SIMULATION STUDIES ON USE OF SALINE WATER FOR IRRIGATION IN SEMI-ARID ENVIRONMENT

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ABSTRACT

Diagnosis in water management is being supported more recently with the help of physically based numerical models simulating the water and salt balance. This paper presents computer aided water management for interpretation of field experiments and for predicting future scenarios. An agro-hydrological model was first calibrated and validated for local conditions (Hisar, India) and subsequently used for predicting long term impacts. Various water management response indicators are used to interpret the impact of both medium (4 years experimented) and long term (next 10 years simulated) use of such saline waters on soil environment and sustainable crop production. The present simulation study showed that the prolonged use of high salinity waters (EC ≥ 7 dS/m) with normal irrigation (preplant with 8 cm canal and postplant with 6 cm saline water) in semi-arid areas should be restricted on medium to heavy textured soils because high salinity proved detrimental to relative transpiration and ultimately to the grain yield. Salinity hazard index was inflated by 92 to 146% and relative transpiration was suppressed by 40 to 60%. Consequently, simulated wheat and pearlmillet crop yields were down to 37 and 18 q/ha for 7 dS/m water and to merely 25 and 13 q/ha for 14 dS/m water during 15th simulated year, compared to 62 and 31 q/ha realized under canal water in the beginning in 1989-90. However, simulations showed that prolonged use of marginally saline water (EC = 3.5 dS/m) under normal irrigation and even of moderately saline water (EC = 7 dS/m) under heavier irrigation (12 cm canal pre- and 10 cm saline postplant water depths), on such medium to heavy textured soils, with a sub-surface drainage system, need not be forbidden. Reasonably good crop yields could still be obtained in the range of 46-48 and 21-22 q/ha for wheat and pearlmillet crops. Drainage effluent of 7.6 dS/m salinity from using 7 dS/m water continuously over 14 years indicates sustainability in using such moderate quality waters. But for highly saline waters (EC ≥ 14 dS/m) such long term usage needs to be restricted on such soils in semi-arid areas where even the heavier amounts of irrigation failed to depress salinity hazard and elevate crop transpiration to any noteworthy levels, grain yields remaining below 30 and 15 q/ha for the two crops.

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INTRODUCTION

The importance of irrigation in world's agriculture is well known. It is used on a large scale mainly in arid and semi-arid areas. All over the world where irrigation is being practiced, waterlogging and salinization are known phenomena. Approximately 25% of the world's total irrigated area is affected by such forms of land degradation and about 36% in India. In central and north-west Haryana (India), most lands have soils and ground waters often rich in salts. The consequent waterlogging and soil salinization pose immediate threat to the sustainability of agricultural production in this part of Haryana where the water table has risen at a rate of 10 to 30 cm annually during past three decades with 0.47 million hectare area already within 3 m from ground surface during June 1996. This area is further marked by inland drainage basin conditions with no natural outlets for drained and/or pumped water. Saline water was considered in the past as a non-usable resource. However, now the old standards are changing and new practices are being adopted (Oster,1995). Recent studies indicate a potential for the use of saline drainage/irrigation waters for crop production (Rhoades et al., 1989; Hamdy et al., 1993; Kumar et al., 1996, Kumar, 1998). Diagnosis in water management is recently being supported more and more with the help of physically based computer models simulating the water and salt balance dynamically. This paper presents computer aided water management for interpretation of field experiments and also for predicting future scenario. An agro-hydrological model was first calibrated and validated for local conditions by using the field observed data of 4 years and then simulations were extended for a period of over 10 years with waters (i) of actual field salinity 3.5 dS/m ($SW_{3.5}$) and of hypothetical salinities of 7.0 (SW_7) and 14.0 (SW_{14}) dS/m vis-a-vis canal water (0.3 dS/m = CW), (ii) with normal irrigation mode (IM_1): preplant irrigation with 8 cm of canal water and postplant irrigation with 6 cm of saline water and (iii) also with a heavier irrigation mode (IM_2): preplant irrigation with 12 cm of canal water and postplant irrigation with 10 cm of saline water.

WATER AND SALT BALANCE

Water balance clearly shows the existence of a close relationship between irrigation and drainage. In one dimensional unsaturated/saturated soil profiles, the water balance is accounted as:

$$\Delta W = P + I_{rr} + Q - T_{act} - E_{act} - E_i - R - D_r \qquad (1)$$

where ΔW is the water storage change in a vertical soil profile, P the gross natural precipitation, I_{rr} the man-induced irrigation, Q the flux through the bottom of the vertical soil profile (positive = seepage, negative = natural drainage), T_{act} the actual crop transpiration, E_{act} the actual soil evaporation, E_i

the precipitation intercepted by foliage, R the runoff and D_r the drainage.

In humid regions artificial sub-surface drainage D_r is required so as to remove excessive soil moisture arising from precipitation whereas in arid and semi-arid irrigated regions D_r is needed to control ΔW so as to keep the salt balance close to neutral. A small over irrigation ($I_{rr} >> T_{act}$) is usually preferred in order to maintain salinity within acceptable limits by leaching the soil profile. Therefore, both irrigation and drainage need to be considered simultaneously for improving water management systems. The salt balance of the soil profile can be accounted as:

$$\Delta C = I_{rr}\, C_{ir} + Q\, C_q - D_r\, C_{dr} \qquad (2)$$

where ΔC is the salt storage change in the vertical soil profile, $I_{rr}\, C_{ir}$ and $Q\, C_q$ are the salt loads through irrigation and seepage, and $D_r\, C_{dr}$ the salt disposal through drainage system. The solute concentration has been expressed in mg/cm^3.

WATER MANAGEMENT RESPONSE INDICATORS

Yield has long been and is still perceived as the main indicator for evaluating the success of a water management strategy but is, however, unable to explain the long term changes in waterlogging and salinization induced from irrigation and drainage. Apart from yield, ΔW and ΔC, which describe a net drying/wetting (ΔW) and salinization/desalinization (ΔC) effect, also need to be given due weightage in justifying a certain water management practice. The concept of classical irrigation efficiency (Wolters, 1992) is, no doubt, quite useful for evaluating the advantages/disadvantages of irrigation by describing the water losses through soil and plant root system but it does not address the response of the vadose zone to the soil profile moisture and salt storage changes. For systematic and fast assessment of a certain water management scenario, use of suitable water management response indicators have been proposed (Bastiaanssen, 1993, Kumar et al., 1996). Two of such indicators viz., relative transpiration ($RT = T_{act}/T_{pot}$) and salinity hazard index (SHI = Actual soil salinity/Critical soil salinity) have been used in this study. Actual soil salinity is in fact the weighted root zone soil salinity averaged over the growing season. The critical soil salinity is the salinity at which crop yield reduction manifests.

SWASALT: ON-FARM SIMULATION MODEL

One dimensional physically based model SWATRE (Feddes et al., 1978 and Belmans et al., 1983) was taken as basis for the numerical water flow experiments for present study. The working group at Hisar calls the model as SWASALT (Simulation of WAter and SALT). It is a versatile code and has proved its utility in various hydrological studies under widely varying climatic and agricultural conditions (The Netherlands: Feddes et al., 1988; Egypt: Feddes and Bastiaanssen, 1992; India: Kumar, 1994; Kumar et al., 1996; Kumar, 1998). It may be used for scheduling irrigation, designing drainage, assessing percolation, predicting long term waterlogging and/or salinization and transport of substances such as solutes, nitrogen and pesticides (Boesten and van der Linden, 1991).

SWASALT simulates soil water flow in the unsaturated/saturated zone, based on Richards' equation and includes water uptake by roots in the form of a sink term. The sink term is a function of the potential transpiration rate T_{pot}, rooting depth and the total suction head in the root zone h_{tot} (Feddes et al., 1978). The T_{pot} is obtained by bifurcating potential evapotranspiration ET_{pot} into potential soil evaporation E_{pot} and T_{pot} according to leaf area index LAI (Belmans et al., 1983):

$$E_{pot} = ET_{pot} \exp(-0.6\ LAI) \quad (3)$$

$$T_{pot} = ET_{pot} - E_{pot} \quad (4)$$

The h_{tot} is taken as a function of both matric pressure head (h_m) and osmotic pressure head (h_{osm}):

$$h_{tot} = h_m + \varepsilon\ h_{osm} \quad (5)$$

where ε, an empirical crop dependent salinity sensitivity factor, has been included to reflect crop response to salinity (Bastiaanssen et al., 1996).

Finally T_{act} is estimated as:

$$T_{act} = \alpha(h_{tot})\ T_{pot} \quad (6)$$

where $\alpha(h_{tot})$, a sink term variable, is a function of h_{tot} and have values from 0 to 1. Thus the effect of both water and salinity stress on ET is accounted.

The model outputs daily water and salt balances, profiles of: soil water content, solute concentration and pressure head, patterns of root water uptake and of flux divergence. The model simulations of the water and salt balances of the unsaturated zone can be used to support the field interpretations by: (i) quantifying the water and salt balances each day, (ii) predicting combinations of water and soil quality conditions for which field trials are not available/practicable, and (iii) studying the long term impact of variable irrigation and drainage regimes on soil environment.

FIELD EXPERIMENTS

Experiments on use of saline water with different combinations of canal and saline drainage water were conducted during 1989 to 1993 for the cereal crops of wheat and pearlmillet. These experiments were carried out at the research farm of the Haryana Agricultural University at Hisar (India), where a tile drainage system is installed at an average depth of 2.70 m and at spacing of 24 m. The irrigation water treatments selected were (i) Canal Water, CW (ii) Saline Water, SW (iii) canal water in Alternation with saline water, AW, and (iv) canal water Mixed with saline water in 1:1 ratio, MW. This paper discusses the complete annual cycles of wheat-pearlmillet rotations with various saline water treatments. The composition of the experimental loamy soil is presented in Table 1.

Table 1: Soil Texture, Bulk Density (ρ_b), Saturation (Θ_s) and Residual (Θ_r) Soil Moisture

Depth (cm)	Soil layer	Sand	Silt	Clay	Texture	Θ_s	Θ_r	ρ_b (gm/cm^3)
		----per cent----				(cm^3/cm^3)		
0-20	I	46.5	23.6	29.9	scl	0.52	0.01	1.45
20-80	II	37.9	45.8	16.3	l	0.42	0.00	1.46
80-200	III	13.3	59.7	27.1	sicl	0.42	0.01	1.44

wherein scl abbreviates for sandy clay loam, l for loam and sicl for silty clay loam.

The pF curves, estimated from van Genuchten et al. (1991) approach of the three loamy soil layers (Kumar, 1992) are presented in Fig.1. In the field preplant irrigation was applied with 8 cm canal water while postplant irrigation, with different irrigation water treatments, was scheduled at IW/CPE ratio of 0.9, IW being the depth of irrigation water fixed at 6 cm and CPE the cumulative pan evaporation.

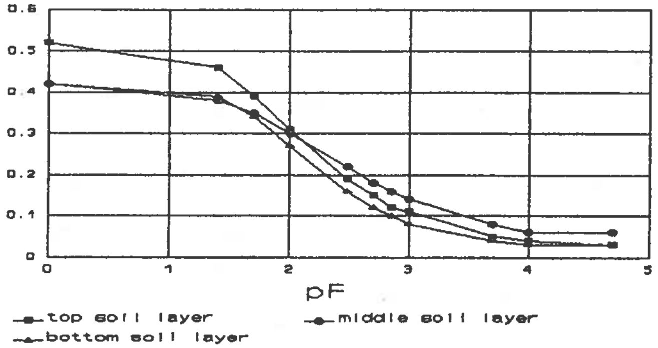

Fig. 1. pF Curve of the Reuse Experiment Soil Profile Layers

LONG TERM SIMULATION STUDY

Simulations for the extrapolation study were carried out, starting from the date of wheat 1992-93 harvest (day 110/1993) to over a decade, in order to observe and compare the long term performance of two extreme water quality management treatments of fresh (canal) water and saline (drainage) water. Simulations were also carried out for hypothetical high salinity waters, SW_7 (7 dS/m) and SW_{14} (14 dS/m), besides for the actual marginal salinity (3.5 dS/m) drainage water from the field, $SW_{3.5}$. Two modes of irrigation selected for present study were: i) Normal (IM_1) with 8 cm preplant canal and 6 cm postplant saline water depths and ii) Heavier (IM_2) with 12 cm preplant canal and 10 cm postplant saline water depths. The calibration and validation study between model predictions and field observations was realised using the 1989-93 reuse experiment data. The field observed water table depths, soil moisture content profiles, salinity profiles and crop yields could be compared satisfactorily with the model predicted values (Table 2). It may be noted that the yield was not simulated but estimated from the simulated relative transpiration values using crop response factors of 0.95 for pearlmillet and 1.1 for wheat (Doorenbos and Kassam, 1979). The soil and plant water relationships, thus calibrated during the 1st year (1989-90) and validated for the next three years (1990-93) of the reuse field experiment (Kumar, 1994; Kumar et al., 1996), were kept as such for the extrapolation study as per the norms of simulation process.

Table 2. Calibration and validation results for the experimental period of 1989-93

Treatment	Year/Crop	Water table		Soil moisture		Soil salinity		Yield difference (ton/ha)
		n	SEE (m)	n	SEE (cm^3/cm^3)	n	SEE (g/l)	
CW	WH-90	15	0.08	8	0.011	8	0.98	0.82
SW	WH-90	15	0.08	8	0.007	8	1.77	0.29
CW	PM-90	8	0.30	8	0.036	8	0.80	0.18
SW	PM-90	8	0.30	8	0.031	8	1.71	0.16
CW	WH-91	15	0.18	8	0.011	3	0.81	0.52
SW	WH-91	15	0.17	8	0.013	3	1.25	0.15
CW	PM-91	6	0.07	12	0.034	9	1.17	0.13
SW	PM-91	6	0.09	12	0.034	9	1.92	0.12
CW	WH-93	11	0.21	28	0.017	15	1.45	0.12
SW	WH-93	11	0.30	28	0.023	15	2.05	0.03
CW	PM-93	68	0.19	64	0.023	43	1.25	-
SW	PM-93	68	0.20	64	0.025	43	1.83	-
Average			0.18		0.022		1.42	0.25

where WH represent wheat, PM the pearlmillet, n the number of observations, SEE the standard error of estimate, CW the canal water and SW the saline drainage water of 3.5 dS/m.

INTERPRETATION OF THE RESULTS

The annual complete cycles for 15th year of simulation, comprising of wheat and pearlmillet rotation, have been considered for analysing and discussing the results obtained. Water management response indicators (WMRI) of relative transpiration, salinity hazard index and the grain yield have been presented in Tables 3 and 4 with both irrigation modes for wheat and pearlmillet crops. Results of 1989-90, the first year of experimentation, have also been included so as to facilitate comparison. The trend of different water management response indicators (Tables 3 and 4) foretell the danger of using saline water continuously over prolonged periods of over 14 years under normal irrigation (IM_1). The salinity hazard index was inflated by 92 to 99% and stood at unsafe and dangerous level of 2.1 for the wheat and pearlmillet crops during the final (15th) year of simulation for 7 dS/m water, compared to the near target value of almost 1 for canal water (0.3 dS/m) in the first (reference) year of 1989-90. Consequently, relative transpiration registered a decline of about 40% for wheat and pearlmillet, resulting into quite poor grain yields of 37 and 18 q/ha for these crops, compared to 62 and 31 q/ha obtained from canal water in 1989-90. Continuous use of still poorer quality (14 dS/m) water further suppressed the crop transpiration by 20% over 7 dS/m water, culminating into very poor grain yields of 24.5 (wheat) and 13.3 q/ha (pearl millet) in the final year of present study. The salinity hazard index elevated to quite alarming value of 2.7 for these cereal crops with a phenomenal increase of about 150%. However, irrigation waters of marginal salinity ($SW_{3.5}$) could produce reasonable yields of about 46 and 22 q/ha for wheat and pearl millet despite being applied continuously for over 14 years since 1989-90 and need not be forbidden as such (Tables 3 and 4). These extrapolated results strongly suggest that the continued and prolonged use of waters of salinity 7 dS/m and greater should be forbidden on such medium to heavy textured soils under normal irrigation (preplant CW with 8 cm and postplant SW with 6 cm).

Table 3: Relative Transpiration (RT), Salinity Hazard Index (SHI) and Grain Yield (q/ha) for Wheat

Indicator	Irrigation Mode	Reference Year		Final 15th year of Simulations			
		CW	$SW_{3.5}$	CW	$SW_{3.5}$	SW_7	SW_{14}
RT	IM_1	0.88	0.86	0.81	0.66	0.53	0.35
	IM_2	-	-	-	0.84	0.68	0.43
SHI	IM_1	1.08	1.14	1.28	1.67	2.07	2.66
	IM_2	-	-	-	1.28	1.68	2.33
Yield	IM_1	61.50	60.10	56.6	46.1	37.0	24.5
	IM_2	-	-	-	59.4	47.5	30.0

where IM_1 is preplant CW irrigation of 8 cm and postplant SW irrigation of 6 cm and IM_2 the preplant CW irrigation of 12 cm and postplant SW irrigation of 10 cm. Reference year refer to the first year of field experiments.

However, when irrigation applied was at greater depths under mode IM_2 with these varying salinity waters, both the relative transpiration and salinity hazard index were improved considerably because of improved salt leaching. Consequently, crop yields were also improved. Marginal salinity water ($SW_{3.5}$)

expectedly, affected largest improvement and the yields were enhanced by 31% (46.1 → 59.4 q/ha) and 23% (21.6 → 26.6 q/ha) for wheat and pearlmillet over those under normal irrigation, with 29 and 21% improvement in salinity hazard. Even with moderately saline water SW_7, leaching was quite satisfactory under heavier irrigation so as to cause a decline of 19 and 15% in SHI and an incline of 28 and 19% in RT for the two crops, with enhanced grain yields (37 → 47.5 q/ha: wheat and 17.6 → 21 q/ha: millet). Water of higher salinity (14 dS/m, SW_{14}), however, had little effect in reducing soil salinity and enhancing crop transpiration and yields (Tables 3 and 4) even under heavier application mode.

Table 4. Relative Transpiration (RT), Salinity Hazard Index (SHI) and Grain Yield (q/ha) for Pearlmillet

Indicator	Irrigation Mode	Reference Year		Final 15th year of Simulations			
		CW	$SW_{3.5}$	CW	$SW_{3.5}$	SW_7	SW_{14}
RT	IM_1	0.92	0.89	0.81	0.65	0.53	0.40
	IM_2	-	-	-	0.80	0.63	0.44
SHI	IM_1	1.05	1.14	1.28	1.70	2.09	2.70
	IM_2	-	-	-	1.35	1.77	2.46
Yield	IM_1	30.60	29.60	26.9	21.6	17.6	13.3
	IM_2	-	-	-	26.6	21.0	14.6

where IM_1 is preplant CW irrigation of 8 cm and postplant SW irrigation of 6 cm and IM_2 the preplant CW irrigation of 12 cm and postplant SW irrigation of 10 cm. Reference year refer to the first year of field experiments.

These long term simulations indicate the possibility of prolonged application of even moderately saline waters (upto 7 dS/m) on such medium to heavy textured but drained soils with heavier irrigations for achieving still reasonably good yields of about 48 and 21 q/ha for wheat and pearl millet crops even after over 14 years of continuous use (Tables 3 and 4). It may be recalled that almost similar simulated wheat and pearlmillet crop yields (46 and 22 q/ha) were realized from continuously applying marginally saline water (3.5 dS/m) for over 14 years under normal irrigation mode.

Thus, continued and prolonged application of marginally saline water (3.5 dS/m) under normal irrigation (IM_1) and even of moderately saline water (7 dS/m) under heavier irrigation (IM_2), on such medium to heavy soils but with a sub-surface drainage system, need not be forbidden since reasonably good yields (46-48 and 21-22 q/ha) could still be achieved for wheat and pearlmillet even in 15th year. For highly saline water of 14 dS/m such long term continuous use, however, need to be restricted on such soils where even the heavier irrigation failed to elevate crop transpiration and depress salinity hazard to any noteworthy levels, with crop yields remaining below 30 and 15 q/ha.

Table 5: Solute influx (through irrigation, I_{rr} C_{Ir}, and seepage, Q C_Q) and outflux (through drainage, D_r C_{Dr}) rates, drainage water salinity ($C_{Dr}=D_rC_{Dr}/D_r$), soil profile salinity in 0-100 cm (C_{100}) and water table depth (W T) during final 15th year of simulation

Parameters	Irrigation mode	CW	$SW_{3.5}$	SW_7	SW_{14}
I_{rr} C_{Ir}, (t/ha)	IM_1	0.9	7.6	15.3	30.3
	IM_2	-	12.6	25.4	50.5
D_r C_{Dr}	IM_1	7.3	11.5	17.2	30.1
(t/ha)	IM_2	-	18.7	30.3	54.9
C_{Dr},	IM_1	3.6	4.5	5.7	8.5
(dS/m)	IM_2	-	5.6	7.6	11.6
C_{100}	IM_1	8.8	11.6	13.7	17.4
(dS/m)	IM_2	-	9.3	12.0	16.5
WT	IM_1	2.2	2.1	2.0	1.9
(m)	IM_2	-	2.0	1.9	1.7

QC_Q = 7.85 t/ha, average constant flux provided specified for all cases

where IM_1 presents preplant CW irrigation of 8 cm and postplant SW irrigation of 6 cm, IM_2 preplant CW irrigation of 12 cm and postplant SW irrigation of 10 cm, and C_{100} and W T present the averaged values for the final simulated year

Average constant flux, provided as an input for calibrating and validating the model in order to closely compute the groundwater table, was kept as such during extrapolation studies (solutes seeping at steady 7.85 t/ha/yr, Table 5). The reason was that the present study fields, located at the edge of the subsurface drainage system, were directly in contact with adjoining high water table fields without such drainage facility. Under such typical boundary effects, seepage influx plays crucial role in salt balance, compared to the situation where fields are located within a drainage system. That was why the solute influx (through irrigation and seepage) exceeded the outflux (through drainage) and even in case of canal water irrigation about 1.5 ton salts were added per annum per hectare. The mystery of the declining relative transpiration (0.9 down to 0.8) and crop yields (down by 4-5 q/ha) on prolonged use of even non-saline water is, thus, unfolded. Salt accumulation was at higher rates of 4, 6 and 8 t/ha/yr when saline waters of 3.5, 7.0 and 14.0 dS/m were used over 14 simulated years under normal irrigation. As the irrigation depth was increased under IM_2 mode, salt leaching became more effective, with rates of salt accumulation being reduced by almost half to 1.8, 3 and 3.5 t/ha/yr (Table 5).

Simulated use of highly saline water (14 dS/m) for over 14 years left behind a drainage effluent of 8.5 dS/m under normal irrigation which further aggravated to 11.6 dS/m under heavier irrigation mode. For less saline waters (7.0 and 3.5 dS/m) these values were 5.7 and 4.5 dS/m under normal irrigation (IM_1 mode), and 7.6 and 5.7 dS/m under heavier irrigation IM_2 (Table 5). The moderate quality (7.6 dS/m) of the drainage effluent from continuous application of the moderately saline water (7 dS/m) over 14 years indicates sustainability in its use, of course under heavier irrigation mode. During the 15th year of simulations, soil profile salinity C_{100} (averaged over 0-1 m) was quite high at 17.4 dS/m for 14 dS/m water even under greater irrigation depths of 12 cm whereas for other less saline waters SW_7 and $SW_{3.5}$, it was 12 and 9 dS/m. The water table stood at 2.2 m under canal water irrigation during 15th simulated year and at 2, 1.9 and 1.7 m for 3.5, 7 and 14 dS/m waters (under heavier irrigation) but still well below the root zone and safe for waters of marginal to moderate salinity ($SW_{3.5}$ and SW_7). It is interesting to note that the increased water application depth of 24 cm under heavier irrigation, over the normal, is only 4 cm in non-saline water but 20 cm in saline water. The scenario appears very attractive because it would help reduce the load both on the demand of decreasingly available fresh water and on the disposal of increasingly available saline water. But for effective leaching with heavy irrigations, good soil drainage, either natural or artificial, is however a must.

CONCLUSIONS

The performance of even good quality water did worsen a little because of the dominance of seepage term owing to the situation of the present study fields being on the edge of a sub-surface drainage system, directly in contact with adjoining high water table fields (without such a facility). The salt influx resulting from seepage proved quite crucial for the soil water-salt balance and affected all the water quality treatments. Thus the soil water and solute balance may behave less favourably for such edge-situated fields as compared to the fields lying within a sub-surface drainage system.

The present simulation study indicated that the prolonged use of high salinity waters (EC $\geq$ 7 dS/m) with normal irrigation should be restricted on medium to heavy textured soils in semi-arid areas because increasing salinity in these waters proved detrimental to the relative transpiration and eventually to the grain yield. Long term use of such saline waters, under normal irrigation, inflated the salinity hazard alarmingly (92 to 160%) and suppressed the crop transpiration critically (40 to 60%). Consequently, wheat and pearl millet crop yields were down to 37.0 and 17.6 q/ha for 7 dS/m water and to merely 24.5 and 13.3 q/ha for 14 dS/m water during the final (simulated) 15th year, compared to 61.5 and 30.6 q/ha realized form canal water application during the first (reference) year of field experimentation on reuse of saline (drainage) water.

However, the continued and prolonged use of marginally saline water (EC = 3.5 dS/m) under normal irrigation (8 cm canal water pre- and 6 cm saline water postplant depths) and even of moderately saline water (EC = 7 dS/m) under heavier irrigation (12 cm canal pre- and 10 cm saline postplant), on such medium to heavy soils but with a sub-surface drainage system, need not be forbidden since reasonably good crop yields could still be obtained in the range of 46-48 and 21-22 q/ha for wheat and pearlmillet crops. But for highly saline waters (EC ≥ 14 dS/m) such long term use needs to be restricted on such soils in semi-arid areas where even the heavier amounts of irrigation failed to elevate crop transpiration and depress salinity hazard to any noteworthy levels, the crop yields remaining below 30 (wheat) and 15 q/ha (pearlmillet). Besides low crop yields, another disturbing scenario is the alarmingly high salinity developed both in the drainage effluent (12 dS/m) and also in the root zone soil profile (17 dS/m) during the 15th year of present simulation study.

After continuous simulated application of moderately saline, 7 dS/m, water for over 14 years, moderate quality of the drainage effluent of 7.6 dS/m indicates the feasibility of its sustainable reuse under heavier irrigation. Interestingly, the increased water irrigation depth of 24 cm, in excess over the normal irrigation, is just 4 cm in fresh water but a good 20 cm in saline water, thereby utilizing less of highly competitive fresh water but more and more of the increasingly available saline water.

Similar long term simulations are being carried out further with irrigation depths of 10 cm (for the present 12 cm) of preplant fresh water and 12 cm (for the present 10 cm) of postplant saline water so as to explore the attractive potential of utilizing saline ground/drainage waters so as to help reduce the load on the disposal of drainage effluent and check water table rise and soil salinization in the areas underlain by saline groud water.

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