MANAGING SOIL SALINITY THROUGH CONJUNCTIVE USE OF SURFACE WATER AND GROUNDWATER: A SIMULATION STUDY

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ABSTRACT

Growing water scarcity in semi-arid areas has accelerated the pace of groundwater use to sustain irrigated agriculture. It has acquired the central role in the food security and socio-economic development of rural poor in many south-Asian countries. In the Indus Plains of Pakistan, the groundwater is already contributing up to 50 percent of the total water available at the farm gate. This groundwater is exploited by over half a million private tubewells and used for irrigation both in isolation and in conjunction with canal water. The groundwater quality in the Indus is highly variable ranging from fresh to extremely saline. By mixing groundwater with the canal water, farmers tend to decrease the risk of soil salinization. Farmers mix groundwater with the canal water in different ratios without full awareness of the hazards associated with its long-term use. As a result, about 6 million hectares in Pakistan are affected with salinity and about 40,000 hectares are being wasted every year. Therefore there is every motivation to invest more money and efforts to develop strategies for the sustainable use of groundwater and surface water resources.

In this study, Soil-Water-Atmosphere-Plant relationship model SWAP has been used to evaluate the behavior of crops and soils under different groundwater irrigation regimes. The simulations are performed for a period of 15 years using actual climatic data for wheat-cotton cropping systems of the Pakistani Punjab. Three different groundwater qualities (Fresh with EC of 1.0 dS/m; Marginal with EC of 1.5 dS/m and Saline with EC of 3.0 dS/m) are mixed in four different ratios (25%, 50%, 75% and 100%) with the canal water. In total 12 combinations of groundwater and canal water were evaluated for their impact on crop production and soil salinity. The results indicate that mixing of fresh groundwater with the canal water in any ratio will not cause severe salinity problems except for below average rainfall years. Therefore special leaching arrangements should be made for drought years. For the marginal groundwater areas, mixing of groundwater and surface water in a 1:1 ratio will be the most feasible option. Mixing of groundwater more than this ratio can create serious salinity problems in the long run. For the highly saline groundwater areas, mixing of groundwater with the canal water in any ratio will not be a suitable strategy as this will not help in minimizing the risk of soil salinization. The soils can go out of production due to high salinity just after 3-4 years. Therefore for these areas, other options such as growing more salt tolerant crops should be encouraged.

Keywords: Conjunctive use, soil salinity, groundwater quality, mixing ratios, modeling, surface water, relative transpiration, Pakistan, Rechna doab,

1. INTRODUCTION

Increasing demand and decreasing water quality has put enormous pressure on the agriculture sector to use its available water resources more efficiently. These pressures are a result of the increasing demand for food and ever more limited possibilities for the extension of irrigation to other areas due to scarcity of land and water resources and costs of development (Shanon, 1992). Due to increasing population, the need for more water services and infrastructure is increasing. The World Commission on Water has estimated that, over next 20 years, annual investments in the water sector need to rise from $ 75 billion to $ 180 billion (World Bank, 2003). These investments are needed to provide underlying infrastructure in rural and urban areas and to provide services for human and industrial sectors.

The surface water resources of Pakistan are finite and potential for increasing water supplies is limited and there is a likelihood of further reduction in surface supplies through capacity losses in the reservoirs due to siltation and climate change. Therefore the difference between crop water requirements and surface water supplies has to be met through the use of relatively degraded water resources such as groundwater and urban and industrial wastewater. Over the last three decades, the groundwater has gradually acquired a vital role in the development of agricultural and rural economy of Pakistan (Qureshi *et al.*, 2002). Presently, about 60 billion cubic meter (BCM) of groundwater is annually pumped in Pakistan for irrigation purposes, which accounts for about 50-60 percent of total water available at the farm gate. This huge amount of groundwater is extracted through the use of over 600,000 small capacity (0.028 m^3/sec) private tubewells operated by country made diesel engines of 10-16 hp capacity (Qureshi and Mujeeb, 2003). The historical development of private tubewells in Pakistan is shown in Figure 1.

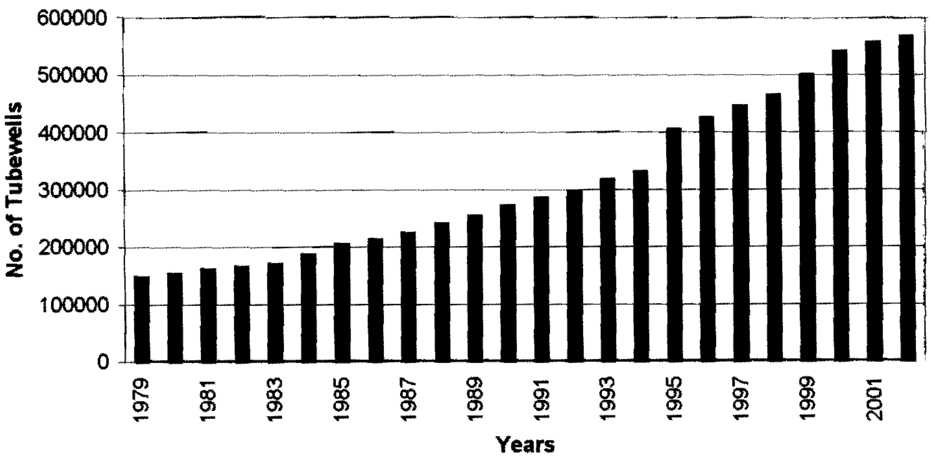

Figure 1. Development of private tubewells in Pakistan.

The exploitation of useable groundwater provided an opportunity for the farmers of these areas to supplement their irrigation requirements and cope with the vagaries of the surface supplies. The availability of groundwater for irrigation has transformed the concept of low and uncertain crop yields to more secure and predictable form of crop production. However, the present uncontrolled and unregulated use of groundwater is replete with serious consequences as it is depleting the fresh groundwater. The farmers are using groundwater for irrigation without full awareness of the hazard represented by its quality, which is aggravating the problem of secondary salinization. As a result, salt affected soils have become an important ecological entity in the Indus Basin of

Pakistan. It is estimated that nearly six million hectares area is already affected with this menace, of which about half is in irrigated areas (WAPDA, 1989). Out of this estimated area, about two million hectare are abandoned due to severe salinity (Wolter & Bhutta, 1997).

In Pakistan, groundwater is used for irrigation both in isolation and in conjunction with the canal water. Isolated use of groundwater is mainly adopted to accommodate significant fluctuations in the canal supplies due to rotational system and breaks in the rainfall in rainfed areas. Mixing of groundwater with the good quality canal water is done to increase the flow rate for proper irrigation. By doing this farmers also tend to decrease the salinity of the irrigation water in order to reduce the risk of soil salinization. Although evidences exist that mixing of saline and non-saline irrigation water is less effective in keeping soil salinity levels lower than applying cyclic irrigations (Hussain *et al.*, 1990; Shalhevet, 1994; Kumar, 1995), this strategy is widely practiced in Pakistan. Figure 2 shows that the conjunctive use of canal water and groundwater for irrigation is taking lead over the isolated use of canal and groundwater. Over the last 10 years, about one million hectare more area in the Punjab has gone to the conjunctive mode of irrigation.

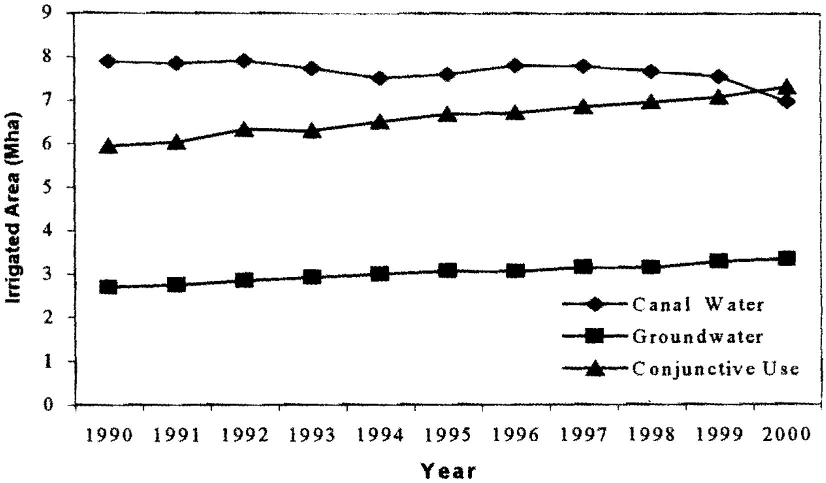

Figure 2. Trends in groundwater use for irrigation in the Punjab Province of Pakistan.

In Pakistan, considerable work has been done to develop guidelines for the safe use of different quality waters for irrigation (Ahmad, *et al.*, 1990). However, these efforts remained confined to field level experiments and no serious attempt was made to evaluate the long-term consequences of these studies on crop production and soil salinization. The developed strategies were therefore regarded as local and short-term solutions and could not get the attention of farming community. Repeating field experiments for a series of years is laborious, time consuming and expensive.

Dynamic simulation models that can calculate soil water and solute transport originating from all water resources in combination with crop growth, are best tools to provide a rapid, flexible and relatively inexpensive means of estimating the effects of various irrigation management practices on crop production under a variety of climatic and physical conditions (Bradford and Latey, 1992; Teixeira *et al*, 1995). This study is aimed at evaluating the long-term effects of different quality irrigation water (obtained through mixing of low quality groundwater in different ratios with the good quality canal water), on soil salinity for the conditions prevailing in the wheat-cotton agro-climatic zone of Central Punjab, Pakistan. For this purpose, soil water flow model SWAP (Feddes *et al*, 1978; Belmans *et al*, 1983) calibrated and validated by Sarwar *et al.* (2000) was used.

2. DESCRIPTION OF SWAP MODEL

SWAP (Soil, Water, Atmosphere and Plant) is a one-dimensional model to simulate water flow and solute transport in a heterogeneous soil-root system, which can be under the influence of groundwater. The model is designed to simulate the transport processes at field scale level as well as during entire growing seasons (Kroes *et al.*, 1999). The SWAP model offers a wide range of possibilities to address practical questions in the field of agriculture, water management and environmental protection. The model has been successfully applied in many hydrological studies for a variety of climatic and agricultural conditions. Options exist for irrigation scheduling, prediction of depth to watertable, soil salinity and leaching of nitrogen and pesticides.

SWAP employs the Richards' equation for the soilwater movement in the soil matrix, subject to specified initial and boundary conditions and with known relations between soil water content, soilwater pressure head and unsaturated hydraulic conductivity. Rootwater extraction at various depths in the root zone is calculated from potential transpiration, root length density and possible reductions due to wet, dry, or saline conditions. Solute transport is simulated using governing equations of convection, diffusion, and dispersion, non-linear adsorption, first order decomposition and root uptakes of solutes.

Crop growth is simulated by using a detailed model WOFOST, which explains crop growth on the basis of processes, such as rate of phenological development, interception of global radiation, CO_2 assimilation, biomass accumulation of leaves, stems, storage organs and roots, leaf decay and root extension. The assimilation rate is affected by water and/or salinity stress in the root zone. SWAP can use simple crop model, when sufficient data is not available or crop growth simulation is not needed. In this case, the user prescribes leaf area index, crop height and rooting depth as a function of development stage. Basic daily meteorological data are used to calculate potential evapotranspiration according to Penman-Monteith.

Irrigation applications (irrigation timing, depth and water quality) can be prescribed at fixed times or user may choose various timing and depth criteria in order to optimize irrigation application. The scheduling options allow the evaluation of impact of different irrigation scenarios on crop growth and salinity development. The SWAP model can also be used to evaluate drainage design and surface water systems.

3. DESCRIPTION OF THE STUDY AREA

The study was carried out in the Rechna doab area of the Punjab Province of Pakistan. The area is part of an alluvial plain between the rivers Ravi and Chenab (31°N and 73°E). The gross area of Rechna doab is about 3 million ha, out of which 2.3 million ha is cultivable land. It is one of the oldest and most intensively irrigated areas of Pakistan. Rice, wheat, cotton and sugarcane are major crops. Next in importance are maize and forage crops. Wheat-cotton rotation is by far the largest cropping system in the area. The average cropping intensity is about 140 percent. Rechna doab is a major contributor to overall crop production in the Punjab. About 32 percent of wheat and over 22 percent of cotton produced in Punjab, comes from the Rechna doab.

The climate of the area is continental, sub-tropical and characterized as semi-arid with large seasonal fluctuations in temperature and rainfall. Summer is long and hot, lasting from April through September with minimum day-time temperature ranging from 21°C to 49°C while in winter (November-February), it varies between 5 to 27°C. The spring and fall months are more or less limited to March and October.

The average annual rainfall is about 350 mm and the class A Pan evaporation about 2000 mm. The doab area is located on the fringe of the monsoon belt, and about two third of the average annual rainfall occurs from June to September. One third falls in winter as low intensity frontal rains. Rainfall is generally scout and sporadic, and therefore, not a dependable source of water for agriculture production.
The soils of the area are mainly loam to silt-loam underlain by highly conductive aquifer of loamy sand to sandy loam. The internal drainage of these soils is highly restricted and surface drainage features are unfavourable. The problems of soil salinity are wide spread and about 10 percent of the area is affected by severe salinity (Qureshi *et al.*, 2002). The surface water supply system in the Rechna doab consists of a network of irrigation canals. The operation of this system is based on continuous water supplies and is not related to actual crop water requirements. The distribution of water to the farmers is based on a fixed rotational system of 7 or 10 days cycle called '*warabandi*'. This means that each farmer is allowed to take an entire flow of the canal outlet once in 7 or 10 days and for a period proportional to its landholding. Due to inadequacy, unreliability and variability of surface supplies, the farmers have turned more and more to the use of groundwater for irrigation regardless of its quality.
The model was calibrated for the field conditions on the bases of actual soil, crop, climate and irrigation data (Sarwar, 2000). Wheat-cotton rotation was used for the simulations. Different soil and crop parameters used as input for SWAP calibration are given in Table 1 & 2. The validated model was used to simulate the scenarios to investigate the impact of different quality groundwater either alone or in conjunction with good quality canal water on soil salinity build up.
Table 1. Input parameters used in the SWAP model. The h_1 to h_4 values refer to the sink term theory of Feddes *et al.* (1978).

Input parameters	Wheat	Cotton
Boesten parameter, β (cm1/2)	0.63	0.63
kc-value for full crop cover	1.15	1.15
Maximum rooting depth (cm)	110	160
Limiting pressure heads (cm)	h1= -0.1; h2 = -1.0; h3 = -500; h3' = -900; h4 = -16000	h1= -0.1; h2 = -1.0; h3 = -500; h3' = -900; h4 = -16000

Table 2. Calibrated Van Genuchten-Mualem (VGM) parameters used to describe soil hydraulic properties in the SWAP model.

Parameters	Layer 1	Layer 2	Layer 3
Depth of Layer (cm)	0-30	30-280	>280
Soil Texture	loam	Silt loam	loamy sand
Residual moisture content θres	0.0	0.0	0.028
Sat. moisture content θsat	0.384	0.509	0.40
Sat. hyd. cond. Ksat (cm d-1)	60	40	72
Shape parameter α (cm-1)	0.0085	0.0090	0.014
Shape parameter n (-)	1.35	1.45	2.663
Shape parameter λ (-)	1.0	1.0	0.5

4. MODEL APPLICATION FOR SCENARIO CALCULATIONS

The calibrated SWAP model (Sarwar *et al.*, 2000) was used to simulate the effects of conjunctive use of surface water and groundwater on crop transpiration and soil salinity. For model simulations, potential evapotranspiration (ET_{pot}), irrigation and rainfall data was used to describe the upper boundary condition, whereas groundwater levels were used as bottom boundary condition. ET_{pot} was calculated by multiplying the crop factors (kc) of wheat and cotton with the reference evapotranspiration (ET_o). ET_o was determined by Priestly and Taylor method (Priestly and Taylor, 1976). The limiting pressure heads for wheat and cotton were taken from Taylor and Ashcroft (1972). The soil hydraulic properties were defined by Van-Genuchten and Mualem paarmeters (Van-Genuchten, 1980; Mualem, 1976) and were adapted from Sarwar *et al.* (2000).

Salinity surveys conducted in the Rechna doab during 1990-96 show that average salinity of soil profile up to a depth of 2.0 m varies between 1.5 and 2.6 dS/m with an average value of about 2.0 dS/m (Raza and Choudhary, 1998). As depth-wise salinity data were not available, this average value was used as an initial condition for the salt balance simulations. For salinity stress the response functions of Mass and Hoffman (1977) were used. For this study, on average, five irrigations to wheat and five irrigations to cotton were assumed, along with two pre-sowing irrigations, one for each cotton and wheat crop. The depth of each individual irrigation was taken as 65 mm (Vehmeyer, 1992). Therefore total amount of irrigation water applied (excluding rainfall) to both wheat and cotton crops during a year were 780 mm.

In Rechna doab area, groundwater quality varies from North to South (Figure 4). In the upper part of the doab, groundwater is relatively fresh (EC < 1.0 dS/m) and it keeps on deteriorating as we go to the downstream end of Rechna doab. In middle, there are several pockets where groundwater quality is marginal (EC = 1.5 - 2.7 dS/m) and in lower part of the doab groundwater is highly saline (EC > 2.7 dS/m). This ranking of groundwater quality is based on the criteria developed by WAPDA (Latif and Lone, 1992) (Table 3). Because of this poor quality, groundwater is usually applied in conjunction with the canal water.

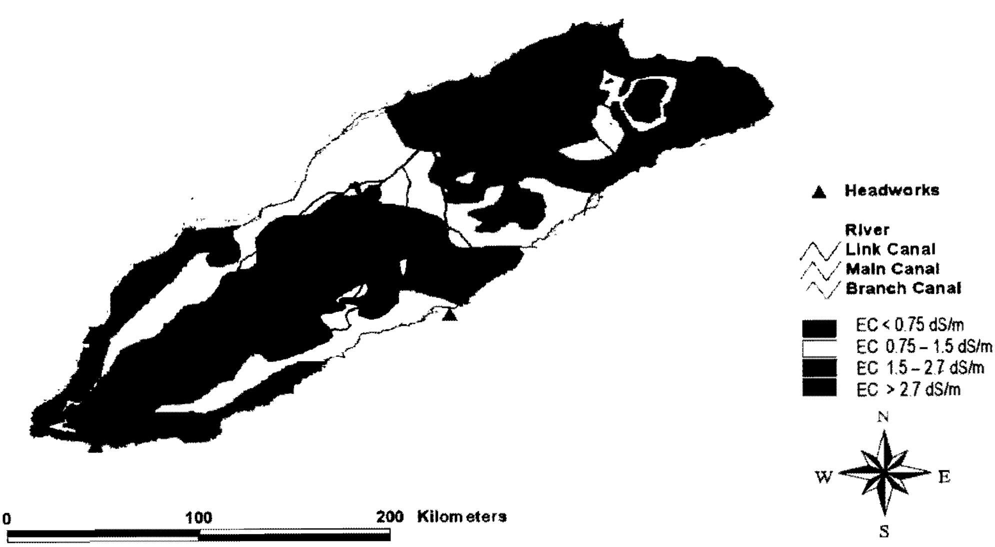

Figure 4. Groundwater quality in Rechna Doab

Table 3: Water quality standard for irrigation based on electrical conductivity.

Category	EC (dS/m)
Fresh	< 1.5
Marginal	1.5 - 2.7
Hazardous	> 2.7

In order to develop conjunctive water use strategies for the Rechna doab, 12 different scenarios were developed. Three groundwater qualities mentioned in Table 3 were mixed with the canal water (EC = 0.3 dS/m) in four different ratios (i.e. 25%, 50% and 75% and 100% ratios). The resultant water quality (EC) after each mixing was used in the model to evaluate long-term effects of this water quality on salinity build up in the root zone. Table 4 gives an overview of the 12 scenarios used for this study.

Table 4. Description of 12 different scenarios evaluated in this study.

Scenarios	Description	Resultant quality of irrigation water (dS/m))
Fresh Groundwater (FGW) (EC = 1.0 dS/m)		
FGW100	100% FGW and 0% CW	1.00
FGW75	75% FGW and 25% CW	0.83
FGW50	50% FGW and 50% CW	0.65
FGW25	25% FGW and 75% CW	0.50
Marginal Groundwater (MGW) (EC = 1.5 dS/m)		
MGW100	100% MGW and 0% CW	1.50
MGW75	75% MGW and 25% CW	1.20
MGW50	50% MGW and 50% CW	0.90
MGW25	25% MGW and 75% CW	0.60
Saline Groundwater (SGW) (EC = 3.0 dS/m)		
SGW100	100% SGW and 0% CW	3.00
SGW75	75% SGW and 25% CW	2.30
SGW50	50% SGW and 50% CW	1.65
SGW25	25% SGW and 75% CW	0.98

5. RESULTS AND DISCUSSIONS

5.1 Conjunctive Water Management in Fresh Groundwater Areas

Figure 5 shows the salinity development in the root zone when fresh groundwater is used for irrigation in different ratios with the canal water. The simulations were performed for a continuous period of 15 years using actual climatic and rainfall data. Figure 5 shows that there is a clear effect of irrigation water quality on the salinity of the soil profile. The EC_e values represent the average root zone salinity calculated at 1.0 m deep root zone at the end of each simulation year. Irrigation with fresh groundwater alone (EC = 1.0 dS/m) does not guarantee the long-term sustainability as the year with below average precipitation (years 6 to 10) enhances soil salinization in the root zone immediately, which might affect the water uptake by the roots (less crop transpiration). However, mixing fresh groundwater with 25 % canal water will keep the root zone salinity below the threshold value of 4.0 dS/m, although a slightly increasing trend may be witnessed. The value of 4.0 dS/m is usually considered for non-saline soils for most of the crops in Pakistan (Mulk, 1993).

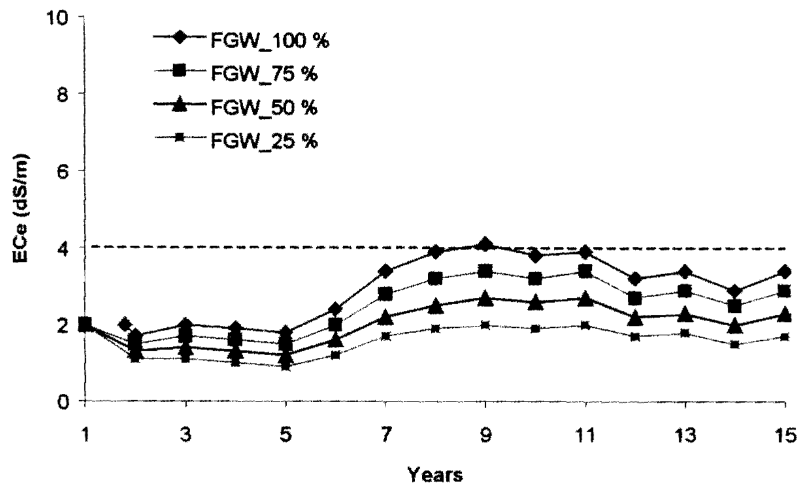

Figure 5. Temporal dvelopment of average root zone salinity as influenced by the conjunctive use of fresh groundwater (EC = 1.0 dS/m) and canal water in four different ratios.

Figure 6 presents the salt build up at different depths of the root zone as influenced by irrigation water quality at the end of simulation period of 15 years. Irrigation with fresh groundwater alone accumulates salts in shallow depths (i.e. 90-120 cm). The salinity development is shown only up to 120 cm rooting depth because presence of excess salts at this depth are mainly responsible for reducing crop transpiration by limiting root water uptake. During dry years when soil temperatures are high and leaching of salts due to monsoon is low, these salts can move to upper layers due to capillary action. This phenomenon could be much more strong in the areas where groundwater tables are shallow. Mixing groundwater and canal water with a 1:1 ratio sufficiently reduces the salinity up to 1.0 m of the soil profile thereby minimizing the chances of movement of salts to the upper layers of the soil profile during the dry and hot years.

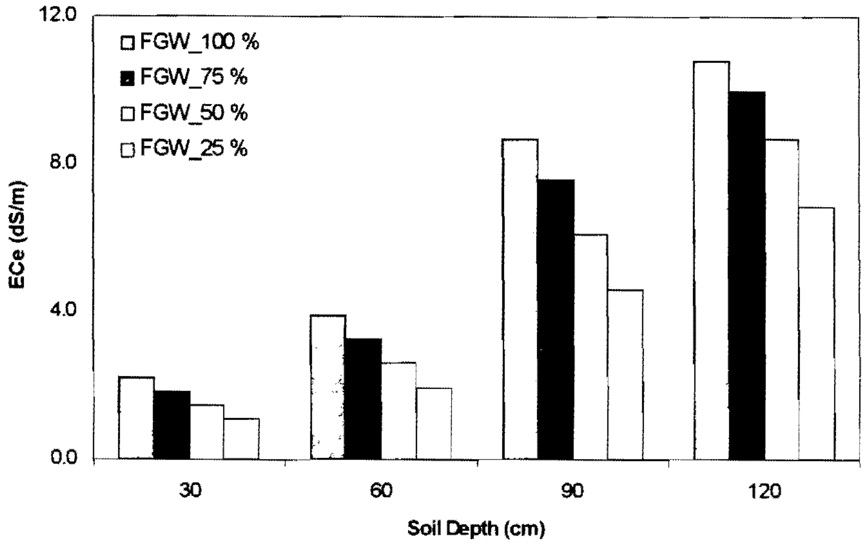

Figure 6. Development of salinity at different depths in the root zone as influenced by the conjunctive use of fresh groundwater and canal water in four different ratios.

The impact of different quality irrigation water on crop transpiration is summarized in Table 5, which indicate the average transpiration for 15 years of simulation under each of the 12 simulated scenarios. The analysis of the 15 years transpiration data reveals that for average rainfall years, maximum relative transpiration for both wheat and cotton can be obtained regardless of the ratio with which canal water and groundwater is mixed. However, in relatively dry years, relative transpiration can be reduced substantially i.e. relative transpiration for year 6 reduced to 0.86, which is 11 percent lower than a normal or wet year. This reduction can be attributed to increased salinity in the root zone due to insufficient leaching and higher crop water demands due to relatively higher temperatures. This means that farmers need to adjust their irrigation applications according to the changing climatic conditions.

Table 5. Relative transpiration of 12 different combinations of canal water and groundwater.

Scenarios	Rainfall (mm)	Irrigation (mm)	T_{act} (mm)	T_{pot} (mm)	TR (-)
		Fresh Groundwater Scenarios			
FGW100	375	780	903	867	0.96
FGW75	375	780	903	875	0.97
FGW50	375	780	903	882	0.98
FGW25	375	780	903	893	0.99
		Marginal Groundwater Scenarios			
MGW100	375	780	903	840	0.93
MGW75	375	780	903	848	0.94
MGW50	375	780	903	854	0.95
MGW25	375	780	903	868	0.96
		Saline Groundwater Scenarios			
SGW100	375	780	903	802	0.88
SGW75	375	780	903	812	0.90
SGW50	375	780	903	828	0.92
SGW25	375	780	903	839	0.93

5.2 Conjunctive Water Management in Marginal Groundwater Areas

Figure 7 shows that with the direct application of marginal groundwater for irrigation (without mixing with the canal water) or mixing it with 25 percent of canal water, the root zone salinity for the first 5 years remains within safe limits and does not cause any reduction in crop transpiration. However, after this period, salinity increases sharply and reaches to a certain equilibrium with more or less a constant salt storage. The small variations in the salt storage over the subsequent years can be ascribed to differences in average annual precipitations. Mixing of marginal groundwater and canal water with a 1:1 ratio can ensure long-term sustainability as this can keep the root zone salinity below threshold levels.

Figure 8 shows the distribution of salts in the root zone when marginal quality groundwater is used for irrigation directly or in different proportions with the canal water. The highest salinity build up can be observed at the depths of 90 and 120 cm depths regardless of mixing ratios. It is evident from the graph that in marginal groundwater areas, present irrigation practices of farmers can only help in pushing the salts to a depth of 90 cm. Therefore occasional additional leaching with fresh water will be necessary to keep these salts well below the root zone in order to reduce the risk of upward movement of salts through capillary rise. While applying saline water for additional leaching, one has to be careful particularly in shallow groundwater table areas.

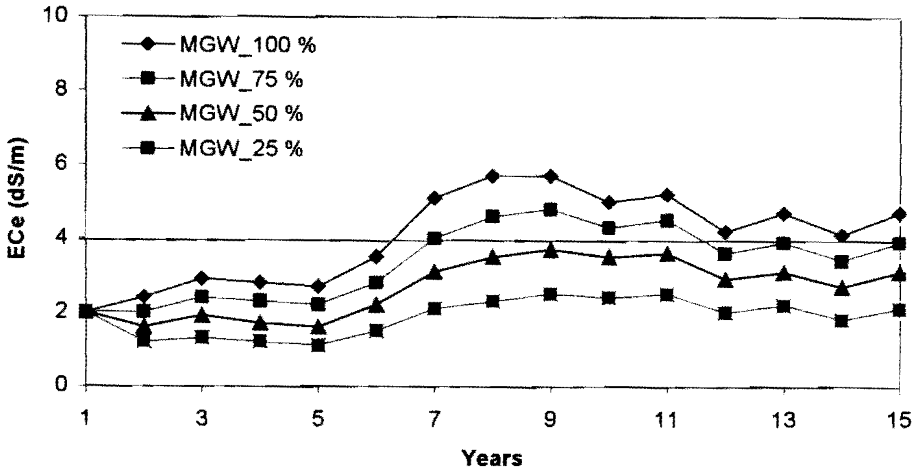

Figure 7. Temporal development of average root zone salinity as influenced by the conjunctive use c marginal groundwater (EC = 1.5 dS/m) and canal water in four different ratios.

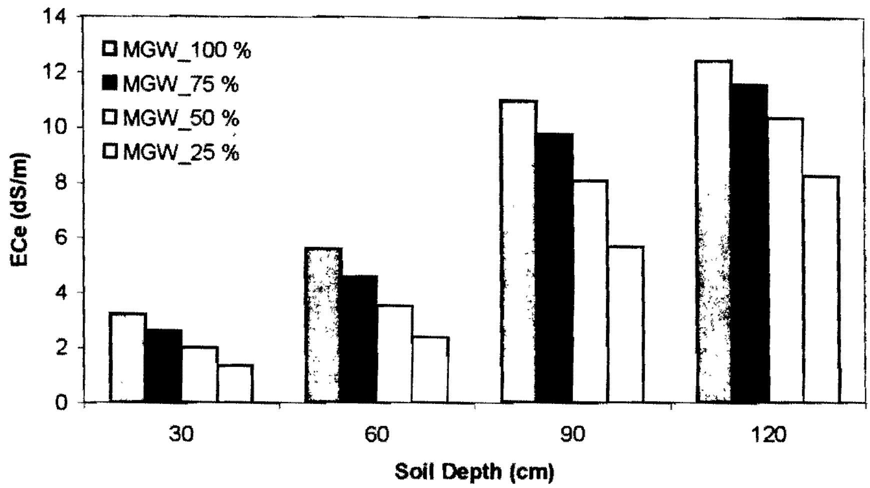

Figure 8. Development of salinity at different depths in the root zone as influenced by the conjuncti' use of marginal groundwater and canal water in four different ratios.

Sarwar and Bastiaanssen (2001) have also shown that for saline water irrigations, the effect shallow groundwater table is very pronounced. As plants are constrained in their capacity extract water under highly saline conditions, the infiltrated water pushes the groundwater up. Tl phenomenon not only increases the root zone salinity but also create waterlogging conditioı This is one of the major reasons for rising groundwater table in the Indus basin of Pakist Therefore for these areas, deficit irrigation with some compromises on yields could be a bet option than applying extra saline water for leaching.

The crop transpiration analysis shows (Table 5.) that, in general, yields in marginal groundwa areas are lower than in fresh groundwater areas. In relatively dry years, chances of increase root zone salinity and consequently reduction in crop yields will be much higher. Therefore farmers of these areas need a careful planning of their irrigation and leaching requirements during dry years.

5.3 Conjunctive Water Management in Saline Groundwater Areas

The combined analysis of figures 9 and 10 shows that irrigations with saline groundwater directly or in conjunction with canal water by any ratio will be a complete disaster. The root zone salinity will start shooting up above the threshold value just after 2-3 years and by the end of 15 years, it will reach up to 10 dS/m. Figure 15 illustrates that whole soil profile will be highly salinized and the EC_e values at depths of 60 to 120 cm will reach to the 20 dS/m level markedly restricting the crop production.

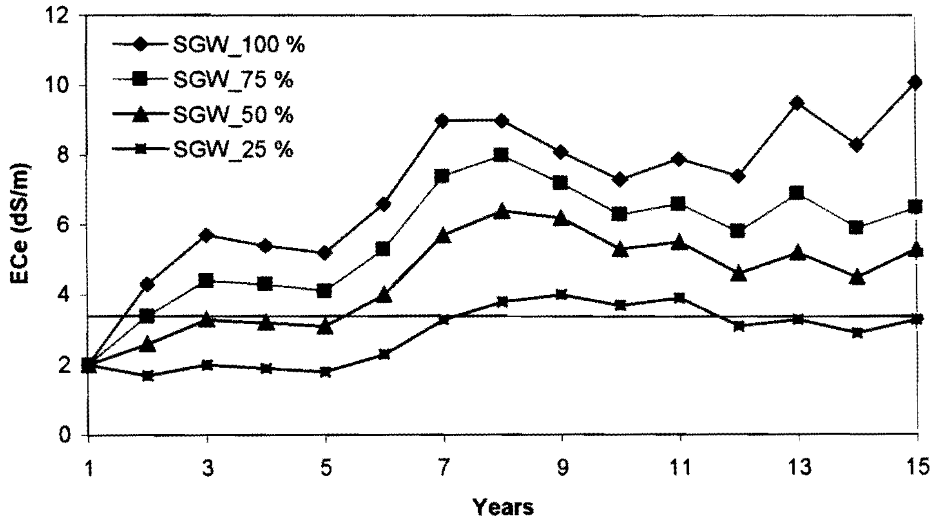

Figure 9. Temporal development of average root zone salinity as influenced by the conjunctive use of saline groundwater (EC = 1.5 dS/m) and canal water in four different ratios.

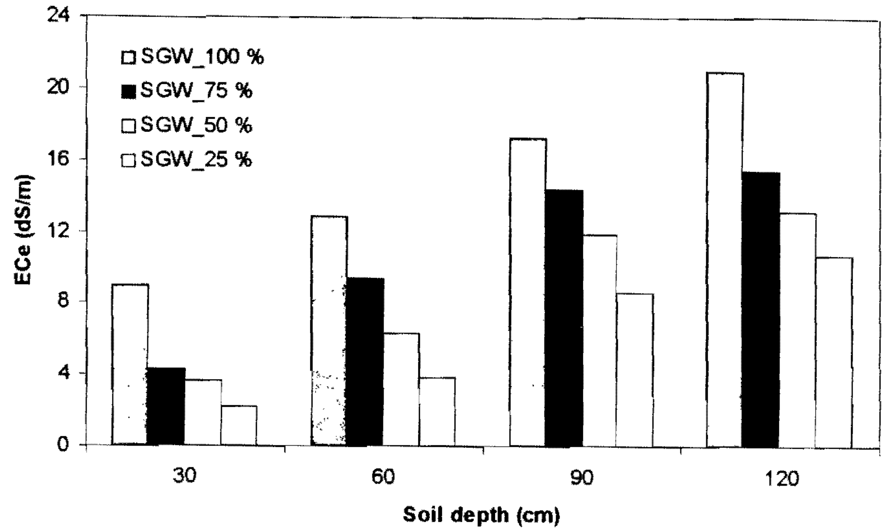

Figure 10. Development of salinity at different depths in the root zone as influenced by the conjunctive use of marginal groundwater and canal water in four different ratios.

6. CONCLUSIONS

From the simulation results, the following conclusions can be drawn:

In fresh groundwater areas (EC = 1.0 dS/m), the farmers present irrigation practices (i.e. using 780 mm of irrigation water in a year) provide sufficient leaching to push the salts below root zone regardless of the ratio with which it is mixed with canal water. However, FGW_{100} and FGW_{75} scenarios showed an increasing trend in root zone salinity, which can effect crop transpiration in below average rainfall years. Therefore farmers need to adjust their irrigation amounts according to the changes in climatic conditions.

In marginal groundwater areas (EC = 1.5 dS/m), the risk of secondary salinization will be much more higher than fresh groundwater areas. The results of long-term simulations reveal that irrigation applications according to MGW_{100} and MGW_{75} scenarios will take 4-5 years to build up root zone salinity to the level where it will start affecting crop transpiration. The reductions in crop transpirations during relatively dry years will be much more severe in marginal groundwater areas. These reductions can go up to 10 percent when FGW_{100} scenario is taken as reference. In marginal groundwater areas, present irrigation practices of farmers will accumulate most of the salts to a depth of 90 cm. Therefore additional leaching with fresh water will be necessary to push these salts well below the root zone to reduce the risk of moving these salts in the upper layers due to capillary rise.

The modeling results demonstrate that using saline groundwater (EC = 3.0 dS/m) for irrigation either in isolation or in conjunction with the canal water (by any ratio) will be a complete disaster and lands will become salinized in just 3-4 years. Sustainable crop production in these areas is linked with the installation of efficient drainage systems and periodical flushing of salts from the root zone. In the absence of drainage systems, leaching of salts with saline water will only accelerate the process of soil salinization and lands will go out of production even at a faster rate. Under such conditions, adaptation of more salt tolerant crops such as eucalyptus or phreophytes

could be a better option.
The temporal variations in crop transpiration and root zone salinity revealed that in (semi-) arid areas, the deviations in annual precipitations from an average year are very critical to maintain fragile equilibrium between different water and salt components particularly when poor quality groundwater is used for irrigation. Ideally, water allocations and applications should be based on the exact calculations of crop evapotranspiration, precipitation and salinity build up and reviewed yearly. However, for the present fixed rotational irrigation system of Pakistan, this will remain a constraint. Therefore much will depend on the farmer's proper understanding of on-farm water management practices.

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