# The Promise of Conjunctive Management of Surface and Groundwater in Sindh

Shared Discussion Paper

1

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# The Promise of Conjunctive Management of Surface and Groundwater in Sindh

## Shared Discussion Paper

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## Abstract

This paper presents the case for optimizing water management in Sindh Province, particularly in making better use of groundwater. Balancing groundwater and surface water supplies may systematically reduce the area under water logging and may free up water for horizontal expansion or other uses. It may facilitate the new development or extension of existing canal systems.

A second issue in water management in Sindh is to make better use of salinity. There are several options to achieve high yields by using relatively saline groundwater, which need to be better developed.

With its strategic location in a region with high demand for agricultural crops Sindh could transform into an agricultural powerhouse.


## 1. Groundwater resources

Sindh Province forms the southern part of the Indus Plain, which lies below Guddu, forming the narrowest width of Indus Plain below the confluence of Panjnad River with Indus and near the abrupt bend in the Suleiman Range. The climate of Sindh is hot and arid. Average annual rainfall is within 265 mm. The maximum temperature in summer exceeds 40° C. Evaporation in Sindh is higher than elsewhere in Pakistan. Annual lake evaporation varies from 1524 to 2160 mm (60 to 85 inches) in the irrigated areas and generally exceeds 2,286 mm (90 inches) in the adjoining desert areas.

The Indus is almost the sole source of surface water for the Province of Sindh. About 40% area of the province is under irrigation through the canals off-taking from three Barrages in Sindh: Guddu, Sukkur and Kotri. Irrigation supplies to Sindh Province are around 56 BCM (45 MAF) (BCM= Billion Cubic Meters, MAF= Million Acre Feet).

The most important groundwater area in Sindh is the Indus Plains, which is recharged from the meandering river and from the irrigation network. The Indus River in Sindh Province generally flows on a ridge and is hence mainly influent – meaning that it feeds the aquifers systems alongside it rather than being fed by it. Some of the flow drains towards the desert in the east. Another part flows towards the Khirthar Hills. In the Rabi season, when the flow in the river below Sukkur Barrage is almost zero, the river receives groundwater, especially the left bank.

The groundwater situation in Sindh is in stark contrast to Punjab. Whereas in Punjab groundwater is a main source of water in the canal commands, in Sindh this is not the case (see right side of the graph in Figure 1). Assessment of groundwater abstraction in Sindh by ACE-HALCROW (2002) is about 4.3 BCM where as a study by IWMI has estimated the discharge through tubewells is even lower; still at 2.15 BCM (about 2 MAF). In other words, groundwater use stands at less than 4-8% of surface water use, whereas in the canal areas of Punjab the use of surface and groundwater at farm level are approximately 50 : 50. These figures may need to be updated, but in general groundwater is an underutilized resource in the canal-irrigated areas of Sindh. A large part of the groundwater use in Sindh is from the riverine areas where there are no irrigation canals and soils are relatively sandy. In the canal command areas there is relatively limited use of groundwater.

There is a need to rethink and consider the introduction of conjunctive management of surface and groundwater in Sindh for a number of reasons:

- It can free up canal water and make it possible to expand the area under cultivation or intensification in Sindh;
- It can reduce water logging and hence contribute to higher yields and better public health;
- It can improve drinking water conditions, especially in areas with high saline groundwater tables by creating the space for fresh water lenses;
- It will improve sanitary conditions, as an unsaturated zone above the watertable is maintained which prevents

that sewerage is in direct contact with the shallow groundwater;

- It will make high value precision agriculture possible and introduce 'on demand' irrigation within the canal systems, as farmers can use water when required;
- It will be better possible to store high floods by creating more storage space in the shallow aquifers.

## 2. Waterlogging and salinity

Part of the explanation for the lower groundwater usage in Sindh is the salinity of groundwater. Groundwater quality in Sindh is generally mainly fresh and useable (within 1500 PPM - Parts Per Million) along the Indus and in the irrigated area but deteriorates away from the river. The native groundwater of the Lower Indus Plain is highly saline, but has been partly replaced by fresh water through the movement of the Indus over millennia. The fresh water zone stretches to 30 kilometer towards the eastern part of the Indus. On the west bank there is an extensive fresh water zone north of Sukkur that however narrows down to 15 kilometer from the bed of the Indus in Dadu. The reason is that the Indus moved more on the eastern side. The deep freshwater zone – i.e at 50 meter depth in Sindh is estimated to be 30%. In addition to these fresh water zones with fresh water available at largest depth, there are additional extensive shallow fresh water zones with fresh groundwater

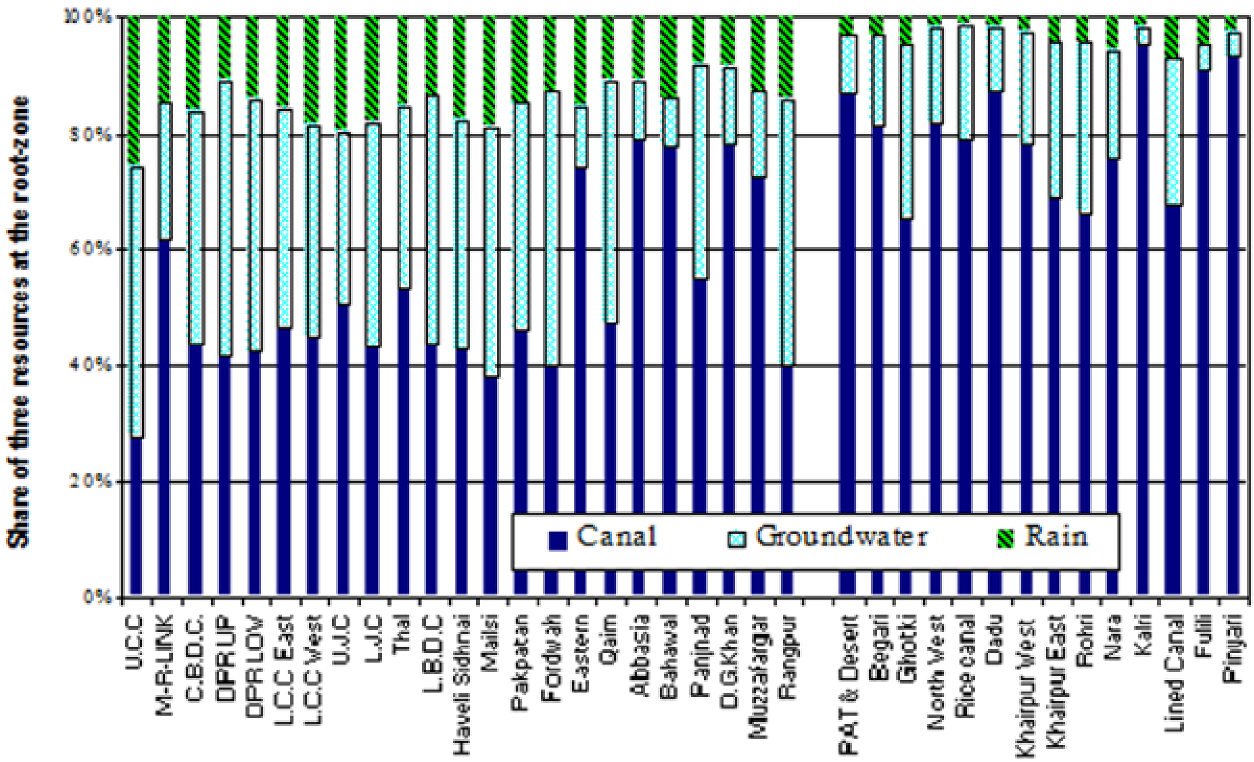



*Figure 1: Proportion of surface, groundwater and rain water used in canal commands (Source: Zaigham Habib. 2008).*

available up to 40 - 50 meter depth overlaying deeper saline groundwater (Panwar, 1969). The total freshwater zones at shallow depth (15 meter) is tentatively estimated at 46%.

Another explanation for the limited use of groundwater is the high surface irrigation supplies in several of the canal commands in Sindh. These high irrigation duties – apart from giving rise to water logging (Figure 2) – have created a disincentive to farmers to use groundwater even in areas where groundwater is fresh (see Box 1). On top of this the distortions in the irrigation supplies through direct outlets, tampered off-takes or canal seepage has created overabundance of water in several places, making pumping of freshwater unattractive because either virtually free surface water supplies were more than sufficient or land is waterlogged and unproductive.

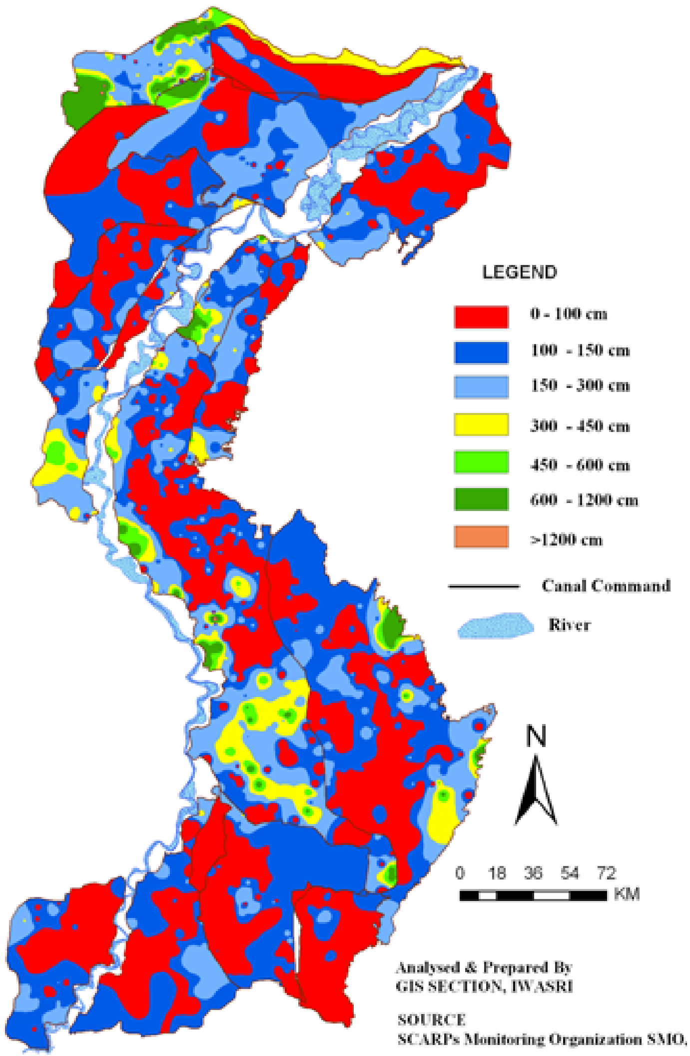
In comparison to Punjab private tube well development has not taken a big flight in Sindh. Whereas in Punjab the number of tubewells is in excess of 1,000,000 and has made higher crop intensity possible as well precision farming. The estimated number of tube wells in Sindh in 2000 was slightly over 28,000 (Qureshi et al 2003), a number that may have increased but is thought not to exceed 75,000. Tube well densities in different canal commands are in the order of 2 to 3 private tube wells per 100 ha (Lashari and Memon 2000, van Steenbergen 2002) – but in the canal commands of the canals that start from Guddu Barrage (Begari, Ghotki and Desert) wells for instance are virtually non-existent with the exception of the tail reaches and the higher lands, if though the shallow groundwater in many areas is fresh. A shape of how things could be if surface water supplies would not be overabundant is the groundwater exploitation in the Kunner - II Minor (near Hyderabad), where tube well density is 6.6 per 100 hectares – related to relatively better groundwater qualities and the proximity to a major market. Another example are the higher lands in Pano Aqil in the Ghotki command areas where canal supplies are inadequate and tubewell densities even exceed 15/100 ha. In general, even in some fresh groundwater zones tubewell densities are low and there is also evidence of fresh SCARP (Salinity Control

## Box 1: Jalbani Distributory

Jalbani Distributary takes off from North West Canal and has a command area of 8,642 acres. The irrigation duty for the Distributary is high – 12.15 cfs/1,000 acre (84 l/s/100 ha) (cfs = cubic foot per second), even though it is overlays an area with fresh groundwater. The actual water delivery per acre is even higher as not more than 50% of the command areas is used in any season.

Even during the drought period 1998-2002 surface water supplies – even though reduced with 5% to 10% - were abundant and there was no interest among farmers to compensate for the lower supplies by developing shallow wells. The drought helped to lower water tables, as observed from SMO Observation Well No.LS-78 for the period 1996 to 2006. Whereas the water table remained 1 to 1.5 m deep on an average during 1996 to 1998, it fluctuated between 1.5 to 2 m from NSL (Natural Surface Level) during the years 1999 - 2002. The main reason was the reduction in water supplies in the Ratto Dero Branch and Jalbani Distributary. The lower water deliveries were particularly beneficial for the rice cultivation in the kharif season. Here the area cultivated increased from 1,119 acres (452 ha) to 1,704 acres (692 ha). This was partly offset by a reduction in the area cultivated with wheat in rabi, which dropped from 3,224 acres (1305 ha) to 3,082 acres (1,247 ha). Wheat production remained the same, but rice production increased with 8%.

*(Source: Saeed et al, 2009).*



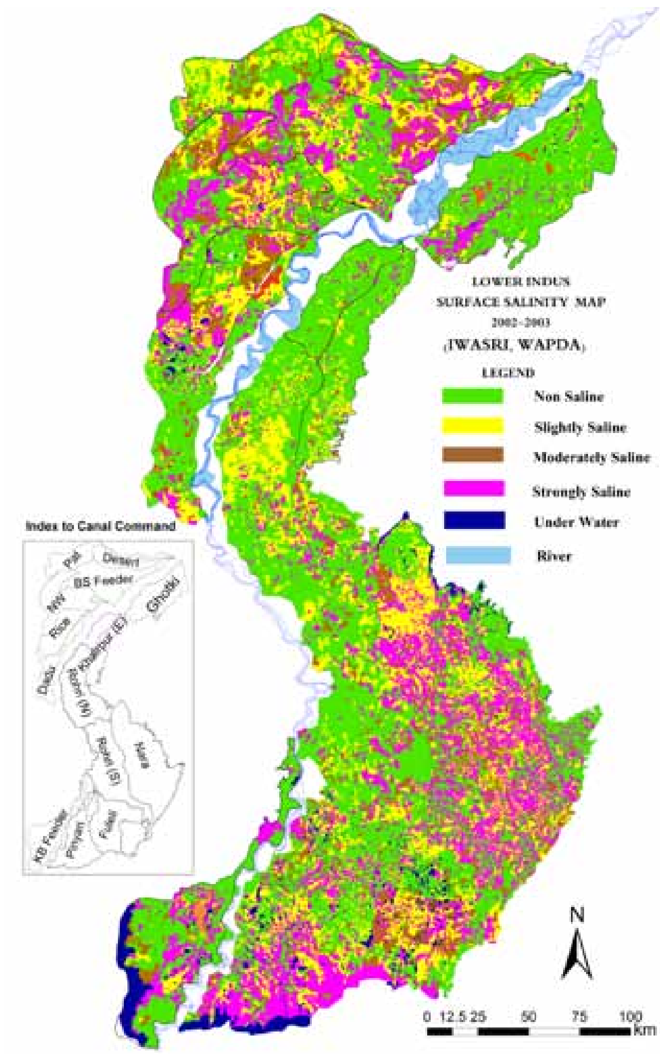




*Figure 2: Water logging in Sindh post monsoon 2011 (Source: Basharat et al., 2014).*

*Figure 3: Surface soil salinity Sindh (Source: Basharat et al., 2014).*

and Reclamation Programme) tubewell water being routed directly to disposal canals and not used in agriculture. Low tubewell densities also apply to saline zones – here there are hardly any tubewells. In comparable saline groundwater areas in Punjab the number of tubewells is considerably higher.

The overgenerous surface irrigation supplies, especially in some canal commands, reduce the need for additional groundwater irrigation (Ahmad and Kutcher 1993). Several studies have also argued that in many areas of particular Northern Sindh a layer of fresh water floats on the more saline layers that could be exploited more extensively among others by skimming wells (Ahmad and Kutcher 1993). Some small tube wells and dug wells already use these thin lenses along canals and distributaries in several parts of Sindh, where water is relatively short (canal tail ends in area with low surface irrigation supplies). In many areas however, surface water supplies in the canals fed from Guddu Barrage are so high that there is little incentive to pump. In the post-monsoon period the entire areas is water logged. The waterlogging in this part of Sindh is expected to even get more dramatic with the construction of the Rainee Canal that will impede the natural drainage towards the eastern desert.

Sindh also has more widespread surface salinity than other parts of the Indus System (Figure 3). Surface salinity caused by capillary rise in areas with high water tables is particularly common in areas with reduced dry season supplies or low irrigation supplies in general and in wastelands surrounding heavily water logged lands.

## 3. Need for improved management of water resources in Sindh

The consequence of the low use of groundwater in Sindh is that the water buffer is not well managed. The high irrigation duties and supply irregularities are a major explanation for the extensive water logging in Sindh Province with particularly slightly low lying areas filling fast. In 2011, 69.6% of the irrigated area was water logged (see Table 1) with water tables within 1.5 meters and 36.0% of the land was severely water logged (water table within 1 meter). In acreage the affected area is colossal: 2.19 Mha in post monsoon 2011.

Water logging is causing a range of problems. It suppresses farm yields, but the impacts go further. Water logging also creates public health problems, due to the difficulty of developing rural sanitation facilities in water logged areas and the large prevalence of human and animal diseases related to water logging.

A main driving force for this extensive water logging are the high and generally outdated irrigation surface irrigation allocations. Water logging appears to be particularly persistent in the areas, served by non-perennial canals. These canals receive copious supplies in the Kharif season, causing the water table to rise significantly, but to fall again in the winter season, when the canals are not flowing. Rice Canal in Larkana Area is one of the main example of this phenomenon (Figure 4), where the water table fluctuates between 1 - 3 meters during Kharif and Rabi. This annual cycle of rise and fall of water table has brought the salts

*Table 1: Groundwater table depth in canal command of Sindh (2011)*

| Water table depth (in meter) | Area (Mha) | Proportion (%) |
|---|---|---|
| Less than 1.0 | 2.19 | 36.0 |
| 1.0 - 1.5 | 2.04 | 33.6 |
| 1.5 - 3.0 | 1.29 | 21.2 |
| 3.0 - 4.5 | 0.34 | 5.5 |
| 4.5 - 6.0 | 0.09 | 1.6 |
| More than 6.0 | 0.01 | 2.0 |
| Total area covered | 5.96 | 100 |

*(Source: SMO).*

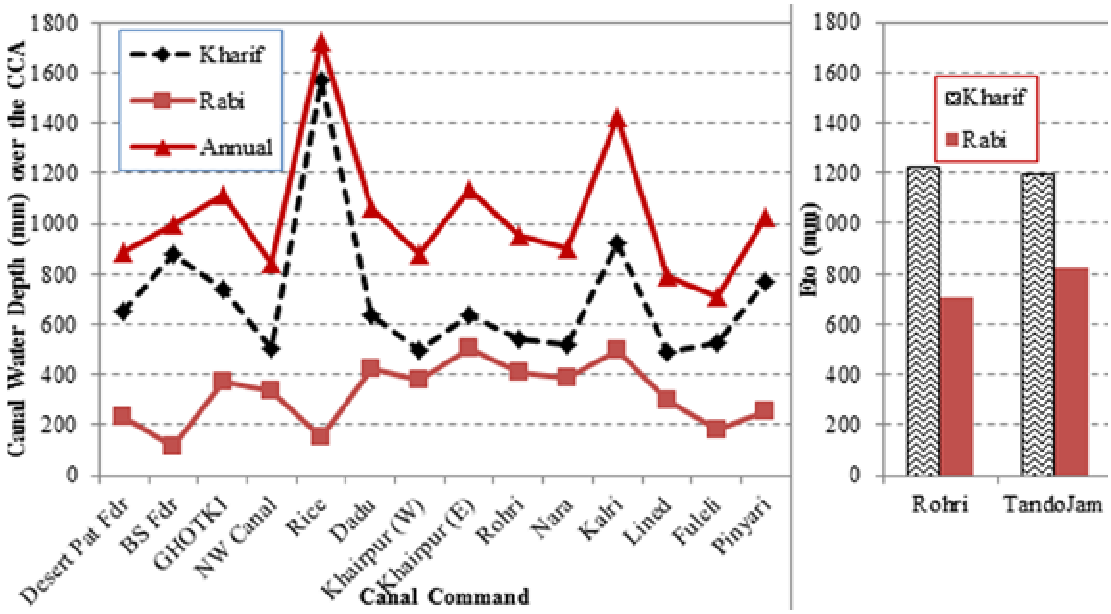



*Figure 4: Comparison of canal water supplies amongst the irrigation systems in Sindh (Source: Basharat et al., 2014).*

to the upper soil strata (Mukarram 1994). Some canals are converted officially or unofficially in perennial canals now, after the commissioning of the Tarbela and Mangla Dams that by regulating the flow made 24% more water available for irrigation. Canal duties were however not officially recalibrated after this additional water became available. The problems in the perennial channels in Sindh are different from the non-perennial channels. In the perennial channels the water duties are generally lower (though still higher than elsewhere in the subcontinent). Here salinity is concentrated on areas with deficient surface water supplies, where there is not enough water for leaching accumulated salts. This often concerns the tail reaches of the channels.

The situation could be very different, as the lessons from the 1998 - 2002 drought shows (as well as the drought year of 1988). In 1998 - 2002, El Nino effect causes rainfall to reduce with more than 50% and the releases from Tarbela to drop with 9% and from Mangla with 37%. This translated in Lower canal deliveries in the country. Overall, there were 12-25% less from preceding years. Interesting in this period crop production did not suffer. If anything, across the board it even increased. Area under different crops like wheat, rice, cotton and sugarcane increased as 0.8%, 6%, 4% and 6%, respectively during drought period (1999 - 2002) as compared to before drought period (1989-98). Wheat, rice cotton and sugarcane crop yields increased as 18%, 15%, 9% and 4% respectively during drought (1999-02) as compared to before drought (1989-98), particularly in areas with uniform high groundwater tables, such as Badin and Thatta[1].

*[1]) The increase in production was not uniform in areas with limited surface supplies (higher land and tail reaches) and no possible access to fresh groundwater yields had a set back.*

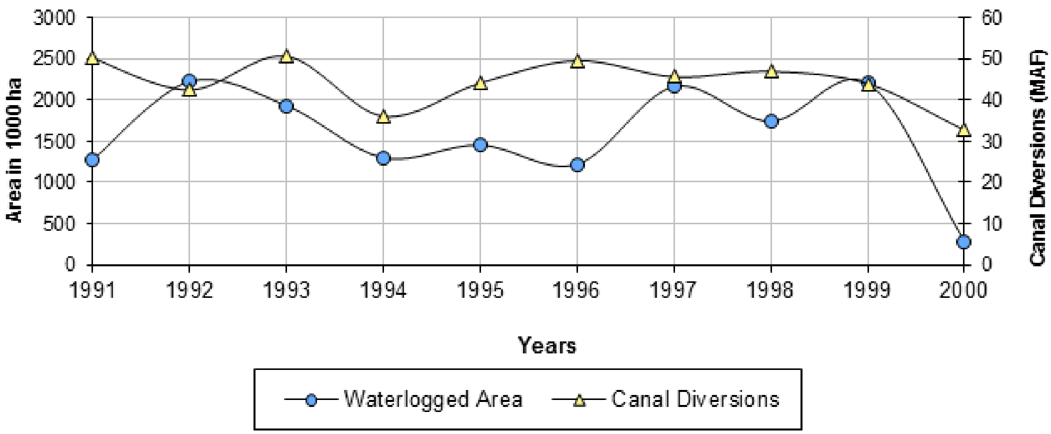



*Figure 5 : Water logging and canal supplies in Sindh (1991-2000) (Source: Rasheed, 2002).*

The waterlogged area in fact fluctuates enormously from year to year (Figure 5). The explanation is the reduction in the percentage of the waterlogged areas in the drought years due to the reduced in flow, the increased groundwater use and the more economical use by the farmers. Particularly in low-lying areas with heavy soils water logging and salinity disappeared (for instance in Badin and Mirpurkhas).

The gist of Figure 5 is that:

- The waterlogged area increased from 1.272 Mha in 1991 to 2.26 Mha in 1992 responding to canal diversions of 50.30 MAF in 1991-92;
- It then dropped to 1.30 Mha in 1994 as the surface water flows reduced to 36.1 MAF;
- The waterlogged area fell from 2.22 Mha in 1992 to 1.22 Mha in 1996;
- In 1999-2000 due to drastic reduction in available supplies the waterlogged area even reduced to 285,000 ha, hence;
- There is a very strong case to re-evaluate the surface water allocation in Sindh in normal years, because at present normal years bring huge increases in water logging and reduced crop production[2].

The same finding is repeated in a more detailed analysis of a number of canal commands and distributaries in Sindh. Below the reduction of pre-monsoon water logging for North West Canal and Rohri Canal is shown in the same years (Figure 6 and 7).

The water management system with the high water logging entails enormous water losses. For Sindh province some 74 - 80% of the available groundwater recharge is lost in the form of non-beneficial evaporation. This loss could have been used for productive use (as potential recharge), results from canal losses and irrigation returns. It occurs over both the fresh groundwater zones and saline groundwater zones of the province, in the ratio of 25 : 75 by area.

Groundwater balance for the Province in broad terms and

*[2]) Monitoring under the SCARP Transition Project showed no indication of groundwater-induced secondary salinization in Moro and Sakrand, but instead suggests that in recent years soil salinity has improved, due to increased private tubewell development and the leaching this made possible (SSTNRPP 1997). This suggests that it is worthwhile to look into option of draining saline water to create more storage for fresh water recharge.*

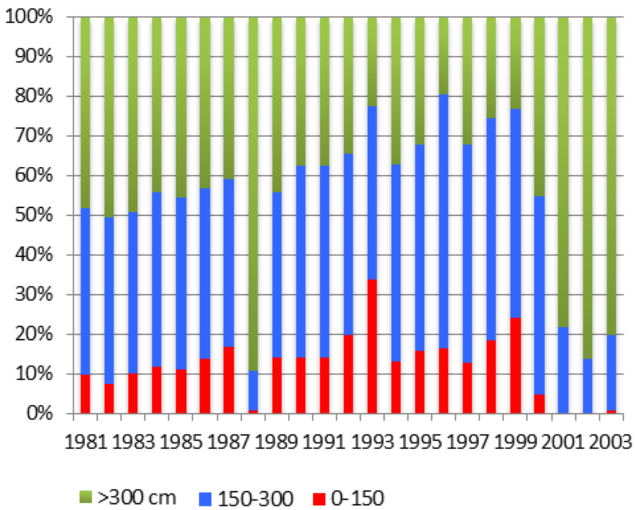



*Figure 6: Development of pre-monsoon water levels Rohri Canal 1981-2003 (Source: Saeed, 2009).*

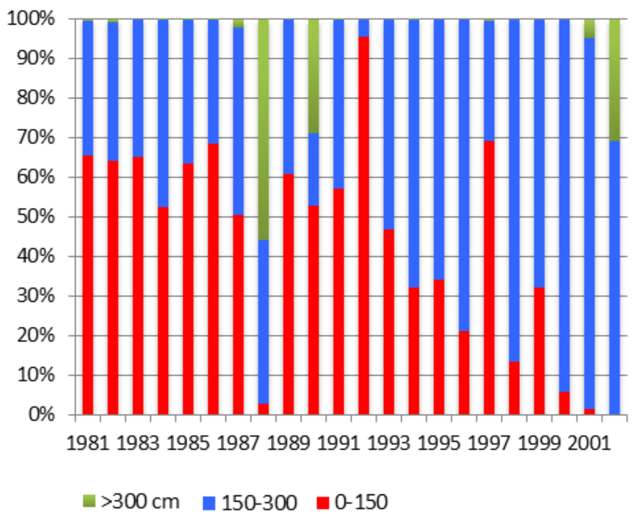



*Figure 7: Development of pre-monsoon water levels Northwest Canal 1981-2002 (Source: Saeed, 2009).*

considering average rainfall and canal flows is given in Table 2.

Figure 6 and 7 indicate the order of magnitude. The budget shows colossal amount of non-beneficial evapotranspiration of around 17 BCM – which can be saved partly by lowering the water table – or reducing seepage from canals system – even canal supplies in certain areas and using groundwater – even use of brackish water through adjustment of the cropping pattern and introduction of for instance fish ponds.

In addition because of widespread water logging, water productivity in Sindh is also major step down from Punjab – for the different canal commands it ranges between 0.32 and 1.15 kg per $m^3$ for wheat – in Punjab the median 1.08 kg per $m^3$. In the Indian Punjab it is 1.42 kg per $m^3$ being again 35% higher than in the Punjab in Pakistan (Bastiaanssen 2010). Variation of water productivity in different command areas under the Sindh Irrigation System and overall productivity are shown in Table 3.

In addition there are special problem spots. These are areas with very high saline groundwater at present, foreclosing the use of groundwater for drinking water for instance. The lower Left Bank, areas of the Indus (Badin and Thatta) - in this respect - is the premier problem spot and a “water management disaster” area even by international standards. The high saline groundwater here is very much in the root zone and water logging and salinity continue to persist. It is caused by the high erratic irrigation supplies (often in the Kharif when there is less demand elsewhere) and the flat topography of this area plus the worsened natural drainage due to tidal effect having moved upstream after the scouring out of the Tidal Link. The impact does not only concern agricultural productivity but also basic drinking water supplies. With groundwater levels being as high as it is - no fresh/ brackish water lens can form in the area that would at least provide some relief. The main source of drinking water is the highly polluted water in the three main irrigation canals running in the area. The situation in Badin and Thatta has of course further worsened by the 2010 floods – consolidating and further spreading the high water tables.

*Table 2: Groundwater balance for Sindh*

| Recharge Components (BCM) | Normal Year |
|---|---|
| Recharge from Rainfall | 2.42 |
| Recharge from Canal System @ 15 % of 56 BCM | 8.34 |
| Return flow from Irrigation System @ 22.5 % of net flow | 10.58 |
| Return flow from Groundwater Abstraction @ 22.5 % | 0.97 |
| Recharge from Rivers | 0.37 |
| **Total** | **22.68** |
| **Discharge components (BCM)** | **Normal Year** |
| Groundwater Abstraction (Public and Private) | 4.30 |
| Non-beneficial (Evapotranspiration (ET[1]) losses | 16.96 |
| Base flow to rivers | 1.42 |
| **Total** | **22.68** |

*Table 3: Overall water productivity (WP) in various canal commands in Sindh*

| Area Water Board | ET (mm) | Biomass (kg/ha) | WP (kg/m³) |
|---|---|---|---|
| Khairpur West | 1,281 | 14,820 | 1.15 |
| Rice | 1,225 | 12,380 | 1 |
| Rohri | 1,203 | 12,153 | 0.98 |
| Ghotki | 1,083 | 10,622 | 0.96 |
| Khairpur East | 1,105 | 10,530 | 0.9 |
| Pat Feder | 1,004 | 8,437 | 0.8 |
| Begari | 1,148 | 8,359 | 0.71 |
| Desert | 1,152 | 8,303 | 0.7 |
| Dadu | 1,042 | 7,657 | 0.69 |
| Northwest | 1,130 | 7,961 | 0.68 |
| Nara | 1,098 | 7,009 | 0.61 |
| Gaja Branch (Old Fuleli) | 1,371 | 7,760 | 0.55 |
| Fulelli | 1,287 | 5,791 | 0.44 |
| Lined (Tando Bago) | 1,304 | 5,437 | 0.41 |
| Pinyari | 1,277 | 5,178 | 0.39 |
| Kalri | 1,228 | 4,192 | 0.32 |

*(Source: Noordman, 2005).*

Also, outside the Indus Plains there is scope to improve groundwater management. The Thar Desert is one of the most densely populated deserts in the world. As one moves towards the South of the desert annual rainfall increases considerably, reaching 350 mm/year. The rainfall pattern however is highly variable and characterized by spells of dry years, causing outmigration as even drinking water sources fail. The groundwater in Thar Desert is mainly saline - with salinity of water in terms of electrical conductivity in 86% of the area - ranging between 2,000 and 10,000 μS/cm. Generally this is unfit for consumption, but under duress water quality up to 5000 μS/cm can be considered (Zaigham 2001). It has been argued that there is scope to develop groundwater resources in the Thar in a more systematic manner, particularly in the dune zone, where coal bearing sedimentary units and basement formation have remarkable potential. Moreover, recharge of the aquifers is immediate and the quality of deep groundwater can improve after long pumping.

## 4. An agenda for change

### 4.1. The imperative

There are several reasons why a rethink of water management in Sindh is the need of the day and why groundwater management will have to be integrated in overall water use. The first reason to modernize water management in the Province is to keep up with increasing population of the Sindh and the need to better capture the opportunities on agricultural markets. Better conjunctive water management of surface and groundwater will also improve drinking water availability and public health. There is a need to optimize water use, because canal supplies from Tarbela and Mangla may be structurally reduced as siltation increases and higher dead storage has to be maintained and also the effects of climate change make themselves felt.

Furthermore, the many recent floods in Sindh create an additional imperative for an upgrading of water management. The 2011 floods were caused by 'freakish' rainfall and made worse because the drainage system had limited capacity. The Left Bank Outfall Drainage System for instance was designed to remove the saline effluent not to drain the storm water. The drainage capacity was further reduced by the lack of maintenance and encroachment of drains and waterways. When the floods developed these were made worse by breaches in the drains because of high storm water flows and because of deliberate cuts in canals, drains and roads. The floods are made worse by the high groundwater tables – meaning that the excess water has nowhere to go but to transform into a flood. If water tables were lower there would have been the capacity to absorb part of the excess water. Three months after the events water was still impounded in large areas (see Figure 8).

The changes should engage all stakeholders – professionals, politicians and foremost farmers and other water users. The framework of participatory irrigation management that has taken off in Sindh should be the guiding mechanism to discuss and implement these changes, as the engagement of farmers and supportive capacity building is essential.

### 4.2. An agenda for conjunctive groundwater management in Sindh

An overhaul of the water management system in Sindh would have six action points.

**Action point 1: Rationalize irrigation duties**

The first is to properly manage the shallow groundwater resource and put an end to the widespread water logging – taking lessons from the drought years 1999-2002. This should be done primarily by adjusting current canal supplies and irrigation duties. At present the irrigation duties per canal command are highly variable and defy current logic. Some canals have extremely high duties (Figure 2). The supplies to different areas become even further unbalanced and considerably more water is diverted than the design discharges. An example is Ghotki Feeder which already has high duties of 6.6 cusec per 1000 acres but on top of this receives as much as 30-40% more supplies.

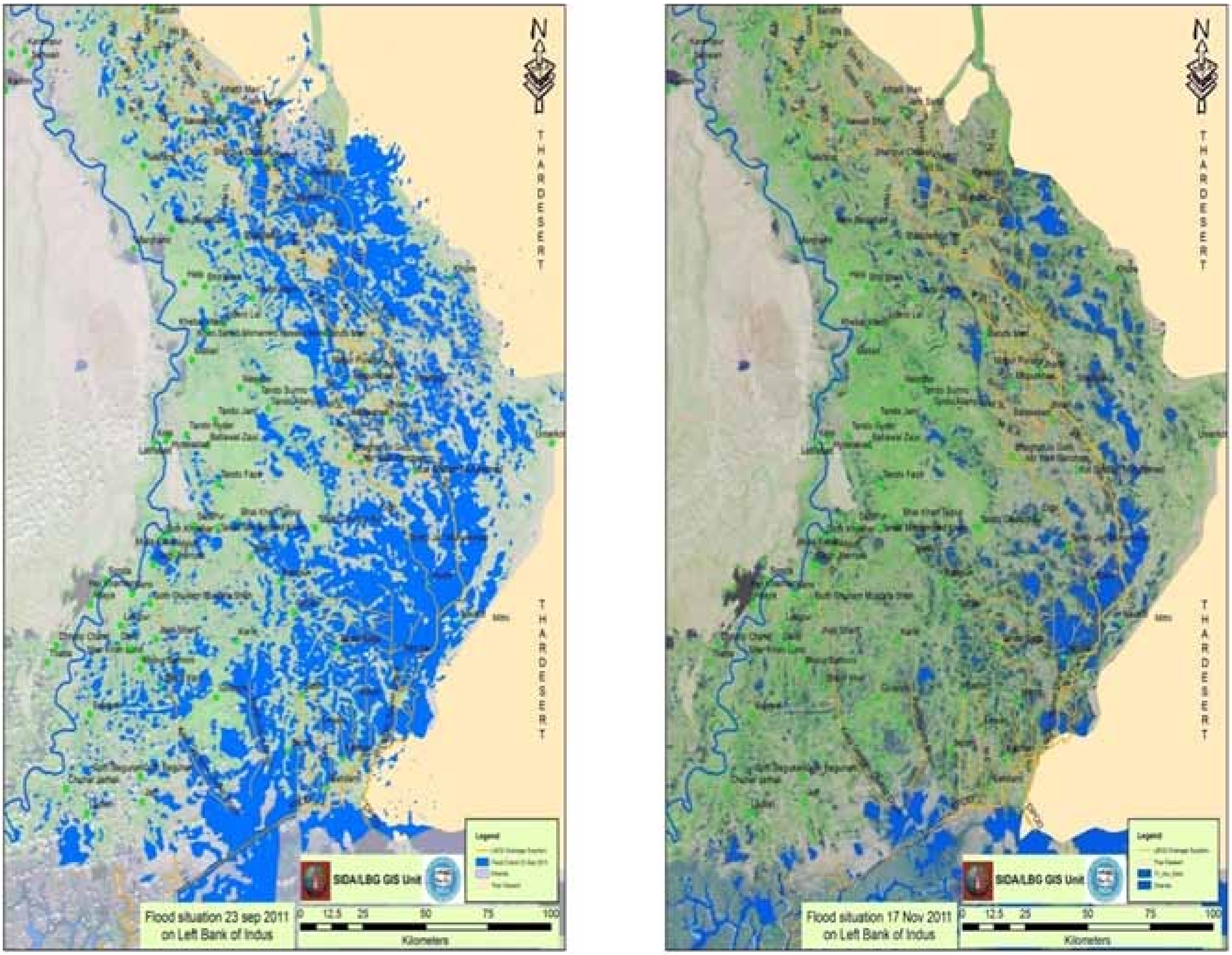



*Figure 8: Areas inundated after the 2011 floods (25 August and 17 November 2011).*

The result of these high duties is water logging and large volumes of non-beneficial evaporation, which reduces productivity, worsens public health and stands for the overall loss of water. In such high supply areas canal tail end or higher lands at times have higher crop yields than the waterlogged head reaches.

The irrigation duties should be set so to develop an optimum balance between surface water supplies and groundwater availability and usage and guidelines may developed in support of this. This requires that:

- surface water seepage is equivalent to recharge

- by groundwater use or in other words: beneficial evaporation;
- surface water supplies are set at an optimum scarcity so that they encourage groundwater pumping as a complementary source;
- where groundwater is of marginal quality that the mixing of supplied surface water and pumped groundwater results in useable water quality.

In a number of areas the supply of surface water may need to be curtailed (by reduced supplies or by rotations), not only to encourage supplementary groundwater irrigation, but to reduce the area that is waterlogged and cannot be used productively. Where the government is not intervening, farmers are taking the initiative to line their watercourses by their own means to prevent seepage and waterlogging (Figure 9).

The reduction of surface water supplies should go hand in hand with the introduction of water saving farming techniques (e.g. greenhouses, mulching, and soil amendments such as press mud), micro-irrigation and the introduction of other less water demanding crops.

In other areas surface supplies may be increased, also to have more recharge through canal seepage. This is particularly from low-lying water-short areas in tail sections with fresh groundwater. Shifting excess water to such areas may achieve a higher level balance in these areas, where the additional ground and surface water serve to support higher intensities – as in the lower section of Rohri Canal[3].

To grow rice and sugarcane in the very flat lands of Sindh without adequate drainage makes water logging with all ill-effects on water productivity and public health inevitable.

*Figure 9: In Tandoallahyar, farmers decided to line their watercourse to prevent seepage and waterlogging.*

In areas with highly saline groundwater the lowering of the water table will create space so that fresh water lenses can form on top of the saline water tables – fed by seepage and rainfall. This will at least make it possible to improve the availability of drinking water in such areas[4]. If the fresh water lenses are thick enough they can also be excessed for agriculture by dug wells or properly spaced skimming wells.

In areas with fresh or marginal groundwater the canal supplies should be adjusted in such a way that a balance is achieved between using surface water and groundwater. Surface water supplies from the canals need to ensure the right mixes of water qualities and to have water left for recharge. Canal supplies should be lowered so as to encourage groundwater pumping, especially in areas with fresh groundwater. The use of groundwater also makes it possible to have more precise agriculture and leads to much higher water productivity – by providing a psychological

*[3]) In Rohri Canal high water tables occur in patches due to seepage from the canal, the large number of direct outlets in places or blocked natural drainage, but in other areas water availability is low. Particularly in fresh groundwater areas a reallocation of water from areas that are oversupplied would increase productivity by canal supplies and pumped groundwater.*

*[4])This is what happened for instance in the Drainage IV area where the drainage project made it possible for such fresh/brackish water lenses to develop and this was a major boost for local drinking water supply.*

cushion to the farmers for water use as and when required.

The management of the surface water supplies for conjunctive management requires the political courage and leadership to take this on as well water balance models for the different canal command to sustain this. Table 4 shows a broad agenda for the six main commands in Sindh.

**Action point 2: Increase and intensify the irrigated areas**

This leads to the second agenda item – which is that better buffer management in the canal commands among others by revisiting the irrigation duties will save enough water within the Provincial quota to consider expanding the command areas and even developing new canals in Sindh. There are areas where expansion is possible on either bank – preferably areas are chosen with relatively fresh or marginal quality groundwater and relatively sandy soils so that highly conjunctive systems can develop right from the start. Going by the experience of the drought period it may be possible to develop an additional area of 500,000 ha. At present some of this expansion is happening already in an uncontrolled manner, with water in drains being fresh due to the large excess flows and being pumped by farmers. Progressive farmers are finding ways to overcome surface canal shortages, especially during Kharif. In Tandoallahyar, at the tail of the canal system, a farmer dug his own surface drain, which is recharged by seepage from nearby fields and canals in periods of high surface water supplies. During Kharif, when canal irrigation duties decrease, he would pump water from the drain into its watercourse (Figure

*Table 4: Broad agenda for the six command areas in Sindh*

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

10). This way, not only he avoids water shortage but he also prevents waterlogging in his fields.

In reassessing the irrigation duties the current reuse from drain may need to be considered and regularized.

Moreover the better use of shallow groundwater will also make it possible to intensify and extend the cropped areas through more groundwater irrigation by:

- The promotion of shallow irrigation wells in general;
- In some areas that have heavy soils by promoting and regulating the collection and reuse of drainage water – creating special buffers;
- Particularly in the part of the Province where fresh water overlays saline water, by carefully promoting multi-strainer skimming wells – that exploit water at very shallow depth. In several such areas nowadays the groundwater is exploited by conventional tubewells and local up coning of saline water is a tangible risk. There is a need for better guidance on the sustainable use of groundwater and the benefits of skimming wells.

  Combined with a rationalization of surface irrigation supplies this can create the safe and productive exploitation of thin fresh water buffers in the areas with shallow fresh groundwater and deeper saline groundwater. The occurrence of skimming wells is now patchy. In some areas they are common and even jointly owned (Figure 11) but in other areas they are relatively unknown. Their popularity in some areas is related to the fact that simpler drilling technology could be used for low depth low diameter multiple strainers: the same technology that is used for hand pumps.

In general promoting the use of shallow groundwater pumping. As a water demanding crop such as sugarcane is in many areas (including the sandy riverine tract) grown exclusively on groundwater, the financial feasibility of this type of agriculture is proven. However, costs of pumping may further be reduced by the application of water saving measures (see next paragraph), the introduction of fuel saving measures on the pump sets and the application of solar or wind energy. In Sindh, water logging is exacerbated

*Figure 10: Surface drains recharged by seepage are used for irrigation during periods of water scarcity.*

*Figure 11: Along the Imam Canal in Badin, farmers that cannot afford their own skimming well, are sharing one among 7 - 8 farmers to irrigate rice nurseries during Rabi.*

by the limited number of functional tubewells. Electricity cuts are the norm during Kharif, aggravating the problem. In order to overcome the energy crisis, several farmers in Hyderabad district took initiative and installed solar energy fuelled pumps. Thanks to this, groundwater levels are kept under control and water supplies are guaranteed (Figure 12).

**Action point 3: Improve field water use efficiency**

In close relation with the above, it is important to look at field water management practices too. An improvement in the agriculture system – particularly in the rice-wheat system in Sindh needs attention. Methodologies such as precise land leveling and mechanized operation have shown a lot of boost in agriculture production and water saving up to 50%). Direct seeding, the introduction System of Rice Intensification or other methods of alternate drying and wetting and growing rice in areas with saline groundwater as experimented earlier have the promise of saving water and increasing yields at the same time. In general the rice-wheat system has much to improve (Aslam, M. 1998): a large effort in ensuring equitable and reliable supplies (so as to avoid excessive water being monopolized in certain areas at the cost of reliable supplies elsewhere); restoration of the main irrigation systems and modernization learning from the programs currently implemented; the introduction of alternate drying and wetting at least after panicle initiation; better irrigation scheduling; direct seeding and the development of better field bunds so as to retain and control water better at standing depth.

There are several other examples of farmers applying water saving techniques and achieving high yield and avoiding the water logging that is all-pervasive in the land around them. Examples are the systematic use of mulch (from banana or mango leaves) that reduces evaporation and increases the organic matter in the soil, the application of press mud from sugar mills (Figure 13) and the use of greenhouses.

By leaving leaves of mango, banana, papaya, and other crop residues as mulching at the root of the trees, farmers can decrease water demands by up to 50% through decreased evaporation. Doing this they also prevent soil salinisation and augment soil organic matter contents (Figure 14).

*Figure 12: Solar energy fuelled pump.*

*Figure 13: Rohri: Using press mud from sugar mills as soil amendment - reducing the need to irrigate and improving soil fertility.*

*Figure 14: Mulching with tree leaves decreases evaporation, saves water and prevents salinization.*

*Figure 15: Low cost greenhouse made with bamboo and plastic sheets.*

Another successful example is that of a progressive farmer in the North of Sindh who constructed a very low cost greenhouse with bamboo sticks, ropes and plastic sheets (Figure 15). With this system he could substantially decrease water demands and increase his vegetable production. Now he also employs his neighbours on his farm.

Furthermore, the wasteful 'pancho' system whereby standing water in rice fields is drained before applying fresh water and rice more or less grows on flowing water as practiced in the rice growing areas would need to be discontinued. This will require investment in constructing additional field channels, so that each field can be served separately, as well as investment in drainage for low lying areas.

**Action point 4: Well targeted and selective drainage investment**

The fourth point is a well-targeted and selective drainage investment program. The high non-functionality of all drainage systems (70-90%), including the recently constructed LBOD, gives a clear message to be very judicious in drainage investment. The experience from LBOD moreover was also that due to the uncertainties in establishing the drainage coefficient in some areas, 'too much' drainage facilities were foreseen and that even before all facilities were operational the system was in balance again. It is important to make a clear distinction between drainage for storm water removal (only surface drains) and root zone drainage (tubewells, tile drainage and surface drains).

There are a number of guiding principles. In principle in, for storm water drainage:

- Priority should be given to unblocking surface drains closed by roads and railway tracks and make adequate cross drainage on new and old infrastructure compulsory;
- In some cases local dugouts may also serve to lower groundwater tables and as local freshwater storage – such as borrow pits from construction;
- Care should be taken not to 'over drain' and make sure water tables are lowered but not to too large a depth; so that the beneficial effects on soil moisture from water tables are safeguarded.

In addition, for root zone drainage:

- The main aim is to create enough storage space in the upper soil layers to ensure adequate soil aeration for crop growth and ideally in saline areas allow the development of fresh water lenses that can be used for local drinking water systems. In addition, this root zone aeration would help to avoid rainfall flooding as was observed in 2011 on left bank areas;

- There is no reason at all to develop or maintain public drainage facilities in fresh groundwater zones, as normally most of the drainage requirement would be taken care off by private pumping in such areas. Such private pumping may be further stimulated by the curtailing and rationalization of surface supplies, as described above;
- Ideally, where root zone drainage is provided there should be the possibility flexibility in water levels and no uniformity: some crops (rice) can tolerate high water tables and for other crops sub-irrigation is beneficial. It is better to have a controlled drainage system that accommodates the different requirements;
- There should constructive cooperation between farmers and government. There are by now several examples of farmers maintaining and even in investing in drainage facilities (Figures 16 and 17). Joint agreement and support in the provision of sophisticated O&M needs to be there;
- Finally, biological drainage – in particular the promotion of eucalyptus tree stands – needs to be more systematically promoted. It is understood that at present farmers often do not replant their eucalyptus trees because of the effect of the trees/ leaves on the soil fertility. This requires the introduction of other eucalyptus varieties and also the promotion of local concentrated eucalyptus forest rather than isolated stands.

There is a large scope and responsibility of the current generation of water professionals to do better. The response to water logging and salinity in Sindh in general has not been to prevent the problems and use the excessive water supplies into a potential as argued above, but to respond to the problems by investment in watercourse lining or drainage investments.

Investment in drainage however is the measure of last resort targeted at the areas that most need it– where possible the problem should be prevented by better managing surface supplies. In addition there is an urgent need to restore natural drainage path that are now often blocked by road and railway development or urban expansion. In areas with clays moreover limited investment in drainage can be considered where soils are clayed and discharge through tubewells or dug wells would not work. An example of a

*Figure 16: In Ghotki, a road borrow trench is serving as a local drain.*


*Figure 17: Award given after organizing farmers comprehensive desilting of canals and drains in Makhi.*

guidance in this respect is the soil map for one command (Figure 18).

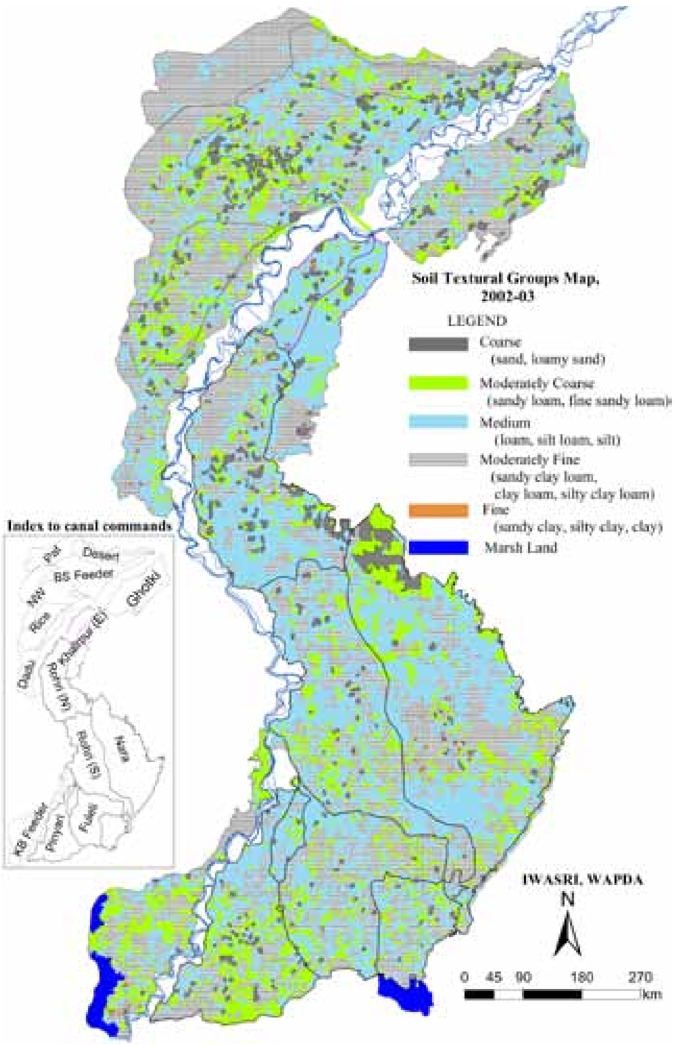



*Figure 18: Soil textural groups in Lower Indus plain.*

**Action point 5: Make use of storm water**

A fifth related agenda item in an overhauled water system is to turn the menace of floods into an opportunity and overhaul the storm water drainage system so as to create overflow areas in the dry areas. These areas should be chosen in such a way that the floods thus spread and infiltrated can be used to build up soil fertility and use shallow groundwater. This will further increase the agricultural potential of Sindh Province. Also a lowered groundwater table will help to better absorb flood events when they arrive. Some use of excess water is already made: in some of the tail areas farmers have constructed small multifunctional storage pond that are also used for herders and their livestock for instance (Figure 19).

**Action point 6: Adapt to saline conditions in some areas**

Finally, a larger effort should be made to adapt to the saline conditions that are natural in Sindh, both of the extensive occurrence of saline groundwater (in 70% of the land) as well as the soil salinity (affecting 20% of the land). There are several strategies to adapt to salinity. An important one is the introduction of bio-saline agriculture and brackish pond fisheries (Figure 20).

Bio-saline agriculture can make use of salt-loving halophytes and special varieties - such as Sesbania sesban, an appreciated fodder shrub that can yield as much as 7.5 t/ha of dry matter or fodder grasses belonging to the family of the Poaceae. In addition, recent research indicates that even existing varieties of common crops (wheat, sorghum, sugar-beet, potatoes, etc) can – after selection, adapt surprisingly well to the use of brackish water, particularly on free draining soils. A number of farmers are using locally selected wheat varieties in fact (Figure 21).

Other promising adaptation measures concern crop agronomy – from planting on ridges (Figure 22) to use special salt-tolerant microbial agents. High value fruit trees such as mango for instance, that badly tolerate saturated and saline soil conditions, are planted on top of field bunds (Figure 23).

*Figure 19: In the very tail end areas in Bhadin District, the rural community is confronted with extreme soil salinity and waterlogging in addition to water scarcity. Here, Villagers are constructing small multifunctional ponds to overcome water shortage.*

*Figure 20: Ghotki: Waterlogged land used as fish pond.*

*Figure 21: An innovative farmer along the Dhoro Naro Minor grows different wheat varieties to adapt to varying levels of soil salinity. On the most affected soils (on the right) he grows a local salt tolerant wheat landrace.*

*Figure 22: Ghotki: Onions grown on ridges to minimize the contact with salts that accumulate between the ridges.*

To start this process it is important to have an update understanding of groundwater quality at shallow and deeper depth, soil conditions and shallow stratigraphy and water levels. All these factors will contribute to the optimum conjunctive water use model for the concerned part of the command areas. The monitoring of water tables and groundwater quality needs to be fully resumed and extended to non-SCARP areas. The changes in water management require considerable discussion with farmers and rural leaders, but as there is a considerable win-win this is possible. There is also a need for action and study in a number of areas such as:

- Assessment of optimum water duties for different command areas and sections thereof, looking also at the highest value cropping patterns;
- Developing local water buffering and water storage strategies;
- Promotion and improvement of techniques such as skimming wells and biological drainage;
- Addressing the issue of bringing down pollution in the drains – in particular from sugar mills;
- Explore precise scope for saline agriculture in the coastal areas.

Moreover there is a need to get the process going at practical levels as well with pilot activities at the level of minors and distributaries in the different part of the province.

Whereas Punjab has the ambition to turn into a regional agricultural powerhouse, Sindh has much potential too to catch up.  Situated close to good shipping lines in a region with impressive economic growth Sindh cannot afford to deny itself the ample opportunities within its own land and water resource system.

*Figure 23: Fruit trees planted around the fields on top of earth bunds to escape excessive salinity and waterlogging.*

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