Irrigation Water Quality Assessment and Salinity Management Strategies in Bahawalpur Division, Pakistan

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Abstract
Economy of Pakistan is agricultural based and it mainly dependent on canal supplies. Due to rapid population growth, there has been a dramatic increase in the intensity of ground water exploitation leading to decline water table and deteriorate ground water quality. Tube well water is one of the most common resources to support the irrigation in situation of canal water scarcity. Considering the importance of tube well water, present study was conducted for the quality assessment of tube well water to provide guidelines to farmer and researches for better crop production by adopting water management strategies. Total 1400 water samples were collected from Bahawalpur division during the year 2017. These samples were analyzed and categorized according to suitability criteria of water quality evaluation. 38.64 percent water samples were found fit, 7.65 percent were marginally fit and 53.7 percent water samples were found unfit for irrigation purpose. Majority of water samples were found hazardous for irrigation purpose. There is need to analyze the existing water resources and recommending comprehensive conservation and management strategies in view of catering the planning requirements for the future.
Keywords: Salinity, Sodicity, Ground water, Bahawalpur, Pakistan.

INTRODUCTION:

The country`s agriculture is almost wholly dependent on irrigated areas which produce more than 90% of agriculture production. Water is becoming a limiting factor for crop production in many parts of the world, especially developing countries like Pakistan. There is 35.19 % contribution from canal irrigation, 40.88 % contributions from canal + tube well and 19.9% from tube wells as irrigation source. Current population of Pakistan is 210-220 million and projected to reach 227 million by 2025 (GOP, 2016-17). Until the beginning of the 1990s, gravity-fed surface irrigation dominated the irrigated agriculture of Pakistan. By the early 1990s, groundwater irrigation had surpassed surface irrigation (Van der Velde and Kijne, 1992). More than 50% of Pakistan's irrigated lands are now served by groundwater wells (Chaudhary *et al.,* 2002). On average, every fourth farming family has a tube well and a large proportion of non-owners purchase groundwater through local, fragmented groundwater markets (Pakistan Water Partnership PWP, 2001) and (Qureshi and Akhtar, 2003). Irrigation water represents an essential input for sustaining agricultural growth in Pakistan's arid to semi-arid climate. Groundwater is gradually turning saline along with increase in the depth of water table. High pumping costs of groundwater are a limitation towards its use by many small farmers (Shakir *et al.,* 2011). Impact of forthcoming climatic changes on water resources is erratic and country lacks in infra structure to sustain pressure imposed by droughts and floods. Irrigation with low quality water may cause an excessive accumulation of salt in the soil profile that affects the crop yields, quality of produce and the choice of the crop to the grown. The ground water irrigation coupled with high pumping cost and salinity hazards make it more important that ground water irrigation be used efficiently and judiciously, agriculturist have increasingly sunk tube wells to keep their business afloat.

The region surrounding Bahawalpur to the west, called the Sindh, is a fertile alluvial tract in the Sutlej River valley that is irrigated by floodwaters, planted with groves of date palms, and thickly populated. The chief crops are wheat, gram, cotton, sugarcane, and dates. Sheep and cattle are raised for export of wool and hides. East of Bahawalpur is the Pat, or Bar, a tract of land considerably higher than the adjoining valley. It is chiefly desert irrigated by the Sutlej inundation canals and yields crops of wheat, cotton, and sugarcane. Farther east, the Rohi, or Cholistan, is a barren desert tract, bounded on the north and west by the Hakra depression with mound ruins of old settlements along its high banks; it is still inhabited by nomads. Sutlej is the south-easternmost of the five rivers of the Punjab, the other four being its two main tributaries, the Beâs and the Chenab, together with two branches of the latter. Below the confluence of the Beâs, the river is sometimes called the Ghara, and its lowest course, after receiving the Chenab, is called the Panjnad ("five rivers").

The common quality characteristics considered are electrical conductivity (EC), sodium adsorption ratio (SAR), and residual sodium carbonate (RSC),(Idrees & Shafiq,1999).To avoid indiscriminate use of ground water, proper management practices are deemed necessary, keeping in view the crop to be grown and the soil to be used((Suarez & Lebron, 1993; Ghafoor et al., 2000; Qadir et al., 2001).This paper aims to discuss the difficult and complex challenge of ground water quality management in Pakistan and suggest future pathways to preserve this precious resource to sustain irrigated agriculture to ensure food security.

MATERIALS AND METHODS:

1400 ground water samples were collected from running tube wells of all the tehsils of Bahawalpur Division covering four sides (north, east, west and south) of each tehsils in plastic bottles after ½ hour of tube well operations. The collected water samples were analyzed at Rice Research Station Bahawalnagar, for EC, Ca + Mg, Na, CO_3, HCO_3 and Cl. Then the sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were computed (Anonymous, 1954) by following formulas of U.S .Salinity Lab. Staff (1954).Based on the values of EC, SAR, RSC, water samples were categorized using the international standards (Anonymous, 1954).

$$SAR= Na/\{(Ca + Mg)/2\}1/2$$

$$RSC\ (me\ L^{-1}) = (CO_3^{2-} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

Where the concentrations are expressed in milli equivalents per liter (me L^{-1}) (Richards, 1954).

Table 1. Analysis techniques with references.

Parameters	Technique	Instrument make and model	Method Reference
Electrical Conductivity(EC)	Conductivity meter	AD3000,Bench Meter	Richards (1954)
Na and K	Flame photometry	PFP-7, Jenway	Richards (1954)
Ca, Mg, CO_3, Cl and HCO_3	Titrimetric method	-	Richards (1954)

RESULTS AND DISCUSSIONS:

Irrigation water quality parameters (Table 2) were assessed on the criteria given by Soil Fertility Research Institute Punjab (Malik *et al.,* 1984) while others are for comparison purpose. The data was analyzed statistically for mean, standard deviation and percentage following the procedure described by Steel and Torrie (1980). The parameters EC, SAR and RSC were calculated from primary data (i.e. EC, Ca + Mg, CO_3, HCO_3 and Na).

Table 2. Irrigation water quality criteria

Parameter	Status	Richards, L.A.(1954)	WAPDA (1981)	Muhammad (1996)	Malik *et al.* (1984)
EC (µS cm^{-1})	Suitable	750	<1500	<1500	<1000
	Marginal	751-2250	1500-3000	1500-2700	1001-1250
	Unsuitable	>2250	>3000	>2700	>1250
SAR	Suitable	<10	<10	<7.5	<6
	Marginal	10-18	10-18	7.5-15	6-10
	Unsuitable	>18	>18	>15	>10
RSC (me L^{-1})	Suitable	<1.25	<2.5	<2.0	<1.25
	Marginal	1.25-2.50	2.5-5.0	2.0-4.0	1.25-2.5
	Unsuitable	>2.5	>5.0	>4.0	>2.5

Salinity

Salinity is the concentration of all soluble salts in water or in the soil. In water, salinity is usually measured by its electrical conductivity (EC), which is a measure of the concentration of ions in water or in the soil solution. Ions are positively charged, that is, cations, and negatively charged, anions. The international standard for measuring salinity is decisiemens per metre (dS/m), but several other units of measurement are still in use. Dissolved substances within the roots such as salts and sugars attract water through the root membrane, from where it moves to the rest of the plant. This process continues as long as the concentration of dissolved substances inside the roots is higher than that of the soil water available to the plant. If the soil water salt concentration is too high the plant will not be able to absorb water: it will wilt and begin to die. The point at which this happens depends on the type of plant, the salt concentration of the water, and the type of salts in the soil water. As a general guide, chloride and sodium ions in the salts do the most damage to plants. Irrigating with water high in these salts can be detrimental to plant growth, affect plant yields and ultimately threaten the plant's survival.

EC readings are a general indicator of the salt concentration. They do not tell you the type of salts or their relative concentrations. When EC levels are high you should find out what the specific ions are so that you can adjust your irrigation practices accordingly.

The Figure 1 illustrates that the test results for EC of all sampling points lies within Bahawalpur Division.

Figure.1

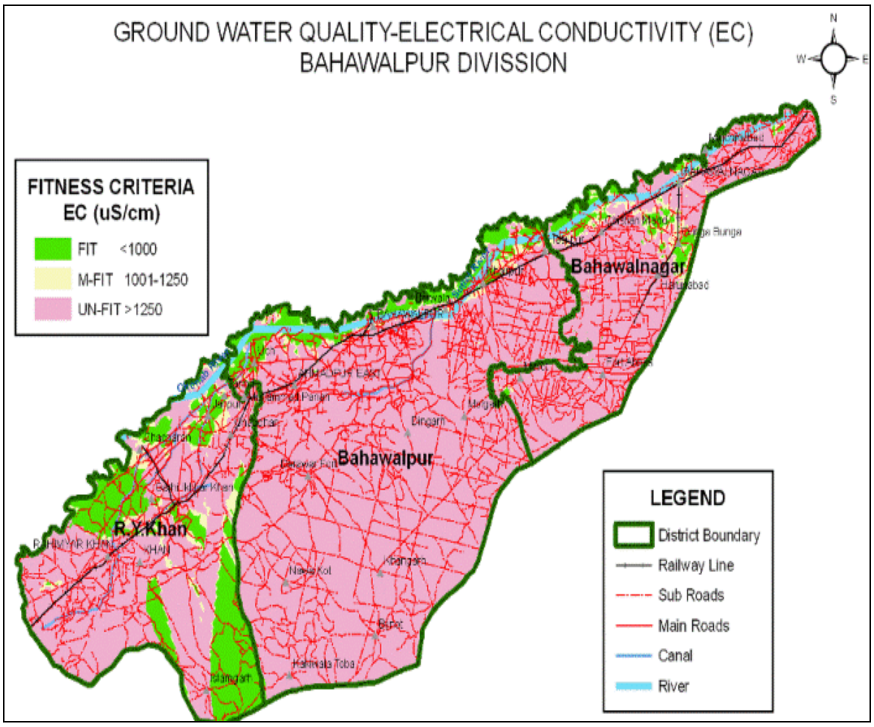


Table 3. Range, mean and standard deviation (S.D.) of irrigation quality parameters of ground water, Division Bahawalpur

Parameter	Range	Mean	Standard Deviation
EC (µS cm^{-1})	140-23850	2297.25	2065.50
SAR	0.01-94.50	6.46	5.59
RSC (me L^{-1})	0-11.46	0.45	0.36

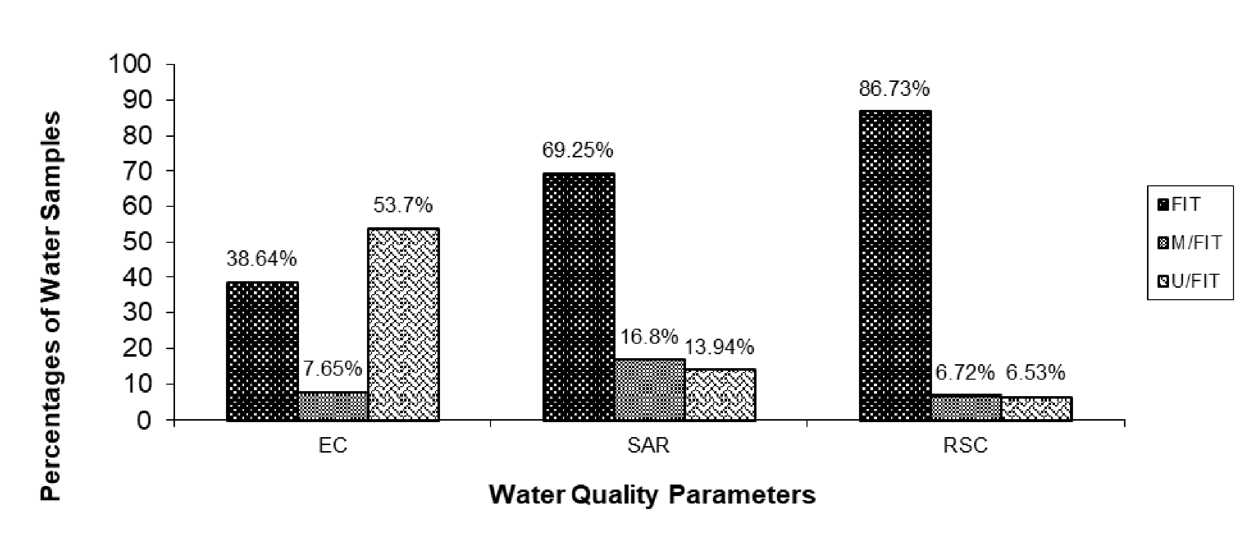
The classification of water samples on the basis of EC (Fig.2) indicated that EC of 38.64% water samples were within safe limits (<1000 µs/cm) whereas, 53.7% samples were unfit (>1250 µs/cm) and 7.65% were marginally fit (1000-1250 µs/cm) for irrigation. The EC of all water samples ranged from 140-23850 µs/cm with a mean value of 2297.25 µs/cm & standard deviation of 2065.50 (Table 3).

Sodicity

Sodicity represents the amount of exchangeable sodium cations in water or in soil. In water, sodicity is expressed as a sodium absorption ratio (SAR), which relates sodicity to the amount of calcium and magnesium ions in the water (Emerson and Baker, 1973).

Salinity affects plants directly, but sodicity may have an indirect effect on plants, as it first affects the soil. The use of sodic water can in time turn a non-sodic soil sodic, and can worsen sodicity in a sodic soil. If irrigation water with high SAR is applied to a soil, the sodium in the water can displace the calcium and magnesium in the soil .This will cause a decrease in the ability of the soil to form stable aggregates and loss of soil structure. This will also lead to decrease in permeability and infiltration of the soil to water, leading to problems with crop production (FAO, 1992).

Figure 2: Irrigation Water Quality of Bahawalpur Division



The classification of water samples on the basis of SAR (Fig.2) indicated that SAR of 69.25 % water samples were within safe limits (<6) whereas, 13.94% samples were unfit (>10) and 16.8% were marginally fit (6-10) for irrigation. The SAR of all water samples ranged from 0.01-94.50 with a mean value of 6.46 & standard deviation of 5.59(Table 3). The Figure 3 illustrates that the test results for SAR of all sampling points lies within Bahawalpur Division.

Residual sodium carbonate (RSC) exists in irrigation water when the carbonate (CO_3) plus bicarbonate (HCO_3) content exceeds the calcium (Ca) plus magnesium (Mg) content of the water. Where the water RSC is high, extended use of that water for irrigation will lead to an accumulation of sodium (Na) in the soil.

Fig. 3

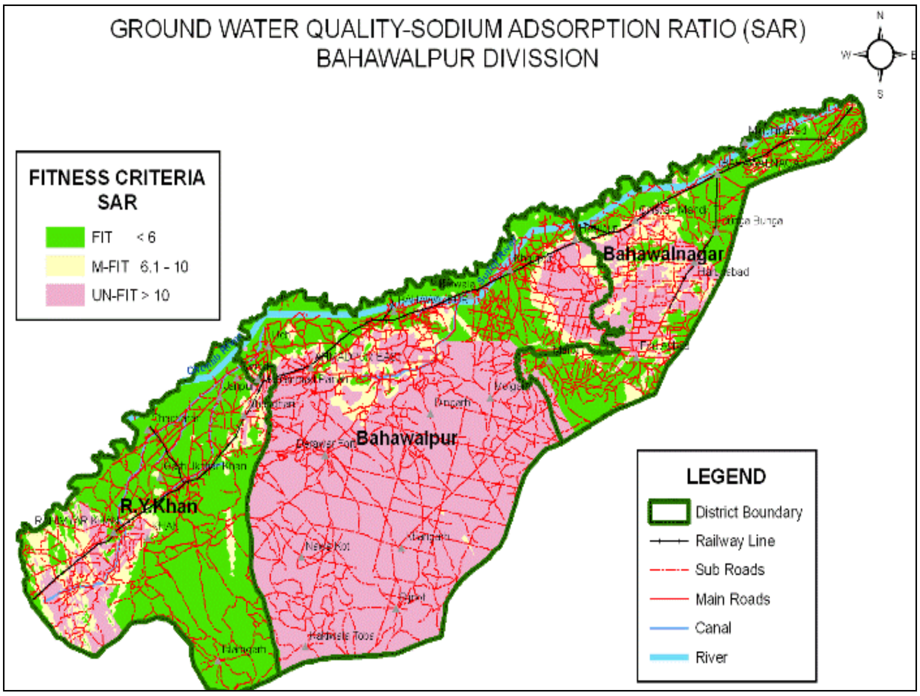


Fig.4

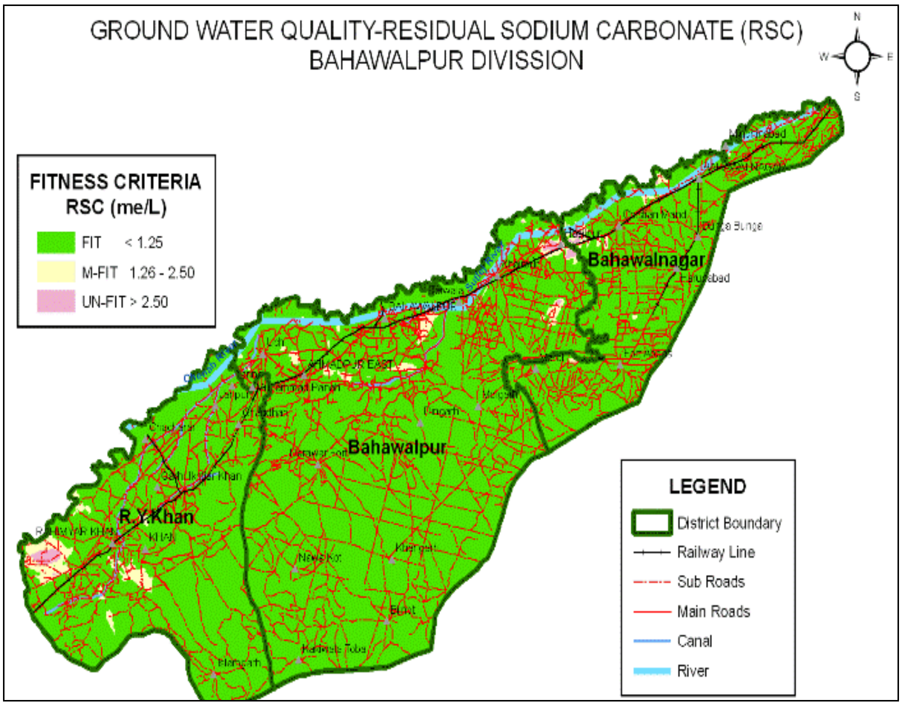


Table 3 showed the classification of water samples on the basis of RSC. The RSC ranged from 0-11.46 me L^{-1} with mean value of 0.45 & standard deviation of 0.36. RSC of 86.73% water samples were within safe limits (<1.25 me L^{-1}), only 6.53 % water samples were unfit (>2.50 me L^{-1}) and 6.72% water samples were marginally fit (1.25-2.50 me L^{-1}) due to higher RSC. High value of water RSC must be used for monitoring of soil salinity by laboratory analysis and good irrigation techniques (Nishanthiny *et al.*, 2010).The Figure 4 illustrates that the test results for RSC of all sampling points lies within Bahawalpur Division.

Conclusions and Recommendations:

The frontline challenge is not just supply-side innovations but to put into operation a range of corrective mechanisms before the problem becomes either insolvable or not worth solving. Therefore Pakistan needs a serious debate about whether to pump their aquifers to the maximum and be very poor thereafter, or manage abstraction and be somewhat poor today. Adverse interactions are likely to turn into a serious situation if proper attention is not given to address the problems.

Techniques for controlling salinity that require relatively minor changes are, more frequent irrigations, selection of more salt-tolerant crops, additional leaching, preplant irrigation, bed forming and seed placement. Alternatives that require significant changes in management are changing the irrigation method, altering the water supply, land-leveling, modifying the soil profile, and installing subsurface drainage.

Good quality water, if available, is required for irrigation to supplement tube-well water which will dilute its level of SAR. Other option for amelioration of excessive water (SAR) is through lining of water courses with gypsum stones. Management options for improving high water (RSC) include dilution with canal water and neutralization of carbonate and bicarbonates with the application of acids such as sulfuric acid or acid former such as elemental sulfur. Amendments such as gypsum, press mud and manure should be applied to reduce the ill effect of ground water on soil.

References

- Anonymous, 2016. Pakistan Statistical Year Book, 2016. Federal Bureau of Statistics Division, Govt. Pakistan, Islamabad, Pakistan.
- Anonymous, 1954. U. S. Salinity Lab. Staff. Diagnosis and Improvement of Saline and Alkali Soil. USDA Hand Book 60. Washington D.C. US.
- Chaudhary, MR; Bhutta, NM; Iqbal, M and Subhani, KM. 2002. Groundwater resources: use and impact on soil and crops. Paper presented at the Second South Asia Water Forum, 14–16 December, Islamabad, Pakistan.
- Emerson, W.W. and A.C. Bakker, 1973. The comparative effect of exchangeable Ca: Mg and Na on some soil physical properties of red brown earth soils. The spontaneous dispersion of aggregates in water. Australian J. Soil Res., 11:151–2

- FAO.1992.The use of saline waters for crop production. Irrigation and drainage paper 48. FAO, Rome.
- Ghafoor, A.,M.Rizwan and G. Murtaza,2000. Utilization of brackish water for reclaiming different textured saline-sodic soils having different ECe to SAR ratio. pp. 121-8.In: Natl. Seminar on Drainage in Pakistan. 16-17, 2000, Jamshoro, Hyderabad, Pakistan.
- Government of Pakistan (GOP), 2017. Economic Survey of Pakistan 2016-17, Finance Division, Islamabad, Pakistan.
- Idris, M. and M. Shafiq. 1999. Irrigation quality of groundwater in Quetta division of Balochistan.

Pakistan Journal of Soil Science 16:119-122.
- Malik, D.M., M.A. Khan and T.A. Chaudhry. 1984. Analysis method for soil, plant, and water. Soil Fertility Survey and Soil Testing Institute, Punjab, Lahore, Pakistan.
- Muhammad, S. 1996. Soil salinity sodicity and water logging. p. 472- 506. In: Soil Sci. A. Rashid and K.S. Memon. National Book Foundation Islamabad, Pakistan.
- Nishanthiny, S.C., M. Thushyanthy, T. Barathithasan and S. Saravanan. 2010 Irrigation water quality based on hydro chemical analysis, Jaffna, Sri Lanka. American- Eurasian J. Agric. & Environ. Sci. 7:100-102.
- Pakistan Water Partnership (PWP). 2001. The Framework for Action for Achieving the Pakistan Water Vision 2025. WAPDA: Lahore, Pakistan.
- Qadir, M., A. Ghafoor and G. Murtaza, 2001.Use of saline-sodic waters through phytoremediation of calcareous saline-sodic soils. Agric.Water Manag., 47:1–14.
- Qureshi, AS and Akhtar, M. 2003. Effect of electricity pricing policies on groundwater management in Pakistan. Pakistan J. Water Res. 7: 1–9.
- Rafique, M., 1990. Soil resources and soil related problems in Pakistan. P. 16–23. In: Ahmad, M., M.I. Akhtar and M.I. Nizami (ed.). Soil Physics Application under Stress Environment. Proc. Symp. Applied soil physics in stress environment, Islamabad, Jan. 22–6, 1989. BARD Project, PARC, Islamabad, Pakistan.
- Richards, L.A. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agri. Hand Book No. 60, U.S. Government Printing Office, Washington, D.C., USA.
- Shakir, A. S.; Rehman, H.; Khan, N. M. and Qazi, A. U. 2011. Impact of canal water shortages on

Ground water in the lower Bari doab canal system in Pakistan. Pak. J. Engg. Applied Sci., 9: 87-97.
- Singh, R.B., P.S. Minhas, C.P.S. Chaulian and R.K. Gupta. 1992. Effect of high salinity and SAR waters on salinization, sodification and yields of pearl millet and wheat. Agricultural Water Management 21: 15-25.
- Steel, R.G.D and J. H. Torrie. 1980. Principles and Procedures of Statistics. 2nd Ed.,McGraw-Hill Book Company, New York.
- Suarez, D. L. and I. Lebron, 1993. Water quality for irrigation with highly saline water.In: Towards the Rational Use of High Salinity Tolerant Plants, 2: 289–397.
- Van der Velde, EJ, and Kijne, JW. 1992. Salinity and irrigation operations in Punjab. Pakistan: are there management options? Paper at Workshop on IIMI-India Collaborative Research in Irrigation Management (Lahore, IIMI), Pakistan.
- Water and Power Development Authority. 1981. Atlas – Soil salinity survey of irrigated areas of Indus basin 41 million acres. Survey and Research Organization Planning Division, WAPDA, Lahore.