IRRIGATION-DRAINAGE AND WATERLOGGING-SALINITY ISSUES IN LOWER INDUS AND THE POSSIBLE SOLUTIONS

By

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ABSTRACT

To irrigate the command area, 48.76 MAF of surface water is allocated for Sindh, which is provided through network of irrigation system; however, the availability is normally 10-12% less than this allocation. Groundwater use is about 4.3 BCM, which is unplanned altogether. In contrary, groundwater has considerably higher potential, but it is unexplored, the major reason behind, being the ample availability of canal water and absence of any policy by the government, for utilization of groundwater potential. Almost 50% of the culturable command area in Lower Indus does not have drainage facilities. With minimal natural slope, surface drainage system can only cater for removal of any standing water on adjoining fields. Further, any surface drainage system is not meant for root zone drainage. Therefore, waterlogging is a permanent feature in Sindh and a major hindrance in increasing the cropping intensity, which is almost double in Punjab as compared to Sindh.

To avoid waterlogging, with minimal investment on drainage, fresh assessment of optimum groundwater development potential for different areas in Lower Indus is required. For the purpose, a comprehensive fresh survey of depth wise groundwater quality is recommended. Fresh assessment of crop water demand, simultaneously keeping in view the groundwater use potential for different areas, needs to be accomplished for each canal command. This would help in developing 8-10 ft cushion for avoiding waterlogging and providing excess rainfall storage and avoid flooding, as observed in 2011. This will also increase in cropping intensity, which is almost half, as compared to Punjab.

1. INTRODUCTION

Sindh is the second largest province of Pakistan. The Indus River irrigates major portion of Sindh and a very small part of Balochistan province is also irrigated with Pat Feeder Canal from Guddu Barrage and Kirthar Branch from North West Canal off-taking from Sukkur Barrage. The total gross command area (GCA) of the Lower Indus (Sindh and Balochistan) is 5.92 Mha with cultureable command area (CCA) of 5.43 Mha. The major field crops sown in Sindh are wheat, cotton, rice, and sugarcane, which utilize 68 percent of the total cropped area. Sindh also produces horticulture crops: mangoes, bananas, dates, and chilies.

The Indus River enters Sindh province at an elevation of 75 m (246 ft) above mean sea level (amsl). The level of flood pain falls southwards at an average rate of 12.5 cm / km

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(eight inches/mile). The river lies on a slight ridge, which slopes away in lateral direction up to Larkana, thus it has influent behavior and loses water to the underlying aquifer.

To irrigate the command area, 48.76 and 3.87 MAF of surface water is allocated for Sindh and Balochistan, respectively, which is provided through network of irrigation system; however, the availability for Sindh is normally 10-12% less than this amount. Groundwater use is about 4.3 BCM (HALCROW & ACE, 2003), which is unplanned altogether. In contrary to this limited use, groundwater has considerably higher potential, but it is unexplored, the major reason behind, being the ample availability of canal water and absence of any policy by the government for utilization of groundwater potential.

1.1. Surface and Ground Water Use

Sindh is the second largest province of Pakistan. The Indus River irrigates major portion of Sindh (about 41 percent) through the canals off-taking from three Barrages in Sindh: Guddu, Sukkur and Kotri. A very small part of Balochistan province is also irrigated with Pat Feeder Canal from Guddu Barrage and Kirthar Branch from North West Canal, off-taking from Sukkur Barrage. Sindh has a diversion capacity of 111 BCM (90 MAF); but as per Water Accord 1991, Sindh's share is 60.15 BCM (48.76 MAF). However, post Tarbela, actual diversions to Lower Indus are around 53.04 and 2.47 BCM (43 and 2 MAF), for Sindh and Balochistan, respectively (Basharat et al., 2014).

The climate of Sindh is hot and arid. The maximum temperature in summer exceeds 40^{o} C. Evaporation in Sindh is higher than elsewhere in Pakistan. According to the map of mean annual rainfall in Pakistan, by Pakistan Meteorological Department (PMD, 2010), annual precipitation ranges from about 100 to 200 mm in parts of Lower Indus Plain to over 1000 mm near the foothills in the Upper Indus Plain. On the other hand, lake evaporation increases in north-south direction from 1270 mm at Peshawar to 2800 mm at Thatta (Ahmad, 1982).

Sindh relies almost entirely on the Indus River, because almost 70 % of the area is underlain with saline groundwater. Based on groundwater investigations carried out under Lower Indus Project in 1950s and 1960s, out of the total command areas of Guddu and Sukkur, 17.4% has salinity of 750 ppm or less, 7.3% area having salinity levels of 750 to 1500 ppm (Ahmad, 1995: pp.6.41).However, shallow groundwater with variable thickness has developed with passage of time, due to leakage from the irrigation system. But, it is supposed that only about 5-6 BCM (4-5 MAF)of groundwater is pumped annually, both in the riverine (without canal irrigation) and irrigated areas, when there is shortage of canal water supplies in the system. The fact that IBIS has only small online storage, thus due to non-utilization of groundwater storage, it can be said that irrigation system is totally supply based. Thus, farmers occasionally face water shortages.

1.2 Comparison of Drainage Facilities in Sindh and Punjab

Drainage facilities in Sindh Province have been provided over a gross command area of 2.724 Mha (6.732 Ma). These facilities include the installation of 6138 tubewells (4190 FGW and 1948 SGW), construction of 9185 km surface drains (including interceptor) and 2046 km sub-surface drains (Tile drains) at a cost of Rs.28.952 billion (WRPO and IWASRI, 2004). Right Bank Outfall Drain (RBOD) Stage-I and III, on right side of the river is an additional development, which will facilitate an additional area.

Data analyses have shown that almost 50% of the culturable command area does not have drainage facilities (Table 1). The present surface drainage density is usually not more than 3-7 m / ha which leaves much of the land without a surface drainage system. Average land surface slope in Sindh is 12.5 cm / km (eight inches/mile); whereas, in Punjab it is about 27 cm / km. With this minimal natural slope, surface drainage system can only cater for removal of any standing water on adjoining fields, that too if the field slopes and inlets are properly maintained. It is further elaborated that the surface drainage system is not meant for root zone drainage. Therefore, waterlogging is a permanent feature in Sindh and a major hindrance in increasing the cropping intensity, as it had been in Punjab. The cropping intensity was 102.8, 110.5 and 121.7% during 1960, 1972 and 1980, respectively (Ahmad, 1995), and now operating at about 172% (Mirza and Latif, 2012) and even higher in certain areas. This provides the reasoning that why the cropping intensities are almost double in Punjab as compared to Sindh, as quoted by Mirza and Latif (2012) that the cropping intensities vary from 116.7% in Sindh Cotton Wheat zone (SCWS) to 234.0% in Punjab Sugarcane Wheat zone (PSW).

Table 1: Existing drainage facilities, up to June, 2001 (WRPO and IWASRI, 2004).

Province	Gross Area (Ma)	CCA (Ma)	Surface Drains (km)	Subsurface Drainage						
				Tubewells (Numbers)			Inter-ceptor Drains (km)	Tile Drainage		
				FGW*	SGW**	ScW***		Length (km)	Area (Ma)	
									GCA	CCA
Punjab	10.357	9.220	3402	8065	1985	-	6	2810	0.235	0.164
Sindh	6.732	5.710	9031	4190	1587	361	154	2046	0.105	0.089
NWFP	0.884	0.884	971	491	-	-	-	7756	0.658	0.137
Balochistan	0.177	0.161	322	-	-	-	-	-	-	-
Total	18.150	15.793	13726	12746	3572	361	160	12612	0.998	0.390

*Fresh Groundwater; **Saline Groundwater;***Scavenger Wells

2. O & M OF IRRIGATION AND DRAINAGE SYSTEM IN LOWER INDUS

Agriculture in Sindh depends on irrigation network, which is badly deteriorated, starting from the barrages till the outlets, the last point in the jurisdiction of the department. Despite the largest irrigation diversion capacity, many farmers in Sindh, especially those at tail ends are either facing shortage of irrigation water due to silting up of Mangla and Tarbela reservoir and/or inequitable water distribution due to corruption and poor maintenance of the irrigation infrastructure. Despite huge development, and maintenance and repair (M&R) budget in billions, the irrigation infrastructure in Sindh including barrages, head regulators, cross regulators, bunds and embankments are in shabby conditions requiring attention of irrigation managers and all concerned. Drains are choked along the length and poorly operated (especially, pumping stations), thus causing extra flow depths than the designed. The irrigation bungalows are abandoned;

field offices are inactive, officers do not have interest in system rehabilitation and maintenance and major portion of the M&R budget leaks in the form of corruption at various levels. Sale of water and rent seeking has become a norm. Floods are frequent and destroy agriculture, play havoc with people. There is need for restructuring and capacity building of irrigation department; otherwise things would worsen with passage of time.

A field tour was conducted in irrigated areas of Sindh, during December 8-15, 2014. The main purpose of this field visit was to observe the actual performance of both the irrigation and drainage systems, observe waterlogging, salinity and crop conditions, some of the highlights are as explained below.

2.1. Surface and Tubewell Drainage in Nawabshah

In the area from Mirpur Khas to Sanghar, not a single drainage tubewell was observed in operating condition. Many of them are almost abandoned, with transformer and mains wire stolen. A big mistake in the placement of the tubewells was that the tubewell sites were selected on a regular grid. Thus, a greater potential was there for theft of the installed equipment, as compared to if the tubewell housing would have been near the farmer dwellings. Surface drains were observed with poor operation and maintenance conditions, as result, many of the fertile lands have been abandoned (Figure 1).

Systematic and project based development is absent in Sindh, due to political involvement and shortcut approaches. That is, before rehabilitation of LBOD, there were 189 scavenger wells in Nawabshah, each consisting of 1.5 cfs, fresh water pumping for irrigation and 2.5 cfs saline water pumping for drainage. During last PPP government on special efforts by President of Pakistan, Asif Ali Zardari, a rehabilitation program for 32 tubewells was planned. However, only 18 tubewells were rehabilitated. Twenty three new tubewells for saline pumping, and three tubewells for pumping water from depressions to surface drains were also installed, as part of rehabilitation program in Nawabshah. Most of these wells were selected with political favoritism. With this rehabilitation program, waterlogging conditions in the these areas have improved. Before taking up the rehabilitation program, a field survey was carried out , during which it was observed that only 5% of the wells were in working condition, (Source: Sub-engineer of Irrigation Department in Nawabshah).

Figure1: Almost fully choked drain (U-left), waterlogged, and barren/saline lands (U-right), along Sanghar-Mirpur Khas road; patchy wheat crop near Mirpur Khas, due to waterlogging and salinity (L-left);good stand of Banana, along Nawabshah-Qazi Ahmad road (L-right).

2.2. East Khairpur Tile Drainage Project

Areas where tile drainage sumps are not working, crops' health expose of the poor drainage conditions in the area (Figure 2). According to the sub-engineer (irrigation department) some of the canals e.g. Sathio canal and Mirwah have surplus water. However, there is lack of irrigation water for tail-end farmers of Pantin minor. Four tile drain sumps were visited during this visit, out of a total of 45 sumps. According to the Sub-engineer, 22 out 45 tile drainage sumps are working, which altogether have 34 cusecs (cfs) design pumping capacity. However, their actual pumping is far less than this design capacity. The most important of the reasons is lack of proper maintenance of pumps, many of them have broken/corroded delivery pipes. The other important reason for low performance is choking of collector and lateral lines, and therefore, the areas even close to pump sumps were observed with standing water and surface salinity. All these factors show lack of proper water management in the area regarding: firstly, when and how much to apply irrigation water; secondly, at what depth to maintain groundwater level, so that it can avoid waterlogging and salinity.

2.3. Sukkur (Right) Command Area

Most of the area on right side of the Indus (except along the river) has high groundwater salinity, therefore, surface water entering into Hamal and Manchar lakes is also salty. Particularly, people living in and around Manchar lake are facing drinking water and health problems. Government has started a program of providing salt treatment plants for the public. The incoming water to the treatment plant in Manchar Lake has TDS of about 1900 ppm, whereas reject water has a TDS of about 7000 ppm. There are about twelve treatment plants near Manchar Lake, some of them are working. This shows the severity of the salt issues in the area and demonstrates the need for proper water management that avoids mobilization of salts present in the aquifer (particularly through capillary action).

During low flows with an average discharge of about 200 cfs, the water quality of Main Nara Valley (MNV) drain shoots up to 10,000 ppm. A treatment plant is currently in planning/design stage, with an inflow of 50 cfs and an outflow of 40 cfs for irrigation and 2 million gallons per day (MGD) for drinking water supply for Dadu city and Johi town. The plant will use pallet reactor (Australian technology), the planned site area is 25 acres. The construction will be started under the supervision of WAPDA. Five such projects are in planning stage for construction at Rs.2.5 billion (2010 cost). Calcium (Ca) and Magnesium (Mg) will be by product for selling, which will recover about 50-60% cost of the project.

Due to poor water management in the area (extra ordinary allocation during Kharif), waterlogging and salinity conditions in the Sukkur (R) command, sowing of the wheat crop was not possible at all, in many areas. Thus, giving rise to low cropping intensities, also, patchy wheat crop was observed, as shown in Figure 3. Vast area were observed with standing water in the fields (Figure 4), lands lying just along the main drains were without drainage.

Figure 2: EKTD Project showing poorly maintained sumps, drains, standing water, as well as, well established date palm trees, in areas with balanced irrigation and drainage.

Figure 3: Lands with patchy or even without wheat crop due to very wet soils and salinity.

Figure 4: Waterlogged and saline lands between KN Shah, Mehar and Hamal Lake (NW and Rice commands).Guddu (Right Command)

2.4. Guddu (R) Command

Mostly right of way of the irrigation canals are without plantation. Irrigation channels from smallest to largest capacity have lost their regime, section and profile (Figure 5 and 6). Farmers are habitual to control the flow of the irrigation channel passing nearby their outlets (Figure 6). This type of misdeeds are easy, at least for the smaller channels, where they can plug the irrigation channel easily and divert all flows to their outlets, especially when the channels are not flowing with full capacity. Similarly, during no or low crop water requirements, farmers plug their outlets and pass all the discharge to downstream areas. This shows the helm of affairs of the Sindh Irrigation Department, which is allowing deterioration of the irrigation and drainage system, possibly to its maximum possible. Thus, the Sindh irrigation department has almost lost the control over equitable distribution of the canal water.

Figure 5: Upper left-Sindh Feeder crossing Shikarpur-Kandhkot road, oblique crossing is de-routing the channel; others showing standing water - Shikarpur-Kandhkot road.

Figure 6: Unner Wah channel (upper right)lost its alignment and x-section; other pictures showing farmers' full authority to divert (or otherwise) water to their outlets.

Farmers are using their full authority to divert (or otherwise) water to their self-designed outlets. The outlet shown in Figure 6 (upper right) is a special example of gigantic size (discharge) that was closed with bushes. This shows absence of irrigation officials and officers from their assigned duties. The extent of corruption, is such of high level (80-90% of the M & R budget goes to commission, as told by an irrigation official) that the system condition looks like it has never been maintained.

3. WATERLOGGING AND SALINITY DISTRIBUTION IN LOWER INDUS

A further non-sustainable practice in Lower Indus, which is important here due to its connection with groundwater level, is soil salinization. It is caused by too shallow groundwater levels. If in arid climates, the groundwater table rises within 2 to 3 m from the ground surface (e.g. due to excess irrigation and lack of natural drainage), evaporation of groundwater through capillary rise starts. These dissolved salts precipitate and accumulate in the topsoil, finally leading to infertility of the land.

3.1. Present Depth to Watertable in Lower Indus

The data collected by SMO, WAPDA, for October 2011, was analyzed in ArcMap, for evaluation of areas under different depth to water table (DTW) ranges as shown in Figures 7 and 8. Accordingly, 36% area is with flooding conditions or within a DTW of 1.0 m, and another 33.6% area is having DTW within the range of 1.0 to 1.5 m. Thus, an area of about 69.6% root zone is waterlogged. The waterlogging conditions in the area remain more or less, the same every year, except a little better situation before monsoon, due to less canal supplies during Rabi season. Thus, one can well imagine about the alarming conditions for cultivation of Rabi crops. Consequently, cropping intensity is almost half in Sindh as compared to Punjab, as stated by Mirza and Latif (2012),that cropping intensities varies from 116.7% in Sindh Cotton Wheat zone (SCWS) to 234.0% in Punjab Sugarcane Wheat zone (PSW)

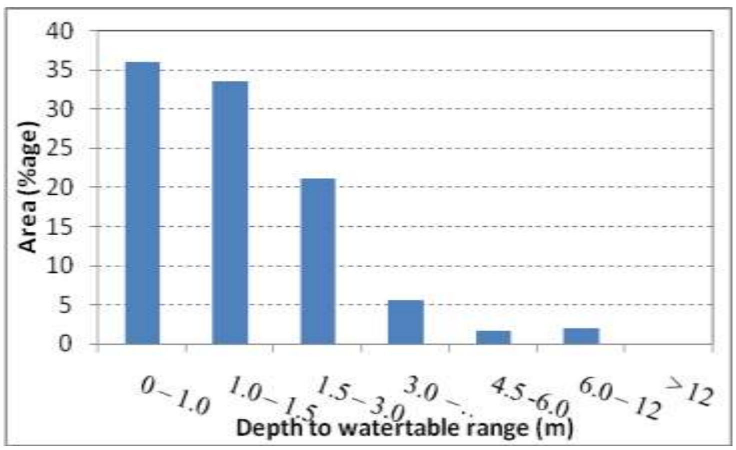

Figure 7: Percentage areas under different DTW ranges in Lower Indus, as on October 2011.

3.2. Waterlogging Situation during Drought Period in Lower Indus

Drought prevailed for four years (1998-2002) in Indus Basin, response of irrigation and drainage in Lower Indus is important in that context. Therefore, the areas under waterlogging were mapped afresh from the GIS work of IWASRI in 2000-2004. The areas under different DTW ranges, for June and October 2001, are given in Table 2 and shown in Figure 9 and 10, respectively. Accordingly, 0.68 and 47.6% area was within a DTW of 1.5 m, from the land surface. Most of this waterlogged falling in Rice, North West and Kalri commands.

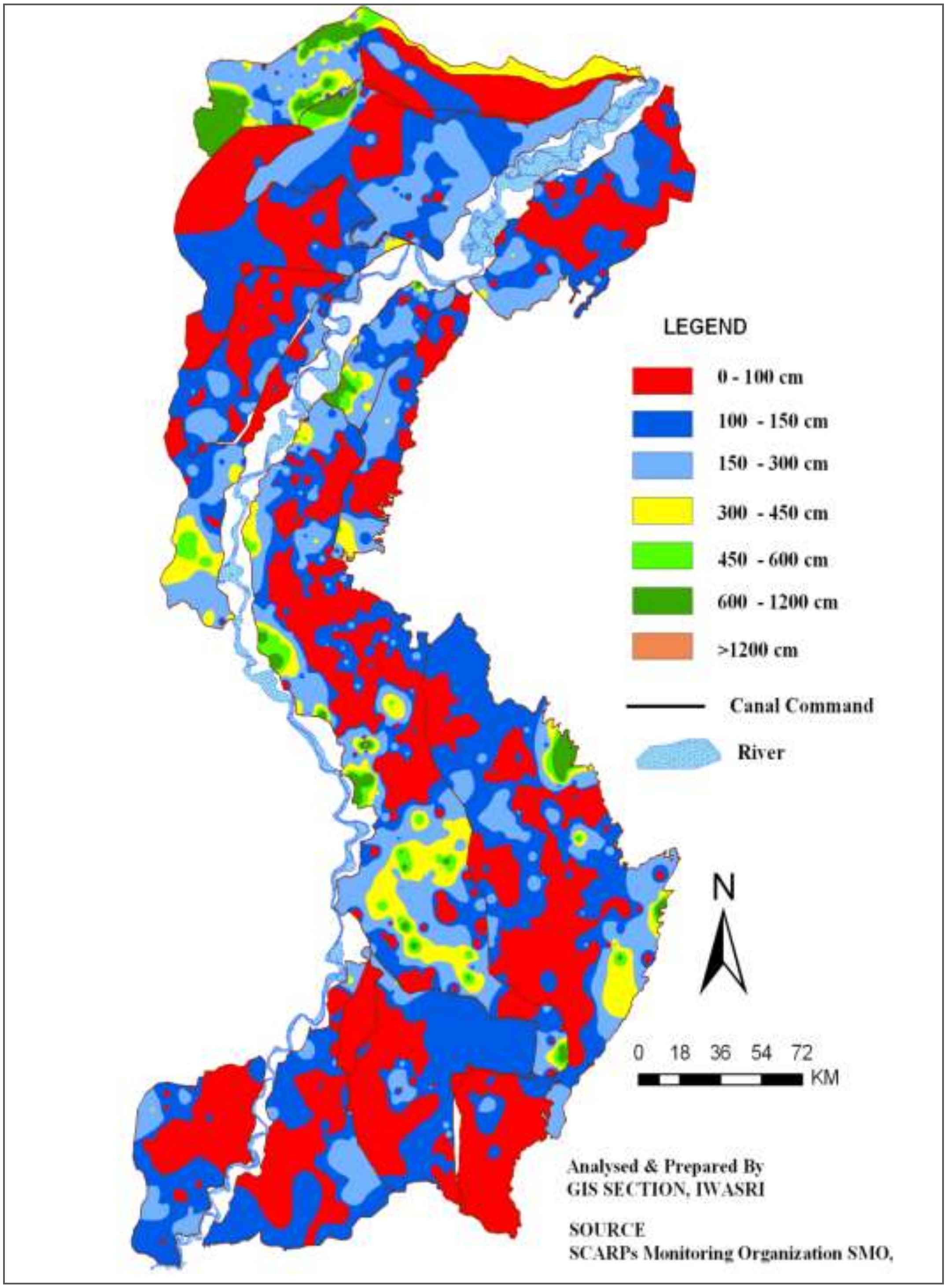

Figure 8: Depth to water table in Lower Indus (October, 2011).

Table 2: Area under different DTW ranges in Lower Indus, June and October 2001.

Area (000 ha) during	Depth Range of Watertable (cm. below NSL)						
	0-100	100-150	150-300	300-450	450-600	600-1200	> 1200
June 2001	11	28	3007	2021	379	321	3
October 2001	1422	1326	1653	782	293	287	4

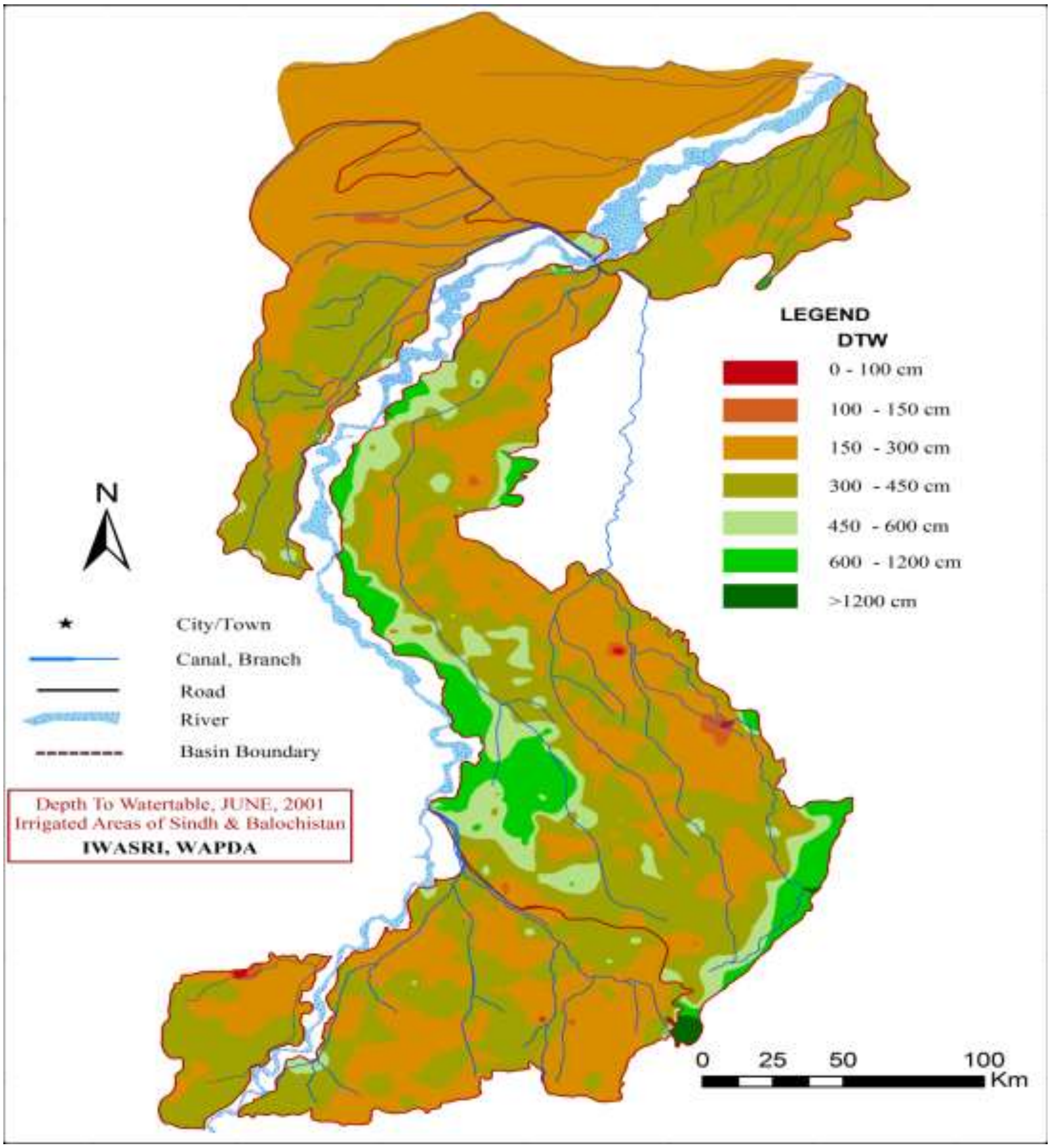

Figure 9: Depth to water table in Lower Indus, June 2001.

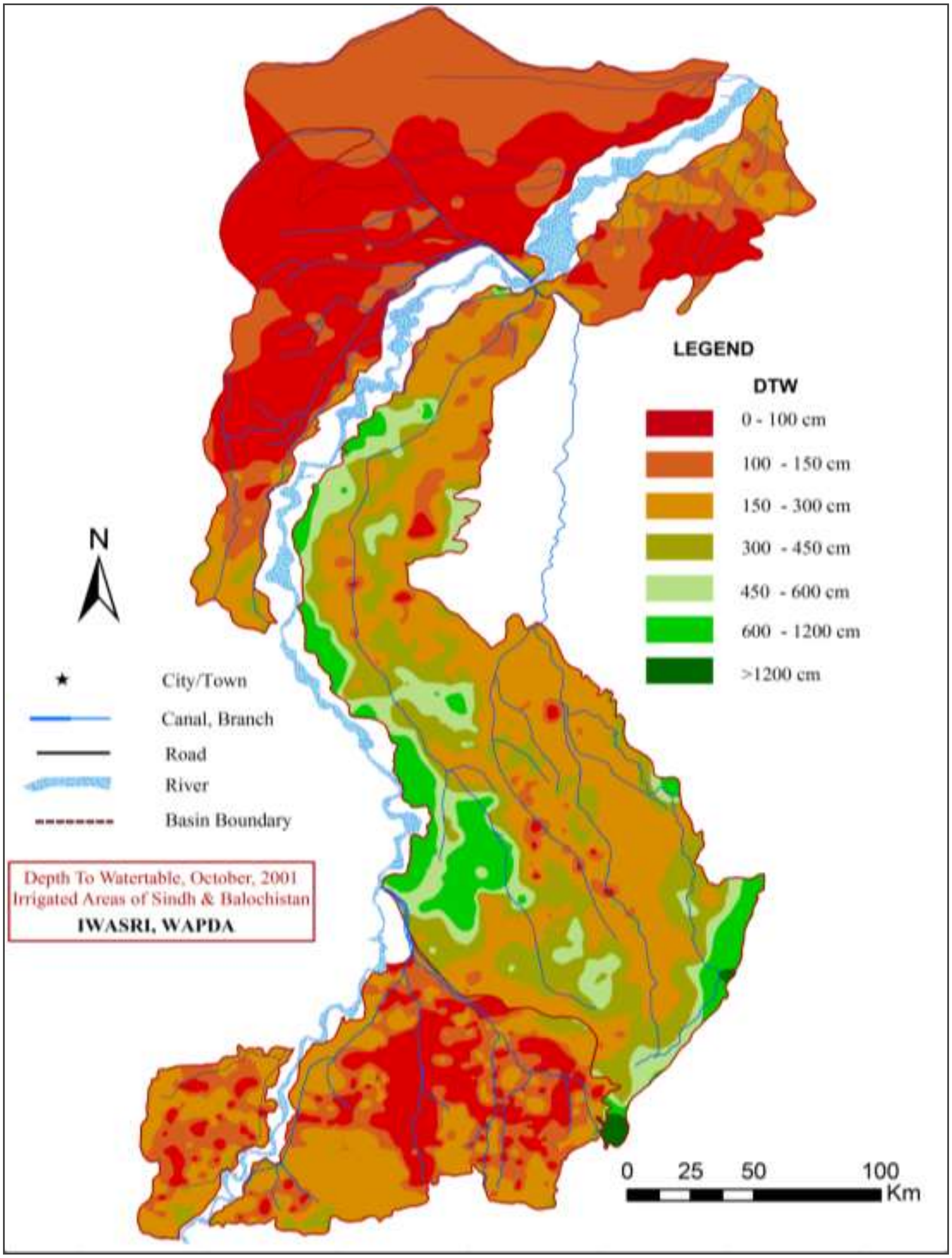

Figure 10: Depth to water table in Lower Indus, October, 2001.

3.3. Groundwater Quality in Lower Indus

Groundwater quality is a major issue in Lower Indus area, affecting crop germination and yields over huge area. The only detailed and dependable information in this regard was collected during the course of hydrogeologic investigations carried out by Lower Indus Project, a number of bore holes 100 to 1,300 feet in depth, were drilled in Guddu, Sukkur and Kotri Barrage commands to determine the quality of groundwater and its horizontal and vertical variation.

The general pattern of groundwater distribution in the Lower Indus Plains is one of good quality water immediately adjacent to the river with increasing salinity away from the river. A lesser quantity of good quality of water is available on the right bank of the river than on the left. This is due to the proximity of limestone hills on the right bank and to the poor aquifers associated with piedmont plains. Another feature of importance is the complete absence of usable groundwater in the deltaic area, south of Hyderabad, except in some shallow pockets in the fairly recently abandoned river beds of the Gaja command. Some of the most saline groundwater of the region is found in the delta where samples with salinities twice as high as sea-water have been obtained. Throughout the region, the salinity of groundwater increases with depth and no case could be recorded where saline water overlies fresh water. Based on the depth wise electrical conductivity, carried out under the Lower Indus Project in 1960s, groundwater quality is shown in Figure 11. According to this map, good quality groundwater is only available along the Indus River, on both sides. Percentage areas under different groundwater quality range (ppm) in the commands of Guddu and Sukkur, as given by Ahmad (1995, Table 5.17, p.6.41), are shown in Figure 12.

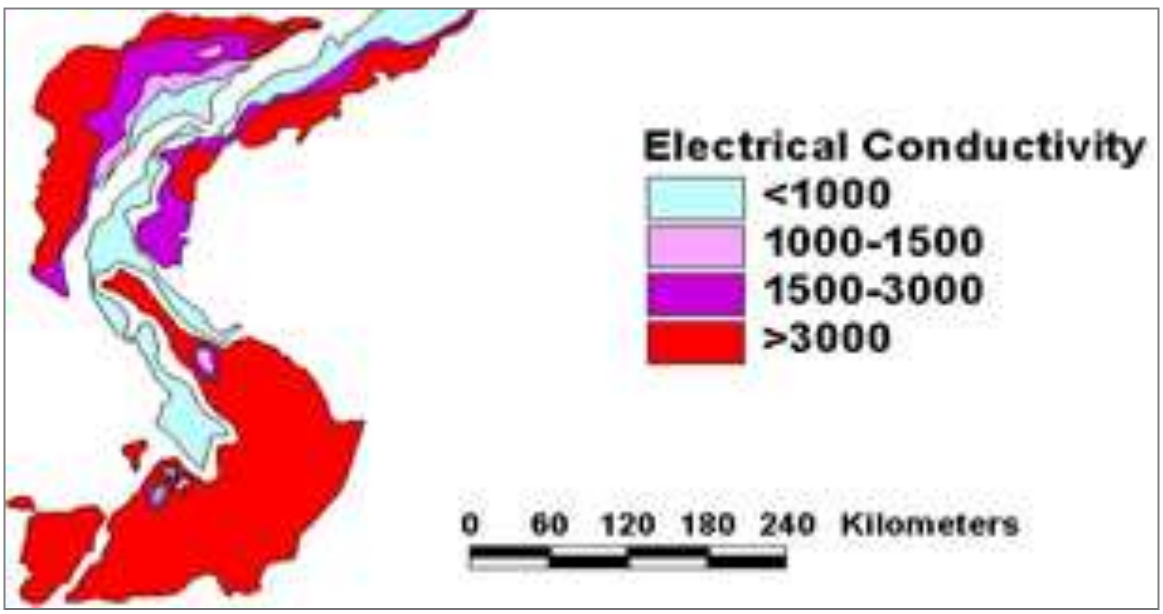

Figure 11: Deep groundwater quality in Lower Indus (Qureshi et al., 2004).

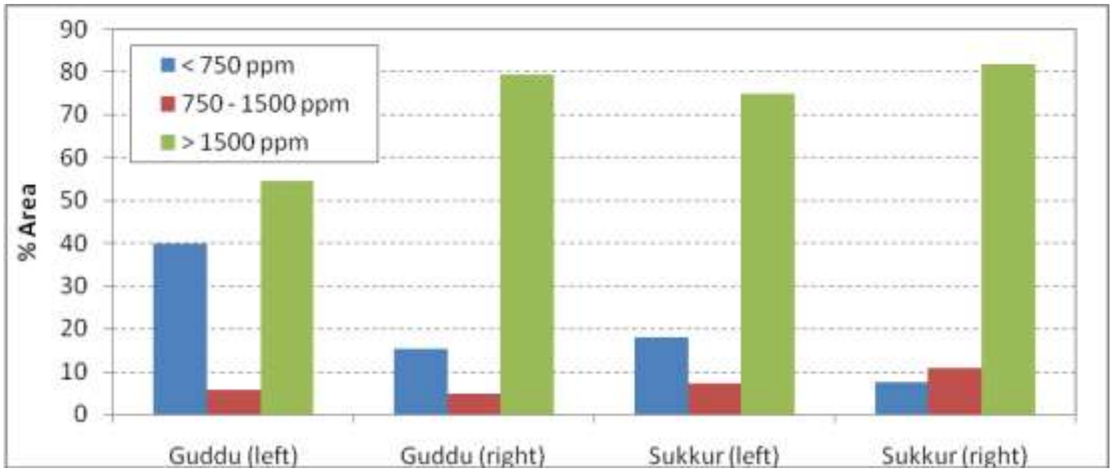

Figure 12: Areas under different groundwater quality ranges in Guddu and Sukkur commands.

SMO, WAPDA has started regular monitoring of groundwater quality from the tubewells and hand pumps. The data for October 2010 was mapped in to useable marginal and hazardous classes with EC criteria and results given in Table 3 and shown in Figure 14. According to the results 46.77% of the area in Sindh is declared as useable and 40.92% as marginal and only 12.31 % as hazardous. These results show little higher fresh groundwater in Sindh, as it is well established that about 30 % area has useable groundwater quality. The discrepancy lies in the fact that the samples collected by SMO, are mostly from shallow sources. Regarding hand-pumps, mostly the people install them, where there is fresh water lens, or just near the irrigation canal. Also the hand-pumps would be shallow, may be 20 to 30 ft.

A major discrepancy in this map seems to be in Nara canal, particularly in Khairpur and Sanghar areas, where there is maximum surface salinity. Naturally, shallow groundwater quality should have been poor in areas with maximum surface salinity, but this is not the case in many areas in this map, including Nara command areas. In case of Nara canal command, the groundwater quality is useable over an area of 80.86%, marginal in 15.61% and hazardous in 3.53. The reason of major portion of the command exhibiting fresh groundwater quality lies in the fact that out of 237 total groundwater samples, 198 were taken from hand-pumps and only 39 samples were from tubewells. Similarly, for the Pat feeder command, only fifteen samples were taken and all of them from hand-pumps (depicted 96.6% as fresh and 3.4% as marginal). Thus, the groundwater quality depicted in Figure 13, represents mostly the upper 3 to 6 m (of the aquifer, which is recharged from the irrigation leakages, and thus not representative of the aquifer which could be exploited with tubewells. However, there are areas where, groundwater quality is fresh and fresh to marginal up to a depth of 25 to 30 m. This shallow groundwater layer can be exploited by installing specifically designed skimming wells, depending upon the depth wise distribution of groundwater quality. This kind of groundwater development would require a detailed and specifically designed groundwater quality survey in irrigated areas of Lower Indus.

Table 3: Shallow groundwater quality in Lower Indus (October, 2010).

Useable [EC(µS/cm) < 1500]		Marginal [EC (µS/cm): 1500 to 2700]		Hazardous [EC(µS/cm) > 2700]	
Area	%age	Area	%age	Area	%age
6974295	46.77	6280965	40.92	1771105	12.31

3.4. Lessons from Surface Salinity in IBIS as Surveyed During 2001-03.

This section is limited to the analysis and comparison of surface salinity survey 2001-2003 of the four provinces, with the previous survey conducted in 1979-81. The surface salinity has been categorized into four classes S1, S2, S3 and S4, according to level of salinity. The comparison of two surveys shows a remarkable improvement in S2, S3 and S4 categories in Punjab, which have been converted into non-saline areas, i.e. non-saline areas increased from 86% in 1978-79 to 93% in 2001-03, as shown in Figures 14 and 15.

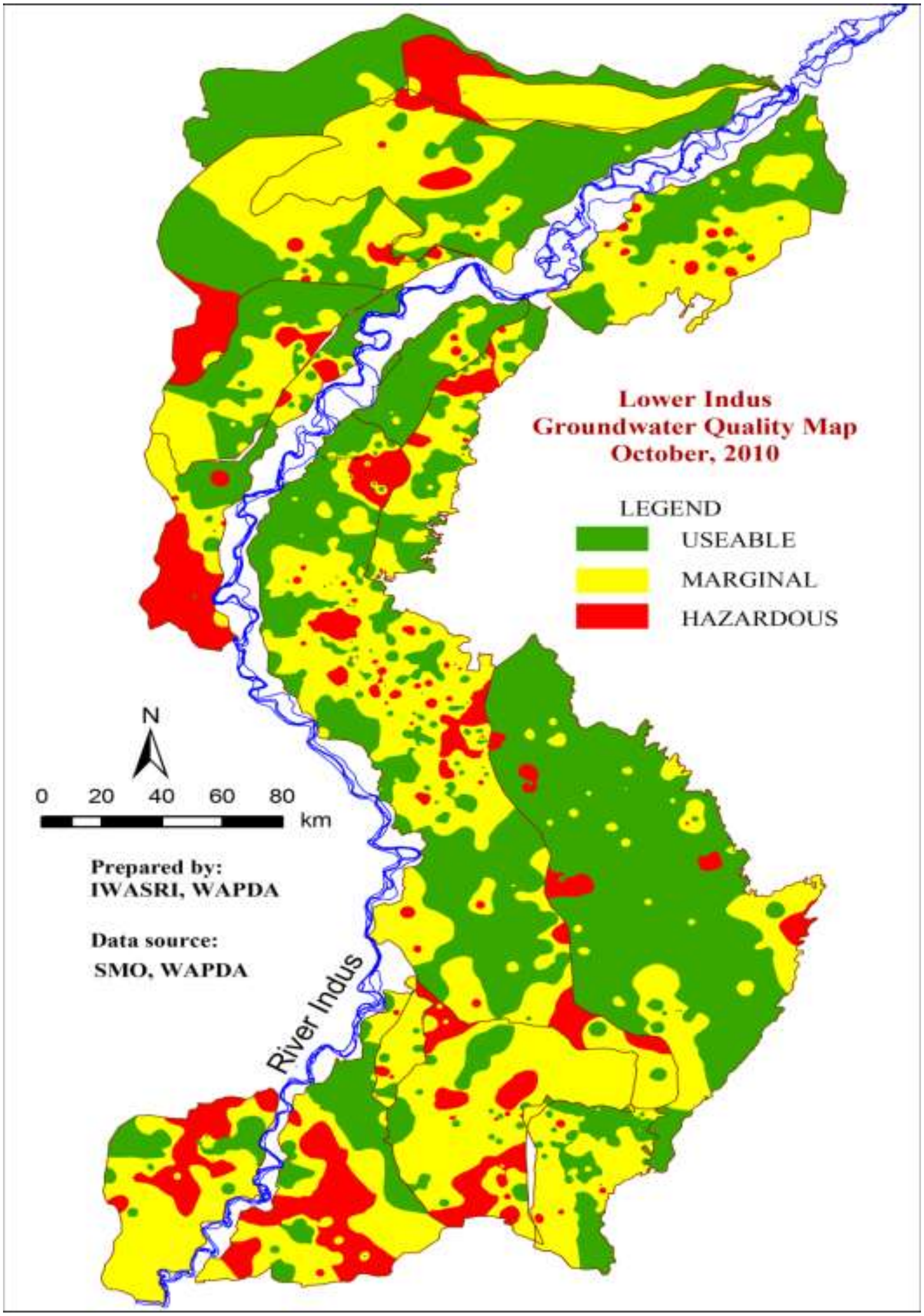

Figure 13: Shallow groundwater quality (SMO data) in Lower Indus (Oct, 2010).

On the other hand in Sindh-Balochistan, the non-saline area has decreased from 54% in the previous survey to 49% in 2001-03. Thus, in Sindh province deterioration has been noticed in almost all categories, and the salt affected area has increased. One of the most obvious reasons for this contrasting behavior, in changes in surface salinity, in Punjab and Lower Indus, is lowering of water table in Punjab. On the other hand, increased waterlogging conditions in Lower Indus, particularly after the provision of higher canal supplies after commissioning of Mangla and Tarbela Dams, and the absence of conjunctive use of canal and groundwater leading to lack of drainage in the root zone, had been the major factors for increase in surface salinity. The latest available surface salinity survey (2001-03) results for Lower Indus are given in Table 4 and shown in Figure 16.

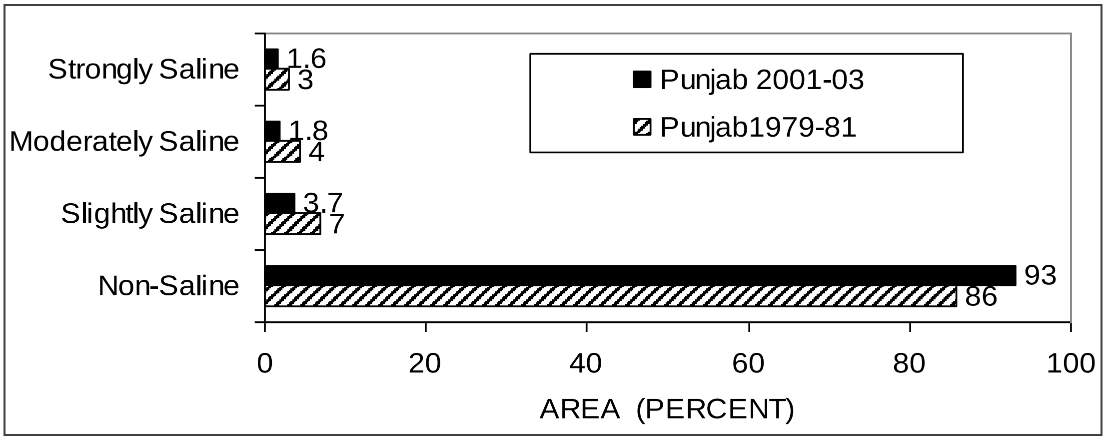

Figure 14: Comparison of surface salinity in Punjab for the periods: 1979-81 and 2001-03

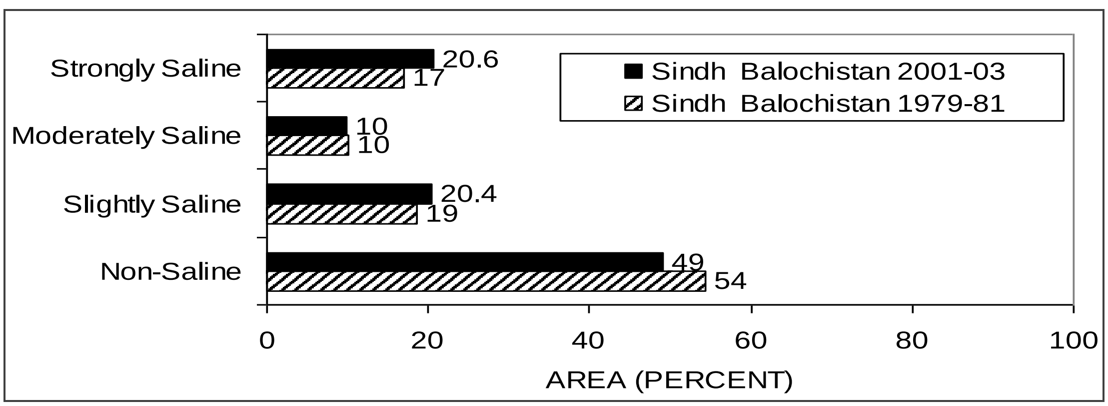

Figure 15: Comparison of surface salinity in Lower Indus (Sindh-Balochistan) for the periods: 1979-81 and 2001-03.

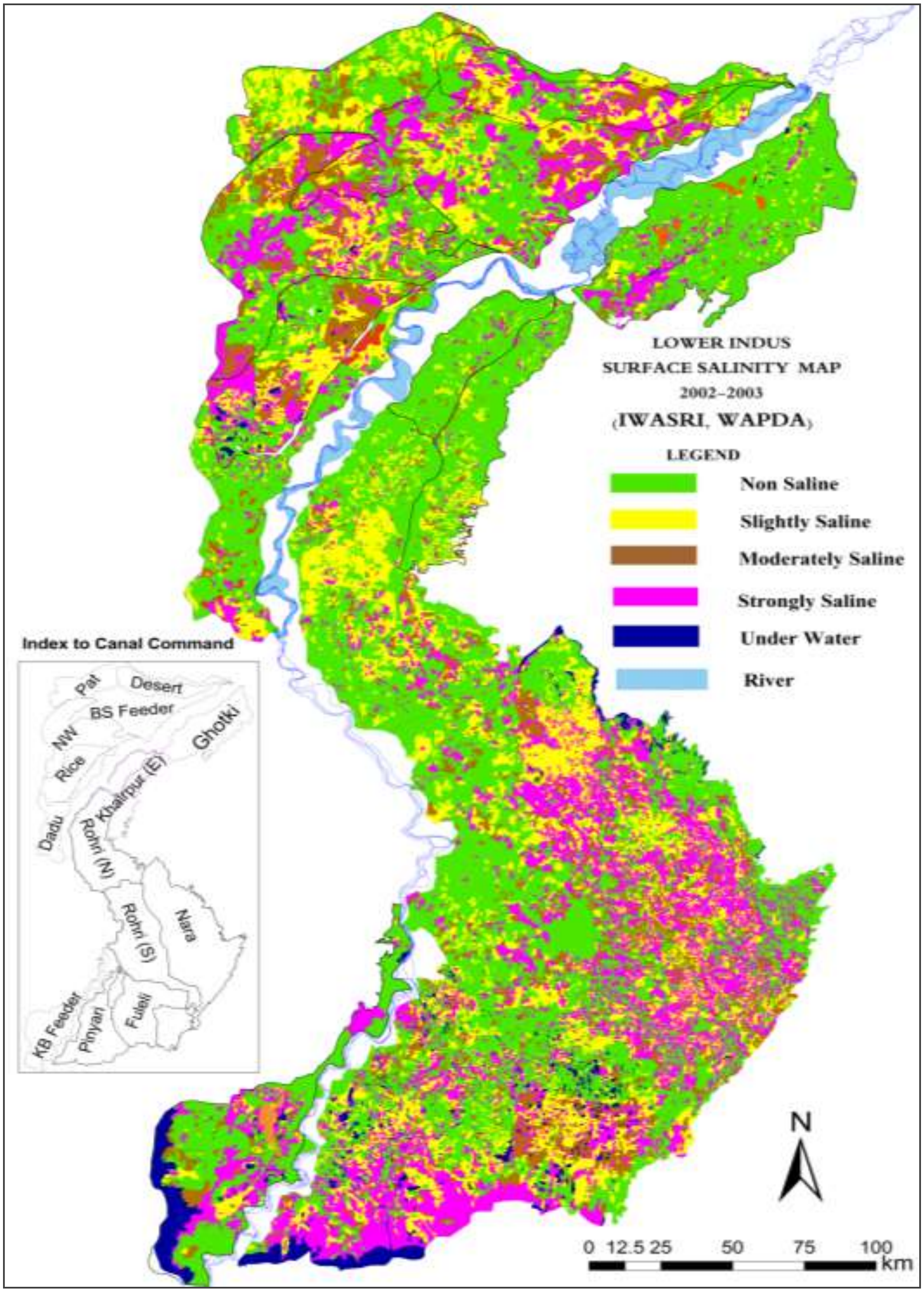

Figure 16: Surface salinity in in Lower Indus, as observed during 2002-03.

Table 4: Areas (ha) and percentage under different surface salinity classes in Lower Indus.

	Area (ha)					Percentage			
Canal Command	**S1**	**S2**	**S3**	**S4**	**Total**	**S1**	**S2**	**S3**	**S4**
Pat Feeder	132132	90015	31115	10827	264089	50.0	34.1	11.8	4.1
Desert	57617	51702	25847	52943	188109	30.6	27.5	13.7	28.1
North West	158398	73845	70246	103420	405909	39.0	18.2	17.3	25.5
Begari Sindh Feeder	184216	98485	70921	125659	479282	38.4	20.5	14.8	26.2
Rice	88039	62571	51803	41196	243609	36.1	25.7	21.3	16.9
Dadu	155505	35655	24406	27989	243555	63.8	14.6	10.0	11.5
Ghotki	326660	24722	10719	36601	398702	81.9	6.2	2.7	9.2
Khairpur West	107241	7036	3725	3904	121907	88.0	5.8	3.1	3.2
Khairpur East	143401	34826	14340	12291	204858	70.0	17.0	7.0	6.0
Rohri North	339946	147962	28360	46770	563038	60.4	26.3	5.0	8.3
Rohri South	367470	113284	40643	101615	623012	59.0	18.2	6.5	16.3
Nara	329999	229570	103503	321298	984370	33.5	23.3	10.5	32.6
Fuleli	16921	12026	6138	10871	45956	36.8	26.2	13.4	23.7
Lined Channel	70787	62081	36286	46215	215369	32.9	28.8	16.8	21.5
Kalari	154940	36964	27143	71322	290369	53.4	12.7	9.3	24.6
Pinyari	143529	74928	20506	158286	397250	36.1	18.9	5.2	39.8
Total area (ha)	2776800	1155673	565703	1171207	5669383	49.0	20.4	10.0	20.7

4. IMPACT OF DROUGHT IN OVER IRRIGATED AREAS OF LOWER INDUS

A drought period persisted in Pakistan for four years from 1999 to 2002, which affected the water supply in the country, especially for agriculture. IWASRI conducted a study in IBIS to find out the extent of drought and its impact on canal supplies, crop production and groundwater levels (Saeed et al., 2009). Six canal commands, two each in provinces of Punjab and Sindh and one each in KP and Balochistan were selected for the study. Further, a total of 10 distributaries were selected for study from these selected canals. There was 2-9% decrease in water supplies during the drought in these branches and distributaries. The results from the study for Jalbani distributary of Rattodero Branch falling in the North West Canal system in the Province of Sindh, are presented here under.

An increase in depth to watertable during drought period, as compared to the normal historical period was observed in the area, pre-monsoon DTW, in SMO Observation Well No. LS-78 in Command of Jalbani Distributary (off-taking from Rato Dero Branch) is shown in Figures 17, as a reference. Groundwater quality of the command area is good for irrigation as reported by the farmers during field visit but they did not feel need for tubewells installation for groundwater irrigation in the command area of the distributary. As shown in Figure 18, waterlogged area successively vanished in North West Canal, towards the end of drought (2002 and 2003). Consequently, percentage of cropped area in Jalbani distributary, also increased successively, towards the end of drought period (Figure 19).

Saeed et al. (2009) concluded that:

- Area under different crops, like wheat, rice, cotton and sugarcane was increased by 0.8%, 6%, 4% and 6%, respectively during drought period (1999-02) as compared to before drought period (1989-98).

- The crop yield (based on agricultural statistics of Pakistan, 2005) of wheat, rice cotton and sugarcane crop yields were increased by 18%, 15%, 9% and 4%, respectively during drought period (1999-02) as compared to before drought period (1989-98).

- Watertable depth increased from 1-3 meter during drought (1999-02) as compared with before drought period.

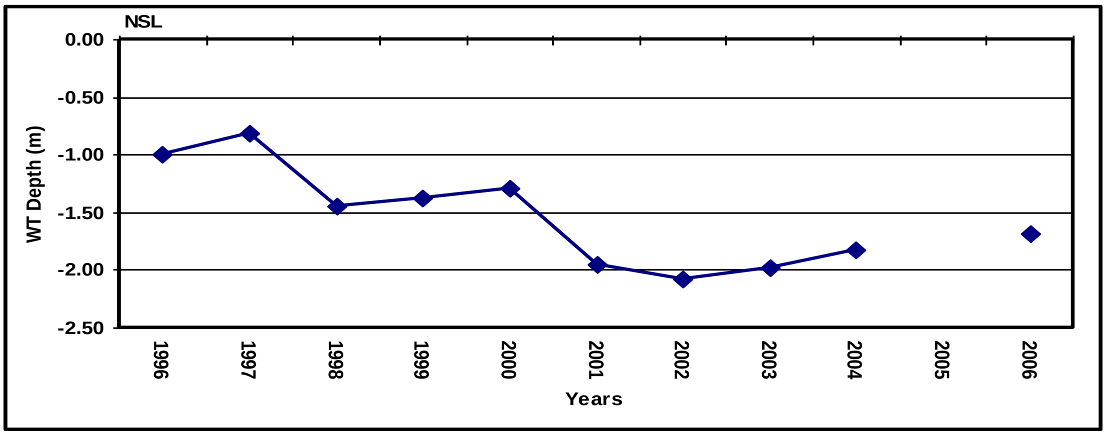

Figure 17: Pre-monsoon DTW in SMO Observation Well No. LS-78, in the command of Jalbani Distributary (Saeed et al., 2009).

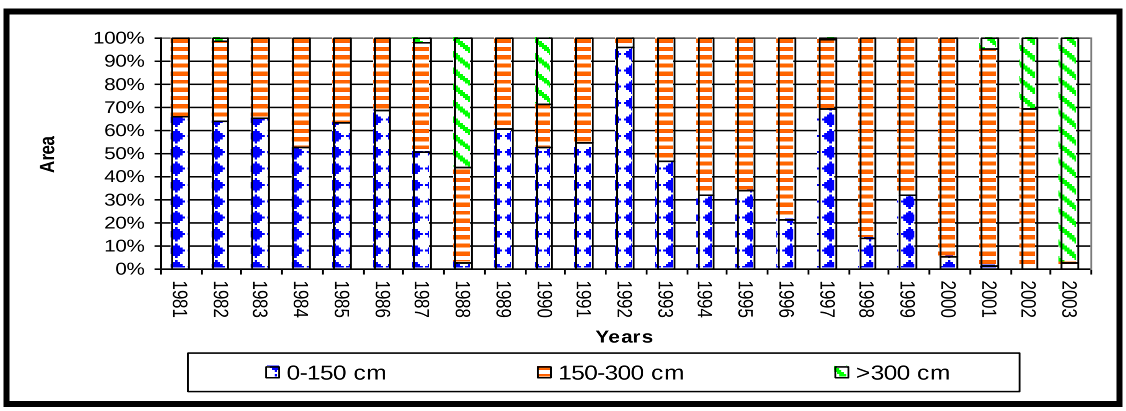

Figure 18: **Pre-Monsoon area under different DTW in North West canal command** (Saeed et al., 2009).

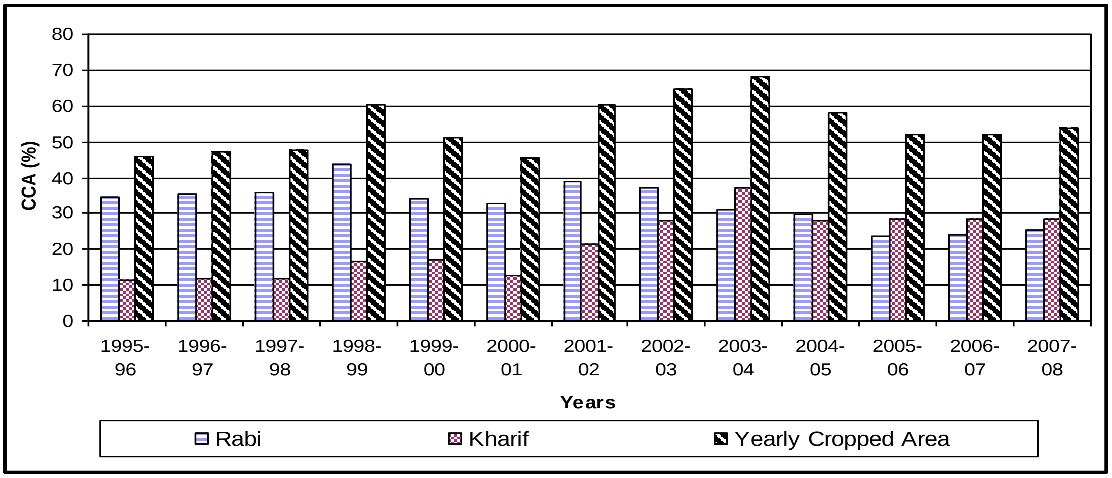

Figure 19: Cropped area (%) during Rabi, Kharif and Yearly basis in the command of Jalbani Distributary **(**Saeed et al., 2009)**.**

5. Irrigation Water Allocations in Lower Indus

In order to check the reasons for flooded lands and waterlogging conditions, Rabi, Kharif and annual canal supplies to all the irrigation systems in the Lower Indus Plain, were divided by the respective CCA (Table 5). The depth of water (mm) over the CCA is shown in Figure 20, for comparison purpose. Accordingly, the Rice and Kalri commands are getting the maximum canal supplies. Annual average supplies to Rice command is 1723 mm, whereas the annual reference crop evapotranspiration (ET_o), at Rohri is 1931.4 mm (Kharif: 1226.4 and Rabi:705.0 mm).

The non-perennial canals are suffering the most from this twin menace of waterlogging and salinity. These non-perennial areas receive more than required supplies in the Kharif season, thus, the watertable rises significantly, which also acts as secondary menace for sowing of Rabi crops, particularly the wheat. At the onset of the Rabi season, fields are with standing water or more than the optimum moisture contents for seed germination. With these conditions, salts also rise to the surface, due to bare land evaporation. Thus, many of the lands offer only one cropping, mostly rice. Rice Canal is one of the prominent examples of such a situation, where the watertable fluctuates between 1-3 meters during Kharif and Rabi. This annual cycle of rise and fall of watertable brings the salts to the upper soil strata, and also mobilize extra salts for downstream water users, like Hammal and Manchar lakes.

After the commissioning of the Tarbela and Mangla Dams, about 24% extra water was made available for irrigation, thereafter some non-perennial areas were converted officially or unofficially to perennial. The problems in the perennial channels in Sindh are different from the non-perennial channels. Here salinity is concentrated on areas with deficient surface water supplies, where there is not enough water for leaching salts. This often concerns the tail reaches of the channels.

Table 5: GCA and CCA of irrigation system in Lower Indus (source: Sindh Irrigation Department and IWMI (1998).

Canal	GCA (acres)	CCA (acres)	FSD (cfs)
Begari Sindh feeder	1081942	1001910	14764
Desert Pat Feeder	1051717	1046971	13275
Ghotki Feeder	1011118	851539	8490
Dadu Canal	601918	557212	5200
Khairpur East feeder	559977	373666	1938
Khairpur West Feeder	405737	399346	1894
Nara Canal	2581336	2273251	12875
North West Canal (+Kirthar)	1108897	1066226	9450
Rice Canal	528357	486670	10658
Rhori Canal	2725745	2594889	14100
Akram Wah (Lined Channel)	517682	491516	3714
Fuleli Canal	1003100	920847	15026
Kalri Begar Feeder	643688	592232	9100
Pinyari Feeder	804526	777181	13626

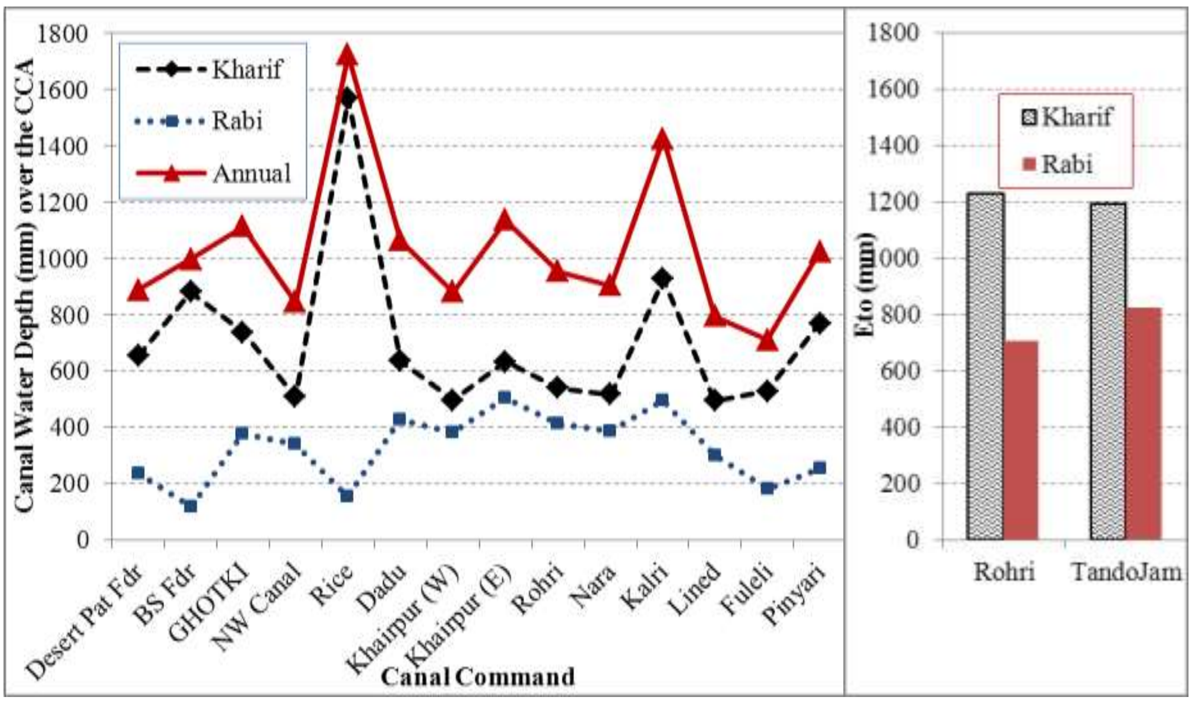

Figure 20: Comparison of canal water supplies amongst the irrigation systems in Sindh.

6. Need for Conjunctive Management

Farmers' groundwater pumping requirement obviously depends on canal supplies, i.e. a farmer with enough canal supplies has to depend very minimally on groundwater and vice versa. Such impacts of natural rainfall are also obvious on groundwater pumping requirement. Thus, groundwater pumping and its management needs, depend wholly or partially on annual normal rainfall and available canal supplies. Conjunctive water management can better accrue the benefits when system administrators control ground and surface water simultaneously: at the watercourse, canal command and basin levels to optimize productivity, maintain equity, and environmental sustainability. This control on surface water can induce an indirect control on groundwater, thus avoid long-term waterlogging and groundwater depletion. Such planning is needed at IBIS, provincial and canal and watercourse command levels, to raise crop water productivity by reducing misuse of water, where rainfall and canal water have higher combined availability.

Consequently, less use of groundwater and absence of any provision for groundwater drainage in Sindh do not allow building up of fresh groundwater buffer and, therefore conjunctive management of canal and groundwater is not possible in the current circumstances. Thus, high canal supplies and irrigation system malfunctioning (tail-enders getting less or even no supplies in certain area) are a major explanation for the extensive waterlogging in Sindh Province, particularly, even slightly low lying areas filling fast. In the year 1999, about 38.5 % of the irrigated area was waterlogged, steeply rising from 1959 when it stood at 12.4%. Waterlogging is causing a range of problems. Despite low cropping intensities, it causes reduced farm yields, and at the same time creates public health problems, due to the difficulty of developing rural sanitation facilities in waterlogged areas.

At least a very simple solution can be adopted for areas where certain depth of fresh groundwater lies over the saline groundwater, i.e. based upon crop water requirement, and keeping an allowance for groundwater pumping by the farmers themselves, these areas should be allocated less canal water. This will surely reclaim a lot of waterlogged lands in the area. Therefore, the proposed approach would certainly help to increase cropping intensity and improve economy of the area. Farmers will be able to grow both Rabi and Kharif crops. Otherwise, at present, cropping intensity is low due to vast areas with standing water, and during Rabi season wheat crop cultivation is not possible due to extra ordinary high moisture contents or standing water.

7. CONCLUSIONS

Unfortunately, huge system of irrigated agriculture in Sindh has not provided designed set objectives of poverty reduction. This is due to lack of coordinated water resources research and its implementation for irrigation management, poor long-term water policies, and especially poor operation and maintenance of the irrigation system. A major portion of groundwater balance in Lower Indus goes to non-beneficial evaporation. Otherwise, this can be usefully exploited with well-planned conjunctive use of surface and groundwater.

However, implementation of rational surface water management, utilizing the groundwater potential is also not so easy – it will require a major technical input from the concerned irrigation and water related institutions, working at federal and provincial level. Concerned water management agencies will need to adopt major cultural shift from engineering based supply approaches to hydrologic and water management approaches. A major part of Punjab's agricultural success has been based upon the use of groundwater irrigation, with about one million tubewells. Groundwater irrigation caused massive reduction in waterlogging; rather groundwater depletion is now an issue in Punjab. Otherwise, this reduction in waterlogging was not possible, with engineering approaches alone.

The government has taken many steps regarding surface water management, both in Sindh and Punjab, especially canal and watercourse lining. Now, after every few years of operation, it is essential to closely monitor the aquifer water-level response and to check the extent of changes in groundwater balance. That is the recharge to groundwater is reduced by lining in Punjab, but the situation is different in Sindh. The component of seepage, reduced by engineering measures (such as canal lining) in Sindh, should have been with the intention of diverting water to demands in other areas. This could have resulted in a two prong positive impact, i.e. reduction in waterlogging and salinity, and release of water for acute shortage areas e.g. Thar Desertand other water deficit areas.

Following are the specific findings of this research:

- Investments in drainage have been significant in Pakistan during the decades of 70s to early 90s, waterlogging still affects large tracts of land: especially the intense waterlogging and salinity in Sindh. This can be attributed to poor water management, rather than engineering approaches for irrigation and drainage

- Also, in spite of 12-25% reduction in canal supplies in IBIS, during drought period of 1999-2002, the area under different crops and the crop yields increased as compared to before drought period. It was particularly, due to reduction in waterlogging in Sindh, during the drought.

- Non-beneficial evaporation in Sindh, due to waterlogging conditions prevailing over more than 50% of the area is a major challenge in enhancing water productivity in the province. This can be taken up by provision of irrigation supplies matching with demand and increased groundwater irrigation (obviously drainage), to provide cushion for storage of irrigation leakages and excess rainfall. Thus, rainfall flooding as observed in 2011, on left side of Indus River in Sindh, could have been avoided. This groundwater buffer can be very efficiently utilized by deep and shallow skimming wells, in areas with deep and shallow lenses of fresh groundwater, respectively;

- Fresh assessment of cropping patterns and intensities, and the corresponding crop water requirement, along with existing allocations, is the first and foremost requirement for rationalizing canal water allocations;

- For improving groundwater situation in Punjab, and demand based supply to farmers in Sindh, construction of mega reservoirs should be the first priority for the country.

- Even after the improved water supply patterns with the operation of Tarbela and Mangla reservoirs, chronic perennial/non-perennial allocations are being continued without any logic, and therefore, need to be re-evaluated. Examples are: huge canal supplies to Rice canal during Kharif, creating flooding conditions, therefore, big loss to potential yields during Rabi.

8. Recommended Action Points for Lower Indus

- For the assessment of optimum groundwater development potential for different areas in Lower Indus, a fresh survey of depth wise groundwater quality is urgently required to ascertain and enact conjunctive water management potential.

- Fresh assessment of crop water demand, simultaneously keeping in view the drainage quantum and groundwater use potential needs to be accomplished for each canal command, as the groundwater quality varies drastically in different areas. This would help indeveloping 8-10 ft cushion for avoiding waterlogging and providing excess rainfall storage and avoid flooding, as observed in 2011.For promoting conjunctive use of canal and groundwater, further needed steps will be as under:

  - Reallocation/Rationalization of canal water supplies

  - In irrigated areas with deep fresh groundwater-canal supplies be reduced;

  - In areas with shallow fresh groundwater, skimming wells need to be promoted;

- Practical demonstration to the farmers regarding possibility of growing paddy with less water and thereby provide optimum moisture content for Rabi crops, especially the wheat crop is the need of the hour. This will help in changing the mindset of the farmer regarding misconception of over irrigation;

- Irrigation and drainage infrastructure improvement is urgently needed, including rehabilitation of irrigation channels profile and sections according to the design.

- Eradication of corruption in operation and maintenance of the irrigation and drainage system and thereby improve the equity of water distribution to the farmers; and

- For achieving the last two objectives, capacity building of the irrigation department, both technical and managerial, along with feeling the responsibility of the job is necessary. For this, overall improvement in governance in the province is a first and foremost requirement. Otherwise achieving the end goal cannot even be imagined.

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