SALTMOD MODEL VALIDATION AND APPLICATION IN SEGWA MINOR CANAL COMMAND AREA[1]

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ABSTRACT

Model SALTMOD was validated by comparing model predictions with the field observations on soil salinity and drain discharges and depth of water table collected during 2000 – 01, for the Segwa minor canal command. After installation of drainage system, soil salinity of root zone was found to reduce from 12 dS/m to around 7 dS/m in the first year, which was also predicted by the model, similarly the model predicted steady increase on salinity levels each year which was confirmed from field tests. The model forecasts salinity levels of 8 dS/m by 2010 thus making the land uncultivable, if precautionary measures are not taken in the canal command area. Investigations were made to study the impact of drain spacing in the form of Q/H relations, drain depth, depth of irrigation water application on soil salinity. It predicts that at 45 m drain spacing the depth of drains should be at least 1.2 m below ground level, for irrigation water quality of 0.9 dS/m, for maintaining the salinity levels at around 2.5 dS/m. The model also shows that salinity levels of 2.5 dS/m could be maintained if irrigation water supplies (IWS) remain at least 20 % lower. Therefore, SALTMOD could work as an effective tool to forecast various situations once the model is calibrated and validated for the region and could help during design of drainage system.

Keywords: Salinity, SALTMOD, Sub surface drainage, water logging, salt – water modeling

1 INTRODUCTION

Ukai-Kakrapar is the major irrigation project in South Gujarat. This is the biggest multipurpose project in Gujarat State built on river Tapi. The Kakrapar weir was constructed as stage I and regular irrigation in its command commenced in 1957. The Ukai dam was constructed as stage II and regular irrigation and construction of Ukai canal distributors systems was started in 1974 and completed by 1983. The total cultivable command area of the project is 3.31 Lakh ha distributed in Surat (1.9 Lakh ha), Valsad (0.96 Lakh ha) and Bharuch (0.45 Lahk ha) districts.

Before inception of canal irrigation farmers used to take only one rain fed crop during kharif season. The main crops at that time were pigeon pea, sorghum, etc. However, kharif paddy was also grown in small area. The ground water table was at around 10 m depth. So most of the good quality rain water percolated into the soil. There were only few open wells and pond in every village, which were used for domestic and drinking purposes. These water bodies eventually worked to recharge the deep aquifers. Due to thick vegetative cover all around and sustained ecosystem, rainwater leached all the accumulated salts during the year. Water table was deep and there was absolutely no salinity during that period.

Later, with the inception of canal irrigation in mid seventies, cropping pattern changed significantly, the farmers switched to high water requiring and perennial cash crops. Due to shift in cropping pattern in the canal command areas, sugar factories came up which prompted farmers of adjoining areas also to shift to sugarcane - paddy cultivation. Cultivation of other crops is of lower priority. The other important crops of the command which were formerly grown in the rainy season are now cultivated in the rabi / summer season under irrigated conditions. With the availability of cheap irrigation water, many head end farmers use excessive amounts of water. The excessive use of irrigation water combined with high rainfall in the area led to rapid rise of water table, resulting into development of water logging and salinity in large areas. This resulted in poor quality irrigation in non-command areas making the soil saline. The water tables in Ukai Kakrapar command within 1.5 m and 1.5 to 3.0 m were reported to be in an area of 13000 ha and 106000 ha respectively. Though no regular survey data on salt affected soils is available, it is estimated that about 60,000 ha of the command area has problem of salinity, particularly in the coastal areas (Parikh et. al. 1999).
Models are the effective tools for studying different scenarios based on the basic theories of nature, available database and logical assumptions where data is lacking, as it is not possible to conduct numerous field experiments due to infinite number of combinations of input parameters, which exist in nature. Therefore, it is very useful to calibrate the model on the basis of pilot area studies and use it for studying various scenarios under particular agro climatic situation. The model studies will save:

- Time of experiment
- Huge amount of expenditure in conducting field studies
- Human energy in the form of involvement of scientific and other staff
- Errors involved in field studies

Hence from data collected from the pilot area during last six years of the project and using model SALTMOD Version 1.3 (November 2001), an attempt was made to build various scenarios of salt build up and varying water table status. In this version of SALTMOD, the original model of Oosterbaan (2000) was modified and rice crop is included to suit the cropping system of India. Earlier, Oosterbaan and Abu Senna (1990) had used the model for predicting drainage and salinity status of Nile delta in Egypt.

2 STUDY SITE

A 188 ha block in Segwa minor of Surat branch in Kakrapar irrigation command was selected for operational research on drainage and related aspects. It is located in between 73o 2' 51" to 73o 3' 25" E longitudes and 21^{o} 12' 18" to 21^{o} 13' 31" N latitudes. The site encompasses four villages Segwa, Sevni, Asta and Vansda Rundhi in the Kamrej taluka of the Surat district at the Segwa minor ex. Surat branch of Kakrapar L.B.M.C. The area is bounded in the North by Surat branch, Natural drain in South, Segwa minor in the west and a cart road in the East. This area is about 10 km inside towards East of Mumbai - Ahmedabad road (National highway No. 8). A metaled road-joining village Segwa and Vansda Rundhi is bifurcating the area almost equally towards the East and the West. About one third of the area on the eastern side of this road is irrigated by tube wells while remaining is irrigated through canal water. Conjunctive use also exists in some parts of the canal command. Water logging coupled with initiation of secondary salinization is deteriorating the soil health and crop productivity in the pilot area.

The study site has a flat topography with approximately 3 % slope. Soil texture is clayey with clay content of more than 40 % and basic infiltration rate of 5 cm / day, indicating that there would not be any problem in leaching down the salts. Soil pH was found to be 8.3 and quality of ground water poor, weighted mean of irrigation water quality was 0.9 dS/m. Soil and water quality samples were analyzed in the laboratory of Water Management Research Unit of Gujarat Agricultural University, Navsari. Average Hydraulic conductivity was found to be 0.3 m / day through the single auger hole method at several points in the pilot area. Sub surface drains were laid at 45 m spacing at 1.2 m drain depth. Soil samples were also collected from different soil layers and their respective total porosity and effective porosity determined in laboratory by standard procedures explained by Ritzema 1994.

2.1 Model Calibration and Validation:

The data used in SALTMOD are collected before and after installation of drainage system. The model was calibrated by using the data on cropping pattern, water table, hydraulic conductivity, salinity status, leaching efficiencies, drain discharges, depth of irrigation water applied and soil properties of the pilot area. Sub surface drains were laid at 45 m spacing and 1.2 m drain depth The input parameters used in the model calibration are shown in Tables 1 and 2. Weather data of Bardoli meteorological station was used to estimate the potential evapo-transpiration of crops grown in the pilot area. For calibrating the model, natural sub surface drainage and leaching efficiency are the parameters, which were calibrated. Field observations on water table and soil salinity of the three seasons of the first year 2000-01 were used for calibrating the model and subsequently the projections were made starting from the year 2000 till 2010.

2.2 Determining the natural sub – surface drainage :

Natural subsurface drainage (Gn = Go – Gi) is defined as excess of the horizontally outgoing water minus the horizontally incoming ground water in m / season. The values were determined by keeping value of Gi as zero and arbitrarily changing the Go values and finding the corresponding values of depth to water table (Dw) and total amount of subsurface drainage water (Gd) values from the model prediction and that with the field observations. Taking into account 1st season (5 months), 2nd season (4 months) and 3rd season (3 months), the arbitrary Go1, Go2 and Go3 values, i.e. Go values for the first, second and third seasons respectively are in groups : 0 (0.000, 0.000, 0.000), .018 (0.012, 0.004, 0.002), .020 (0.014, 0.005, 0.001), .040 (0.020, 0.012, 0.008), .050 (0.030, 0.010, 0.010), .075 (0.040, 0.025, 0.010), .100 (0.065, 0.025, 0.010) and .125 (0.085, 0.025, 0.015). As the inflow Gi is taken equal to zero, the Go values of all the three seasons together give the annual Gn value. Table 3 shows final Dw and Gd values one year after installation of drainage system. The table shows that Gn values at around 0.018 coincided with the observed depth of water table in 1st, 2nd and 3rd season respectively at 0.80, 0.90 and 1.05 m. and observed drain discharge of 0.085, 0.055 and 0.020 in the three seasons respectively. Therefore annul natural sub surface drainage amounts to Gn = 0.018, from which follow Go1 = 0.012, Go2 = 0.004 and Go3 = 0.002 m / season for the 1st , 2nd and 3rd season respectively.

Since the area is canal irrigated and cropping pattern is same, since inception of canal irrigation so there would not be any drastic changes in water application so drainage results would be similar in subsequent years after installation of drainage system.

2.3 Calibration of leaching efficiency

The leaching efficiency of root zone / transition zone is defined as the salt concentration of the water percolating from the root zone / transition zone into the underground divided by the average salt concentration of the soil water in the root zone transition zone. Leaching efficiency of the root zone (Flr) is given the range of arbitrary values 0.2, 0.4, 0.6, 0.8 and 1.0 and the corresponding salinity results of the programme are compared with the actual field observations. The graphical representation of leaching efficiencies of root zone and transition zone are depicted in Fig 1 and Fig 2 respectively. The observed salinities were found to be close when the Flr and Flx were given a 0.7 value. However, while calibrating for leaching efficiency of transition zone very slight difference was observed amongst different efficiencies (Flx) mainly because of the existing sub surface drains, as they drain out the salts in the upper layer itself and only part of leached water passes through the transition layer. Further, after first three years irrespective of any variation in leaching efficiency of transition zone, the root zone salinity does not get affected.

2.4 Scenario Building

2.4.1 Prediction of soil salinity with drainage system

Prediction of salinities for 10 years period with sub surface drainage system is shown in Fig 3. The root zone salinity (Cr4) decreased form 12 dS/m to around 7 dS/m in the first year and after 3 years the salts get leached to the acceptable limits of 2 to 3 dS/m. The soil salinity above drain level (Cxa) increased from 7 dS/m to around 9 dS/m during the first year, as salts from the top layers leached down thus increasing the salinity above drain level. Thereafter the Cxa values constantly declined reaching the acceptable range in third year and varying from 2 to 3 dS/m thereafter. However, the soil salinity below drain level (Cxb) declines at slower pace and would come below 4 dS/m only after 10 years. The figure shows an interesting feature that (Cqf) the salinity of the transition zone which was assumed to be 2 dS/m shows slight increase from 2 dS/m with time because part of the leached salts from the root zone layers would percolate to the transition layer.

2.4.2 Reconstruction of the initial situation :

Prediction of salinities for 10 years period without sub surface drainage system is shown in Fig 4. This is the initial condition at the time of start of the drainage project. The model shows the average soil salinity of the whole pilot area, at the rooting zone varies from 6 to 7 dS/m and shows a steady increase, though at a slow pace over the years, reaching the levels of 8 dS/m in second season of 10th year. Figure also depicts that after first year during kharif season Cr4 values are the lowest in the rooting zone because good quality rainwater leaches down the salts from the top layer. During rabi and summer season due to capillary action the salts accumulation is more than kharif season. The model predicts that salt concentration of transition zone increases from 2.5 dS/m to 3.5 dS/m in 10 years however the salt of aquifer remains at 2 dS/m level.

2.4.3 Effect of varying drains spacing on root zone salinity :

Variation in root zone salinities (Cr4) due to change in drain spacing, which would ultimately affect the Q/H relation ship is depicted in Fig 5. The drain discharge (Q) was measured periodically using a bucket and a stopwatch at a point where lateral drain was discharging in the collector. Simultaneously head of water (H) above the drain level was measured between two laterals drains. Therefore with reference to the observed Q/H value, 20 %, 40 %, and 60 % of 0.0015 both on higher and lower side was studied using the model. It could be seen from the figure that only when the Q/H was 0.0009 (60 % less than .0015) the root zone salinity remained above 3 dS/m, also when Q/H was 0.0006 (40 % less than .0015), the curve overlapped with that of Q/H .0009; whereas for rest of the cases the salinities dropped and stabilized at around 2.5 dS/m.

2.4.4 Effect of varying drains depth on root zone salinity :

In this scenario, keeping drains at constant spacing of 45 m and keeping all the other parameters constant, the effect of root zone salinity by changing the depth of drains is studied. Root zone salinities as affected by the drain depth are shown in Fig 6. The model was run for 10-year period for predicting the root zone salinities, when the irrigation water quality was around 0.9 dS/m which is the weighted mean of irrigated area from well, canal and drain water. The model shows that when the irrigation water quality was 0.9 dS/m, the drains should be kept at least at 1.2 m below ground level when spaced at 45 m spacing, to bring the salinity levels to around 2.5 dS/m. It could be seen from the figure that any increase in drain depth beyond 1.2 m would not have any impact on the effective rooting layer (0.85 m) salinity levels, on the contrary it would increase the cost of system installation. The model shows that when drains are kept at lower depths of 1.0 and 1.1 m below ground level and with the irrigation water quality of 0.9 dS/m, the root zone salinity remain above 3 dS/m.

2.4.5 Effect of changes in irrigation water applied on root zone salinity :

The fig 7 shows the variation in root zone salinity due to change in irrigation water supplies in the second and third seasons. Moreover, the figure is showing the effect of input parameters, which continue for ten years. In these model runs, the effect on salinities due to 20 % and 40 % increase and decrease in irrigation water supplies from the present levels was studied. It could be seen that when the water supply was 20 % higher (1.2 IWS) the salinity remain higher than 5 dS/m, whereas when the irrigation water supply was 40 % higher (1.4 IWS) the salinity drops to around 4 dS/m may be because so much excess water would leach some of the salts through surface flows. The model shows that at 40 % higher irrigation supply, water table will come to surface and the salts present at the surface will be leached out through surface flows. However, when the irrigation water supply was kept 20 % and 40 % lower than the present supplies the salinities remain at around 2.5 dS/m.

2.4.6 Effect of varying drains depth and irrigation water applied on water table :

Depth of water table due to variation in drain depths (Dd) and irrigation water supplies (IWS) is shown in Fig 8. The model runs show that the water table remain 1 m below the ground level when either the irrigation water supplies are kept at the present level or below the present supplies. Similarly, the water table could be kept at lower than 0.8 m below ground level only when the drains are kept at more than 1 m below ground level.

3 CONCLUSIONS

The model SALTMOD for the Segwa minor canal command, once it was calibrated and validated with the data collected in the Segwa pilot area predicted fairly correct trends.

Canal command areas will further get salinized and cultivation of crops would become impossible, if suitable drainage system is not provided.

SALTMOD is an effective tool to forecast various situations once the model is calibrated and validated for use in a given agro climatic situation. The model could also help during design of drainage system once the basic input parameters are known.

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5 SYMBOLS USED

Cqf Salt concentration of the soil moisture in the aquifer, when saturated, at the end of the season (ECe in dS/m)

Cr4 Salt concentration of the soil moisture in the root zone, when saturated, in the fully rotated land at the end of the season (ECe in dS/m)

Cxa Salt concentration of the soil moisture in the transition zone aquifer above drain level, when saturated, at the end of the season (ECe in dS/m)

Cxb Salt concentration of the soil moisture in the transition zone aquifer below drain level, when saturated, at the end of the season (ECe in dS/m)

Cxf Seasonal average salt concentration of the soil moisture in the transition zone, when saturated, at the end of the season (ECe in dS/m)

Dd Depth of sub surface drains (m)

Dw Seasonal average depth of the water table below the soil surface (m)

ECe Electrical conductivity of the soil saturation extract (dS/m)

Flr Leaching efficiency of the root zone (-)

Flx Leaching efficiency of the transition zone (-)

Gd Total amount of subsurface drainage water (m^3 / season per m^2 total area)

Gi Horizontal incoming ground water through the aquifer (m^3 / season per m^2 total area)

Gn Excess of the horizontally outgoing over horizontally incoming ground water flow through the aquifer (m^3 / season per m^2 total area)

Go Horizontally outgoing ground water flow through the aquifer (m^3 / season per m^2 total area)

IWS Irrigation water supply during a particular season

Q/H1 Ratio of drain discharge and height of the water table above drain level (m/day per m)

6 REFERENCES

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Table 1 Season-wise input parameter for use in SALTMOD

S.No.	Parameters	Season 1	Season 2	Season 3
1	Duration	15^{th} Jun to 15^{th} Nov	15^{th} Nov to 15^{th} Mar	15^{th} Mar to 15^{th} Jun

2	Crop grown	Sugarcane, Paddy	Sugarcane	Sugarcane, Paddy
3	Water sources	Canal, Well	Canal, Well, Drain	Canal, Well, Drain
4	Fraction of area occupied irrigated crop other than rice	0.60	0.75	0.60
5	Fraction of area occupied irrigated rice crop	0.15	0.00	0.15
6	Fallow / Barren	0.25	0.25	0.25
7	Rainfall (m)	0.90	0.02	0.10
8	Water used for irrigation in crops other than rice (m)	0.30	1.00	0.80
9	Water used for irrigation in rice crops (m)	0.65	0.00	1.40
10	Potential evapo transpiration of other than rice crops (m)	0.80	0.50	0.50
11	Potential evapo transpiration of rice crops (m)	1.35	0.00	0.90
12	Potential evapo transpiration form un irrigated area(m)	0.80	0.70	0.75
13	Outgoing surface runoff (m)	0.28	-	-

Table 2 Other input parameter for use in SALTMOD

S.No	Parameter	Value
1	Storage efficiency	0.750
2	Depth of root zone (m)	0.850
3	Depth of transition zone (m)	6.000
4	Depth of aquifer (m)	50.00
5	Total porosity of root zone	0.500
6	Total porosity of transition zone	0.500
7	Total porosity of aquifer	0.600
8	Effective porosity of root zone	0.050
9	Effective porosity of transition zone	0.050
10	Effective porosity of the aquifer	0.200
11	Initial salt content of the soil moisture (dS/m) at field saturation in	
	Root zone (m)	2.000
	Transition zone (m)	2.000
	Aquifer	-
12	Mean salt concentration of irrigation water in the pilot area (dS/m)	0.900
13	Initial depth of water table from ground surface (m)	1.000
14	Critical depth of water table for capillary rise (m)	1.600

Table 3 Determination of natural drainage

	Season I		Season II		Season III	
Gn	Gd	Dw	Gd	Dw	Gd	Dw
.000	.098	.76	.054	.90	.020	1.05
.018	.088	.81	.054	.90	.020	1.05
.020	.088	.81	.053	.91	.019	1.06
.040	.082	.83	.050	.92	.018	1.07
.050	.082	.83	.048	.93	.015	1.09
.075	.077	.86	.040	.98	.015	1.09
.100	.064	.92	.039	.98	.014	1.04
.125	.053	.96	.037	.99	.012	1.11
Observed	.088	.80	.054	.90	.020	1.05

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