almost 165 times in 8 years. Based on experiments in Punjab from 1980 to 1985, it was concluded that use of Gypsum for Khurianwala soil and subsoiling plus Gypsum for Ghandara soils produced best results (Ahmad *et al.* 1998).

69. Water course improvement and laser land levelling reportedly helped conserve water and improve water productivity and biosaline agriculture—plants that survive in saline soils and have monitory value, all were tested and in some cases well demonstrated with the farmers/communities. Biosaline agriculture could be potential intervention at this scale. Potentially, it could create "bright spot" demonstrating a good example of living with the nature. Sheikh and Ashraf (2009) evaluated use of low quality groundwater for crop production at farmers' field in Punjab, Pakistan. They found that from 15% to 40% more area can be irrigated as compared to the farmers' practices by adopting the following strategies:[13]

(i) leaching of salts at the end of cropping season is required for use of saline groundwater.
(ii) mixing canal and groundwater in the ratio of 25:75 is more appropriate for use of sodic water.
(iii) a hybrid combination of mixing-cum-cyclic or cyclic- cum-mixing mode is more reasonable for use of saline-sodic groundwater. The reduction/stability in soil properties (ECe, SAR, infiltration rate) has been observed in most of the treatments.

Canal Command Scale and Integrated Research Sites

70. A canal command is potentially a hydrological control unit that is suitable for (a) planning and management of interventions such as drainage (horizontal or vertical; surface or subsurface) and (b) based on performance indicators monitoring and evaluation of the interventions. This scale also provides opportunity to assess the accumulative or combined impacts of farm-scale and canal command scale interventions. Canal command area in Indus basin varies from a few thousand hectares to hundred thousand hectares and it offers flexibility for up- and down-scaling as needed. Sarwar *et al*. (2007) based on field experiment covering 500 ha in Surezai area near Peshawar concluded that farmers' rehabilitation of the collector open drain helped lowering of water table, made land cultivation possible and increased crop yield.

[12] The author's experience of these projects.
[13] Caution: reduction in soil properties (ECe, SAR, infiltration rate) was noted in most of the treatments.

71. The BVDP introduced the concept of integrated research sites (IRS) and tested various livelihood options in salt-affected soils with the farmers. At IRS Kasilain in Punjab, the project used approach of raising range on abandoned salt-affected land (ICARDA 2006). The Soil Salinity Research Institute (SSRI) Punjab was research partner at IRS, Kasilian with the farmers. The electrical conductivity (EC) varied from 4 to 39 within the IRS. The survival rate of different range species was encouraging: Acacia nilotica (94%), Iple Iple (90%), Atriplex numularia (78%) and Atriplex modesta (78%). After 3 years (2003-2006), the average pruned material was 1.09 kg per plant. The plant height of Acacia nilotica varied from 14.6 feet, 18.3 feet and biomass varied from 135 kg to 231 kg for all the three fields at the IRS, which was a good success. The farmers trials on crops (cotton, rice, sorghum, millet) using marginal quality groundwater showed modest success. The farmers obtained yields: cotton (2.1 ton/ha); rice (1.9 ton/ha); sorghum (8 ton/ha) and millet (7.8 ton/ha). Unfortunately, water and soil quality data was not available due to termination of the project and closing of IRS and long-term effect of saline groundwater use could not be assessed.

River Basin Scale

72. River Basin Scale (RBS) is suitable for strategic planning, assessment of linkage interactions and benefit optimization. RBS is important for improvement of SAWM in the Indus Basin for disposal of drainage effluent that fits in the existing large scale and contiguous irrigation system. It also provides opportunity to assess the impact of upstream actions at downstream. Strategy to improve SAWM in Indus Basin may be benefitted from review/development of Indus Basin Drainage Plan (IBDP) for medium to long term actions. The drainage plan should identify, screen and rank the appropriate interventions at all the scales and should be the basis for investment in the drainage subsector.

3.10 Groundwater Management—A Neglected Segment

73. Groundwater supports almost 50% of irrigation supplies and a large proportion of domestic and industrial needs in the Indus Basin in Punjab. It offers a low-cost water reservoir and acts as buffer against drought. It is a mean of equitable water distribution and it facilitates demand-driven water uses. However, groundwater use requires informed regulation due to underlain brackish strata, over pumping and saltwater intrusion and possibility of secondary salinization. Also, groundwater of the Indus plain is charged with dangerous limits of bicarbonate and sodium contents and their indiscriminate use can make the soils alkaline and impermeable and is suggested to not install the tubewells in areas where concentration of bicarbonate or sodium is very high (Mohammad and Bearing, 1962).

74. In some parts of Sindh, abundance of surface water is disincentive for the farmers to use fresh and shallow groundwater for irrigation. Recharge from the canals continues to rise groundwater causing water logging and salinity, declined agricultural production and health hazards. In 2011, the groundwater table was less than 1.0 m over 2.19 million ha area (36% of the 5.96 million ha of irrigated agriculture land), between 1.0 and 1.5 meters over 2.04 million ha (33.6%) between 1.5 and 3.0 meters over 1.29 million ha (21.2%), and between 3.0 and 4.5 meters over 0.34 million ha (5.5%).[14] Flooding in summer, further aggravate the shallow groundwater table. Shallow groundwater combined with flooding cause salinity, low agricultural

[14] Lashari *et al* 2015 with source from SCARP monitoring organization.

production and public health risks. Reallocation of surface water and conjunctive use of both the surface and groundwater can free up some of the surface water for other uses, lower the groundwater table, reduce salinity, increase agricultural production and reduce health risks (Lashari *et al.* 2015).

75. The key disadvantages of unmanaged and unregulated conjunctive use are that upstream areas experience rising water tables whereas tail-end areas are exposed to increased salinity problems due to excessive use of poor quality groundwater (Qureshi, 2014). Unfortunately, groundwater management is grossly neglected. There is no strong ownership, no or little technical guidance of aquifer in use and no regulatory framework and enforcement of groundwater laws. A couple of assessments under various projects and initiative were carried out which strongly suggest a need for technical, institutional and policy and legal framework leading to the managed aquifer. This is critical for both water and salinity perspective.

76. On a positive note, Punjab has very recently developed groundwater legal and regulatory framework, which is at a stage of review and approval. This is one step forward and should be appreciated. However, the framework is not backed by comprehensive assessment and policy, weakness of the regulatory framework will only be known during implementation. Further, institutional arrangements for management of groundwater remain sketchy. A comprehensive assessment of groundwater monitoring and management in the Indus Basin is required. Qureshi (2015) examined the benefits of groundwater development, institutional approaches and resource management and concluded that groundwater management in Pakistan requires multifaceted actions focusing both on supply- and demand-side solutions including stabilizing aquifer, revisiting conjunctive use of surface and groundwater, increasing productivity of groundwater use and improving groundwater governance.

4. SUMMARY, LESSONS LEARNED AND FUTURE DIRECTIONS

77. **Salinity is more than Biophysical Problem.** Salinity is a socio-economic, environmental and well-being problem. It degrades land, reduces agricultural productivity and causes health hazards. In Pakistan, salinity affected 40% of the irrigated land which is double the World average of 20%. In Indus Basin, groundwater induced secondary salinization caused abandoning 40,000 ha land annually (WAPDA, 1989). The Country suffered from high cost due to waterlogging and salinity: crop yield of salt-effected soils varied from 25% to 40% of the yield from normal soils (Ahmad, 1968); land degradation (salinity is part) caused an estimated loss of $250 million per year (Haider *et al*. 1999), and a total damage cost of about $2.0 billion (water-logging = $0.5 billion; salinity = $1.5 billion (Anjum *et al.* 2010). Damage cost due to poor living standards, health hazards and declined livelihood opportunities and forced migration was not accounted.

78. **The Salinity Factors are Interlinked in Complex Manner.** Natural settings, inappropriate management actions and flawed farmers practices cause salinity. The main factors causing salinity are: (i) salt in the original soil profile; (ii) irrigation-induced accumulation of 14. 4 million ton salts in the soil profile and groundwater, annually (NESPAK and MMI, 1993);[15] and (iii) use of low quality groundwater for irrigation. Marginal quality groundwater use adds 100 million ton of salts to the soil surface every year (ICID, 1991). The surface water through canals adds an additional 50 million ton of salts to the system every year (Qureshi, 1993).[16] On an average one ton of salt is added to one hectare of irrigated land annually (NESPAK and MMI, 1993).

79. Water and salinity are linked with natural, socio-economic and environmental factors and processes in a complex manner. For example; irrigation from surface or groundwater accelerates soil salinity but over irrigation may be needed to leach the existing salts in the soil profile. Farmers concern is that water for irrigation should be available when needed with no or low attention to the water quality. Water managers concern is low flexibility in the supply-driven canal irrigation system. Policy-makers concern is priority setting and reallocation for water, food, energy and households water security and safety. The political government's concern is low agricultural productivity, food shortage and unrest. Finding workable and sustainable solution is challenging.

80. **Salinity and Agricultural Water Management has been Challenging.** The SAWM approach is viewed through related policy, strategy and investment in infrastructure. Draft NWP (2012) recognizes the salt build up in irrigated agriculture, increased intrusion of saline water in the Indus delta, groundwater management planning and regulatory zones, secondary salinization, water logging, and research as the main focus areas. Pakistan water sector strategy, 2002, identifies among others, deteriorating irrigation and drainage infrastructure and water quality, , water logging and salinity and disposal of saline drainage effluent as the main issues. It emphasizes IWRM, regulating groundwater, improving water quality, reducing water logging on 2.8 million ha and providing long-term and safe solution of saline drainage effluent as the main objectives. The strategy also prepared short-, medium-,and long-term action plan (Government of Pakistan, 2002). So far, implementation of the strategy action plan remains weak. Of the

[15] [Refer to para 6]: Of an average annual salt inflow of 33 million ton to the Indus Basin, around 16.4 million ton is washed to sea and remainder 16.6 million ton remains within the system. Only 2.2 million ton is deposited in series of evaporation ponds. A balance of about 14. 4 million ton of salt accumulates in the soil profile, underlying strata and the aquifer of the Indus Basin.

[16] The two references [NESPAK and MMI, 1993 and Qureshi, 1993] shows a large difference of annual salt accumulation but both signify the issue.

planned investment of $11 billion, hardly any significant work on waterlogging and salinity, drainage and groundwater was completed during the strategy period from 2002 to 2017.[17]

81. With some exceptions, the institutions did not meet the requirements of changing environment. Lacking in evolution and declined capacity, most of these institutions have become non-responsive and irrelevant with time. Some of the best institutions in the past are now struggling for survival. Water and salinity related legislation was insufficient and enforcement was weak. The mega projects with some early success became liability due to inadequate MOM. Groundwater and drainage remained on low priority after failure of NDP in 2002. The infrastructure-based approach of SAWM dominated and masked the potential of participatory and community-based approaches. The main lesson learned from SAWM are as follows:

General

1. In the Indus Basin, salinity persists and continue to affect water and land productivity and accelerate land degradation.
2. The cost of land degradation induced by waterlogging and salinity is high and negatively impacts the food security and economic development.
3. Seasonal fluctuation of the extent of saline area depends on several factors including groundwater uses, water availability for leaching, rainfall, drought, floods, soil treatment, crops and management practices. Therefore, difference in reported values of the salt-affected area is explainable.
4. Implementation of Strategy 2025 may require an immediate midterm review; particularly for SAWM. It may help restructuring the action plan and incorporating the lessons learned.
5. Improved water management is important for management of salt-affected land. Conjunctive use of surface and groundwater is part of the solution, if appropriately implemented.
6. Groundwater management is critical for management of salt-affected land but little attention was paid to this important resource. Given, the importance of groundwater for (i) management of salt affected land, (ii) minimizing the impacts of drought, (iii) acting as buffer against climate change impacts, (iv) improved land and water productivity, and (v) meeting social needs; improving the groundwater governance is important.
7. Punjab's efforts preparing groundwater law is appreciated but absence of proper assessment and knowledge base, it may face implementation difficulties. A parallel assessment and groundwater information system may help in effective implementation. Appropriate institutional arrangement for groundwater management will be absolutely necessary. ADB's on-going capacity development assistances for revival of River Ravi and institutional transformation and upcoming TA loan may help and complement the other parallel efforts for effective SAWM.[18]
8. Sustained production from irrigated agriculture requires technical knowhow and skills of surface and groundwater, soil, crop and climate. For example; shallow groundwater can be advantageous for sub-irrigation, if it does not constrain plant root zone. So managed groundwater aquifer is important. It means reduced cost of irrigation with no decline in crop yield.

[17] The strategy period runs through 2002 and 2025.
[18] ADB approved the capacity development technical assistances: institutional transformation in 2016 and revival of Ravi basin in 2017. A technical assistance loan to prepare future irrigation, drainage and water sector projects is in process of approval in 2018.

9. Maintenance and operational management (MOM) has been a generic problem associated with almost all public sector projects and should be duly considered in investment planning.

Farm-Scale interventions

10. Several farm-scale interventions have shown good results including use of gypsum, leaching, deep ploughing, adding animal manure, salt tolerant crops and grasses, biological drainage. This experience can be successfully adapted in the areas of similar geographical and socio-economic environments. For upscaling, agro-climatic, hydro-ecological and socio-economic characterization, ranking and bundling can help improve adoption rate. The interventions that increase farmers' profitability are more likely to have high adoption rate.
11. Farmers advisory and information system (irrigation, weather, soil-moisture, market, disaster) may help better manage the water and salt-affected soils. Field level interventions such as grading for uniform application of irrigation water can help reducing the danger of over or under irrigation and improving the yield.

Mega Projects

12. The mega projects had comparative advantages: resource availability, political will and immediate development focus. Some of the mega projects such as SCARP, SCARP transition and Punjab groundwater development projects were rated successful achieving their specific objectives. LBOD was rated partially successful and NDP was rated unsuccessful.
13. Implementation of the mega project faced several challenges. Quality at entry problem, complexity and stakeholders' non-cooperation and low institutional capacity have been identified as main causes of unsuccessful mega projects. The other weaknesses of the mega projects include: (i) high investment cost, (ii) ineffectual maintenance and operational management, (iii) inflexible to change and innovations, and (iv) low sustainability. Their impacts continued to decline. Groundwater governance was very weak lacking at policy, strategy and operational levels such as regulatory framework and enforcing mechanisms. NDP failed due to flawed design.
14. The mega projects had mix impacts at the farm, canal command and basin scales. For example, at farm scale, SCARP in fresh groundwater areas increased cropping intensity, crop yield and farmers' income. At canal command scale, the SCARP lowering groundwater levels reduced waterlogging and salinity, augmented the canal flows contributing to the reliable irrigation supply and increased agricultural production. At basin scale, it reduced land degradation, stabilized agricultural production and contributed to the water and food security.

Future Directions

15. Although NDP was unsuccessful, but it drafted the drainage sector strategic research and development plan (SRDP). Exposing the weaknesses it has set the pathway for institutional reforms in future.[19] Updating the SRDP for groundwater, salinity and drainage; educating the stakeholders' and building a broad-based consensus can lay the foundation for sustainably improved SAWM in the Indus Basin.
16. Combating salinity does not necessarily mean eradicate salinity. Often, eradicating salinity may not be a cost-effective solution. The SAWM may be viewed through the

[19] SRDP can be part of a broad-based Indus Basin Plan. The Plan may cover cross-sectoral water interactions including identifying strengths and weaknesses, possible conflicts or threats and synergies, and management planning that paint Indus Basin's global picture and is flexible to allow conducive actions at local or regional scales.

community's livelihood opportunities and reduced risk to the land and people living in the salt-affected areas. Learning to live with salt-affected soils could be one of the management options. Farmers need alternate options to increase the profitability from the saline land. A part of future investment in SAWM may be guided through the concepts of "living with salinity", reduced risks and improved livelihood of the people. This may require investment in awareness raising and people capacity building.

17. The Indus Basin's water, salinity and drainage issue is complex and has several unsuccessful stories. A least harm, cost-effective and early impact approach for SAWM is needed. Based on critical review of the water and land governance—policy, strategy and institution are part; an informed SRDP should guide on the future investment in SAWM in the Indus Basin in medium to long term. In short term, however, well-planned, farm-scale and farmers based tested interventions may help for immediate impacts on land, water and people.
18. Identifying the bright spot and best land practices within the Indus Basin and characterizing, screening and ranking them for upscaling could be one of the efficient and cost effective way to approach the salinity problem.
19. Basin-based investment and management planning, strategic framework for MOM and establishing, monitoring, evaluation and feedback mechanisms may help sustainably improve the management of water and the salt-affected soils. Combinations of basin-based planning, command area-based monitoring and farm scale interventions or local actions could be better strategy to address the issue.
20. A preliminary Design and Monitoring Framework for a potential future project is in Appendix 4 for further brainstorming.

References

Ahmad, H. B. (1968) Economics of Soil Erosion in Gujrat District. M.Sc. Thesis, Department of Agricultural Economics, West Pakistan Agricultural University, Lyallpur.

Ahmad, B., Ahmad, M., Gill, Z.A. 1998. Restoration of Soil Health for Achieving Sustainable Development Growth in Agriculture. The Pakistan Development Review 37:4, Part II, 997-1015.

Ali, T. and Kahlown, A. 2001. Role of Gypsum in Amelioration of Saline-Sodic and Sodic Soil. International Journal of Agriculture and Biology. Web. http://www.ijab.org accessed 24 December 2017.

Anjum, S., Wang, Lc, Xue, Li, Saleem M.F., Wang, Gx and Zou, Cm. 2010. Desertification in Pakistan: Causes, Impacts and Management. Journal of Food, Agriculture & Environment, Vol.8 (2). www.world-food.net accessed 25 December 2017. Original reference is: Sheikh, I. A. 1991. Country report of Pakistan. Proc. Information Seminar on Waterlogging and Salinity in Some Problematic Countries. Lahore, Pakistan.

Bhatti, M.A., Kijne, J.W., 1992. Management of groundwater abstraction in Gugera Branch. In: Vlotman, W.F. (Ed.), Proceedings of the 5th International Drainage Workshop on Subsurface Drainage on Problematic Irrigated Soils: Sustainability and cost effectiveness, vol. III, 8–15 February 1992. Lahore. Water and Power Development Authority (WAPDA)–International Waterlogging and Salinity Research Institute (IWASRI), Lahore, Pakistan, pp. 3.73–3.85.

Government of Canada and Government of Pakistan. 1958. Landforms, Soils, and Land Use of the Indus plain, West Pakistan. Published for the Government of Pakistan by Government of Canada; A Colombo plan Cooperative Project, Toronto. http://www.pide.org.pk/pdf/PDR/1963/Volume2/250-278.pdf accessed 25 December 2017.

Government of Pakistan, 1997. Agricultural Statistics of Pakistan 1996-97. Ministry of Food, Agriculture and Co-operatives, Food and Agriculture Division, Islamabad.

Government of Pakistan. 2017. National Policy Dialogue on Salt-affected Soils held on 7 March 2017 in Islamabad. www.fao.org/pakistan/news/detail-events/en/c/522681/ accessed 27 December 2017.

Government of Pakistan. 2002. Pakistan Draft National Water Policy. Ministry Water and Power (also revised in 2012), Government of Pakistan, Islamabad.

Government of Pakistan. 2002. Pakistan Water Sector Strategy. Office of the Chief Engineering Advisor/ Chairman Federal Flood Commission, Ministry of Water and Power, Government of Pakistan, Islamabad

Haider G, Prathapar SA, Afzal M, Qureshi AS. 1999. Water for Environment in Pakistan. Paper presented in the Global Water Partnership Workshop, 11 April 1999, Islamabad, Pakistan. Islamabad, Pakistan. In: Qureshi, A.S. 2011. Water Management in the Indus Basin in Pakistan: Challenges and opportunities. Mountain Research and Development, 31(3):252-260. 2011. International Mountain Society. https://waterinfo.net.pk/sites/default/files/knowledge/Water%20Management%20in%20the%20Indus%20Basin%20in%20Pakistan%20-%20Challenges%20and%20Opportunities.pdf accessed 30 December 2017.

Hussain, N. and Mehdi, M. 2008. Objectives and achievements of Soil Salinity Research Institute.

https://www.researchgate.net/publication/272245248_OBJECTIVES_AND_SALIENT_ACHIEVEMENTS_SOIL_SALINITY_RESEARCH_INSTITUTE_SSRI_Pindi_Bhattian_Pakistan accessed 2 February 2018.

ICARDA. 2006. Annual Reports 3, 4 and 6. Barani Village Development Project. International Center for Agricultural Research in the Dry Area, Aleppo Syria and Country Unit.

ICID, 1991. Country Report on Irrigation and Drainage Development in Pakistan. International Commission on Irrigation and Drainage Annual Report for Asia.

Javed, M. 1989. Impact of Different Water Table Depths with Special Reference to Rice Growing Area of Sheikhupura District. M.Sc. Thesis, Department of Agricultural Economics, University of Agriculture, Faisalabad.

Bakhshal Khan Lashari, Habib Ursani, Mohamed Basharat, Frank van Steenbergen, Mustafa Ujan, Zarif Khero, Naseer Essani Memon, Sukru Esin, Abdul Wasay Sheikh, Mir Aijaz Hussain Mahar, Afsheen Bashir, Ghazala Channar, Arshad Hussain, Munir Amed Mangrio, Shafi Muhamemed Kori, Ghulam Hussain Wagan, Shah Nawaz Chandio, Atta Muhammed, Mansoor Ahmed, Ali Ahmed Detho, Agha Akhtar Mehmood, Kousar Ali, Amber Jawad, Abdul Wahid, Shakir Habib Memon, Afshan Mallah, Cecilia Borgia, Shamshad Gohar. 2015. The Promise of Conjunctive Management of Surface and Groundwater in Sindh. Shared Discussion Paper. Meta Meta groundwater Magazine.

Bhutta, M. N. and Smedema, L. K. (2007). One hundred years of waterlogging and salinity control in the Indus valley, Pakistan: a historical review. (personal communications with Mohammad Nawaz Bhutta on 15 February 2018). Published in Journal of Irrigation and Drainage. Volume 56, Issue Supplement S1. December 2007.

Khan, S., Tariq, R., Yuanlai, C. Blackwell, J. 2004. Can Irrigation be Sustainable? New directions for a diverse planet". Proceedings of the 4th International Crop Science Congress, 26 Sep – 1 Oct 2004, Brisbane, Australia. Published on CDROM. Web site www.cropscience.org.au

Mohammad, G. and Bering, C. 1962. Water Logging and Salinity in West Pakistan: An Analysis of the Revelle Report. A review Article. Institute of Development Economics, Karachi, Pakistan. http://www.pide.org.pk/pdf/PDR/1963/Volume2/250-278.pdf accessed 25 December 2017

Mustafa, U. 1991. Economic Impact of Land Degradation (Salt Affected and Waterlogged Soils) on Rice Production in Pakistan's Punjab. Ph.D. Thesis, Unpublished, University of Philippines at Los Banos.

NESPAK and MMI. 1993. Feasibility Study of National Drainage Program I. National Engineering Services of Pakistan and Mott MacDonald International, Pakistan.

Pakistan science foundation blog 28 January 2013 article Saline Agriculture in Pakistan-A Profitable Way to Tackle Salinity

Qureshi, A.S., Asghar, M.N., Ahmad, S., Masih, I., 2004. Sustaining crop production under saline groundwater conditions: a case study from Pakistan. Aust. J. Agric. Sci. 54, 421–431. In Qureshi A.S., McCornick, P.G., Qadir, M., and Aslam, Z. 2008.Managing Salinity and Water Logging in the Indus Basin. Agriculture Water Management 95(1):1-10. https://www.researchgate.net/publication/222935494_Managing_salinity_and_waterlogging_in_tht_Indus_Basin_of_Pakistan accessed 23 February 2018.

Qureshi A. L., Lashari B. K., and Kori, S. M., and Lashari, G. A. 2011. Hydro-salinity behavior of shallow groundwater aquifer underlain by salty groundwater in Sindh, Pakistan. Paper presented at Fifteenth International Water Technology Conference, IWTC-15 2011, Alexandria, Egypt.

Qureshi, A.S., Shah, T., Akhtar, M., 2003. The Groundwater Economy of Pakistan. International Water Management Institute, Colombo, Sri Lanka 23 pp (IWMI Working Paper No. 64).

Qureshi, A.S. and Sarwar, A. 2009. Managing Salinity in the Indus Basin of Pakistan. International Journal of River Basin Management Vol. 7, No. 2. https://www.researchgate.net/publication/261994457_Managing_salinity_in_the_Indus_Basin_of_Pakistan accessed 18 December 2017.

Qureshi, A.S. 2014. Reducing Carbon Emissions through Improved Irrigation Management: A case study from Pakistan. Irrigation and Drainage 63: 132-138.

Qureshi, A.S. 2015. Improving food security and livelihood resilience through groundwater management in Pakistan. Full Length Research Paper. Global Advanced Research Journal of Agricultural Science (ISSN: 2315-5094) Vol. 4(10) pp. 687-710, October, 2015. Copyright © 2015 Global Advanced Research Journals. http://garj.org/garjas/home accessed 18 January 2018.

Qureshi, R. H. 1993. Alternative Strategies for Tackling the Soil Salinity Problem. Faisalabad: Department of Soil Science, University of Agriculture.

Sarwar, T., Bilal S. M., Naveedullah, Khan M.J. and Tariq J. 2007. Management of Small-Scale Water Logging through Surface Drain Maitenance. Sarhad J. Agric. Vol. 23, No. 2, 2007.

Scheumann, W. and Memon Y.M. 2003. Reforming Governance Systems for Drainage in Pakistan: Toward an Interdisciplinary and Integrated Approach to Agricultural Drainage. Agriculture and Rural Development Working Paper no 11. The World Bank, Washington DC. http://documents.worldbank.org/curated/en/557541468283497201/pdf/716540NWP00PUB0kistan0final0format1.pdf accessed 8 February 2018.

Shah, T., Debroy, A., Qureshi, A.S., Wang, J., 2003. Sustaining Asia's groundwater boom: an overview of issues and evidence. Nat. Resource Forum 27, 130–141.

Shahzad, R., Jamil, S., Rahman,S and Iqbal, Z. 2017. Salt Stress and its Impact on Crop Productivity in Pakistan. Agri Hunt blog in May 2017. https://agrihunt.com/articles/salt-stress-and-its-impact-on-crop-productivity-in-pakistan/ accessed 30 December 2017.

Sheikh, A.A. and Ashraf, M. 2009. Use of Low Quality Groundwater for Sustainable Crop Production. Agriculture with low quality groundwater. LAMBERT academic Publishers.

Soil science by A Rashid chapter no 16 "soil salinity, sodicity and water logging. Page no 471-506

UNDP and Government of Pakistan. 2006. Project Report for Biosaline Agriculture II. Punjab Community Development Project for Rehabilitation of Salt-affected and Waterlogged Lands.

WAPDA. 1989. PC-II Performa for monitoring Salinity Control and Reclamation Projects, SCARPs for the period 1989–1993. SMO Publication, Water and Power Development Authority, Lahore, Pakistan.

WAPDA. 2006. Survey Report. Salinity and Reclamation Directorate, SCARP Monitoring Organization, Water and Power Development Authority, Lahore Pakistan. In Zaman, S. and Ahmad, S. 2009. Salinity and Water Logging in the Indus Basin of Pakistan: Economic Loss to Agricultural Economy. Research Briefings for Managing Natural Resources for Sustaining Future Agriculture Vol. 1, No. 4. Pakistan Agriculture Research Council, Islamabad. http://waterinfo.net.pk/sites/default/files/knowledge/Salinity%20and%20Waterlogging%20in%20the%20Indus%20Basin%20of%20Pakistan%20Economic%20Loss%20to%20Agricultural%20Economy.pdf accessed 12 December 2017.

Zaman, S.B., Ahmad, S. 2009. Salinity and Waterlogging in the Indus Basin of Pakistan: Economic Loss. Managing Natural Resources for Sustaining Future Agriculture. Research Briefings Volume (1), No (4), 2009. http://waterinfo.net.pk/sites/default/files/knowledge/Salinity%20and%20Waterlogging%20in%20the%20Indus%20Basin%20of%20Pakistan%20Economic%20Loss%20to%20Agricultural%20Economy.pdf accessed 10 December 2017.

Zia, S., Mahmood, T., Baig, M.B. and Aslam, M. 2003. Land and Environmental Degradation and its Amelioration for Sustainable Agriculture in Pakistan. Quarterly Science Vision, Vol. 9, No. 1-2 (July-December).

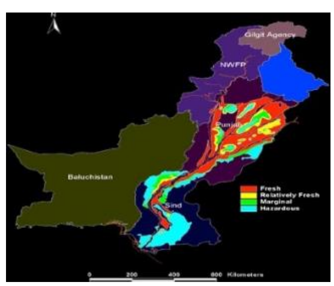
Appendix 1

Consultant Terms of Reference

- The consultant will review and summarize the Government of Pakistan's salinity management strategy for the Indus Basin of Pakistan and policies for controlling salinity.
- The consultant will undertake a critical review of salinity management approaches in the Indus Basin of Pakistan taking into account the technical, environmental and social aspects. This should include:
  - (i) A critical review of past projects, including those from ACIAR, ADB and World Bank.
  - (ii) Identification of project outcomes, costs and benefits, lessons learnt and long-term impacts.
  - (iii) An appraisal of whether recommendations from such projects have been adopted.
- The critical review should indicate any differences in outcomes, lessons and impacts between salinity management approaches at farm scale, canal command scale and basin scale.

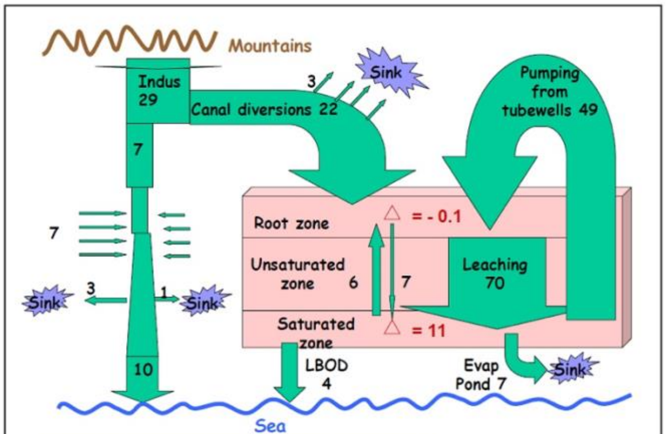
Appendix 2
Comments and Response Matrix

[Thanks to all the reviewers for their valuable comments and thereby contribution]

No.	Comment	Response
	Richard Culas	
1	There can be a clarity of the causes of salinity management and groundwater extraction. Because it is sated that increased groundwater extraction causes salinity but on the other hand more groundwater extraction is cited as a way for reducing the salinity problem.	It is better clarified in para 9. Groundwater extraction acts in two ways. In water logging or shallow groundwater areas, it helps reducing water logging and salinity. However, pumping from saline water zone for irrigation adds salts to the soil profile (up-conning or deep pumping) causing salinity. These two mechanisms have been referred at two different places and are relevant.
2	How waterlogging and salinity are related. They can be either related or unrelated issues. The other concern is that salinity can cause waterlogging but waterlogging can also cause salinity. This can be clarified with the location specific examples from Punjab and Sindh.	The issue is elaborated in section 2 under causes. Waterlogging induced salinity was more common case in the Indus Basin
3	Is it possible to include recent references on the salinity related impacts and data for Pakistan? There are some data provided on the extent of the salinity impacts in Pakistan, in relation to both physical and economic contexts.	Unfortunately, significant information on salinity impacts are not available for recent years. Funding constraints and institutions in transition have negatively affected the research capacity in water and salinity. IWASRI has drastically downscaled its operation and provincial research is in transition after devolution in 2010. Earlier, failure of NDP in 2002 also affected project-based research.
4	The terms used for 'holistic' and 'integrated' approaches can be elaborated (no overlaps).	The SRA uses “holistic” for approach and “integrated” for framework. This note maintains it.
5	Soil salinity and sodicity, how they can differ and be managed	Although water induced salinity and sodicity are part of similar process but their management differs. Salinity was managed through leaching and agricultural and biological practices. The sodicity however, needs soil amendment and was managed through use of Gypsum.
6	Fig 1 missing	Figure 1 is provided which is just indicative representation of spatial distribution of salinity but does not add significant value.  Fig. 1– Spatial distribution of composite groundwater quality in the Indus Basin of Pakistan (Qureshi et al., 2004).

7	Salinity management in relation to both surface and groundwater, so the issues surrounding both can be highlighted.	The relevant parts have been strengthened.
8	The reasons for the failures of previous schemes/ projects/ policies/ institutional approaches can be provided in some details.	The reasons for failure have been adequately elaborated but further detailing may make the note voluminous. For example, evaluation of NDP (design complexity), which is one of the reason for the project failure, is covered under one complete study/report by the World Bank.
	Bakhshal Lashari (MUET)	
9	Give few examples of best practices being adopted by the progressive or any farmer for managing the salinity and water logging control (Example: In Sindh I know one farm - Nawazabad Farm, he is managing water logging and salinity very effectively by using tile drainage, shallow tubewell, conjunctive ground and surface water, using gypsum etc.)	I reviewed work by ICARDA and SSRI and DRIP plus your provided information (Thanks for that). I have provided some information but unfortunately, documented authenticated information of “bright spots” that had impacted, are rare and not available.
10	Identify the major institutes who are working or have done significant research work on salinity management-though he has mentioned few like WAPDA and IWASRI etc	Discussion on the institutions is elaborated.
11	During LBOD project, I remember drainage beneficiary groups and probably women groups were established to look into the drainage side (If possible add some examples)	Unfortunately, I could not find successful DBG. In fact, DBGs was the weakest part of the institutional reform. Please see below an interest discussion and finding on DBG in Sindh. “Another major concern that has been misplaced somewhere in the debate on institutional reforms was the wholesale ignorance of drainage affairs during the implementation of reforms. Such an observation was particularly valid for the low-lying topography of the NC-AWB and LBC-AWB, where the farmers highly acknowledged the importance of the drainage network in maintaining the fertility of their farmlands. It was gathered that almost half of the FOs in both of NC-AWB and GC-AWBs had some form of drainage structures such as surface and tube well and tile drains. However, virtually none of those FOs had formed any DBG for managing their drainage structures. The FOs were reluctant to take over the responsibility of drainage management in purview of the payment of drainage levy [Official Correspondent Daily Dawn (2004)]. Since the government was not generating any revenue from the drainage facility, it ignored O&M of these structures until absolutely inevitable. As a result, the state of drainage structures was indeed miserable characterized by chocked drains and nonfunctional tube-wells. It was virtually in a state what the major theorist of Commons Pool Resources have explained as an open access resource [Berkes and Farvar (1989); Schlager and Ostrom (1992)] or an unmanaged common [Hardin (1968, 1994, 1998)—where everybody was a beneficiary but nobody was bearing the management responsibility.”

		[Ref. JUNAID ALAM MEMON and USMAN MUSTAFA. 2012. Emerging Issues in the Implementation of Irrigation and Drainage Sector Reforms in Sindh, Pakistan. *The Pakistan Development Review* 51:4 Part II (Winter 2012) pp. 51:4, 289–301. Web. https://www.researchgate.net/publication/259443590 accessed 26 February. 2018
	Jehangir Punthakey	
12	The structure and coverage of the literature review is good and in particular the building of the case of the issues around salinity in Pakistan.	Noted with thanks
13	In Para 1 you mention "on farm approaches showed limited success and basin wide interventions could not be sustained" It would be interesting if you also shared your insights on what you think will or should work in terms of long term sustainable management of salinity in Pakistan	In the past, the on-farm methodologies and technologies evolved as a result of fragmented research and practices. A systematic and well-planned research results based on environment characterization, screening and bundling to meet the specific needs were not available. Their dissemination and upscaling was weak and impacts remains limited. Lacking in drainage disposal (off-farm and main system) also constrained the impacts of on-farm approaches. As explained, the mega projects suffered from adequate and informed maintenance and operational management. In my opinion, addressing the issue may follow a phased approach. In first phase, strategic and investment plan may be developed and best practices identified and screened. It may include (i) a detailed IB plan and list of investments; (ii) a comprehensive on-farm package that may include screening, ranking and disseminating on-farm proven technologies, removing drainage hurdle that directly impede on-farm productivity, and credit and farmers advisory services; (iii) monitoring mechanism (groundwater, productivity, salinity, drainage) at canal command scale; and (iv) impact oriented projects (groundwater monitoring and management, surface water reallocation, and effective drainage) at basin scale. One plan and several actions that best fit and most conducive. The best approach would be the management of salinity and water within a manageable hydrological/ drainage boundary, which integrate on-farm approaches, conjunctive use of surface and groundwater and effective drainage (off-farm and beyond). Please see draft design and monitoring framework in Appendix 4 for the phase I project. Phase II may take a full fledge invest projects.
14	There is a number of places where the review mentions salinity affected areas between 6.2 and 7 million ha. That seems to be the consensus. Is this figure obtained from mapping? And if so is it possible that there are areas affected by salinity by regions: For example (i) doabs of Punjab; (ii) Canal command areas; (iii) Upper	The numbers have been taken from different references. These have been changing with time. Province wise information is provided in Table 2 and some details in Appendix 3.

	Sindh; (iv) Lower Sindh; (v) Delta regions.	
15	There is also mention that 70% or 4.3 mHa is severely affected – again is this dispersed over the whole basin? Can large areas be identified?	It is dispersed. About 1666 ha in Sindh and 1390 ha in Punjab. Remaining in Balochistan and KP (Refer to Table 2 in the text)
16	The review mentions 2017 – Pakistan's national policy dialogue on slat affected soils. Could we please have any document that you may have on this. Interestingly it mentions that secondary salinization was accelerating on 2 m ha due to GW use. So presumably if we can map the gw quality accurately we should be able identify these areas.	Representatives from International Waterlogging and Salinity Research Institute, Agriculture Extension and Research, national fertilizer companies and USDA, NFDC,IPI, PARC, NARC, ILRI, CIMMYT, ICARDA attended the dialogue on March 7 2017. Unfortunately, the numbers were mentioned in the presentation and proper references are not available.
17	40,000 ha are annually abandoned within Indus Basin due to salinization. How do that come up with this figure?	The original reference is Sheikh, I. A. 1991. Country report of Pakistan. Proc. Information Seminar on Waterlogging and Salinity in Some Problematic Countries. Lahore, Pakistan. Unfortunately, this report was not available.
18	Anjum et al 2010 paper on cost of salinity in Pakistan will be important for Richard and economists	Agreed
19	A figure showing the salt balance for the Indus basin would be particularly useful. There is one by Bhutta et al. shown below. Can we update and perhaps simplify? To give the message that 1 ton of salt accumulates per ha every year.	Bhutta *et al* figure is below. A simplified figure is inserted in the text.  Figure 53: Approximate current salt balance in the Indus Basin (million tonnes a year)
20	Your insights on why some of the mega projects failed was very interesting. It would be good if you can also suggest if you know of a program that was exceptionally successful in transforming irrigated agriculture, controlling salinity, improved livelihoods etc.	SCARP initially solved the problem and its transition timely reduced the government burden. However, it was more successful where direct individual benefits were involved (fresh groundwater tubewells) and it faced problems in common pool cases where communal and indirect benefits were involved (saline groundwater tubewells and off-farm drainage). Construction and operation of reservoirs (Tarbela, Mangla and Chashma) is also a good example. Well-designed mega projects (technical, institutional and O&M) ensuring longtime benefits were successful.

21	You mentioned national institutions such as Council of Common Interest (CCI) – It would be very useful if there is any policy or relevant documents that we can get.	CCI was established and operates under the Country Law and at highest level. Some information are available on net (https://pakistanconstitutionlaw.com/article-153-council-of-common-interests/). Others may be available on special request.
22	Some key references that you have cited would be very useful to get.	My pleasure to assist.
23	Some key points: groundwater and salinization are very closely linked (2 m ha suffer from secondary salinisation due to use of poor quality gw); Groundwater Management – a weak and neglected segment The impact of decline in productivity due to slainisation is another important issue that affects livelihoods; The issue of scale as well as the transient nature of salinity Lack of surface water supplies (quantity as well as timing) is also an issue. on-farm vs. engineering solutions; Policy and regulation Food security and increased intensity of cropping social and economic cost of salinity Indus Basin Salinity Management Plan – this would have to involve all stakeholders need for a new approach – living with salinity;	Agreed. These points provides some guidance on "how to approach the problem". Lack of surface water supplies should be dealt with rationalization and demand management rather than increasing supply at source and may involve reallocation.

Appendix 3

Geographical Coverage of Salinity Control and Reclamation Projects in the Indus Basin (Ahmad, 1998)

Project	Implementation Period	Cultivated Area (ha)	Number of Tubewells	
			Saline Groundwater	**Fresh Groundwater**
Punjab				
SCARP-I	1960-63	462,000	0	2,069
SCARP-II (FGW)	1961-83	603,000	0	2,205
SCARP-II (SGW)	1961-83	223,000	821	0
SCARP-III (FGW)	1969-81	385,000	0	1,635
SCARP-III (SGW)	1969-81	39,000	61	0
SCARP-1 Muridki	1969-73	220,000	0	935
Satiana	1975-77	39,000	51	20
Shorkot, Kamalia	1975-77	62,000	0	101
Allabad	1975-79	82,000	0	623
Minchiabad	1976-80	30,000	23	203
Shahpur	1975-79	45,000	0	258
Total			*956*	*8,049*
KP (Former NWFP)				
Peshawar	1972-82	48,000	0	218
Bannu	1976-82	0	0	176
Y.W. Sharif	1979-80	0	0	97
Total		*48,000*	*0*	*0*
Sindh				491
Khanpur	1963-70	154,000	365	175
North Rohri	1969-79	278,000	0	1,192
Shikarpur	1973-74	6,000	0	50
Larkana	1974-75	2,000	0	35
Sukkur	1977-78	2,000	0	18
Larkana	1977-78	5,000	0	26
Sukkur (R.B.)	1975-79	53,000	0	400
Ghotki	1976-90	162,000	0	1,050
South Rohri	1976-89	152,000	0	1,215
Total		*812,000*	*355*	*4,161*

Source: Ahmad, 1998

Appendix 4

Preliminary Design and Monitoring Framework
for
Proposed Salinity and Agricultural Water Management Project in the Indus Basin, Pakistan

[For brainstorming]

Impact: Improved livelihood and reduced health hazards of the communities living on salt-affected land. The impacts will be achieved together with Government's other initiatives			
Outcome	**Performance Indicators**	**Monitoring Data Source**	**Risk**
Sustainably increased agricultural production of salt-affected land	By 2022 i. Xxxx farmers use improved crop varieties and practices (2017 baseline, none); ii. Land degradation on Xxxx ha irrigated land reduced (2017 baseline, 0)	Government's agriculture statistical annual reports	
Outputs			
1. IB strategic and investment plan developed	By 2021 a. Water including groundwater and salinity problems assessed, (baseline 2018, no);	•	
2. Farmers and practitioners use best practices on established pilot sites in Punjab and Sindh and	By 2021 b. xxxx10-20 integrated pilot sites in Punjab and Sindh established (2017 baseline, 0) c. xxxxx100 farmers trained/exposed to the appropriate technologies and methodologies (2017 baseline, none)	• Project's progress reports • Established pilot sites	Farmers' are not ready to participate
3. Technical, institutional and policy options for sustained agriculture production on the salt-affected land are available	By 2020 a. Current options and management practices evaluated and gaps identified (baseline 2018, no) b. Region-based best practices searched, screened and ranked (baseline 2018, no).	• Assessment reports • Best practices report	
4. Enhanced capacity of participating institutions and farmers.	By 2020 a. Xxx researcher improved their education; b. Xxxx papers published; c. Xxxx research stations strengthened; d. Xxx farmers network use best practices; e. Researchers and practitioners network established.	• Project's progress reports	
Activities	[The activities should be designed once agreement on outcome and output is achieved].	•	

[1] The impacts will be achieved through accumulative efforts by the Government and farmers through other similar initiatives.