Use Of Poor Quality Groundwater Through Conjunctive Water Management

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ABSTRACT

Water is a limiting factor for agricultural production in arid and semi-arid climatic conditions. The main source of irrigation in Pakistan is derived from vast canal system. The amount of available surface water is, however, inadequate to meet crop water requirements. The deficiency is supplemented with groundwater, which is often of poor quality and unfit for irrigation purposes. Its continuous use leads to soil degradation. There is a shortage of 1.5-acre feet of water per cropped acre in the culturable command areas, which affects the crop yield and creates serious problem of salinization of productive lands.

Pakistan has 55 million-acre feet of groundwater reserves. Half of this water can be used for crop production by adopting appropriate technologies while the remaining half is hazardous and cannot be used for crop production without treatment. Poor quality groundwater can, however, be utilized for crop production in conjunction with canal water in light textured soils. Although conjunctive use of fresh and saline water results in improvement of infiltration rate and reduction of salinity and sodicity of upper soil layers but its continuous use causes accumulation of sodium ions in lower layers leading to reduced permeability.

Poor quality groundwater can be better utilized through its cyclic use i.e. alternate irrigation of canal and tubewell water, which causes less built up of salts in soil profile than conjunctive water application. Both rice and wheat give better yields by cyclic use of saline water with canal water than conjunctive use as irrigation with fresh water flushes the salts added by preceding irrigation of poor quality water. In areas of acute water shortage, wheat can be grown with tubewell water whereas canal water can be used for growing rice during the abundant water supply period. The water so applied for rice crops also flushes down the salts. Saline-sodic and sodic groundwater can also be successfully utilized for crop production through its treatment with Sulfurous Acid and Gypsum. This technology is also helpful in reclaiming sodic/saline-sodic soils for better crop yields. Adopting furrow and bed planting technology in poor water quality areas may further ensure crop growth. Similarly, by adopting other Resource Conservation Technologies such as reducing canal irrigation losses at primary secondary and tertiary level, precision land leveling and Zero tillage Technologies may enhance crop productivity using poor quality groundwater along with canal water.

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INTRODUCTION

The need for more efficient water management is gaining recognition due to the increased cost of water supply, the growth in the demand of water, and greater environmental and social impacts of water programs. "Conjunctive use" of surface and groundwater resources provides opportunities for increasing net benefits to the water users. The concept of conjunctive use of groundwater and surface water resources was originated in the late 1940s in the arid Western United States in response to the water problems of that period. Today, the conjunctive use concept is widely accepted by water resource planners and is considered prerequisite to optimal water utilization.

Conjunctive use may be implemented in a number of ways as well. One of the examples is of a situation where good quality surface water is available in limited quantity, whereas poor quality groundwater is relatively plentiful. The concept of "conjunctive use" would blend waters from the two sources of differing qualities to obtain more water of poor, but acceptable quality [1]. The blending should vary with the relationship between yield and water quality for a particular crop and soil.

Adequate food production is a pressing need in many less developed countries. In Pakistan, the production of food can potentially be increased several times over the present supply. The land resources of the Indus Basin agricultural system far exceed its related water resources. It is, therefore, of paramount importance that the scarce water resources be optimally developed and managed. Chaudhry et al. (1974) discussed an optimal conjunctive use model for the Indus Basin, Pakistan [2].

Due to drought conditions prevailing since 1997 to date, the surface and groundwater reservoirs were depleted which resulted into destruction of vegetation and orchards. The animals and human beings suffered from severe food and water shortages. It is, therefore, the need of the hour to adopt Water Management Techniques like conjunctive water management using poor quality groundwater being treating with Sulfurous Acid and adopting Furrow and Bed planting for augmenting inadequate surface water and saving available water through other resource conservation techniques such as reducing canal irrigation losses (at primary, secondary and tertiary level), precision land leveling and Zero tillage technology.

USE OF POOR QUALITY WATER THROUGH CONJUNCTIVE WATER MANAGEMENT AND TREATING WITH SULFUROUS ACID (H_2SO_3)

Water is a limiting factor for agricultural production in arid and semi-arid climatic conditions. The main source of irrigation in Pakistan is from vast canal system. The total water diversions from the rivers and streams are estimated to be 142 million acre feet/year and the amount diverted to canals is 103 million acre feet per year; 39 million acre feet of water enters into the Arabian Sea without any proper management. The conveyance and other losses from canal head to the field comprise about 50% resulting in net diversions of only 51.5 million-acre feet. Given that the cultural command area is 34.6 million acres, indicates that the water supply to the field is only 1.5-acre feet. The optimum requirement for crops is 3-acre feet per acre. This means that there is a shortage of 1.5-acre feet per cropped acre in the culturable commanded area [3]. This shortage of water is affecting the crop yield and creating serious problem of salinization of productive lands. The amount of available surface water is, however, inadequate to meet crop water requirements. The deficiency is supplemented with groundwater, which is often of poor quality (unfit for irrigation purposes). Its continuous use leads to soil degradation. Pakistan has 55 million-acre feet of groundwater reserves [4]. Half of this water can be used for crop production by adopting appropriate technologies while the remaining half is hazardous for irrigation. Poor quality groundwater can, however, be utilized for crop production in conjunction with canal water in light textured soils. Although conjunctive use of fresh and saline water results in improvement of infiltration rate and reduction of salinity and sodicity of upper soil layers but its continuous use causes accumulation of sodium in lower layers leading to reduced permeability. Area irrigated by different sources in Pakistan is given in table 1.

Pakistan has 55 million-acre feet of groundwater reserves. Half of this water can be used for crop production by adopting appropriate technologies while the remaining half is hazardous and cannot be used for crop production with out treatment. Poor quality groundwater can, however, be utilized for crop production in conjunction with canal water in light textured soils. Although conjunctive use of fresh and saline water results in improvement of infiltration rate and reduction of salinity and sodicity of upper soil layers but its continuous use causes accumulation of sodium ions in lower layers leading to reduced permeability.

Table 1: Area Irrigated by Different Sources (Million Hectares) in 1999-00

Data Type	Punjab	Sindh	NWFP	Baluchistan	Total
Total Area	13.85	2.52	0.92	0.80	18.09
Water Allocated (BCM)	68.8	59.97	10.80	4.76	144.33
Govt. Canals	3.93	2.39	0.39	0.40	7.11
Private Canals	-	-	0.37	0.08	0.45
Tube wells	2.65	0.13	0.09	0.23	3.10
Wells	0.12	-	0.04	0.02	0.18
Canal & Tube-wells	6.99	-	-	-	6.99
Canal & Wells	0.09	-	-	-	0.09
Tanks	-	-	-	-	-
Others	0.07	-	0.03	0.07	0.17

Data Source: Agricultural Statistics of Pakistan-1999-00

Poor quality saline groundwater can be better utilized through its cyclic use i.e. alternate irrigation of canal and tube well water, which causes less built up of salts in soil profile than conjunctive water application. Both rice and wheat give better yields by cyclic use of saline water with canal water than conjunctive use as irrigation with fresh water flushes the salts added by preceding irrigation of poor quality water. In areas of acute water short supply, wheat can be grown with tube well water, and canal water can be used for growing rice during abundant supply period. The water so applied for rice growing also flushes down the salts. Management of saline-sodic and sodic groundwater by mixing with canal water is one cost-effective option. If availability to canal water is limited then such waters can also be successfully utilized for crop production through its treatment with Sulfurous Acid Generator or Gypsum. Such chemical treatments can also be helpful in reclaiming sodic/saline-sodic soils for better crop yields. Crop growth may further be ensured by adopting furrow and bed planting technology in poor water quality areas, which helps in crop establishment during early growth stages. Adoption of proper water management technologies can help for sustainability of irrigated agriculture without degrading the soils.

There are about 7,00,000 tube wells in Pakistan. Rapid development of groundwater by the private sector is giving rise to the danger of excessive lowering of water tables, impeding threat of secondary salinization due to use of groundwater of marginal quality and intrusion of saline water into fresh water aquifer. It has been estimated that over 60 percent tube wells in the Pakistan are pumping sodic/saline sodic water.

A profile of groundwater quality is given below:

Qureshi, R.H. and Barrett-Lennard E.G. 1998. Saline Agriculture for Irrigated Agriculture in Pakistan
"About 70% of tubewells in the Indus Plain pump sodic water"
Javaid, Azhar M. 2002. Groundwater Monitoring for Resource Management (Dawn of 11 March 2002)
"About 70 per cent discharge of existing wells is saltish and is playing havoc with soil by developing salinity and sodicity front in fertile soils"
Punjab Directorate of Soil Fertility (PAD)
Total Samples: 75, 737
Fit: 32.4%
Unfit +Marg. Fit: 69.6%
Unfit: 55.2--unfit due to: EC (36%), RSC (11.7%), SAR (3.3%), EC+RSC (12.3%), EC+SAR (13.3%), RSC+SAR (3.5%), EC+SAR and RSC (19.9%)-- total RSC "infected unfit" =47.4%
Recent (2002) Tube well Water Quality Survey of Village Bughiana along Ravi River,
Total Tube well =75: Fit water quality Tube-wells=26, Unfit water quality Tube-wells=49.
Fit Tube wells=34.7, Marginally fit due to RSC=18.7% and unit due to RSC=46.7%
Marginally unit and unfit tube wells due to RSC=65.3%
Unfit due to SAR=84%, unfit due to EC=94.7%
Punjab Soil Fertility Directorate (March, 2002)
(Village near Khudian, Chunian) Middle of the Ravi and Satluj Rivers)
100% unfit-- all Tube wells pump unfit water for irrigation--EC from 158 to 2660 US/cm, SAR from 9.6 to 17.9 and RSC from 4.4. To 9.7

Due to acute shortage of good quality irrigation water for crops, sweet water is becoming a scarce resource because of its decreasing availability. Dependence upon marginal/poor quality groundwater has been increased due to shortage of canal water for the last three years. Application of saline-sodic/sodic water results in accumulation of salts in soil, increased soil pH, and affects soil fertility through reduced availability of essential nutrient elements.

Use of sulfurous acid generator is an appropriate measure on site treatment of sodic/saline sodic water. It takes small quantity of saline-sodic/sodic water from intake pipe, treats it with sulfurous acid in its mixing chamber, and then discharge treated water through outlet pipes. The water so treated can be applied directly to the fields. The Sweet Water Farming Inc, USA, has fabricated the Sulfurous Acid Generators that have been tested extensively in U.S.A., Mexico, Morocco, Saudi Arabia and Pakistan. In Punjab, Sulfurous Acid Generator was tested for rice, wheat, and sugarcane crops. The results of different studies conducted world-over identified following benefits of the Sulfurous Acid Generator:

- Reduces pH of irrigation water and soil
- Decreases the degree of sodicity in irrigation water
- Reduces build up of salts in soil profile
- Increases infiltration rate of soil
- Improves physical condition of soil
- Activates soil Calcium to replace Sodium from clay complex

- Makes Calcium available as nutrient
- Eliminates the necessity of deep plowing, mixing and abundance of freshwater associated with gypsum application
- Provides faster way of reclamation of soils

Sulfurous Acid Generators are now being manufactured in Pakistan under the license of the Sweet Water International, Inc., Utah, USA near Lahore. The water treated with the sulfurous acid can treat alkaline water (sodic or saline sodic) and or having pH value above 7 and Residual Sodium Carbonates (RSC) more than 1.25. Irrigation with treated water helps in managing root zone salinity for utilization of these soils for crop production.

With Sulfurous Acid Generator treatment, sodic/saline-sodic groundwater resources can be utilized for higher crop production besides reclamation of sodic and saline sodic soils as given in table 2. Its use can be promoted through participatory approach, whereby farmers may share cost incurred on procurement of plant, its installation, operation, and maintenance.

Table 2: Impact of Use of Sulfurous Acid Generator Treated Water on Yield of Crop

WHEAT	Y1	Y2	Yield Increase Y1 to Y2
Irrigated with untreated water:	1042	1095	5%
Continuous Irrigation with.SSG-treated water:	1417	1855	31%
Yield Improvement-Treated vs.non treated:	36%	69%	
RICE			
Irrigated with untreated water:	931	977	5%
Continuous irrigation with SSG-treated water:	1673	2035	22%
Yield Improvement-Treated vs. non treated:	80%	108%	

It is suggested that we should use Resource Conservation Technologies such as Bed and furrow planting, W/C rehabilitation/lining, Laser Land Leveling and zero tillage as ways to create conducive conditions for an effective conjunctive use of ground and surface water resources.

BED AND FURROW SYSTEM

Technology of raising row crops on beds and furrows is gaining popularity amongst the progressive farmers, mainly because the cost of crop production is considerably reduced as a result of water saving and other benefits. Bed shapers are used behind the tractors to form furrow-beds to sow row crops. Some of the advantages associated with furrow-bed-irrigation technology of crop production are:

- Minimum tillage/seed bed preparation reduces over all energy requirements;
- Savings of about 40 percent irrigation water;
- Reduced chances of plant submergence due to excessive rain or over irrigation;
- Lesser crusting of soil around plants and, therefore, more suitable for saline and sodic soils;
- Adaptable for various crops without changing basic design/layout of farm;
- Enhanced fertilizer use efficiency due to local application; and
- Minimum chances of lodging of crops

In view of the above benefits, Bed and Furrow planting of cotton has gained acceptance and popularity amongst farmers in the Punjab during the recent years. Adoption of cotton with bed and furrow shaper has been increased from 500 acres in 1997-98 to 2.00 million acres in 2000-01.

Bed and Furrow plantation technology for wheat has been introduced in the country with the assistance of PARC, Massey University, New Zealand and CIMMYT through Rice-Wheat Consortium of the Indo-Gigantic Plains and was successfully tested during last years in Punjab at different sites on farmers' fields. M/S Green Land Engineering, Daska, has locally fabricated and further refined the planter and equipment has since been released for sowing of wheat, rice, maize, sunflower and vegetables. This technology will be helpful to enhance water productivity and reduce the cost of production of wheat. It is, therefore, imperative to refine this technology and disseminate amongst the farming community to cope with current water crisis.

REDUCING CANAL IRRIGATION LOSSES

The rehabilitation/lining of canals/distributaries and minors come under the purview of provincial Irrigation and Power Departments, whereas rehabilitation of watercourses at farm level is being carried out by the Water Management wings of Agriculture Departments in the provinces.

The results of different studies carried out on irrigation systems of the Indus basin have shown that the major part of the water, which is delivered at canal outlet (mogha), is not fully consumed by the crops. The combined effects of leakage, wastage, and seepage amount to about 40 percent losses of water in the watercourse system. To curtail these huge losses in the watercourses, government of the Pakistan launched country wide On Farm Water Management Program during 1976-77. So far, about 42,000 watercourses comprising more than 150,000 kilometers of earthen improvement, 30,000 kilometers of brick lining, and installation of over 1.5 million water control structures have been improved under the program.

Different evaluation studies regarding OFWM projects indicate significant benefits accruing from implementation of OFWM activities. Measurements have determined reduction in water losses up to 53 percent and increases in delivery efficiency to the tune of 38.5 percent. The resulting increases in cropping intensity have been reported nearly 20 percent, and overall increases in crop yields have been estimated around 24 percent. According to an estimate, 243-Acre Feet of water are saved with improvement of a watercourse per year. As such, about 10 Million-Acre Feet (MAF) of water is being saved annually through rehabilitation/lining of 42,000 watercourses.

PROMOTION OF LASER LAND LEVELING SERVICES

Abdul Sattar et al., 2001 reported that precisely leveled fields at cotton research station, Vehari have shown about 27% saving in irrigation water. They also observed that precision land leveling minimizes the deep percolation and uneven storage of irrigation water in soil profile. Hence, it should be adopted to contain drainage problem and to save precious water resources and foreign exchange involved in drainage installations [5]. Different other studies have indicated that a significant (20 to 25%) amount of irrigation water is lost during its application due to uneven fields and poor farm designing. This leads to over-irrigation of low-lying areas and under-irrigation of higher spots, which results in accumulation of salts in such areas. Over-irrigation leaches soluble nutrients from the crop root zone, makes the soil less productive, and degrades groundwater quality. Moreover, lay out of most of the farms is based on traditional flood basins (Khal-Kiari System) comprising of a number of unwanted dikes and ditches covering a length of over two kilometers in each square. The fields being not properly leveled, cause wastage of land, result in low irrigation efficiencies, and ultimately lesser yields are resulted than the potential. By providing appropriate land farming services to the farmers i.e. surveying, farm planning, farm designing/layout, precision land leveling, introducing improved irrigation methods e.g. borders/furrows, water scheduling etc., it has been observed that such a package [6] can:

(i) Reduce the time of irrigation and amount of water required by up to 50 percent, results in uniform seed germination, and even distribution of soil moisture and fertilizer to the crops;
(ii) Reduce the number and length of field borders and ditches and can, accordingly, increase the irrigated area by about 2% and reduce watercourse length up to 60 percent; and
(iii) Can increase yields as much as 25 percent.

ZERO TILLAGE

With the help of zero-tillage technology, wheat crop in the rice-harvested fields can be best established. It allows utilization and conservation of antecedent soil moisture, time saving due to early planting, and minimize yield losses attributed to soil structural break down under continuous cropping practices. Moreover, it results in water savings, reduction in production costs, and increased wheat yields. The technology has been successfully tested in the paddy areas of the country. Impact assessment of conservation tillage technology (zero tillage) was accordingly conducted by IWMI Pakistan during Rabi 1998-99[7] and it was observed that conservation tillage technology:

- Saves the cultivation cost to the tune of Rs. 500-800 per acre in case of small farmers and Rs 1000-1500 per acre in the case of medium to large farmers.
- Assists early sowing of the wheat crop.
- Saves 30-50 percent irrigation water in the case of first irrigation after sowing and 15-20 percent in subsequent events.
- Reduces weed germination up to a certain extent.
- Improves soil fertility.
- Enhances water and fertilizer use efficiency.
- Accelerate decay process of rice stubble, which improves soil microbial activities.
- Increase wheat productivity in the range of 15-20 percent, if properly implemented.

The popularity of zero tillage technology can be recognized with the broad acceptance of farmers under OFWM activities. During 1996-97 with the help of five zero tillage drills fifty acres of wheat was sown with zero tillage at farmers' fields. While during the last six years 1100 zero tillage drills have been bought by farmers and wheat has been sown on 1,93000 acres during Rabi 2001-2002. It means, On Farm Water Management has succeeded to save rupees two hundred millions farmers' money as input in wheat cultivation through zero tillage technique during 2001-2002 only in one year. In Pakistan five million acres are sown under rice wheat cropping pattern. The goal of On Farm Water Management is to approach 45 thousand villages and five million farmers for introducing the zero tillage technology and saving about 50 billion rupees per annum.

RECOMMENDATIONS FOR THE USE OF POOR QUALITY GROUNDWATER THROUGH CONJUNCTIVE WATER MANAGEMENT

Conjunctive water management using treated poor quality groundwater with sulfurous acid and by adopting furrow and bed planting may enhance crop productivity.

Reducing irrigation losses at canal, distributory and Water course level, promotion of zero tillage and Precision land leveling should be accelerated for augmenting inadequate surface water and using poor quality groundwater.

Research, education, extension and water resource management institutions have to be further strengthened for efficient resource conservation, management and development of water resources.

Existing laws, rules and regulations, if rigorously enforced, can help in resource conservation. Legislative measures can, however, work properly in an educated society. Till that time, more emphasis should be on mass awareness and participatory approach to planning and decision making for a sustainable agriculture.

Resource Conservation Technologies including sulfurous acid generator, furrow and bed planting, watercourse improvement, precision land leveling and zero tillage need to be highly emphasized. Government should provide technical assistance and backup support for their adoption amongst the farmers.

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