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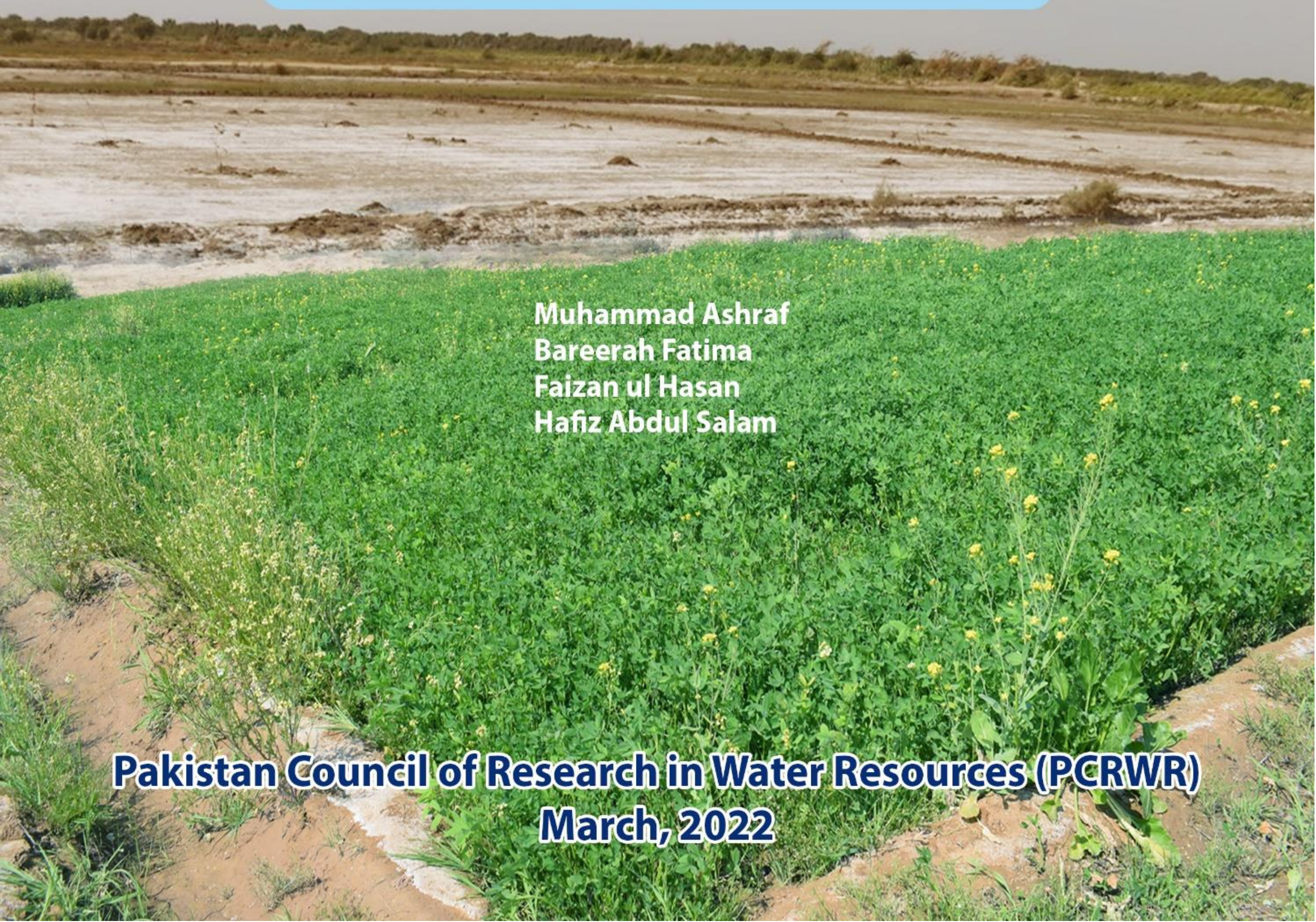
Adapting to Salinity in the Southern Indus Basin (ASSIB) Project

Policy Review

We know where this story is heading, and we know we must give it a different ending—Sir David Attenborough



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Executive Summary

Salinity is an inherent feature of the Indus Basin Irrigation System, along with many other land and water resource issues that need to be managed. The scourge of salinity was first witnessed in the Indus plains in 1945, when the Directorate of Land Reclamation was established in the Punjab Irrigation Department under British rule. The situation became so pronounced that development and strategic initiatives had to be undertaken within the first five years of Pakistan's independence in 1947. Under the Colombo Plan, the extent of salinity was determined using aerial surveys, which was the best possible technology at that time. Over time, many reports and plans by well-recognised experts surfaced, yet the massive development of Pakistan's water resources continued unabated, accentuating the salinity and waterlogging problems due to secondary salinisation. Many strategies and development initiatives needed to be undertaken to manage the salinity problem, even while the irrigation system was still expanding to bring more areas under crop cultivation. From the 1960s onwards, such efforts hastened the need to undertake major projects for drainage and the reclamation of saline and waterlogged lands.

This report provides a chronological review of all these initiatives firstly by analysing literature contributed by professionals of those periods, development reports by relevant institutions, policy discussion papers, technical working papers, project completion reports and departmental websites. Secondly, to supplement this analysis, consultations were organised with relevant organisations and other stakeholders focusing on the southern Indus Basin using a set of key questions that emerged from the literature analysis, as well as a thematic analysis of a report prepared as part of the scoping for the Adapting to Salinity in the Southern Indus Basin (ASSIB) project by Ali (2018). Focus group discussions and individual interviews were conducted to solicit expert perspectives from professionals and other specialists currently working on salinity-related management issues. Transcription and analysis were undertaken both qualitatively using thematic analysis and quantitatively using the MaxQDA tool, and supplemented with organisational mapping to assess the mandate and present work of salinity-related organisations in Pakistan.

The overall analysis of this policy review reveals three core gaps contributing to the ineffectiveness of strategies and programs:

1. Lack of policy guidance for sustainability and planning for implementing a long-term salinity management strategy.
2. Non-consolidation of data collection and research conducted by various organisations and lack of mechanisms to enforce sharing of data.
3. Lack of farmers participation in decision-making processes.

The key conclusion from the study is that the farming community, despite being challenged by the increasing extent of salinity, have had to rely on their own experiential adaptation to enable them to "live with salinity". That is, even after decades of research related to salinity management, farmers have been left to manage their salinity on their own by experimenting with various land conservation and reclamation practices, which could be augmented with more effective and practical solutions through more effective engagement with the research community. The situation calls for a total transformation of attitudes and behaviours, and the contribution of this policy review is to propose a way forward for the sustainability of living with salinity.

1 Background

1.1 Salinity in the Indus Basin

Salinity refers to the accumulation of salts in the root zone, that results in adverse effects on plant growth when plant transpires water but leaves most of the salts in the salt solution supressing plant growth (Kahlown *et al.,* 1998). Concentration of soluble salts plays a critical role in the formation of salt-affected soils particularly in such irrigated areas where evaporation exceeds precipitation (Daba and Qureshi, 2021). Physically saline soil is recognised by the visible white crust of salt on soil surface. Soluble salt content controls the osmotic pressure of the soil solution (Sadiq, 1992). Chemically, if the conductivity of saturated soil extract exceeds 4 dS/m at room temperature and exchangeable sodium percentage (ESP) is less than 15, the soil is regarded as affected from salinity. Likewise, a soil is considered sodic when it contains sufficient exchangeable sodium ion that affects the growth of most plants. In sodic soil, electrical conductivity of sodic soil is generally less than 4 dS/m, pH is as high as 10, and ESP is greater than 15. Sodicity impacts the physical characteristics of soil reducing permeability of water and air through the soil (Sadiq, 1992).

While salinity is historically a natural part of the landscape of the Indus Basin (primary salinisation), it has more recently become inherently associated with human activities of irrigated agriculture (secondary salinisation). Drawing on substantial research into the extent and causes of salinity, most of which is now over a decade old, researchers have highlighted three sources of salinity in the basin:

(i) Soil salinity is inherent in the Indus Basin due to its flat topography, aridity and diversion of natural river courses for the expansion of the irrigation system (Tarar, 2002). It is further increased with depth (Iqbal *et al.*, 2020).

(ii) The Indus River and its tributaries bring about 31.6 million tonnes (Mt) of salts annually. Out of the total salts, about 19.95 Mt are deposited in the canal commands at the rate of 1.25 tonnes per hectare. About 8.81 Mt of salts are drained below Kotri. The remaining 2.8 Mt of salts are retained in either wetlands or join the underlying aquifer through seepage (Saiqa *et al.*, 2022). This massive addition of salt across the Indus Basin is a direct result of the Indus Basin Irrigation System, which diverts water through canals and distributaries onto lands across the Indus Basin.

(iii) Another source of salt in the Indus Basin is the use of groundwater. In Sindh, the groundwater quality is generally worse but groundwater use for irrigation is lower than in Punjab (Ahmad *et al.,* 1998; Young *et al*., 2019). With more pumping of groundwater, there are more chances of salinity build-up in the soil (Ashraf and Saeed, 2006). Irrigating with low or marginal quality groundwater exacerbates the accumulation of salts in the soil profile and plant root zone, causing secondary salinisation, land degradation, and reducing agricultural production (Ali, 2018). As a result, it was estimated in the late 1990s that about 6.2 Mha (35–40% of the total irrigated area) was affected due to the twin problems of waterlogging and salinity (Government of Pakistan, 1997; Ali, 2018), while in 1989, based on research that was current at the time, WAPDA estimated that about 40,000 ha was being abandoned annually because of the presence of shallow and saline groundwater (WAPDA, 1989; Qureshi and Perry, 2021). More recent data from the 2000s suggest that 4.5 Mha across the Indus Basin is affected by salinity (WAPDA, 2007). This variation in estimates emphasises a desperate need for updated and regular assessment of the presence of salinity across the basin.

A recent assessment of soil profile of 0-5 m in the southern Indus Basin showed that 28% of the surveyed region is saline and 20% is saline-sodic. The process of soil salinisation and sodification intensifies in lower parts of Sindh (Iqbal *et al*., 2020).

In the particular case of the lower Indus plains, which have a flat gradient, poor drainage is another reason for waterlogging and salinity. Almost 50% of the cultivable command area does not have drainage facilities (Steenbergen *et al*., 2015). Drainage facilities, though on a limited scale, brought immediate good results over 2.3 Mha of land after the implementation of 18 different drainage projects consisting of surface (open) and sub-surface (tile) drainage (World Bank, 1997). In 2006, an investigation by the National Drainage Program identified that the 1999 cyclones and 2003 floods exaggerated the issues of waterlogging and salinity due to the incapacity of Left Bank Outfall Drain (LBOD) and tidal link (World Bank, 2006). The combined effect of poor drainage and climate change induced rising sea levels in the coastal areas has resulted in an increased risk of coastal flooding, inundation of wetlands and other ecosystems (Ali, 2018).

1.2 Objectives and Scope of the Study

The Adapting to Salinity in the Southern Indus Basin (ASSIB) Project was launched by the Australian Centre for International Agricultural Research (ACIAR) in collaboration with many Pakistani and international organisations. It is intended to become a ten-year program, with the overall aim of exploring how to best build Pakistan's adaptive capacity for living well in salinity affected landscapes, and uses a staged process *viz*. formative research; participatory research; and action research. An initial 2.5-years project aims to develop and investigate adaptation options with people managing and living in salinity affected agricultural landscapes in the southern Indus Basin. This project builds on prior research and project proposal development thus cementing the formative research stage and establishing the processes for the participatory research stage.

This policy review to be undertaken for the ASSIB project was awarded to Pakistan Council of Research in Water Resources (PCRWR) by Mehran University of Engineering and Technology (MUET) and Charles Sturt University, Australia. The terms of references include production of a brief report based on a literature and policy review to identify:

i. Policies and strategies relevant to salinity management in the southern Indus Basin.
ii. Extent to which the policies and strategies so identified are effective using a published approach to analysis.
iii. Government and non-government organisations involved in salinity management with southern Indus Basin farming communities, and the key projects undertaken.
iv. The data the above organisations are collecting.
v. Data that are not being collected through a gap analysis.

The following sections provide a detailed history of salinity management in the Indus Basin followed by an evaluation of the prior work, and the current efforts of relevant organisations. The report concludes with recommendations for future activities.

2 Current Situation

2.1 Methodology

Information provided throughout this section is based on our targeted assessment with four identified knowledge hubs, being: Water and Power Development Authority (WAPDA) – South Zone, International Waterlogging and Salinity Research Institute (IWASRI), SCARP (Salinity Control and Reclamation Project) Monitoring Organisation (SMO) and the Drainage and Reclamation Institute of Pakistan (DRIP), which is part of PCRWR. Libraries of these organisations were explored to develop a catalogue of all published and unpublished research reports, project reports and documents, proceedings of conferences, and journals related to salinity management of the Indus Basin. Only those documents that aligned with the scope of this study were reviewed. Likewise, some organisations identified relevant unpublished reports and salinity-related organisations during Focus Group Discussions (FGDs) but these reports could not be made available despite several attempts. However, the websites of these organisations were reviewed to extract their salinity-related mandate, achievements and present work. In addition, Ali (2018) remained the major source of literature, as per the assigned task. Analysis of this literature was based around the following three themes:

i. Historical development and initiatives of national and provincial governments with regard to the issues of salinity and waterlogging.
ii. Extent, policies and strategies in relation to the problem of salinity.
iii. Dimensions of research conducted in the areas of salinity and waterlogging management.

The findings from our literature review and interviews are annotated with relevant comments, the methods for which are described in Section 3.

2.2 Historical Perspective

Salinisation and waterlogging in the Indus Basin were first formally documented in 1851 in the Western Jammu Command, and was followed by similar reports from other Punjab commands. During 1850–1950, the only known reason for waterlogging and salinity was the expansion of the unlined canal system (Bhutta and Smedema, 2007). Mohammad and Bering (1962) reported that Roger's report to the President of Pakistan indicated an average rise of the groundwater table at a rate of 0.6 m per year. This rise in the water table was linked to 45 to 54% water loss during water conveyance and application. It was reported that out of average annual water diversions of 92.5 billion cubic metres (Bm^3) to canals, only 42 to 50 Bm^3 was available for crops.

Literature suggests that waterlogging and salinity problems in Pakistan were approached through different strategies, projects and programs. Starting in 1960s, it was recognised that some of the waterlogging and salinity problems were related to policy/institutional shortcomings and could be alleviated to a certain extent by adopting appropriate reforms (World Bank, 1994). To begin with, a number of surveys were conducted to determine the extent of salinity and waterlogging in the Indus Basin, starting from the Colombo Plan 1953-54 to WAPDA's Revised Action Plan (RAP) in 1977 (WAPDA, 1979a). An overview of the projects, policy and research evolution since the 1960s is provided in Table 1.

Table 1: Matrix of strategies, projects, institutional evolution

Phase	Policy/Drivers	Development Initiatives		Research
Phase-I	Colombo Action Plan (1953-54)	WAPDA formed (1958)		Irrigation Drainage and Flood Control Research Council (IDFCRC) was established in 1964. This was renamed with a larger mandate as the Pakistan Council of Research in Water Resources (PCRWR) in 1985.
		SCARPs (1964)	Construction of Mega dams, Link canals, barrages (1965-76)	Drainage and Reclamation Institute of Pakistan (DRIP) was established in 1975.
Phase-II	Soil Salinity Survey under Revised Action Plan (RAP) (1977-79)	Horizontal tile drainage introduced (1977)	Lining of Canals, water courses and construction of drains (1970s)	Salinity and waterlogging research in canal commands (1970s), including lysimetric studies for crop water requirement under shallow water table conditions
Phase-III	High floods (1988, 92 & 94)	SCARP transition (1987)	LBOD (1986)	International Waterlogging and Salinity Research Institute (IWASRI) established (1986)
Phase-IV	PIDA Act (1997), EPA Act (1997)	National Drainage Program (NDP) (1997) RBOD-I (1994)	Private groundwater development (1997)	Research studies under NDP
Phase-V	Pakistan Water Sector Strategy (2002)		NPIW (2004)	Draft National Water Policy (2002) Bio-saline agriculture and salinity research

2.2.1 Phase-I

In response to the Colombo Plan, WAPDA was established in 1958 and the Salinity Control and Reclamation Program (SCARP) was launched in 1964 (Bhutta and Smedema, 2007). Responsibility for the implementation of SCARP and other water sector development projects was given to WAPDA. The Government implemented six SCARP projects (SCARP I to SCARP VI) during 1964 to 2000 covering 8 Mha (Ali, 2018). About 16,000 large-capacity tubewells were installed in fresh and saline groundwater areas to control waterlogging and salinity problems through lowering the groundwater table. A summary of SCARP projects is provided in Table 2.

Meanwhile, through a World Bank supported Indus Basin Development Project, several infrastructural developing projects were implemented – a network of five barrages and eight inter-river Link Canals (1965-1970), and two major reservoirs (Mangla in 1967 and Tarbela in 1976) (Briscoe *et al.*, 2005). The soil salinity survey under the Revised Action Plan suggested that vertical drainage through SCARP could control waterlogging and salinity (Bhutta and Smedema, 2007).

Table 2: Summary of SCARP Program

Province	Gross Area (Mha)	CCA (Mha)	Surface Drains (km)	Subsurface Drainage						
				Tubewells (Nos.)			Interceptor Drains (km)	Tile drainage		
				*FGW	*SGW	*ScW		Length (km)	Area (Mha)	
									GCA	CCA
Punjab	1.70	1.51	3,402	8,065	1,985	-	6	2,810	0.04	0.03
Sindh	1.10	0.93	9,031	4,190	1,587	361	154	2,046	0.02	0.02
KP	0.14	0.15	971	491	-		-	7,756	0.11	0.02
Balochistan	0.03	0.03	322	-	-		-	-	-	-
Total	2.97	2.62	13,726	12,746	3,572	361	160	12,612	0.17	0.07

* FGW: Fresh Groundwater, SGW: Saline Groundwater, ScW: Scavenger Well
Source: Basharat and Rizvi (2016).

2.2.2 Phase-II

In the mid-1970s, it was realised that re-circulating saline water through vertical drainage only serves to aggravate the problem. Therefore, the thinking shifted towards horizontal (pipe) drainage systems, particularly in saline groundwater areas (Bhatti, 1987; Qureshi *et al*., 2008). Horizontal tile drainage was introduced through eight tile drainage projects throughout the country. These include: (i) East-Khairpur Tile Drainage (EKTD) project, (ii) Mardan Drainage Project, (iii) Khushab Drainage Project, (iv) Swabi Drainage Project, (v) Fourth Drainage Project, Faisalabad (FDPF), (vi) Chashma Command Area Development Project (CCADP), (vii)

Mirpurkhas Tile Drainage Project (MKDP), and (viii) Fordwah Eastern Sadiquia South (FESS), Bahawalnagar.

As a research organisation, PCRWR played an important role in efforts to mitigate salinisation and waterlogging in the Lower Indus Plain (LIP). In 1975 it established a dedicated centre at Tandojam, the Drainage and Reclamation Institution of Pakistan (DRIP), which worked extensively on horizontal (tile) drainage systems over three decades (1985 - 2017). Apart from tile drainage, DRIP conducted many other research studies on the reclamation of salt-affected soils and the conjunctive management of water sourced from canals and groundwater to control salinity. It also determined crop water requirements for all major crops under variable water table conditions through lysimetric studies (Rao *et al*., 2016 and 2019).

2.2.3 Phase-III

During the 1980-90s, some remarkable achievements were made. Most noticeably, there was the launch of the Left Bank Outfall Drain (LBOD) mega drainage project, as well as the establishment of a set of waterlogging and salinity research institutes. The LBOD was completed in 1995. It involved construction of 195 km long surface drains, 2,000 tubewells, 5,000 structures, and 2,000 km long-buried pipes and improvement in irrigation supplies (Qureshi *et al.,* 2008). The MONA Reclamation Experimental Project (MREP), IWASRI, and Lower Indus Management (LIM) were established under WAPDA with the mandate to undertake reclamation research for saline and waterlogged soils. Since the beginning of SCARP, WAPDA through its Water and Soil Investigation Division (WASID) maintained observation wells to monitor water levels (Mundorff *et al.*, 1972). After the establishment of IWASRI in 1986, this responsibility was shifted to the SCARP Monitoring Organisation (SMO).

2.2.4 Phase-IV

The transfer of SCARP operations was initiated in 1987 to alleviate the burden of SCARP tubewells from the provincial Irrigation Departments. Farmers were instead provided with subsidies in electricity tariffs to operate these SCARP tubewells. In 1997, the Private Sector Groundwater Development Project was launched in Punjab with the aim of increasing productivity of Punjab's irrigation and drainage sub-sector, and thus increase farming incomes (Ali, 2018). Over 6,700 community tubewells were set up, with 85% declared "successful" through independent monitoring, and 2,000 Water User Associations (WUAs) were also formed. Promising new agricultural technologies were demonstrated, including resource conservation through zero tillage for wheat on 60,000 ha (over 2,800 sites), and laser-guided land-levelling on 22,250 ha. During the same period, the Provincial Irrigation and Drainage Authority Act (1997) was enacted, which was aimed at enhancing water governance by increasing farmer participation (Young *et al.*, 2019). The National

Drainage Program (1997-2004) included policy reforms, institutional evolution for the sustainable management of surface and groundwater, and improved maintenance of the irrigation network.

2.2.5 Phase-V

Until the late 1990s, the approach worked well and showed promising results including a major relief from waterlogging and salinity. However, the high floods in 1988, 1992, and 1994 aggravated the waterlogging problem (Basharat and Rizvi, 2016). The Pakistan Water Sector Strategy (Government of Pakistan, 2002) rolled out a plan for short-term, long-term, and safe disposal of saline drainage effluent in order to reduce waterlogging from 2.8 Mha of the Indus Basin irrigated area. The Right Bank Outfall Drainage (RBOD) project was initiated in 1994 to mitigate the environmental damages caused by poorly drained areas of Balochistan and Sindh provinces. The Main Nara Valley (MNV) Drain (or RBOD-I) was designed to bring drainage effluents from the left bank areas of the Indus whereas, RBOD-III brings drainage effluents from Balochistan. This network needed to be completed by constructing RBOD-II, the Indus link drain, to dispose of drainage water to the Arabian Sea. Due to lack of construction of RBOD-II, drainage effluent from RBOD-I is drained into Manchar Lake, which greatly undermines the quality of the Manchar Lake to the detriment of the local environment and livelihood of many people who rely on the lake (Soomro *et al*., 2018; Mahesser *et al.*, 2019).

2.3 Trends and Current Situation

2.3.1 Trends

The Colombo Plan survey of the Indus plains during the 1950s revealed that almost 30% of the 8.0 Mha in the northern zone (NWFP, Kacchi Plains, Doab areas and Banu plains) was either waterlogged or severely saline and was of limited use for agriculture production (Government of Canada and Government of Pakistan, 1958). In the southern zone (southern Punjab and Sindh province), 53% of the 5.0 Mha were waterlogged or poorly drained and 25% were predominantly severely saline. The actual soil survey conducted under RAP in partnership with UNDP showed 3.96 Mha area as saline-sodic and 1.81 Mha as saline all over the country. However, 2.34 Mha and 1.42 Mha areas were found saline-sodic in Sindh and Punjab, respectively (WAPDA, 1979b). The latest estimate based on 2003 data shows that approximately 3.3 Mha of irrigated land is affected with severe surface salinity; 20% in Sindh and 1% in Punjab. The moderately affected areas are over 9% in Sindh (MNFSR, 2012) (Table 3).

Table 3: The extent of surface soil salinity in Pakistan (million hectares)

Province	Total area	Salt free*	Slightly saline*	Moderately saline*	Severely saline*	Misc. Land type
Punjab	10.1	8.81	0.37	0.18	0.16	0.58
Sindh	5.68	2.49	1.11	0.54	1.16	0.39
Balochistan	7.52	0.66	0.02	0.01	0	0.06
KP	0.348	0.15	0.10	0.04	0.04	0.01
Total	16.89	12.11	1.60	0.78	1.36	1.05

Source: MNFSR, (2012). * On the basis of EC of saturated soil extract: Salt free = 0-2 dS/m, Slightly saline = 2-4 dS/m, Moderately saline = 4-8 dS/m, Severely saline = 8-16 dS/m (www.fao.org/3/x5871e/x5871eo4.htm)

PCRWR also analysed soil salinity and sodicity in the LIP during 2014 to 2018 (Iqbal, *et al.,* 2020). It revealed that soil salinisation and sodification increased with depth as the area under normal soil was reduced by half (51% to 29%) while moving from 0 - 5 m to 6 - 10 m depth. In 2017, Pakistan's National Policy dialogue on salt-affected soils (Government of Pakistan, 2017) indicated that over 7 Mha were affected by soil salinity/sodicity, and that secondary salinisation was accelerating annually by about 2 Mha due to use of poor quality groundwater, which warrants reassessment of the extent of salinity.

2.3.2 Strategies and Programs

The problem of waterlogging and salinity emerged as soon as the irrigation system was developed. In order to resolve this issue, a large-scale surface drainage program was launched in 1933. Between 1912 and 1952, a set of strategical measures were adapted to manage this situation, including frequent and extensive canal closures, conversion of areas from perennial to non-perennial cropping, lining of canals, planting of eucalyptus groves, reclamation by rice cultivation, and limited construction of surface drains. By the 1950s, the initial focus was restricted to management of waterlogging mainly due to insufficient data on Indus Basin soil properties. The discussion on salinity started in 1954 when the Groundwater Development Organisation (GWDO) was established to conduct a systematic survey of land and water resources. As part of the Colombo Action Plan cooperative project in 1953, a reconnaissance survey was conducted to observe salinity and waterlogging problems in the Indus Plain. When WAPDA was established, GWDO was transferred to WAPDA as WASID in 1960. As a result, a 10-year SCARP program for waterlogging and salinity reclamation was initiated in 1964. This program was extended up to 1977 through undertaking a series of soil survey projects.

2.3.2.1 Strategy-I

The launch of SCARP projects by WAPDA and a series of soil surveys focused on the following strategies (Tarar, 2002):

i. Increasing cropping intensity to 150% and encouraging rapid growth of agriculture to sustain economic progress.
ii. Developing groundwater use (which inadvertently led to over-extraction and compromised irrigation quality standards).
iii. Providing tile drainage in areas where tubewell pumping was not feasible.
iv. Shifting the public tubewell construction program to saline groundwater areas once usable groundwater zones are covered.
v. Exporting 10% of effluents from non-saline zone to saline zones through surface drains to reduce the rate of salt build up.
vi. Developing regional networks of drainage tubewells and surface drains.
vii. Constructing LBOD/RBOD in Sindh and extending the drainage network in Punjab through a “spinal drainage system”.

During the same period, the Directorate of Land Reclamation determined the feasibility of appropriate cropping patterns for controlling soil salinity. A brief of this proposed rotation system is provided in Table 4. The report identified salinity as the foremost problem in the Indus Basin. It also recommended to keep the cropping pattern in such a way that the concentration of salts is kept out of the root zone. It was also deemed necessary to keep the cropping intensity of soil as near to 200% as possible so that the land does not remain fallow (Asghar and Hafeez, 1961).

Table 4: Cropping pattern for saline and waterlogged soil

Waterlogging/Salinity	Heavy soil with less than 20% salt patches	Heavy soil with more than 20% salt parches	Light soil with less than 20% salt patches	Light soil with more than 20% salt patches
High water table	Rice, wheat, cotton, senji (*melilotus parviflora*) in cotton, sugarcane, maize, fodder, oil seed crop, gram, berseem	Rice-sugarcane, berseem, lentil (*lens culinaris*), sorghum	Mash bean, cotton, millet, sorghum, oil-seed, senji (*melilotus parviflora*) and oil seed crops	
Water table deeper than 1.5 m	Rice, berseem, sugarcane, sorghum, cluster bean, green manure, maize	Rice, berseem, sugarcane, wheat, maize, senji (*melilotus parviflora*), cotton	Mash bean (*vigna mungo*), cotton, senji (*melilotus parviflora*), millet, sorghum, fodder, gram, wheat, oil-seed crop	
Well-aerated light soil			Cluster bean, wheat, maize, millet, turnip, sorghum and mash bean	All crops can grow in light well-aerated soil with preliminary leaching

Source: Asghar and Hafeez (1961).

In the 1970s, an agreement was signed with UNDP to develop a comprehensive plan for the entire irrigated area of Pakistan, and so the Revised Action Plan (RAP) was launched in 1979 following an updated Soil Salinity Survey. The plan focused on:

i. Entrusting all future development of fresh groundwater zones to the private sector.
ii. Phasing out existing SCARP tubewells in usable groundwater areas and replacing them with private tubewells.

In the Fifth Five Year Plan, priority was given to areas of fresh groundwater quality with the objectives to keep groundwater below 3 m depth (Figure 1). However, due to limited financing, saline groundwater tubewells and surface drains were not installed, which consequently resulted in groundwater levels rising to within 1.5 m. As a result, the Sixth Five Year Plan coined the term “disastrous areas” for those where the groundwater table was up to 1.5 m during April/June months. Under this plan, priority was to be given to ongoing reclamation projects to complete them. However, this strategy was also constrained by limited financial resources. The

Seventh and Eighth Five Year Plans also focused on reclamation of waterlogged and saline soils through drainage. Due to financial constraints, the success of these strategies remained limited (Tarar, 2002).

The SCARP tubewells provided additional water supplies, lowered the water table, and increased cropping intensities from 80 to 120% in most SCARP areas (IWASRI, 1998). It is notable that in Eighth Five Year Plan, the subject of Waterlogging and Salinity Research was moved from the category of Water Resources Research to the Managed Irrigation System category.

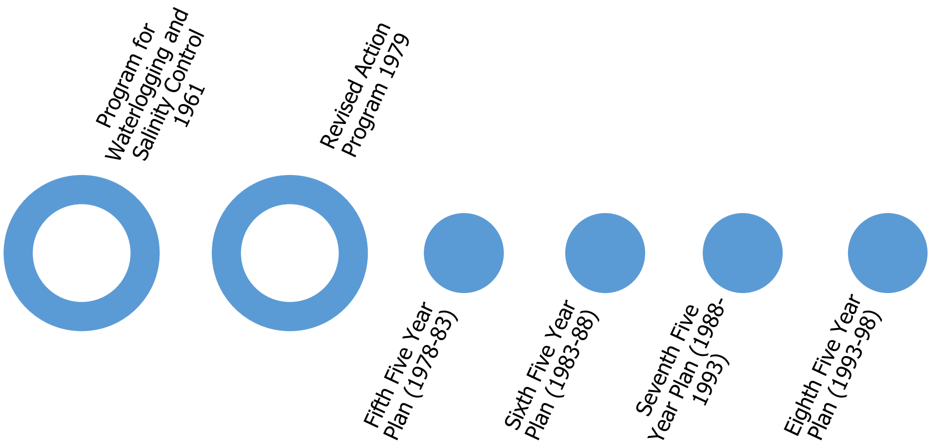

Figure 1: Salinity management plans and strategies since 1954

The above discussion shows that the problem of waterlogging and salinity is as long as Pakistan's national history. Prior to the 2000s, the need for a salinity policy was not considered. Instead, the focus was to identify and implement salinity-related strategies and priorities. After pursuing waterlogging management, the issue of reclamation was mostly diverted to research institutes and departments of agriculture and irrigation. Due to shortage of freshwater supplies and high reliance of poor quality groundwater, the role of research was enhanced.

2.3.3 Role of Research in Salinity Management

Pakistan's 18th Amendment (2010) included the devolution of some powers from the national government to provincial governments. Until this amendment, institutes like the Nuclear Institute of Agricultural Research, Soil Science Research Institutes, Soil Survey of Pakistan, and IWASRI executed nation-wide research projects, while federal research institutions, such as PCRWR and PARC, continued to work on salinity management through their designated research centres.

A review of the available literature shows that research institutions implemented some good projects, and achieved success at a small scale. IWASRI published a National Research Agenda in 1996, prioritising research in waterlogging and salinity. This effort was made after reviewing past and present research conducted by various institutions including IWASRI, LIM, MREP, IIMI (now IWMI), PCRWR, SSRI and NIAB. The agenda provided a framework for research on salinity affected lands. This framework had three pillars: live with salinity, control waterlogging, and reclaim salt-affected soils.

Planning for research was not restricted to technological aspects of waterlogging and salinity management but also included socio-economic components. The research agenda was developed in consultation with the relevant socio-economic think tanks of the country with the following key priorities (IWASRI, 1997):

i. Development of a socio-economic and socio-cultural database.
ii. Strategies of communication to beneficiaries.
iii. Formation of Community Based Organisations.
iv. Economic analysis of agriculture on reclaimed lands.
v. New prospects to improve livelihoods for those living in areas affected by salinity and waterlogging.
vi. Gender sensitive research.
vii. Legal measures that were needed to procure land for drainage.
viii. Inter-linkage between Farmer Organisations and relevant government departments.
ix. Government intervention to mobilise farmer initiatives for resolving waterlogging and salinity problems.

However, much of this agenda was never implemented, and, within a decade of its establishment, IWASRI felt the need to reorient its research, resulting in a thought process on beneficiary involvement for drainage and reclamation projects. In a similar attempt, Kuper and Kijne (1996) assessed the success of farmer-initiated salinity management. They showed that farmers' understanding of salinity as a problem had helped them to plan a strategy for salinity management. Farmers facing the issue of chronic salinity tended to address the problem through the cheapest possible resource, i.e. fresh water application.

Farmers in Pakistan rely on groundwater to increase cropping intensities (Kuper and Kijne, 1996). Therefore, even in spite of the increasing problem of salinity, farmers have been able to gain substantial yields from their lands through increased irrigation, which, in many cases, involves over-irrigation – i.e. applying more water than the crops need. Since the 1970s, per hectare yield of five major crops across Pakistan has increased dramatically: wheat (239%), rice (185%), sugarcane

(166%), maize (432%) and cotton (267%) (MNFSR, 2019). However, conjunctive use of irrigation water by mixing saline, and often sodic, groundwater with fresh canal water remained the most difficult aspect of farmer management. The Department of Interior Panel on Waterlogging and Salinity in West Pakistan's report, it is argued that mixing canal and groundwater should not be permitted for total dissolved salts higher than 7.8 dS/m and that horizontal surface drainage should be mandatory for groundwater salinity of 4.7 dS/m or above (P&D Department, 1964).

Many researchers have highlighted that salinity needs to be carefully evaluated as it varies significantly over time and space, thus making any management option ineffective if not rightly in place. Farmers who participated in the study also emphasised that irrigating a saline soil required high scientific skills. A summary of significant research related to salinity management is provided in the succeeding paragraphs.

Ashraf and Saeed (2006) recommended that to maintain a favourable salt balance within the root zone, management of the processes of salinisation due to irrigation is required. In an estimation of the sodium adsorption ration (SAR), Qadir and Schubert (2002) showed that higher concentrations of Mg^{2+} (magnesium) ions in the soil could exaggerate the impact of $Na+$ (sodium) ions, thus causing dispersion of soil particles and reducing its permeability. Moreover, higher concentrations of Mg^{2+} caused calcium deficiency in the soil. Likewise, performance of plant species also varies in reclamation process. Qadir and Oster (2004) suggested that plants with a higher biomass had a greater potential to withstand salinity and sodicity, and could thus be effective for soil reclamation.

Aslam (2002) recommended that high salt tolerant agro-forestry was a better option than reusing effluent on agricultural land. Farmers have also adopted agro-forestry of acacia and eucalyptus due to their economic benefits, as well as for improved sodicity management. Many other options for making better use of saline agriculture are presented by Qureshi and Barrett-Lennard (1998). However, reclamation of sodic soils is difficult, as it requires a combination of physical interventions and chemical amendments (Ashraf *et al.,* 2004; Qadir and Oster, 2004; Azhar *et al.,* 2001). The application of gypsum is useful for reclamation of saline-sodic or sodic soils followed by leaching. Cultivation of salt tolerant crops are proven to be more cost effective, and their adaptability is higher among farmers compared to chemical applications. Kahlown and Raza (1999) recommended rice-berseem and jantar-wheat crop rotations for sandy loam gypsiferous soil. They also suggested that when irrigation is sourced from saline aquifers, the continuous operation of drainage is a pre-requisite for the reclamation of salt-affected soils.

IWASRI published a review in 1992 of all research on reclamation of salt-affected soils: saline, saline-sodic and non-saline sodic soil (Sadiq, 1992). Leaching through freshwater was regarded as the most successful method for reclaiming saline and saline-sodic soil but this was not valid for sodic soil. The review recommended that future research should focus on reclamation involving a mix of organic matter and industrial by-products such as sulphur, hydrochloric acid and green manure. The review provided that it was difficult to determine the efficacy of any of solutions involving use of kallar grass and sulphuric acid, etc., because the research papers were either not available or these studies were conducted over a short duration. Therefore, it was difficult to establish any reclamation method as a useful strategy.

Increased cropping intensity and preferred cultivation of rice also helped in keeping salts out of the root zone particularly in areas where shallow groundwater was not a problem. Green manuring such as jantar was found to be a good option for treating a sodic soil (Sadiq, 1992; Ashraf and Saeed, 2006). A surveyed farmer reported the reclamation of his sodic soil through mulching of banana crop residue. Certain on-farm management practices such as laser land levelling and bed and furrow method of cultivation were also useful for managing saline and saline-sodic soils. Conjunctive use was recommended only if the aggregate total dissolved salts of the mixed water was not higher than that of threshold limit of the crop to be irrigated (Aslam, 2002). Sheikh and Ashraf (2008) have determined that for sodic groundwater, conjunctive use of canal and groundwater at the proportion of 25:75 offered a manageable solution for farmers. However, in saline-sodic groundwater conditions, cycling application or mixing of canal and groundwater were found more appropriate.

Effective sub-surface drainage is important for any other salt reclamation strategy to work. Ansari and Khanzada (1995) highlighted the importance of drainage particularly for land suffering from the issue of waterlogging. A model study by Parthapar and Qureshi (1999) revealed that if the groundwater was controlled through sub-surface drainage, irrigation needs were reduced by 80% without compromising crop yield.

Screening of plants and selection of varieties is very important. In a comprehensive study in LBOD area, Rashid and Chang (2002) identified several salt tolerant halophytes (salt loving plants) that can also survive under waterlogged conditions.

3 Evaluation of Earlier and Ongoing Work

To obtain some more first-hand knowledge of experiences with salinity affected areas in the southern Indus Basin, PCRWR consulted with key stakeholders including government organisations, NGOs, academics, and beneficiary farmers.

3.1 Methodology

A thematic analysis was undertaken of an unpublished draft report "Improving Salinity and Agricultural Water Management" produced by Akhtar Ali as part of the scoping for the ASSIB project (Ali, 2018). In addition, primary data from focus group discussions (FGDs), interviews and secondary data (key research work and documents provided by the interviewed organisations) were also collected. Accordingly, 4 FGDs were organised (1 each in Lahore, Tandojam, Hyderabad and Rahim Yar Khan) with representatives of key organisations including provincial irrigation and agriculture departments, agricultural universities and other research agencies, agricultural extension agencies, NIAB, WWF, IWASRI, SMO, and local NGOs. One of the FGDs was specifically conducted with WADPA and SMO professionals in Sindh while another was conducted with a beneficiary farming group in Rahim Yar Khan. In addition, three individual beneficiary farmers in Sindh and one farmer in Multan who had been involved in earlier salinity management projects in the region were also interviewed. Interviews with two key professionals of Sindh were also conducted around the same focused questions. The three members of the PCRWR study team facilitated the FGDs and conducted the interviews together as a team.

The PCRWR team was responsible for identification and selection of organisations and interviewees, based on PCRWR's reputation as a national research organisation with geographical representation across the country. PCRWR's Regional Offices are well placed to offer advice to all relevant organisations working on salinity management, both presently and in the past. Formal invitation letters were written to heads of the government departments. Accordingly, each organisation nominated appropriate representative(s) to participate in the FGDs. FGD participants were asked to identify suitable farmers for interviews, which were held at the farmers' properties. All farmers interviewed, except for SCARP VI beneficiary farmers, were wealthy and had large landholdings, and described as progressive farmers given their ability to implement innovative and recommended farming practices. All interviews and FGDs were recorded with all participants providing their informed consent for the recordings to be used for analysis and publication, as long as each person's confidentiality was guaranteed. The recordings included a mix of Urdu and English, with the PCRWR team being responsible for translation of Urdu discussion into English. The transcripts involved clear clarification between comments that came from FGD and interview participants, and any comments made by the research team. Transcription of audios were viewed by the research team involved in FGDs to check for any errors.

The following questions were asked and discussed as part of all FGDs and interviews:

a. What are the policies and strategies relevant to salinity management in the southern Indus Basin?
b. What was the effectiveness of policies and strategies so identified?
c. Which government and non-government organisations are involved in salinity management with southern Indus Basin farming communities, and their key projects?
d. What types of data are collected by organisations responsible for data collection?
e. What are the data gaps that need to be filled to address the salinity issues?

The work of organisations identified in the FGDs and interviews were reviewed through their published and grey literature. Following transcription of all FGD and interview recordings, a thematic analysis was undertaken using the MaxQDA (license 20.4.1.) data analysis tool. The themes used for the analysis are shown in Figure 2 and were framed on the questions used for data collection.

Concept Analysis	• How does understanding of waterlogging and salinity vary among different stakeholders?
Policies and strategies	• What are the policies, strategies, interventions and awareness programs that have been implemented in the past?
Effectiveness of strategies and programs	• How useful were these policies and strategies in resolving the issues supported by success stories and lessons learnt?
Living with salinity	• Is living with salinity an option?
Data collection	• Which organisations are responsible for data collection on salinity? • What are the gaps in data collection?

Figure 2: Thematic areas of analysis through FGDs

Once all the transcriptions were completed, they were imported together with the Ali (2018) report into a single document for segmenting and coding. At first, in each transcription file, the answers to similar questions were segmented on the basis of thematic areas. The codes were named on the basis of the sequence of information appearing in the transcription. The key quotes of the respondents were highlighted to be later used in a summary table for generating links within the information provided.

Most respondents addressed concerns around the theme of policy and strategy with respect to salinity management, which included discussion on future and ongoing projects. The data collection theme was addressed in three different ways: data collection, data gaps and lack of data sharing. Under the theme of effectiveness of policies, a wide variety of codes were developed, i.e. lessons learnt, good impacts of projects, fresh water solutions, canal lining, and project gaps. At the start of each FGD and interview, some respondents also distinguished between the problem of salinity and waterlogging, therefore the code "salinity concept" was developed. The information provided under these coded segments was then co-organised in a summary grid table with key quotes according to thematic areas.

FGD participants are coded as FGD (FGD1-FGD28) for each participant, and individual interviews are coded with S (SI-VI). The summary analysis was also checked by the afore-mentioned team of PCRWR researchers to check for any errors.

3.2 Results

3.2.1 Thematic Analysis

3.2.1.1 Soil Salinity and Waterlogging: Concept Analysis

As per academic consideration, waterlogging and salinity are two different issues: a saline soil cannot essentially be a waterlogged soil. *"Some types of salinity may be managed by the application of abundant water whereas some types also require chemical treatments"* (FGD8). Saline soils are generally categorised into three: saline, saline-sodic and sodic soil types. Typically, a saline soil has excess soluble salts only, while saline-sodic and sodic soils also have insoluble salts such as sodium carbonate and sodium bicarbonates causing the problem of poor drainage. With varying features of salinity, abundant resources, sufficient data and large quantities of freshwater are required to manage the problem of salinity. In this regard, waterlogging may become one of the causes of salinity. Therefore, waterlogging and salinity are regarded as a twin menace given the physical and chemical characteristics of the southern Indus Basin.

“Salinity and waterlogging are twin menace, on certain places, they exist in singularity and in some areas, they precede one after another” (FGD17).

Saline soil cannot essentially be a waterlogged soil, however, in certain places both can co-exist. Moreover, increased accumulation of sodium ions in a saline soil due to poor drainage may deteriorate saline soil into waterlogged soil. As a consequence, salts present in groundwater can be brought to the plant root zone and soil surface through capillary rise (Ali, 2018). In Sindh province, more than 70% land and 90% groundwater is affected by salinity. Except for a few spots, groundwater depth does not exceed 100 m. The shallowness of the groundwater aquifer is the main cause of salinity in Sindh. Aridity of the area further exacerbates the presence of salinity. *“Increase in temperature, lesser rainfall and high evaporation rates had increased the requirement of freshwater in Sindh province. "Lower Indus Project Report 1966" by McDonalds and Partners recommended higher water allowance for Sindh province”*, SVII pointed out.

The geology of the southern Indus Basin is such that the soil parent material is saline with limited groundwater depth. Therefore, the combined impact of geography and soil properties has resulted in both salinity and waterlogging. *“Furthermore, due to flat topography, drainage effluent does not drain to the sea naturally”* (SVII). In addition to the inherent salinity and sodicity of the soil, the Indus Basin Irrigation system also contributes salinity to the agricultural land in its command areas (Ali, 2018).

The increasing pace of salinity and sodicity of the soil is also driven by increased pollution present in canal water and from higher application of fertilisers and pesticides. SVI regarded the increased contamination of canal water to rapid urbanisation, more industrial activity and consequently higher sewerage effluent into canal water. *“At canal closure when the surface water is not available, sewerage water continuously flows into canals increasing the pH up to 12. When surface water supplies resume, despite their dilution effect, highly sodic water flows down to the field. Consequently, citrus orchards are being damaged rapidly in Sargodha”* (FGD23).

Poor management of effluent from mega drainage projects also contributes towards increasing salinity and waterlogging. For instance, Manchar Lake degradation is also attributed to its highly contaminated inflows with drainage water deteriorating the fertile agricultural lands. Similarly, *“SCARP VI project is still functional with water being pumped to evaporation ponds located in Cholistan Desert. The new Rainee Canal is passing nearby these ponds. The seepage from these ponds is destroying groundwater and ultimately impacting negatively the canal command of the Rainee Canal”* (FGD14).

3.2.1.2 Extent of Policies/Strategies relevant to Waterlogging and Salinity

3.2.1.2.1 Existence of policies

"*We are always taught that engine is the strongest part of a vehicle. In fact, it is the steering which is the most important"* (FGD23). Projects are useful and are planned to address a specific problem. The problem involves a sense of direction, such as a national policy or a vision that addresses the problems of salinity and waterlogging, with programs and projects executed to resolve the issue. A policy decision is very important to make people aware of the issue. One example is the complete ban on rice cultivation in the left bank canal command areas in Sindh. The Government of Sindh imposed this ban in March 2021 due to increased waterlogging.

Most experts who chose to respond to the question of waterlogging and salinity suggested that there was no policy to manage waterlogging and salinity. One respondent also hinted that there was political influence impacting on the execution of these projects. *"The project proposal are made for the benefit of the communities. However, at the time of implementation, these plans are changed."*

FGD17 suggested that it was the lack of policy and a comprehensive dataset on waterlogging and salinity that paved the way for political influence and change in scope. Management of water and agricultural resources was significantly altered following the 18th Amendment in the constitution, with provincial governments now having greater responsibility than previously. WAPDA's role being the national institute was restrained to the implementation of inter-state and transboundary projects only (Ali, 2018). The role of WAPDA was not compromised as a mega power sector development authority but its historical role in developing drainage and reclamation projects has been ignored completely. One such example is that WAPDA constructed the Left Bank Outfall Drain (LBOD) and Right Bank Outfall Drains (I & III). The RBOD II component had to connect the inland surface drainage system to the sea. The principal reason for this lag is the shift of this responsibility to Sindh Irrigation Department. There are two different views regarding mega drainage project development strategies for controlling waterlogging. One view, as expressed by academic professionals, is that while LBOD project was properly planned on paper, in reality, observations suggest that at certain points, the LBOD section has been breached and fresh canal water is entering into the LBOD. The alternative view is that the LBOD has been regarded as a very successful project enabling the drainage of low laying areas of the Indus plains as reported by WAPDA and an interviewed expert. An issue with LBOD is that it has a limited capacity of 125 m^3/sec. In the absence of RBOD II, its capacity is compromised in addition to poor repair and maintenance issues.

“If the LBOD was not constructed, given the flat topography of the lower Indus, the entire Sindh province would have been waterlogged. Even during dry periods, the LBOD is flowing at a discharge of 85-100 m^3/sec” (SVII).

Drainage of land is essential to undertake reclamation activities. In most parts of the lower Indus plain, groundwater is brackish besides having parent soil salinity. Most respondents agreed that the parent material of the soils in the lower Indus plain is the major cause of salinity. If land is not drained and groundwater is allowed to rise to the surface, it will bring salts to the surface through capillary rise and evaporation. The lower Indus plain becomes more vulnerable during floods. For instance, SCARP VI was constructed as a result of the 1973 floods aftermath to drain the soil in Rahim Yar Khan district. This project was started in 1976 and completed in 1990. SI and FGD13 both highlighted that after the 2010 floods, there are some pockets of land which are not connected to the drainage network and have now been subjected to an adverse form of salinity.

3.2.1.2.2 Impacts of projects and strategies

3.2.1.2.2.1 Lessons Learnt

"We are proud to say that we have one of the largest irrigation systems in the world. However, we have the world's poorest drainage system" (FGD18). Despite water shortages, a system of high delta crops (i.e. those requiring high water requirements) prevails in the country increasing waterlogging in poorly drained lands. Agricultural fields need to be connected to the surface drainage system to enable continuous leaching of water. Lack of farmer awareness and lack of capacity in the farming system to implement this need on their properties is contributing towards worsening of the salinity and waterlogging situation.

The saline soils require freshwater for leaching of salts. However, with the drainage system, sufficient freshwater was not provided to flush the salts out of the root zone. The same issue is currently being faced by the tail end farmers in southern Punjab. Now farmers are pumping saline water to irrigate their crops. In all drainage and reclamation projects, excess water needs to be provided to flush out the salts. This did not happen due to a number of reasons including shortage of freshwater supplies and the high aridity of the region.

"Poor tubewell operation multiplied the issue of salinity. Such issues occur when there is no proper policy or strategy” (FGD1).

Due to poor maintenance of LBOD passing through sandy soils, the surrounding area has become waterlogged. A key problem with WAPDA's drainage and reclamation projects was that they were not based upon lessons learnt from pilot projects. An example is the experience from East Khairpur Tile Drainage pilot project where PCRWR installed tile drainage on about 500 ha of land:

“Actual project should have been started on the basis of lessons learnt from pilot projects. Full scale project on 25,000 hectares was initiated by WAPDA before the pilot project was completed. Consequently, the project had to be abandoned before its completion. Later on pilot sites were used for demonstration to expert visitors and project teams” (FGD17).

Key lessons learnt from the poor execution of these potentially good drainage and reclamation projects were: weak implementing institutions, lack of coordination and consensus, lack of stakeholder participation and lack of ownership by the communities (Ali, 2018). The drainage and reclamation projects of WAPDA were often installed in rural and remote areas where power outages were common. *“Continued lack of operation damaged machinery”* (SVII). “*Poor site and farmers’ selection was one of the failure of NDP projects as farmers were not able to run the project on long-term basis” (*FGD17).

Referring to an example of the project in which a sunflower crop was to be promoted in Badin district, FGD18 noted that *"We make very good policies but ground realities are too different.”* Farmers were convinced to grow the crop but they had no market access for this commodity. While planning the project, neither consideration was given to market potential, nor to an assessment of the need for pesticide and fertiliser applications. *“Farmer choice and farmer finance”* are regarded as two key drivers of adaptation (FGD23).

Repair and maintenance after the completion of the projects is a major issue which is more critical in the case of waterlogging and salinity. Ali (2018) regarded it as an issue of departmental constraint, under-funding, and administrative challenges of the institutions. Along with the LBOD project, more than 500 deep tubewells were installed, which worked under the operational control of WAPDA. When it was handed over to the irrigation department, no maintenance was carried out. Moreover, there is no contingency strategy particularly when the groundwater table was lowered and tubewells were sunk.

Normally, after construction, WAPDA hands over the project to the provincial irrigation department with the responsibility of operation and maintenance. “*In fact*, *project-based approach is detrimental to overall goal of a program or a strategy. At the planning stage of the project, everything is proper as financial resources are provided to the responsible institutions. However, in longer-term, this arrangement does not sustain and project ends up without real success”* (FGD5).

"Operation and maintenance (O&M) is very important component for the sustainability of the projects. In case of LBOD, lack of O&M by the provincial irrigation department is causing problems. RBOD I & III are working really well but due to delayed construction of RBOD II, the entire project has become ineffective; the reason being political influence over such projects" (FGD13).

From our analysis, we would therefore conclude that WAPDA has been a great implementer of surface drainage system in the lower Indus. Other good impressions left by WAPDA include the construction of the interceptor drains for the collection and reuse of freshwater. As a result, WAPDA was entrusted with the task of managing waterlogging in Shaheed Benazirabad district by the national government in power in 2010.

3.2.1.2.2.2 Success Stories

In the collaborative tile drainage project established by PCRWR, farmers share of the project costs was kept at 25%, and they were expected to pay for all O&M costs. As a result, these projects are still functioning even after 30 years. Referring to the example of Nawazabad Farm, FGD17 remarked that the *"owners of the farm were so convinced about practical application of the technology that they were willing to install it on full payment basis"*. However, they have installed it on cost sharing basis and the system is still operating. On the question of usefulness of the system, SI responded:

"The technology has been very useful as it has reclaimed 40 ha of our farm. We have appointed a guard for the operation of these tubewells if and when needed. We have another 25 ha of land, where we are planning to install the tile drainage system."

Figure 3: Images of operational horizontal drainage at Shahnawaz Farm, Matiari

Nawazabad farm has a total area of 850 ha with tile drainage system covering 40 ha. As reported by the farmers, the system has been very useful ever since in tackling the issue. Through the same collaborative approach, another horizontal drainage system was installed at Saeedabad Sheikh farm. Here the system is installed on 18 ha of land and, as a result, 130 ha of land were reclaimed. When asked about the reason behind the still operational drainage system, SII responded:

“Let me explain you one thing. This system works only if farmer takes the ownership. One of our neighbouring landlords has also installed this system but he does not care therefore, his land is still barren.”

Waterlogging is a key problem at the farm with patches of soil salinity. With the help of this system, the problem has been resolved through a joint effort. Likewise, a horizontal drainage facility has also been installed as part of a recent collaborative PCRWR-led project at Sanghar, and beneficiary farmers have reported that these systems have reclaimed their land long after the 2010 floods.

Figure 4: Interviews with beneficiary farmers of PCRWR’s collaborative tile drainage projects

In addition to collaborative projects, there are certain success stories which are supported through implementation of SCARP projects. Such examples are found in southern Punjab. One key example is SCARP VI project in Liaqatpur, Rahim Yar Khan, where surface drainage was constructed between 1976 and 1990 in the aftermath of the 1973 floods (FGD24). There are 514 tubewells still operating with O&M costs being covered by the Punjab Government through their Annual Development Program. These systems are managed by the Directorate of Land Reclamation of the Punjab Irrigation Department. The FGD with farmers reveals that this project remained very beneficial as it has reclaimed the waterlogged soils and converted the unproductive lands to become productive.

Figure 5: Operational SCARP VI project, Liaqatpur, Rahim Yar Khan

The initial plan was to pump and connect this drain with the drainage network of Sindh. However, the policy regime of that time discouraged and stopped its financing. The effluent was thus diverted into evaporation ponds in Cholistan desert comprising a strip of 120 miles. *"At the time of project design, the issue of saline effluent was not considered. It was realised only in 1995"* (FGD24).

The drainage and reclamation program also included the components of reclamation with flushing of salt. In Punjab, the Directorate of Land Reclamation had "reclamation shoots" through which fresh canal water was supplied during the flood season to reclaim the salt-affected soils at the tail ends of canal reaches.

"The system remains functional till 1994 and 0.5 Mha of salt-affected soils were reclaimed. Later on, due to shortage of water, these lands were again affected" (FGD22).

3.2.1.3 Organisational Effectiveness

Waterlogging and salinity are a twin menace and seldom exist in singularity. While discussing the concepts of salinity, it has also emerged that the nature of salinity also varies across the southern Indus Basin. One respondent said that canal lining of a particular section in Shaheed Benazirabad has made thousands of hectares cultivable. On the other hand, FGD5 commented that the "*lining of Rice Canal passing through Larkana district has detrimental impacts on quality of groundwater, mainly because of reduction in recharge."* Likewise, farmers also reported that lining of major canals and distributaries affected the quality of tubewell water. Seepage from canals has remained a source of fresh groundwater in certain areas. Both Punjab Irrigation Department and WAPDA (South) reported the construction of interceptor drains for the collection of freshwater seepage from canals.

WAPDA undertook a series of works for the management of waterlogging and drainage of land. These were all large-scale projects, which helped provide solutions to the problems being experienced. *"Whatever project or program the federal or provincial government initiated were aimed to resolve the problems and they achieved success initially" (SVII)*. Their failure is mostly attributed to lack of provisions to cover O&M costs, necessitating financial allocation for the repair and maintenance similar to that of the irrigation system.

Collaborative projects provided some relief to the farmers as these involved a mechanism of continuous system O&M as well as farmer training. PCRWR executed projects with 20, 30, 70% cost sharing. Sometimes 100% costs were shared by the beneficiary farmers. On the contrary, "*WAPDA's SCARP were neither owned by the provincial government institutions involved in SCARP transition project nor by the community*" (SVII). Figure 6 shows a summary timeline of these projects.

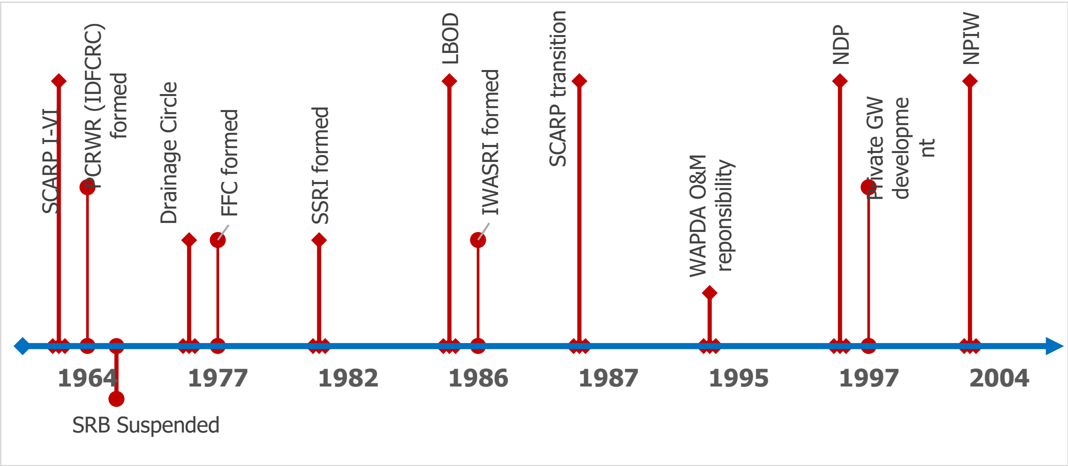

Figure 6: Institutional evolution of projects related to reclamation of waterlogged and saline soils (Source: Ali, 2018)

The task of development of SCARP projects during the period 1964-2000 was entrusted to WAPDA. In 1964, DRIP was established whereas Soil Reclamation Board (SRB) was suspended. In 1977, Drainage Circles as well as the Federal Flood Commission were established. The former focused on O&M of drainage works whereas the later focused on flood forecast and protection works. In 1982, the Soil Salinity Research Institute was formed under the umbrella of the Punjab Agriculture Department. During 1986-1997, WAPDA implemented the LBOD project. In the same year, IWASRI and its allied research organisations were established. In 1987, the SCARP transition project was launched. In 1995 WAPDA again took over the responsibility of O&M of drains. In 1997, the Private Sector Groundwater Development and National Drainage Program were launched.

Drainage and reclamation projects had two components: drainage of poorly drained or waterlogged soil, followed by management of salinity through various approaches. IWASRI and its allied research organisations were established to enable this transition and preparedness of farmers to combat salinity. Farmers in the southern Indus Basin correlate benefits of such projects with reclamation of their lands. *"Due to tile drainage, our entire land which had become barren is now cultivable"* SII reported.

Agriculture departments are mainly responsible for helping farmers grow appropriate crops by managing the land, water and non-water inputs. However, none of the interviewed farmers reported receiving any support to combat salinity from agricultural extension and agriculture departments. In 1985, the Sindh Arid Zone Development Authority (SAZDA) was established with the sole focus of combating desertification and salinity. The organisation was closed in 2002. The Directorate of Land Reclamation acknowledged its efforts to reclaim salt-affected soils through flushing of salts. This method has also been endorsed by the other respondents of FGDs and individual interviewees. "*There is no alternate of freshwater application for the flushing of salts"* remarked SVII. Even after chemical treatment of soil with gypsum or any other chemical, 15-20% excess water from canal irrigation is compulsory to leach the salts out of the root zone. Farmers also reported applying gypsum with initial good results. FGD13 reported that *"Research trial on gypsum efficacy has not shown any promising results. Initially gypsum application shows promising results but later on gypsum accumulates in the root zone aggravating drainage problem of soil."*

3.2.1.4 Contemporary Work and its Effectiveness

A number of subsidised projects were initiated by the provincial agriculture and irrigation departments for reclamation of salt-affected soils through chemical treatment. After their closure, the Punjab Irrigation Department promoted gypsum application at the rate of 70% subsidy to encourage farmers. FGD22 reported that *"Gypsum application had magical effect and farmer yield was enhanced up to 80%*. FGD21 also reported that "*Without gypsum application saline-sodic soils are being converted to sodic soil. That is why extent of salinity is increasing.*" In retrospect, most farmers remarked that the gypsum application helps neutralise the sodic nature of canal or groundwater. "*Placing gypsum stone in field water channel are more effective in terms of cost and efficacy and beneficial to reduce the pH of water"* (FGD23).

The Government of Sindh's Agriculture Department has undertaken many projects for the reclamation of salt-affected soils using chemical amendments through its Annual Development Plans (ADPs). A total of 3,200 ha of land was reclaimed through various methods including the application of gypsum, sulphuric acid and humic acid. These projects were executed in nine districts of Sindh: Badin, Shikarpur, Khairpur, Thatta, Mirpurkhas, Larkana, Jacobabad, Kashmore and Ghotki. Some areas reported a yield enhancement of up to 40%, whereas a few areas reported up to 80% improvement. Because of the success of this project, another project "Remedial improvement of marginal land through effective measure" was executed and 2,430 ha of land were reclaimed. Now the department is working on another project involving bio-saline agriculture targeting 565 ha of land in districts of Badin, Thatta and Sujawal. Likewise, NIAB reported having some work involving the screening of salt tolerant crop varieties and bio-saline agriculture. The department has worked on a farmer collaborative project during 2002-08 where they developed farmer associations to disseminate the knowledge and also developed germplasm for some salt tolerant species.

WAPDA also installed scavenger and skimming wells for extracting fresh water overlying saline groundwater. Punjab Irrigation Department in partnership with PARC is planning to execute a project involving 400 ha of bio-saline agriculture in Cholistan similar to the one developed in Umar Kot by PARC. In this regard, a patch of land is being identified through resistivity survey. In the SCARP VI project, there are certain pockets of fresh water with a total potential of 2.6 m^3/sec. The plan is to use this water in non-command areas of 9-12 thousand hectares.

3.2.1.5 Living with Salinity

"In irrigated areas like Pakistan, we will have to live with salinity as our soil is prone to salinity" (SVII). "We cannot fight with climate change, salinity, and waterlogging. However, we can adapt to these challenges" (SVI). The situation of salinity in the Indus Basin Irrigation system is such that it cannot be removed. However, efforts should be made towards adapting to salinity. A number of plant species are reported to have beneficial impacts on livelihood of the farming communities (Ali, 2018). Even after the treatment of salt-affected and waterlogged soils, FGD 22 remarked that Pakistan farmers will have to opt for saline agriculture for some years as conventional agriculture would not be possible in these areas. Soil reclamation offers only temporary relief to farmers because salts start reappearing immediately afterwards.

Continuous cropping is one of the easiest ways to control salinity. Farmers in major agricultural districts of the lower Indus, such as Badin, Thatta and Tando Muhammad Khan, are managing salinity through continuous cropping. If farmers leave the soil fallow even for one season, salts will accumulate on the surface making the land uncultivable. In this scenario, government should focus on providing salt tolerant crop varieties to support farmers to earn their livelihoods. Screening of salt tolerant crop varieties is very important to survive in a saline environment. "*We have identified some salt tolerant and low delta (low water requiring) crop varieties but need resources to produce them on large scale*" reported FGD1.

Soil salinity exists in the system and farmers are surviving because they have learnt *"how to live with salinity"*. Rice cultivation was regarded as the first option to combat salinity and sodicity of soil in the 1950s (Tarar 2002; Asghar and Hafeez, 1961). In an individual interview, Farmer SI reported that *"Rice cultivation makes soil cultivable. We grow rice just to reclaim soil."* Farmer S2 opted for a block plantation of *Acacia* trees in saline and waterlogged areas. Plantation of *Acacia* offers a socio-economic way out for farmers after 2-3 years, and provides the additional benefit of livestock rearing. *Acacia ampleceps* is a useful variety that can be used as fodder and protein rich hay. Another such plantation crop is Quinoa (*Chenopodium quinoa)*, which is being promoted in Badin and Thatta. These species are not only resistant to salinity and waterlogging but can also provide a protein source for livestock.

As there is no single solution to the chronic issue of salinity, it is essential to work on integration of activities, such as saline agriculture, aquaculture, rainwater harvesting for flushing of salts etc. In case of the lower Indus, chemical amendments and bio-saline agriculture alone cannot address the issue. The first step is to assess the feasibility of a soil reclamation process, such as to provide proper drainage followed by salinity reclamation amendment. In certain areas, where drainage of land is impossible, saline aquaculture may be an alternate livelihood option (Ali, 2018). Convincing farmers to plant *Acacia* is difficult if they only have a small patch of land – unless they can earn their livelihood from another activity such as goat farming. A model needs to be created where all stakeholders are involved. An integrated approach is very useful for "living with salinity". FGD19 reported the example of a farmer who is cultivating *Acacia* trees and getting more benefits than three continuous years of sugarcane cropping. The neighbouring farmer is also managing a goat farm.

Farmers regard salinity and sodicity as *"white salinity"* and *"black salinity"*. White salinity (saline soils) is less harmful, and it is manageable with deep ploughing and excess irrigation. Black salinity (sodic soils) involves poor aeration and poor drainage, and requires considerable knowledge and expertise to manage. Such expertise is not always readily available, as one of the progressive farmers commented: "*A powerful jet is not useful unless its pilot is well trained.*"

3.2.1.6 Salinity-Related Data Collection Efforts

During the interviews and FGDs, the question of data collection brought forward some interesting information. SVII, FGD5 and FGD6 reported that they had to rely on salinity data from the revenue department, which they claimed to be inaccurate and fabricated. Some of the respondents quoted an old 1995 reference regarding the extent of salinity and sodicity in Pakistan. FGD1 noted that they had learnt that Pakistan's land was being salinised at the rate of 16,000 ha per year. SVII reported that in 1966, McDonalds and partners conducted a soil survey of the Lower Indus Plain, and on its basis water allowances were planned for Sindh. Ali (2018) mentioned the reconnaissance survey and aerial photography conducted under the Colombo Plan in 1953.

A brief analysis of past data collection efforts is given in Table 6. Surprisingly, and to the detriment of Pakistan's knowledge base related to salinity, the latest survey of salinity and waterlogging was conducted way back in 1977 as part of the "Revised Action Plan" in partnership with UNDP. This was also the only survey conducted for soil salinity and sodicity using a well-established scientific methodology. The data from the Colombo Action Plan survey of the 1950s served as the basis for the ensuing soil surveys over the subsequent two decades. In 2014-18, PCRWR conducted a soil salinity survey of the southern Indus Basin and determined that in a soil interval of 0.5 m, 28% soil is saline whereas 20% is saline-sodic.

Table 5: History of soil salinity surveys

S. No.	Name of Survey	Year	Agency	Method	Findings
1	Thur Girdawari, (Annual Salinity Survey)	Annually	Land Reclamation Directorate, Punjab Irrigation Department	Conducted by *Patwaries* of Irrigation Department, no analytical base only visual assessment	1992 statistics Out of 11.32 Mha 65% Thur Juzvi (temporary saline) 0.14% Thur Tirk (permanently saline) 5.4% Thur Nau (new saline) 9.86% Thur Panjsala (saline since past 5 years) 19% non-cultivable due to salinity
2	Reconnaissance Survey under Colombo Plan	1952-53	Colombo Plan co-operative Project	Mapping is based on aerial imagery at the scale of 1:40,000	Predominantly waterlogged: 18,783 Predominantly severely saline: 7852 Areas with common saline patches: 17,692 (square miles)

S. No.	Name of Survey	Year	Agency	Method	Findings
3	Lower Indus Project Survey	1966	M/S Hunting Technical Services and MacDonald's and Partners	Electrical conductivity survey of soil from 0-450 cm top-soil layers under two categories; severely saline and moderately saline	Lower Indus Feeder Command Area: Non-cultivable: 40 thousand hectares Moderately salt-affected: 0.384 Mha Seasonal swamps: 0.091 Mha Severely salt-affected: 0.521 Mha
4	Surveys by water and soils investigation division, WAPDA	1960	Water and Soil Investigation Division (WASID)	Enlargement of aerial images 1:15,840. The survey of 4-6 bore holes per square mile to a depth of 304 cm.	Soil survey conducted in Punjab on Doab level; 24% was found to be salt-affected.
5	Surveys by Project Consultants	1974-76	Multiple consultants	Mostly relied on data collected by Water and Soil Investigation Division	Project specific surveys conducted for various projects and through different methods. Results not found.
6	Reconnaissance Survey by Soil Survey of Pakistan	1978	Soil Survey of Pakistan	Aerial imagery of 1:40,000 scale along with topographic sheets of 1:50,000 and 1: 250,000 to determine soil associations.	5.8 Mha (23%) of land is salt-affected in total Indus plains
7	Surveys by WAPDA Planning and Investigation Units.	1975-78	WAPDA Project Planning Organisations	Field surveys were conducted by Southern Planning Organisation of WAPDA for the fresh assessment of salinity.	Mostly visual surveys, data is not available.

S. No.	Name of Survey	Year	Agency	Method	Findings
8	Revised Action Plan (RAP)	1979	Master Planning and Review Division, WAPDA	A combination of fresh aerial photography at the scale of 1:30,000 along with field survey determining soil sodicity and salinity.	Salinity and sodicity profile of soil (8.55 Mha) 0-15 cm = 28% saline, saline-sodic 15-45 cm = 24% saline, saline-sodic 45-90 cm = 25% saline, saline-sodic 90-180cm = 22% saline and saline-sodic
9	Demarcation of groundwater quality zones in lower Indus plains	2014-18	Pakistan Council of Research in Water Resources (PCRWR)	Soil sampling at 25×25 km grid at an interval of 0-5 m and 6-10 m depth. Areas covered: lower Indus plain and southern districts of Punjab province	Soil situation 0-5 m depth interval Normal soil = 51% Saline soil = 28% Saline-sodic = 20% Soil situation 6-10 m depth interval Normal soil = 29% Saline soil = 47% Saline-sodic = 24%

Source: WAPDA, 1979a, Iqbal *et al.*, 2020.

Presently, no scientific database in relation to soil salinity is available. The Department of Land Reclamation reported to have data of soil salinity, but the data are based on a visual analysis of “canal patwari (an official revenue assessor)”. *“If a farmer wants to reduce the rate of Abiana, he requests the patwari to declare his land a salt-affected”* explained FGD5. *“Farmer could be a good resource for data on salinity but we will have to train farmers not to lie in data reporting”* remarked SVI.

Though there is no progress on data collection for soil salinity surveys, a lot of work has been done on determining groundwater quality data. SCARP’s Monitoring Organisation (SMO) has the responsibility for monitoring the impact of SCARP’s projects. The project-based approach in WAPDA has affected SMO’s operation, and its status is unclear after the 18th Amendment. During 2015-19, no data were collected and most of the observation wells were damaged. FGD12 reported that by 2004 soil salinity data collection was also part of SMO’s mandate. However, later on, such data collection was abandoned due to shortage of funds. Moreover, they were never able to collect soil salinity data as they were only monitoring groundwater quality through observation wells. FGD22 also mentioned that the Punjab Government's Soil Fertility Department has data on soil salinity. But in fact, this department and the Soil Science Research Institute only collect data relating to macro/micro nutrients in the soil. Punjab's Agriculture Research Department has dedicated research and laboratories and could conduct soil salinity surveys if provided with resources. During 2005-07, IWASRI also worked on salinity mapping of the country, but this mapping is based on data from SMO's groundwater observation wells.

FGD19 reported demarcation of groundwater quality zones by PCRWR as the only known database. SMO has 5,000 observation wells, 1,000 in Sindh and 4,000 in Punjab, and collects data from these wells twice a year, publishing these data in reports detailing depth to water table, EC, pH and SAR of the groundwater. SMO also measures other parameters in their laboratories. In Punjab, the Irrigation Department has also acquired SMO's observation wells and monitors groundwater quality through its observation wells placed at a grid of 6 km × 6 km. PID has undertaken a division level water quality mapping of Punjab. GIS based maps have also been developed, where saline and waterlogged areas are also marked for each year. SAR and residual sodium carbonate (RSC) mapping have also been undertaken. PID's groundwater atlas provides an idea of waterlogged and saline areas. To determine the salinity and sodicity, exchangeable sodium percentage (ESP), EC and RSC of soil up to a certain soil depth would be required.

3.2.2 Organisational Mapping

A number of public and private organisations are working in salinity management (Table 7), and the interviewed farmers did not report the work of any non-government organisation for salinity management. Farmers also complained about the limited interest they perceived from agricultural extension departments in providing the advice needed. The soil fertility laboratories of the agricultural extension departments in Sindh and Punjab do provide services of salinity and fertility analysis but only to those farmers who approach them. Researchers also have the capacity to work on salinity, but are constrained by limited resources.

Table 6: Organisations working in salinity management

S. No.	Organisation	Mandate	Current activities
	Federal Government		
1	Water and Power Development Authority (WAPDA)	As per WAPDA Act 1954, the organisation is mandated to undertake development of water resources.	Mega drainage and reclamation projects were executed in the past. No such activity is being implemented currently.
2	Pakistan Council of Research in Water Resources	Established in 1964, mandated to conduct, coordinate and promote research on all aspects of water resources.	Regular research activities on salinity management particularly in the Lower Indus
3	Nuclear Institute of Agriculture (NIA)	Atomic Energy Agricultural Research centre was established in 1963. The centre later upgraded to Nuclear Institute of Agriculture (NIA) in 1998. This institute was aimed at developing resistant crop varieties, plant protection and soil sciences.	Currently working on screening of salt tolerant crop varieties.
4	Nuclear Institute of Agriculture and Biology (NIAB)	Established in 1972 with research division for Soil and Environmental Sciences.	The institute worked on soil salinity up to 2002.
5	International Waterlogging and Salinity Research Institute (IWASRI)	Established in 1986 as subsidiary of WADPA to resolve research problems for saline and waterlogged areas.	Focus of this organisation has shifted to mainly research on water sector projects.
6	SCARP Monitoring Organisation (SMO)	Established in 1986 as subsidiary of IWASRI as a project with the mandate to observe groundwater quality as well as soil salinity in SCARP areas.	Maintains 4,000 observation wells in SCARP areas to monitor the quality of groundwater.

S. No.	Organisation	Mandate	Current activities
7	Lower Indus Water Management and Reclamation Research project	Established in 1986 as subsidiary of IWASRI as a project with a mandate is to conduct research related to agricultural water management in Lower Indus.	Conducts field trial research for agriculture in saline and waterlogged areas.
8	Soil Survey of Pakistan	The organisation was responsible for undertaking continuous survey of soil and share its findings with relevant departments. The institute also imparted training to the field staff of Forest, Agricultural Extension and Irrigation Departments and Universities to conduct soil surveys.	After the 18th Amendment, Soil Survey was devolved to provinces. Presently, the salinity and sodicity analysis of soil does not fall in the purview of these directorates.
9	Drainage and Reclamation Research Institute (DRIP)	Also known as Drainage Research Centre (DRC), DRIP was established in the 1960s and merged with PCRWR in 1975. It has focused on drainage of agricultural lands, salinity control, land reclamation, irrigation practices and water management, irrigation and drainage modelling.	Currently, the institute is undertaking a number of salinity management activities in the Lower Indus Basin such as monitoring of seawater intrusion, groundwater quality mapping at canal command level, soil salinity mapping, saline agriculture and aquaculture etc.
10	Pakistan Agricultural Research Council (PARC)	Established in 1951 with a mandate to undertake, promote, coordinate and use agricultural research, and for training.	Conducts research on salinity management in relation to plant sciences at its institute at Umer Kot and Bahawalpur
	Provincial Governments		

S. No.	Organisation	Mandate	Current activities
11	Directorate of Land Reclamation, Punjab Irrigation Department	Established in 1945 as the Reclamation Wing in response to salinity and sodicity in canal commands. By 1994, the organisation reclaimed 5.3 million hectares of land through "reclamation shoots" maintained by the Irrigation Department. PID has a working model of land reclamation through its directorate. This institute has a land reclamation centre at canal command level as well as a system of revenue collection.	• Monitoring of groundwater and salinity relationship • Groundwater quality observations • Working on establishing a bio-saline research farm in southern Punjab
12	Soil Salinity Research Institute	Initially formed in 1992 under the Punjab Agriculture Department for soil reclamation research. Presently working under the umbrella of Ayub Agricultural Research Centre.	Executing a number of projects related to agriculture in salt-affected soil and conjunctive use of saline groundwater. Two key services: • Water and soil analysis advisory services to farmers • Production technologies for cultivation in salt-affected soil
13	Rapid Soil Fertility Research Institute	Working under the administrative control of Ayub Agricultural Research.	A network of 8 laboratories offers services to farmers regarding soil health.
14	Soil and Water Laboratories, Department of Agriculture, Government of Punjab	A laboratory network established in each district of Punjab province.	Offers soil and irrigation water testing facility to farmers on farmer's initiative.

S. No.	Organisation	Mandate	Current activities
15	Soil Fertility Laboratories (Sindh)	A laboratory network is present in 13 districts.	Offers soil and irrigation water testing facility to farmers on farmer's initiative.
16	Agriculture Research Department (Sindh)	Established in 1904, the role of this institute evolved with respect to new issues of agricultural research.	Department is currently executing a project for bio-saline agriculture in coastal districts of Pakistan
17	Sindh Arid Zone Development Authority (SAZDA)	Established in 1985 with the aim of supporting community-based salinity management programs.	The organisation was closed in 2002.
	NGOs/ International Organisations		
18	Thar Deep Foundation	Established in 1998 with focus of Rural Development in Sindh province.	This organisation has not done any work on salinity and waterlogging management.
19	Rural Development Foundation	Established in 2002 for action research and community development for marginalised communities.	In 2019-20, the organisation worked with farmers in two villages for the maintenance of drainage channels, conjunctive use of saline and fresh groundwater and "Huri" (block-plantation) for salt tolerant crop varieties.
20	Thar Foundation	Thar Foundation is a subsidiary of Sindh Engro Thar Coal mining company. It has a broader aim of "think globally and act locally" for people of Thar	The organisation has worked on tree plantations in Tharparkar, and on promotion of bio-saline agriculture.
21	Food and Agriculture Organisation (FAO)	This organisation contains a comprehensive knowledge repository on salinity, salt-affected soil and bio-saline agriculture.	Currently no project is focusing on salinity.

S. No.	Organisation	Mandate	Current activities
22	World Wide Fund for Nature (WWF)	The organisation has several focus areas that also include building community resilience towards disasters and impacts of changing climate.	The organisation is not directly working with respect to salinity management. Previously, it has worked to develop mangroves in coastal areas.
23	Asian Disaster Preparedness Centre		The organisation does not yet have any project but hopes to finance some projects under the 10 year “Living with Salinity” program being promoted by ACIAR.
24	International of Union of Conservation of Nature	IUCN-Pakistan was established in 1985 and has remained an important contributor to environmental work both at community and policy level	The organisation has a high focus on management of coastal zone, biodiversity and ecosystem protection.
	Academia		
25	Sindh Agriculture University, Tandojam	Established as the Institute of Agriculture in Sakrand in 1940, shifted to Tandojam and renamed as Sindh Agriculture College in 1955, which was upgraded as Sindh Agriculture University in 1977.	A Centre for Biosaline Agriculture was established in the Department of Soil Science in 2007 as a part of the 5-year HEC-funded project. The Centre has done considerable work on bio-saline agriculture, and these activities continue. Presently, the Faculty of Agricultural Engineering is executing a project “Spatial variability mapping of Soil Salinity in the irrigated areas of Sindh Province using Satellite Data and Geospatial tools”
26	University of Agriculture, Faisalabad	The university was established in 1961 – earlier it was known as Punjab Agriculture College and Research	UAF’s Institute of Soil and Environmental Sciences worked extensively on salinity

S. No.	Organisation	Mandate	Current activities
		Institute, Lyallpur, which was founded in 1906. For a long time it was the single institution for agricultural education and research in West Pakistan.	management using chemical and biological approaches.
27	US-Pakistan Centre for Advanced Studies in Water (USPCAS-W), Mehran University of Engineering (MUET) and Technology, Jamshoro	USPCAS-W was established in 2014 with the aim of imparting knowledge and research in the areas of water resources, irrigation and drainage engineering and knowledge dissemination to end users. Its parent institute MUET is an eminent university for engineering education in Pakistan.	USPCAS-W has conducted academic research under the subject of salinity management in its nascent age. The centre is currently leading a multi-partner ACIAR sponsored project “Adapting to Salinity in the Southern Indus Basin”.

3.3 Discussion

Our thematic analysis of the literature and FGDs reveals that the problems of salinity and waterlogging were recognised very early after the development of the irrigation system, with a series of five-year development plans outlined to manage the issue. However, the early focus on these issues was dramatically reduced over time. One obvious and most probable reason was policy shifts towards large-scale drainage projects followed by the notion that communities will have to “live with salinity”. However, in order to support any idea of communities being able to live with salinity, the legacy of earlier development, investigative and research projects should have been used to develop capacity of institutions and communities. Some limitations in the approach of salinity management strategies are discussed in the following sections.

3.3.1 Gaps in the Current Governance and Management of Salinity

It has been discussed in detail how salinity and waterlogging are endemic to the Indus Basin. Our analysis of policy and FGDs highlights three core gaps leading to the ineffectiveness of strategies and programs. One major gap was a policy for sustainability and thus a long-term planning strategy. Five-year development plans were intended for economic growth but political priorities shifted at the time of execution. Operational costs for drainage systems were not provided leading to unsustainability of these systems. There was no consolidation of data collected and research that had been conducted by the various organisations. No comprehensive survey has been conducted after 1979 and the focus of research has also shifted after 2004. However, the farmers who have had to “live with salinity” are doing so with limited success, as they do not have other choices.

3.3.2 Policies and Strategies

The National Water Policy was approved in 2018 which also recognised the problem of waterlogging and salinity. The policy vowed to make future infrastructural development in consultation with the provinces in a holistic manner. A pledge for a “National Drainage System” is also a feature of the policy. Watercourse lining is to be promoted in saline and semi-saline areas to avoid conveyance losses. Harvesting of rainwater to flush out salts and to avoid accumulation of rainwater runoff into surface drains was also highlighted. The evident limited understanding of the scale of the problem reveals the extent the inherent salinity problem has been neglected. This might be due to non-availability of sufficient data and information for policy and decision makers.

In drainage projects, strategies were lacking to tackle the drainage effluent, as evidenced in the SCARP VI project where effluent drained into evaporation ponds is now contaminating the command area of the Rainee Canal. Earlier research had strongly discouraged the use of evaporation ponds for effluent management (Chandio and Majeed, 2002; Tarar, 2002). The SCARP VI project was intended to be a solution to waterlogging caused by the aftermath of the 1973 flood, which in turn was an outcome of poor and politically influenced decision-making involving the breaching of the Panjnad section.

The 18th Amendment of the Constitution and associated incomplete devolution of powers represented a final blow to already weakened policies and strategies. Conflicts between WAPDA and PIDs remained unsettled on taking over these systems and carrying out operation and maintenance, resulting in poor post-construction maintenance. Under-funding and departmental hierarchy in budget allocation have been the main constraints resulting in poor maintenance. Reallocation of surface water and conjunctive use of both 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.

3.3.3 Institutional Re-orientations and Drawbacks

No serious data management effort was made after 1979 as can be seen in Table 6. The biggest drawback in salinity and waterlogging data is that it is not based upon any actual contemporary survey. The reclamation shoots of DLR that remained operative during 1945-94 was not sustainable. Bandaragoda and Rehman (1994) reported that the decline in water allocation started in 1979 due to a decrease in water supplies for their shoots. These structures were to be installed at the tail reaches of the tertiary irrigation system and used to remain operational during 79 days of Kharif season when additional supplies were available (Rehman *et al.*, 1997). Administration issues were also the major reasons for the decline in the performance of this system. Commissioning of these systems were not free of political influence. As a consequence, most of these shoots were installed at the head reaches of minors (Bandaragoda and Rehman, 1994).

There are a number of success stories but they have not been disseminated or up-scaled to be used as "lessons learnt" or "best practices". One of the key reasons is that there is a lack of integration among organisations involved. Organisations like IWASRI, SMO, LIM are still functioning in project mode. Therefore, their scope depends on bite-size allocations from the federal budget. For instance, SMO used to work on soil salinity data collection until 2004 but afterwards, this aspect was eliminated from its scope. Presently, the organisation is only provided with funds to collect data and develop an analysis report. It lacks funding to manage the existing 2,000 observation wells or to install new wells. SMO reports that it does not monitor SCARP operations; they only collect groundwater samples from the observation wells.

In addition to gaps in data collection, there are only limited number of organisations who have worked on salinity (Table 7). The Soil Survey of Pakistan is no longer collecting waterlogging and salinity data since its devolution after the 18th Amendment. Current departmental mandates are limited to collection of data on soil physical properties. Surveys of agricultural soil and chemical characteristics of soil is the responsibility of Soil Fertility laboratories in Sindh and Punjab. In Sindh, the department has laboratories in only 12 districts whereas Punjab has laboratories in all districts. These laboratories only provide services to farmers on their requests, and the consequent inability to take full ownership for the problem of salinity has jeopardised farmers' trust in these organisations. This low organisational capacity also highlights where the strategic priorities of the provincial governments lie and the limited vision of the organisations' leadership.

Another key reason for data gaps is that data among the organisations is not being shared. This undermines the quality and authenticity of data and leads to poor quality of reporting. There is non-compliance of the standard operating procedures of projects and a reluctance or no strategy for open data sharing. As for compliance, the PC-V lessons learnt assessment forms required by Pakistan's Planning Commission for each public sector development project have rarely been collected from the organisations involved. Also, organisations such as NIAB, NIA and agricultural research departments, who claimed to have conducted relevant research in soil salinity, are reluctant to share their reports and books. Data restriction in NIAB is so excessive that important pieces of information are censured on the web page leading to poor readability and understanding. During FGDs, NIA and agriculture department officials mentioned some knowledge products on salinity management but they were reluctant to share their reports.

The case of organisations such as WAPDA, including its allied institutes, and PCRWR is different. Their data, project reports and publications of post 1960s are freely available for researchers. IWASRI consistently published a catalogue of research conducted relevant to salinity until 2004. That is why these organisations have always remained a strong supporter of establishing a consolidated database for sharing the project recommendations and to avoid the repetition of work.

3.3.4 Farmer Preparedness

> You make a very high-tech jet plane and do not train the pilot. Our farmer is our pilot, salinity is our war zone and our plane is our project.

The critical value of involving farmers in projects is a key lesson learnt from PCRWR's participatory tile drainage projects. During the execution of these projects, in addition to cost sharing by the farmers, PCRWR also provided necessary training to the farmers for operation and maintenance of the systems. According to Ali (2018), the reclamation activities remained successful in areas where farmers were involved. Farmer involvement through Water User Association (WUAs) has also remained a common feature of all such development projects, and particularly those executed through International Development Association loans (ADB 2003 & 2005). Rehman *et al*. (1997) also emphasised that, to reap the benefits of reclamation projects, farmers must receive information on how to maintain soil quality. However, the component of farmer training has mostly been missing in earlier projects. Programs developed for the training of beneficiary farmers were done either on a limited scale or were never executed. Farmer training is lacking in all policies, strategies and projects. It is rare that a farmer would have been trained to manage the salinity on their land or even informed regarding salinity perspectives.

Attempts are always made to develop participatory research projects and farmers were attracted to adapt the technologies through subsidised schemes. Progressive farmers take initiatives to some extent to reclaim the soils but they also require proper training. Farmer awareness regarding the issue has brought promising results. Even in the present scenario, it is only those farmers who are actively seeking knowledge benefits from such schemes and extension advisory services who can aspire to "survive with salinity". Approximately 89% of farmers in Pakistan own less than 5 ha of land. These farmers do not in general possess sufficient resources to train themselves or to use expensive techniques for salinity management, as highlighted by Kuper and Kijne (1996). Similarly, none of the responding farmers could identify any NGO who has helped them in managing salinity.

4 Conclusion and the Ways Forward

The analysis has revealed three core gaps regarding ineffectiveness of strategies and programs *viz*:

1. Lack of policy guidance for sustainability and planning for implementing a long-term salinity management strategy.
2. Non-consolidation of data collection and research conducted by various organisations and lack of mechanisms to enforce sharing of data.
3. Lack of farmer participation in decision-making processes.

4.1 Long-Term Strategy

Plans for managing the Indus Basin were developed from preliminary assessments and appropriate surveys known at that time. Likewise, research institutions also performed their tasks of undertaking relevant research and consolidation within the financial framework provided to them. However, political and financial priorities of the government took a toll on the effectiveness of these action plans and most of the projects were abandoned half-way.

After the 2002 National Drainage Program, the focus of salinity-related research has shifted. This is clear from the confusion prominent in the National Water Policy 2018 regarding the subject of salinity and waterlogging. In policy, only general recommendations are given for waterlogging and salinity. In a clear indication of the need for infrastructural development, the policy vows to develop a National Drainage System through consultation among the provinces regarding handling of effluent. However, the policy-making institution did not hint at the objective of completing the existing drainage projects, which had been experiencing delays, and had led to deteriorating drainage conditions of the lower Indus Basin. Moreover, the policy-makers did not highlight the importance of institutions to resolve this inter-provincial issue. No aim for a new soil salinity/ waterlogging survey was made to underpin plans for new structural measures or water allowances. In short, the commitments presented in the policy are too shallow compared to the gravity of the issues of waterlogging and salinity being faced.

The 18th Amendment also created new challenges for many of the organisations involved with the salinity issue. After a decade, institutional development in the provinces has not been sufficiently matured to take up responsibilities that had been devolved to them by the federal government. This was particularly relevant in the case of waterlogging and salinity. Feedback from our FGDs and our review of institutional roles reveal no single organisation holding the responsibility for surveying the extent of waterlogging and salinity. Difference of opinions regarding the impacts of drainage projects is very prominent among the institutions consulted.

The research focus on reclamation of waterlogged and saline soils also missed the objective of permanence and continuity. Salinity is a long-term issue which cannot be managed in the matter of months; rather it is a matter of decades. Unfortunately, none of the trial research studies lasted longer than three years, and most comprised of two to three cropping seasons only. Limited research funding ensures limited extent of project duration, and limits transfer of research findings to stakeholders and beneficiaries.

4.2 Data Collection and Consolidation

The FGDs with key stakeholders have not provided a consolidated and fresh database on soil salinity. The Agricultural Statistics of Pakistan also does not provide a clear picture of "waterlogging and salinity extent" in the country. However, data based on groundwater salinity is available with the Punjab Irrigation Department, PCRWR and SMO. Groundwater and salinity data collected by the afore-mentioned organisations are not consolidated into a centralised database.

4.3 Farmer Preparedness

Many farmers are adapting to "living with salinity" through their experience. Generally, farming communities remain challenged by the increasing extent of salinity. The outcomes of salinity research projects also remained restricted to project reports. Only limited research has been proliferated out to farmer fields. Therefore, as a whole, the farming community is not well prepared both in terms of knowledge and skill to take on best practice initiatives.

4.4 Recommendations

Based on the above concluding remarks, the following recommendations are proposed:

Gap 1: Lack of policy guidance for sustainability and planning for implementing a long-term salinity management strategy

i. There is a need to conduct regular surveys to determine the extent of waterlogging and salinity, particularly for the southern Indus Basin. A detailed survey should perhaps be conducted at 10-year intervals. A risk map could therefore be developed to set priorities and strategies.
ii. No single strategy will work in any specific area as learnt from past experiences. Therefore, area specific strategies should be planned and implemented.
iii. As physical soil salinity surveys require huge resources, modern technology and remote sensing techniques can be used instead.
iv. WAPDA and IWASRI could work in collaboration with the provincial Irrigation Departments to help them develop the expertise that WAPDA once had.

v. There is a need for greater coordination between federal and provincial agencies to develop integrated land-water-agriculture management policies and for better implementation of existing policies.
vi. Any policy development on salinity management in future should take into account farmers' choices and financial abilities.
vii. Regular training should be provided for capacity enhancement of agricultural extension providers.

Gap 2: Non-consolidation of data collection and research conducted by various organisations and lack of mechanisms to enforce sharing of data

viii. A salinity management database should be developed to consolidate and avoid duplication of research.
ix. There is a need for installation of (low-cost) automatic flow and water quality sensors at rim stations, headworks (especially at Guddu i.e. Sindh-Punjab border), and major drains to develop yearly salt balances and then setting salinity management targets.
x. Research trials related to "living with salinity" needs to evolve out of a project approach and should be extended in a program mode for at least 10 years.
xi. Data collection on soil salinity should not be restricted to relevant technical disciplines. A shift from prevailing practice is required.

Gap 3: Lack of farmer participation in decision-making processes

xii. Expensive reclamation techniques, such as tile drainage facilities, need to be established with farmer participation to ensure greater effectiveness. Presently, vertical drainage is not feasible, therefore areas with groundwater salinity exceeding 3 dS/m should be provided with horizontal drainage.
xiii. There is a need to focus on screening and development of salt tolerant crop varieties.
xiv. In saline soil conditions, the strategy for leaching out salts at the end of cropping seasons may be adopted. In addition, there is a need for decision support/ water allocation tools for effective use of high flows to re-introduce reclamation shoots especially in deep groundwater areas.
xv. On-farm field trials on salinity and reclamation research should be conducted with farmer involvement.
xvi. Farmer training should be made an integral component of any research or development project related to salinity and water management.
xvii. Clusters of progressive farmers need to be engaged to test their capacities for imparting training to smallholder farmers on their farms.
xviii. Change in curricula at university level is needed. More subjects on salinity management need to be included.

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Adapting to Salinity in the Southern Indus Basin (ASSIB) Project

Adapting to Salinity in the Southern Indus Basin (ASSIB) project has been launched by the Australian Center for International Agricultural Research (ACIAR) in collaboration with many Pakistani and international organizations. This project is part of a 10-year program. The overall aim of this program is to explore how to best build Pakistan's adaptive capacity for living well in salinity-affected landscapes in a staged process viz. formative research; participatory research; and action research.

This initial 2.5-year project phase has been kicked off to determine the adaptation potential of farming communities living in salinity-affected areas and of institutions undertaking research on similar issues. The objectives of this phase are build on prior research and project proposal development pursuing the formative research process and establishing processes for participatory research.

This policy review offers a comprehensive overview of earlier efforts for salinity management in the Southern Indus Basin dating back to the 19th century when the Indus Basin Irrigation System was developed. Conducted through a published research methodology, this policy review also encapsulates the good impacts of earlier efforts, the capacity of the vulnerable communities, best practices, and lessons learned. Through this policy review, ASSIB project offers a rare opportunity to all stakeholders of salinity management in Pakistan in the form of a way forward for filling the identified gaps and avoiding the repetition of work. The report can be accessed from www.pcrwr.gov.pk/publications

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