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RESEARCH ARTICLE

Estimation of Root zone salinity using SALTMOD – a case study

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Abstract

This study aims to estimate the Root zone salinity of salt affected areas of some parts of Gokak and Ramdurg taluks of Belgaum districts and Mudhol taluk of Bagalkot districts, Karnataka, India. The study area falls under semi-arid and drought hit areas. The hydro-salinity model 'SALTMOD' was applied for this study area, which computes the salt and water balance for the root zone, transition zone and aquifer zone. The model was applied to the selected agriculture plots at Gokak, Mudhol and Ramdurga taluks for the prediction of root-zone salinity and leaching efficiency. The model simulated the soil-profile salinity for 20 years under different conditions, viz. with subsurface drainage and without subsurface drainage. The salinity level shows a decline with an increase of leaching efficiency. The leaching efficiency of 0.2 shows the best match with the actual efficiency under adequate drainage conditions. However, without drainage there is a drastic increase in salinity over the years there by indicating the necessity of artificial drainage system .The model shows a steady increase, though at a slow pace over the years, reaching the levels up to 5.8 ds/m to 9.8 ds/m at the end of the 20 years period. If suitable drainage system is not provided, the study area will further get salinized thus making the land uncultivable. From the present study it is evident that it is necessary to provide proper drainage facilities to control the salinity levels in the study area.

Introduction

Groundwater is the major source of water for domestic, agricultural and industrial purposes in many countries. Intensive agricultural activities have increased the demand on groundwater resources in India. Water quality is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices. Once undesirable constituents enter the ground, it is difficult to control their dissolution. The chemical characteristics of groundwater play an important role in classifying and assessing water quality. Geochemical studies of groundwater provide a better understanding of possible changes in quality. Salinity is one of the most severe environmental factors limiting the productivity of agricultural crops. Most crops are sensitive to salinity caused by high concentrations of salts in the soil. Groundwater salinization occurs due to the displacement of salts from the unsaturated zone below the root zone. The impact of irrigated agriculture on ground water salinization can be divided into three processes: (1) concentration of salts as a result of plant water uptake; (2) movement of salts already in the unsaturated zone down into ground water as a result of leaching or subsurface mixing of saline water with better quality ground water; (3) intrusion of saline water into high quality groundwater as a result of excessive pumping for irrigation. It is found that the major cause of groundwater salinization in command areas is due to the introduction of canal irrigation without provision for adequate drainage to take out excess seepage and irrigation water is bound to result in groundwater rise and associated problems of salinity. It is reported that about 6.73 m ha area has been affected by salinity and sodicity in India. The current estimates further indicate that if the present trend of salinity development in canal commands continues, the country will have to face salinity problem in about 13 m ha by 2025. About 25% of the groundwater resources are either saline or brackish or both. The rising salinity of ground water used for water supply and irrigation is a major problem. There are many examples of salinity increase in various parts of the country, particularly in canal command areas. This is because of large scale import of surface water for irrigation to particular region will alter the natural water balance of the area. The ground water regime is particularly affected. The impact of various kinds of management activities such as, increased recharge to the ground water, losses through conveyance and distribution systems and over application of irrigation water.

In modern agriculture large quantities of water soluble materials are frequently applied to the soil surface. Part of these materials remains in the root zone, and part is carried to the groundwater by the flowing water. The imbalance between transported incoming and outgoing salt causes salinization of soils and sub-soils which result in increasing the surface and groundwater salinity. To estimate the magnitude of the hazard posed by some of these chemicals, it is important to investigate the processes that control their movement from the soil surface through the root zone down to the groundwater table. Understanding these processes will make it possible to develop an optimum management schemes for environmental control with the purpose of preventing soil and water pollution. An integrated study is essential to delineate the natural process and anthropogenic processes responsible for the present day salinity and other pollution problems in the groundwater of the study area. In this context, the present study has been carried out in the salinity affected areas of some parts of Gokak and Ramdurg taluks of Belgaum districts and Mudhol taluk of Bagalkot districts.

Study Area

The district of Belgaum is located east of the Western Ghats and is situated in the northwestern part of Karnataka state. It is bordered by the state of Goa on its southwest and Maharashtra state towards its west and north. The districts of Bijapur and Bagalkot of Karnataka state lie towards its northeast and east respectively whereas; the districts of Dharwar and Uttar Kanara lie towards its south and southwest, respectively (Fig.1). The district lies between 15°00’ and 17°00’ north latitudes and between 74°00 and 75°30’ east longitudes. The district comprising of 10 taluks, occupies an area of 13,444 Sq. Km. Bagalkot district is bound by Bijapur in the north, Belgaum in the west, Dharwar in the south and Raichur in the east. The district comprising of 6 taluks, occupies an area of 6593 sq.kms and lies between 15° 49’ & 16° 46’ north latitude and 74° 58’ & 76° 20’ east longitude. The area selected for the study is some part of Gokak and Ramdurg taluks of Belgaum district and Mudhol taluk of Bagalkot district. Ground water is being utilized both for domestic and irrigation purposes.

The area is a gently undulating to a plain terrain, dotted with isolated hills. The elevation ranges from 480 to 729 meters above MSL, sloping from west to east. The area falls in the Northern dry Agro-climatic zone and experiences a semi-arid climate. It is one of the drought -prone districts of the State. The study area falls in the Krishna river basin. The river Krishna, along with its tributaries Ghataprabha and Malaprabha are perennial and effluent in nature and flow in easterly direction. All these rivers enter district on the western side and flow in an easterly direction to join the Bay of Bengal. Average rainfall of Mudhol taluk is 461 mm and 507.60mm, 529.60 mm in Gokak and Ramdurg respectively. Thus, in general, rainfall in the study area gradually increases from west to east. The soils of Gokak and Ramdurg taluks can broadly be classified into red soils and black soils. Red sandy soil, red loamy soil & black cotton soil are found in Mudhol taluk. The study area is underlain predominantly by sedimentary rocks belonging to the Kaladgi group and volcanic rocks of the Deccan Trap. Geologically the area is underlain by various rock types varying from Archaean Crystalline like, gneisses, the Kaladgi sediments belonging to the Precambrian like, the shales, quartzites, sandstones with conglomerates, the dolomites and the limestones, and the Deccan Traps of Cretaceous to Eocene age. The main source of ground water occurring in the area is precipitation, seepage from canals and return flow from applied irrigation. Ground water occurs in the area in the weathered, semi weathered and fractured hard rock, in vesicular zones, bole beds in the area under unconfined, semi confined and confined conditions and are being developed by dug wells, dug cum bores and bore wells. The depth of weathering exceeds 20 m at places. The depth to water level varied from less than a metre to more than 20.0 m below ground level, shallow water table conditions exist along the stream/nala courses, valley bottoms and depressions.

Agriculture is the main occupation of the people in the study area and more than 60 percent of populations are dependent on the agriculture. The major crops grown in the area are Paddy, Wheat, Sugarcane, Ragi, Bajra, Grams, Jowar, Maize, Tur, Sunflower, Pulses, Groundnut, Cotton, Tobacco and Oilseeds. There are two major crop growing seasons mainly Khariff, which starts from July and ends in October and Rabi from November to February.

Methodology

SALTMOD is a computer program for the prediction of the salinity of soil moisture, ground water and drainage water, the depth of the water table, and the drain discharge in irrigated agricultural lands, using different (geo) hydrologic conditions, varying water management options, including the use of ground water for irrigation, and several cropping rotation schedules. The water management options include irrigation, drainage, and the use of subsurface drainage water from pipe drains, ditches or wells for irrigation. The computer program was originally made in FORTRAN by R.J. Oosterbaan and Isabel Pedroso de Lima at ILRI. A user shell in Turbopascal was developed by H. Ramnandanlal, and improved by R.A.L. Kselik of ILRI, to facilitate the management of input and output data. Now, a Windows version is available, written in Delphi by Oosterbaan. Schematic representation of SALTMOD is shown in figure 4.1.

The hydro-salinity model 'SALTMOD' was applied for this study area, which computes the salt and water balance for the root zone, transition zone and aquifer zone. The computation method SALTMOD is based on seasonal water and salt-balance of agricultural lands, which can be expressed by the general water balance equation as

Incoming water = Outgoing water ± Change in storage

Results and Discussion

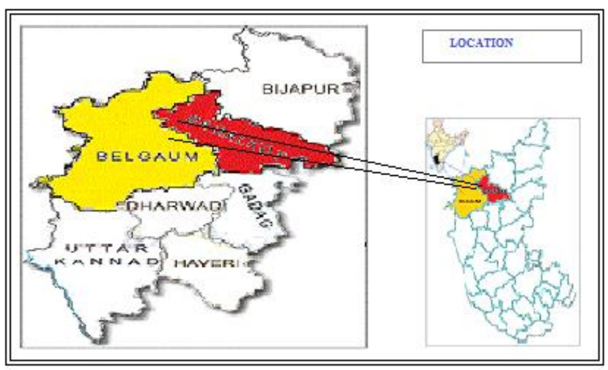

Figure 1: Index map of the Study Area

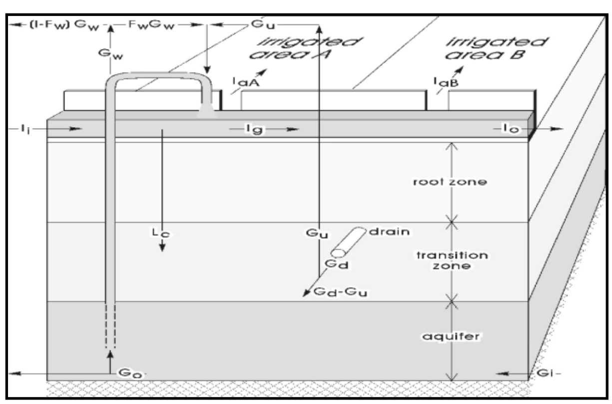

Figure .2: Schematic diagram of SALTMOD

The model was applied to the selected agriculture plots at Gokak, Mudhol and Ramdurga taluks for the prediction of root-zone salinity and leaching efficiency. The detailed method consists of a number of iterative calculations of water and salt-balance equations to find out the final equilibrium in each zone separately. The method calculates the salt-balance for each zone, based on the water-balance of the individual zone and using their respective salt-concentrations of the incoming and outgoing water. The model was run for two seasons (Khariff and Rabi) with full cropping rotations (the rotation index Kr = 4) were adopted. There are two groups of crops viz. A and B per season. The group A crop consists of Sugarcane, Jowar, Maize and Bajra and group B consists of Sugarcane, Wheat, cotton, and Groundnut.

The data required by the model are seasonal average values of the areal fractions of the crops, rainfall, depth of different soil-layers, leaching efficiency values, initial salinity of the different soil-layers, groundwater and irrigation water, evaporation, surface runoff, and reuse of drainage-water, etc. Model takes input-data of each year as average over two seasons, a wet and a dry season. 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 efficiencies of the root zone (Flr) are given a range of arbitrary values and the corresponding salinity results of the program are compared with the values actually measured. The efficiency producing the best match is assumed to be the actual efficiency. The arbitrary Flr values are taken as 0.05, 0.1, 0.2 and 0.3. The model was calibrated (Varadarajan, 2013) by using the data during 2001 to 2005 from University of Agricultural Sciences, Dharwar, Agriculture Department, Irrigation Department and Department of Mines and Geology. Further the validation by using the data from 2006 to 2010.

The root zone salinity is simulated for 20 years using SALTMOD under different conditions such as with sub surface drainage and without sub surface drainage. For the prediction period, it was assumed that, there will be no significant yearly deviations of the input parameters, such as rainfall, irrigation, evaporation, cropping pattern etc., from the observed data given as average input to the model for the period 2014. The seasonal input and other data formats are shown in the table No.1 to 6 for all the locations.

Table 1: Season-wise input parameters of Yadwad (Gokak Taluk)

S.No.	Parameters	Season 1	Season 2	Season 3
1	Duration	4 months	4 months	4 months
2	Crop grown	Sugarcane, Cotton, Jowar, Maize, Groundnut, sunflower	Sugarcane, Jowar, Wheat Cotton, Groundnut, Maize	No irrigation
3	Water Sources	Canal, Well	Canal, Well	NIL
4	Fraction of area occupied (irrigated)	1.00	1.00	0.00
5	Fallow/Barren	0.00	0.00	1.00
6	Rainfall ($m^{3/}$/season/m^2)	0.60	0.00	0.00
7	Water used for irrigation ($m^{3/}$/season/m^2)	1.00	1.00	0.00
8	Percolation losses from the irrigation canal system ($m^{3/}$/season/m^2)	0.01	0.01	0.00
9	Incoming groundwater flow through the aquifer ($m^{3/}$/season/m^2)	0.50	0.30	0.00

10	Outgoing groundwater flow through the aquifer ($m^{3/}$/season/m^2)	0.30	0.20	0.00
11	Potential evaporation ($m^{3/}$/season/m^2)	0.10	0.16	0.00
12	Groundwater pumped from wells in the aquifer ($m^{3/}$/season/m^2)	0.50	0.50	0.00
13	Fraction of water pumped by wells from the aquifer used for irrigation ($m^{3/}$/season/m^2)	0.30	0.30	0.00
14	Outgoing surface runoff ($m^{3/}$/season/m^2)	0.60	0.00	0.00

Table 2: Input Parameters corresponding to Soil and Aquifer properties Yadwad (Gokak taluk)

S.No	**Parameters**	**Value**
1	Storage efficiency	0.60
2	Depth of root zone (m)	0.60
3	Depth of transition zone (m)	2.00
4	Depth of aquifer (m)	50.0
5	Total porosity of root zone (m/m)	0.30
6	Total porosity of transition zone (m/m)	0.30
7	Total porosity of aquifer (m/m)	0.30
8	Effective porosity of root zone (m/m)	0.05
9	Effective porosity of transition zone (m/m)	0.05
10	Effective porosity of the aquifer (m/m)	0.20
11	Initial salt content of the soil moisture (dS/m) at field saturation in	
	Root zone (ds/m)	3.50
	Transition zone (ds/m)	3.1

	Aquifer	-
12	Mean salt concentration of irrigation water in the pilot area (dS/m)	0.50
13	Initial depth of water table from ground surface (m)	1.00
14	Critical depth of water table for capillary rise (m)	2.00

Table 3: Season-wise input parameter of Vantagodi (Mudhol taluk)

S.No.	Parameters	Season 1	Season 2	Season 3
1	Duration	4 months	4 months	4 months
2	Crop grown	Sugarcane, Cotton, Jowar, Maize, Groundnut, sunflower.	Sugarcane, Jowar, Wheat Cotton, Groundnut, Maize.	No irrigation
3	Water Sources	Canal, Well	Canal, Well	NIL
4	Fraction of area occupied (irrigated)	1.00	1.00	0.00
5	Fallow/Barren	0.00	0.00	1.00
6	Rainfall (m$^{3/}$/season/m^{2})	0.50	0.00	0.00
7	Water used for irrigation (m$^{3/}$/season/m^{2})	1.00	1.00	0.00
8	Percolation losses from the irrigation canal system (m$^{3/}$/season/m^{2})	0.01	0.01	0.00
9	Incoming groundwater flow through the aquifer (m$^{3/}$/season/m^{2})	0.50	0.30	0.00
10	Outgoing groundwater flow through the aquifer (m$^{3/}$/season/m^{2})	0.30	0.20	0.00
11	Potential evaporation(m$^{3/}$/season/m^{2})	0.10	0.16	0.00

12	Groundwater pumped from wells in the aquifer ($m^{3/}$/season/m^2)	0.50	0.50	0.00
13	Fraction of water pumped by wells from the aquifer used for irrigation ($m^{3/}$/season/m^2)	0.30	0.30	0.00
14	Outgoing surface runoff ($m^{3/}$/season/m^2)	0.60	0.00	0.00

Table 4: Input Parameters corresponding to Soil and Aquifer properties Vantagodi (Mudhol taluk)

S.No	**Parameters**	**Value**
1	Storage efficiency	0.60
2	Depth of root zone (m)	0.60
3	Depth of transition zone (m)	2.00
4	Depth of aquifer (m)	40.0
5	Total porosity of root zone (m/m)	0.30
6	Total porosity of transition zone (m/m)	0.30
7	Total porosity of aquifer (m/m)	0.30
8	Effective porosity of root zone (m/m)	0.05
9	Effective porosity of transition zone (m/m)	0.05
10	Effective porosity of the aquifer (m/m)	0.20
11	Initial salt content of the soil moisture (dS/m) at field saturation in	
	Root zone (ds/m)	3.40
	Transition zone (ds/m)	3.10
	Aquifer	-
12	Mean salt concentration of irrigation water in the pilot area (dS/m)	0.50
13	Initial depth of water table from ground surface (m)	1.00

14	Critical depth of water table for capillary rise (m)	2.00

Table 5: Season-wise input parameter of Bichaguppi (Ramdurga taluk)

S.No.	Parameters	Season 1	Season 2	Season 3
1	Duration	4 months	4 months	4 months
2	Crop grown	Sugarcane, Cotton, Jowar, Maize, Groundnut, sunflower.	Sugarcane, Jowar, Wheat Cotton, Groundnut, Maize	No irrigation
3	Water Sources	Canal, Well	Canal, Well	NIL
4	Fraction of area occupied (irrigated)	1.00	1.00	0.00
5	Fallow/Barren	0.00	0.00	1.00
6	Rainfall ($m^{3/}$/season/m^2)	0.50	0.00	0.00
7	Water used for irrigation ($m^{3/}$/season/m^2)	1.00	1.00	0.00
8	Percolation losses from the irrigation canal system ($m^{3/}$/season/m^2)	0.01	0.01	0.00
9	Incoming groundwater flow through the aquifer ($m^{3/}$/season/m^2)	0.50	0.30	0.00
10	Outgoing groundwater flow through the aquifer ($m^{3/}$/season/m^2)	0.30	0.20	0.00
11	Potential evaporation ($m^{3/}$/season/m^2)	0.10	0.16	0.00
12	Groundwater pumped from wells in the aquifer ($m^{3/}$/season/m^2)	0.50	0.50	0.00

13	Fraction of water pumped by wells from the aquifer used for irrigation ($m^{3/}$/season/m^2)	0.30	0.30	0.00
14	Outgoing surface runoff ($m^{3/}$/season/m^2)	0.60	0.00	0.00

Table 6: Input Parameters corresponding to Soil and Aquifer properties Bichaguppi (Ramdurga taluk)

S.No	Parameters	Value
1	Storage efficiency	0.60
2	Depth of root zone (m)	0.60
3	Depth of transition zone (m)	2.00
4	Depth of aquifer (m)	30.0
5	Total porosity of root zone (m/m)	0.30
6	Total porosity of transition zone (m/m)	0.30
7	Total porosity of aquifer (m/m)	0.30
8	Effective porosity of root zone (m/m)	0.05
9	Effective porosity of transition zone (m/m)	0.05
10	Effective porosity of the aquifer (m/m)	0.20
11	Initial salt content of the soil moisture (dS/m) at field saturation in	
	Root zone (ds/m)	5.00
	Transition zone (ds/m)	4.70
	Aquifer	-
12	Mean salt concentration of irrigation water in the pilot area (dS/m)	0.50
13	Initial depth of water table from ground surface (m)	1.00
14	Critical depth of water table for capillary rise (m)	2.00

SALTMOD was applied to predict the salinity levels in parts of Gokak, Mudhol and Ramdurga taluks. This will be highly useful for taking up management decisions in the salinity affected areas. The salinity level shows a decline with an increase of leaching efficiency. Prediction of root zone salinity for 20 years with subsurface drainage system is shown in figure 3 to 5.

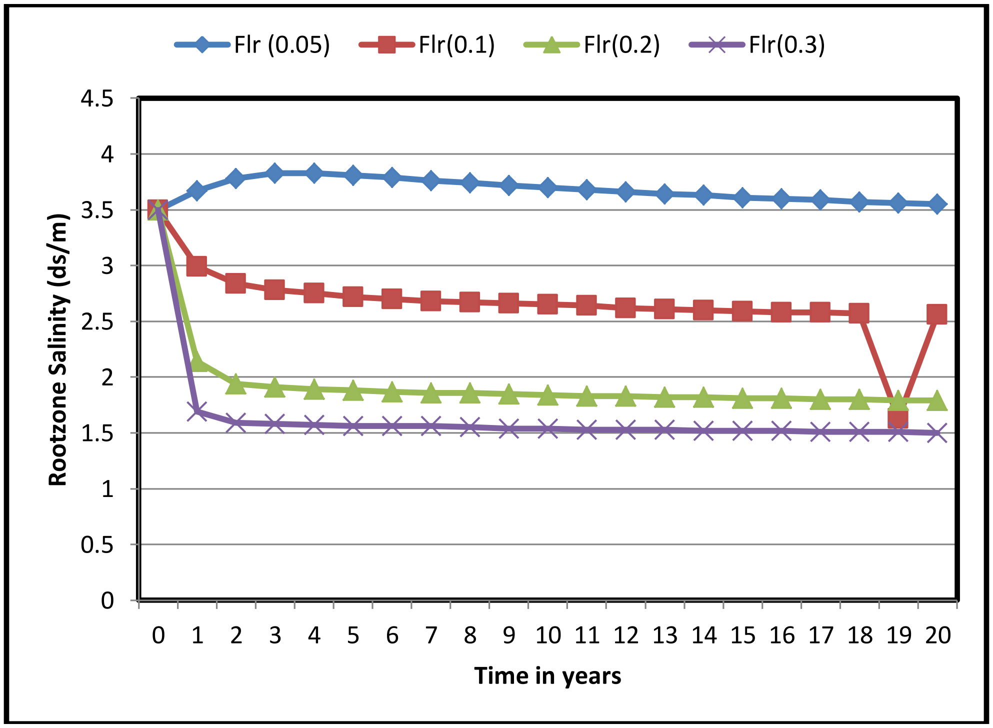

Figure .3.Predicted Root zone Salinity at Yadwad (Gokak taluk) With Drainage

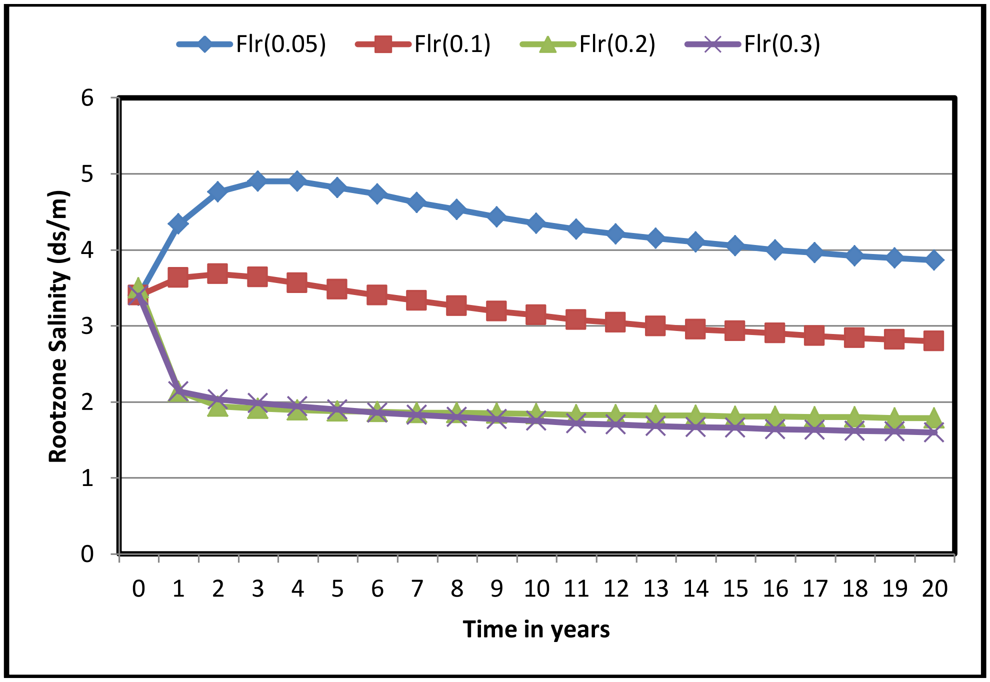

Figure: 4.Predicted Root zone Salinity at Vantagodi (Mudhol taluk) with Drainage

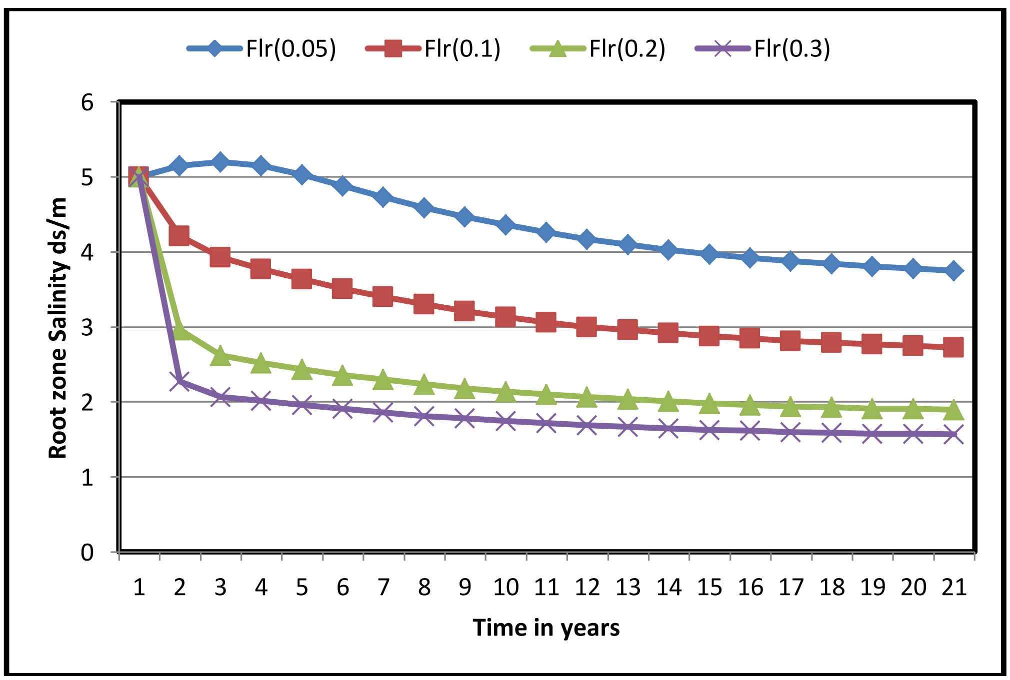

Figure.5 Predicted Root zone Salinity at Bichaguppi (Ramdurga taluk) With Drainage

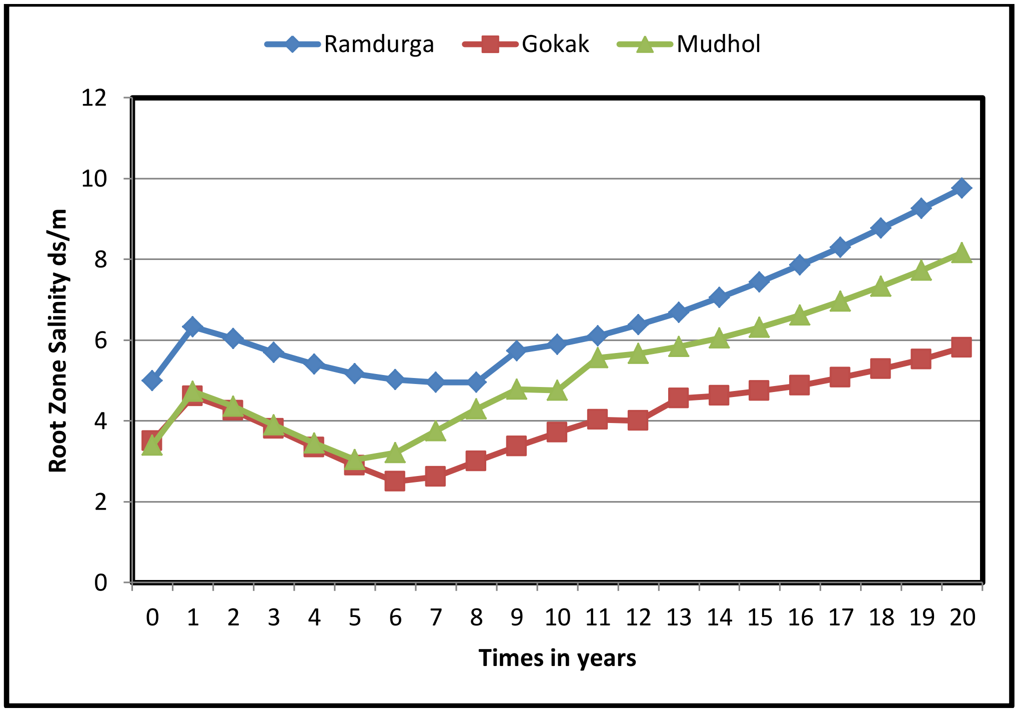

Figure 6 Predicted Root zone Salinity (No Drainage)

The Simulation analysis shows that the concentration of root zone salinity decline after 12 years to the acceptable limits of 2.0 ds/m to 3.0 ds/m with leaching efficiency of 0.10 and became almost constant after 12 years for all the locations. However with leaching efficiencies of 0.2 and 0.3 shows the salinity level to the acceptable limits within initial 2 to 3 years. The leaching efficiency of 0.2 shows the best match with the actual efficiency under adequate drainage conditions. However, without sub surface drainage system there is a decline in salinity level from the initial level till 5 to 8 years and there after drastic increase in salinity over the years, there by indicating the necessity of artificial drainage system. The predicted salinity levels of root zone without sub surface drainage system are shown in the figure 6 for all the locations. The model shows a steady increase, though at a slow pace over the years, reaching the levels up to 5.8 ds/m to 9.8 ds/m at the end of the 20 years period. If suitable drainage system is not provided, the study area will further get salinized thus making the land uncultivable. From the present study it is evident that it is necessary to provide proper drainage facilities to control the salinity levels in the study area.

Conclusions

SALTMOD, a mathematical model is applied to predict the root-zone salinity and leaching efficiency. The model simulated the soil-profile salinity for 20 years under different conditions, viz. with subsurface drainage and without subsurface drainage. The salinity level shows a decline with an increase of leaching efficiency. The Simulation analysis shows that the concentration of root zone salinity decline with leaching efficiencies of 0.2 and 0.3 to the acceptable limits within initial 2 to 3 years. The leaching efficiency of 0.2 shows the best match with the actual efficiency under adequate drainage conditions. However, without drainage there is a drastic increase in salinity over the years there by indicating the necessity of artificial drainage system .The model shows a steady increase, though at a slow pace over the years, reaching the levels up to 5.8 ds/m to 9.8 ds/m at the end of the 20 years period. If suitable drainage system is not provided, the study area will further get salinized thus making the land uncultivable. From the present study it is evident that it is necessary to provide proper drainage facilities to control the salinity levels in the study area.

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