PERFORMANCE EVALUATION OF SUBSURFACE DRAINAGE SYSTEM UNDER UNSTEADY STATE FLOW CONDITIONS IN COASTAL SALINE SOILS OF ANDHRAPRADESH, INDIA

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ABSTRACT

The performance of an executed subsurface drainage system was evaluated under unsteady flow conditions. The impulse-response relation has been studied for two different conditions of drain spacings, namely, the executed drain spacing based on steady state flow conditions and the drain spacing proposed on unsteady state flow conditions, incorporating the effects of drainable porosity. It is found rational to use the "Dezeeuw-Hellinga model" for prediction of impulse response relations in terms of temporal water table fluctuations against rainfall – recharge under unsteady state flow conditions. The responses of a sub-surface drainage system for the impulse of incessant rainfall have been studied. The values of calculated drain spacings varied from 11 to 15 m. However, due to economic conditions, the practical drain spacings of the layout have been fixed at wider value of 35m and 55m. It is found that the drain spacings adopted for unsteady state flow conditions might have resulted in a better performance of the drains compared to steady state drain spacing as depicted by Dezeeuw-Hellinga model run. The drainable porosity being the vital parameter in an unsteady state equation, the Dezeeuw-Hellinga model was also used for varying levels of drainable porosity under given drain spacing conditions. Generally, the reference drainable porosity value is taken as 10 per cent for most of the drainage studies and the influence on drain outflows were compared for an increased value of 20 per cent and decreased value of 5 per cent, since the drainable porosity value in the study area varied from 5 to 20 per cent. It was found that the change in drainable porosity significantly influence the drain performance as depicted by Dezeeuw-Hellinga model run over all the3 standard week of year. The executed sub-surface drainage system has been found satisfactory in bringing down the soil salinity levels to desirable limits below 4 dSm^{-1}. The executed sub-surface drainage system has also resulted in appreciable crop productivity improvements in the locality.

INTRODUCTION

Chemical degradation of agricultural land some times is a result of faulty irrigation water management besides being an inherent problem in several parts of the country. Such degradation may manifest in salinity, sodicity, avidity and a toxic environment in the crop root zone. The result is a reduction or loss of production. Besides chemical degradation, large areas in the country suffer from water congestion due to high rainfall, flat topography, poor water transmission characteristics in the soil profile and lack of natural or artificial drainage.

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Land degradation caused by water logging and soil salinity problems adversely affect the food security and living standards of human beings. The history of irrigation projects in recent times shows that the problems of water logging, salinity and alkalinity are rising even before the full potential of the projects are realized. As a result, much of the investment is irrecoverably wasted. Land drainage plays an important role in maintaining and improving crop yields in problematic soils by way of managing groundwater tables and soil salinity at safer levels.

As sub surface drainage system continuously removes dissolved salts from soil profile, it is apprehended that some amount of various species of water-soluble nitrogen namely, ammonium nitrite and nitrite may also be lost through sub surface drainage water. Thus, it was has chosen to review and comment on some of the studies related water table and salinity control by sub surface drainage in chemically degraded lands. The findings of such studies were based on modeling as well as experimental approaches to assess desalinization in the presence of sub surface drainage; salinization in the absence of adequate drainage; water quality monitoring of drainage effluents; soil salinity distribution in space and time; nitrogen losses *viz* leaching and sub surface drainage effluents. The provision of sub surface drainage would help in reclamation of water logged saline soils in a few years and a wide choice of crops can be grown to achieve full potential of the area. Sub surface drainage designs are now considering the controlled drainage to eliminate some of the negative effects such as over drainage, fertilizer losses and environmental problems. Sub surface drainage research in India has shown a number of positive impacts such as salinity reclamation in 2 to 4 years, increase cropping intensity, advancing of soil trafficability period by 5 to 10 days, increased crop yield by 40-50 per cent, improvement in the quality of produce, increased land value and a better social environment.

MATERIALS AND METHODS

To accomplish the objectives of any drainage scheme, a sound hydraulic design of the system with particular reference to the drain spacing and an appropriate technique to evaluate the performance of the system after layout is essential. A through study of soil characteristics, rainfall pattern and water table fluctuations is warranted towards the design and layout of drainage system. The experimental site is located at the Endakuduru village in Ghantasala Mandal of Krishna District in Andhra Pradesh as shown in Fig: 2.1. The village is located on the Machilipatinam- Challapelli road at a distance of about 18 km southwards from the district head quarter, Machilipatinam. Krishna district lies in south coastal Andhra Pradesh between $15^0 43^1$ and $17^0 10^1$ N latitude and $80^0 0^1$ and $81^0 35^1$ E longitude extending over an area of 8727 Sq. km. with a costal line of 88 km. Majority of the people of the study area are marginal farmers with an average land holding of 0.61 ha. These marginal farmers are generally poor and earn their livelihood by working as labourers to big farmers.

The district occupies an important place in agriculture and rice in the main food crop occupying about 58 per cent of the gross cropped area of 7.59 lakh hectares. The other crops are black grams, green grams, ground nut and sugarcane grown in 1.29, 0.36, 0.29 and 0.17 lakh hectare, respectively. The gross irrigated area is about 63 per cent of the gross cropped area. The experimental site is characterized by a moderate coastal climate throughout the year. the mean annual maximum and minimum temperatures are 36.6^oC and 19.3^oC respectively. The mean annual rainfall is 975 mm of which about 60 percent occurs during south-west monsoon from June to September. A specific feature of the area is occurrence of cyclonic storms, any time usually during September to November, causing torrential rains. The rainfall during September to November may be as high as 40 to 45 percent of the annual rainfall. Endakuduru village and the experimental fields are 1.5 to 2 m above the mean sea level. The land flat and is diked in small units for rice cultivation. It is saline to sodic with high clay content. The soil is deep with no rock formation.

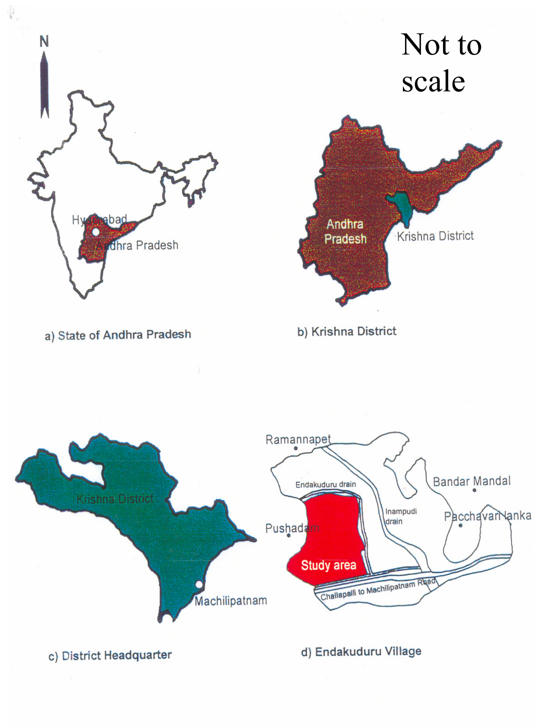

Figure 1. Successive maps of the study area

The soil at the project state, in general, is saline in nature with varying degrees of salinity. The soils with low levels of salinity (EC values less than 4 dS/m) are kept under cultivation with rice-rice rotation. Soils with high salinity content are barren and nothing grows on it with white crust formation on the surface. It is noticed that the project site soils have poor permeability characteristics. The salts are crusted on the surface especially during hotter months with white salt patches on the land surface slightly alkaline in nature i.e., $p^H > 7.00$. The soils deep with no rock formation. Sandy layer is observed at depths more than 2 metres. Normally rice-rice cropping system is followed in Endakuduru village. During *kharif*, rice varieties of about 150-160 days duration and during *rabi*, rice varieties of about 120 days duration are grown. As the village is located at the tail end of the irrigation canal system, the rice transplantation is generally delayed and is done any time between mid-July to mid-August. As a result of delayed showing the yields are reduced by about 10-15 per cent. The area is affected by salt content and drain water is used for protective irrigation for the rice crop. The crop yield in *kharif* is lower compared to *rabi* yield because of less sun light conditions. The rice varieties Chaitanya (MTU-2067), Krishnaveni (MTU-2077) and Swarna usually grown in *kharif* season and the rice variety

IR-64 is cultivated in *rabi* season. However, these yields can be increased by about 20 per cent if proper drainage practices are employed.

RESULTS AND DISCUSSION

As shown in Figure 2, the basic factors that decide the drainage coefficient are hydraulic conductivity, infiltration rate/ percolation, leaching requirement and available water to accomplish leaching. As a preliminary guideline towards design, the least of the above factors will be the deciding parameter for adoption as drainage coefficient. Of the above, the 'K' and the infiltration rate have been found to be 0.144 m/day to 0.028 m/day respectively. Either of the two is very high to be considered as drainage coefficient. As an amount towards finding the leaching requirement, a simple water balance approach was studied.

First, the 20-year monthly rainfalls were arranged in a descending order table for each of the 12 months. The 75 percent probable value of monthly rainfalls at 75 percent probability level of being equaled or exceeded have been plotted. The cumulative monthly evapotranspiration was also plotted in the same graph. The maximum deficit of rainfall was found in December and its magnitude was 1150 mm.

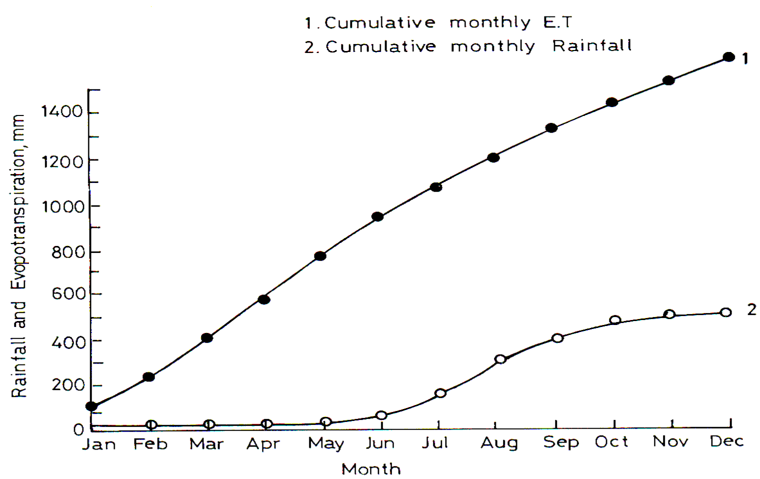

Figure 2. Simple water balance of study area

Leaching requirement is given by the formula:

$$LR = (E-P) \times \frac{\overline{C_i}}{F(\overline{C_{FC}} - \overline{C_i})} \tag{1}$$

Where,

LR = Leaching requirements, mm
E = evapotranspiration, mm
P = effective rainfall, mm
C_i = average irrigation water salt concentration, ml/l
C_{FC} = average salt concentration of soil at field capacity, me/l and

F = leaching efficiency

of the various components of equation, (E-P) was obtained from Fig. was taken as 0.4 for heavy soils, C_i and C_{FC} were worked out from the field measured data of the electrical conductivity during investigations by using the following general relations.

Concentration in me/l = 12 x concentration in dS /m
Concentration at field capacity = 2 x concentration of 1:2 saturation extract
For the present study:

E-P = 1150 mm
F = 0.4 (assumed for heavy soils)
C_i = 12 x EC_i
= 12x(1.6+1.57+1.6+1.9)/4 = 20.01 me/l
C_{FC} = 2x12(20+9.3+11)/3
= 322.4 me/l
Substituting the above values in equation

LR = 1150x20.010/0.4(322.4-20.01) = 190.2 mm
Dividing this by 31 (No. of days in December),
The drainage coefficient DC is obtained as

DC = 190.2/31= 6.14 mm/day= 0.00614 m/day

Due to flat topography, bunded rice fields and absence of surface drainage, the whole of monthly P was considered effective.

Percolation rate from the rice field is 0.012 m/day the possible drainage coefficients work out on various approaches are summarized in Table1

Table 1. Estimated drainage coefficients DC (m/day) by different approaches
Basis of estimation of DC

Particulars	DC, m/day
In- situ saturated hydraulic conductivity	0.144
Basic infiltration rate on initially dry soil	0.02888
Leaching requirement	0.00614
Percolation in puddle paddy fields	0.012

From the above table1, minimum i.e. 0.00614 m/day will be governing recharge rate and is adopted as an initial guideline as drainage coefficient for sub-surface drainage system.

The investigations revealed that sand was encountered beyond a depth of 1 m. the sand layer was of unknown thickness (tested down to 3 m). Hence, the depth of drain was taken as 1 m and depth of impermeable layer as 3.5 m. Since paddy roots are considered effective down to 30 cm from the surface and drain depth has been taken as 1 m, the hydraulic head is taken as 0.5 m, leaving a 20 cm depth of profile below the root-zone to account for capillary rise. For steady state conditions depicting drains flows equality rainfall recharge, Hooghoudt's equations have been used. The steady state drainage equations (Mostly the equations proposed by Hooghoudt's) are based on the important assumption that the drain flows are governed by Darcy's law for a stabilized inflow (rainfall recharge) and over equal outflow (drainage coefficient). Also, the soil is considered to be a homogeneous medium with isotropic hydraulic conductivity. The steady state equations generally do not incorporate the effect of drainage porosity, which is a very important design parameter for true drainage conditions that conform to unsteady state flow. While the study state approach only depicts a simplified, constant relationship between the water table and the drain discharge, the practical situations impose temporal variations in recharge to water table resulting in unsteady flow of ground water towards the drain (both the unsteady state approach are based on the same Dupuit. Forchheimer assumption. The only difference is that the recharge varies with time in unsteady state flows.

De Zeeuw- Hellinga equation is used to describe a fluctuating water table, typical situation humid areas with high intensity rainfall concentrated in discrete storms. In this approach, a non-uniform recharge is divided into shorter time period in which the recharge to the groundwater can be assumed to be constant. Both these situations prevail in the study area. Hence, the unsteady state drainage analysis has been carried out by above-mentioned equations.

Layout of Subsurface Drainage System

The practical layout of a subsurface drainage system should encompass proper alignment and possessing of drain laterals, collector pipes and other intermediate control structures. Care should be taken to ensure that the drainage system installed does not hamper the regular farming operations the layout should also indicate the position of collector points and outlets. The layout should also accommodate for easy modes of observations related to soil properties, water table fluctuations, hydraulic gradient and drain outflows.

As seen from the following Figures 3 - 8, prior to the monsoon of 1997, the system was laid out in 4.0 ha area adjacent to previously taken area of 3.2 ha was put under sub-surface drainage experiment. Baked clay tiles with 6 mm dia perforators 80 mm part on one-third of the periphery in three rows, and 10 cm inner diameter with the bell mouth at one end were used as laterals. The spacing were at 35 m and 55 m apart. The length was 120 m. slope was 0.2 per cent the filters used were river sand along the trench and 100 gms coir fibre at the pipe joints

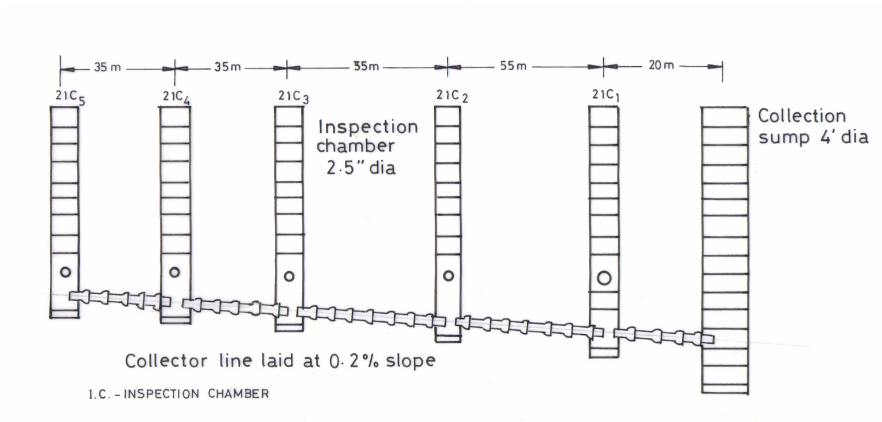

Figure 3. Cut section along collector line

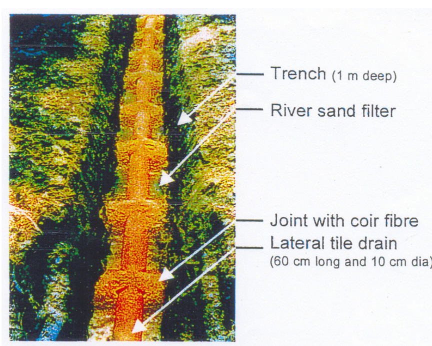

Figure 4. Laying of subsurface drains

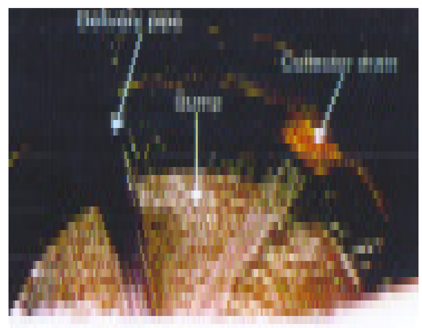

Figure 5. Free flow of collector drain into sump

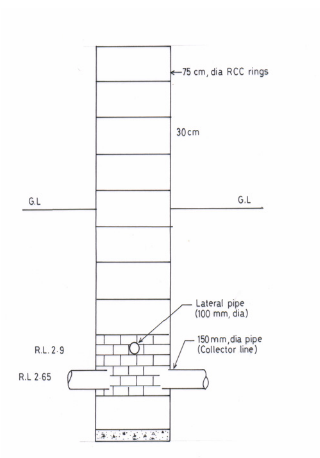

Figure 6. Cut section of inspection chamber

Figure 7. Discharge Measurement in inspection chamber

Each pipe was 60 cm length the laterals were joined to a collector line through sump, inspection chambers made of standard size (0.75 cm dia and 0.3 m height) concrete rings. The collector pipe was of baked clay had an internal diameter of 15 cm with bell mouth at one end and without perforations, was laid at a slope of 0.4 per cent and discharged into a sump well of concrete rings from which the leachate was pumped out into an existing shallow pen drain. Adequate care was taken to maintain the uniformity of the slopes in the lateral and collector line and to negotiate each joint. The bottom of the sump well and the inspection chambers were sealed with cement concrete and were kept sufficiently below the lateral and collector outlet to enable monitoring of the discharge from the drains. The drained water collected in the main sump was pumped out to main drain canal. The main drain water draws towards aquaculture site.

To monitor water table, observation wells installed at half and one- fourth spacing from the lateral and one very close to the lateral.

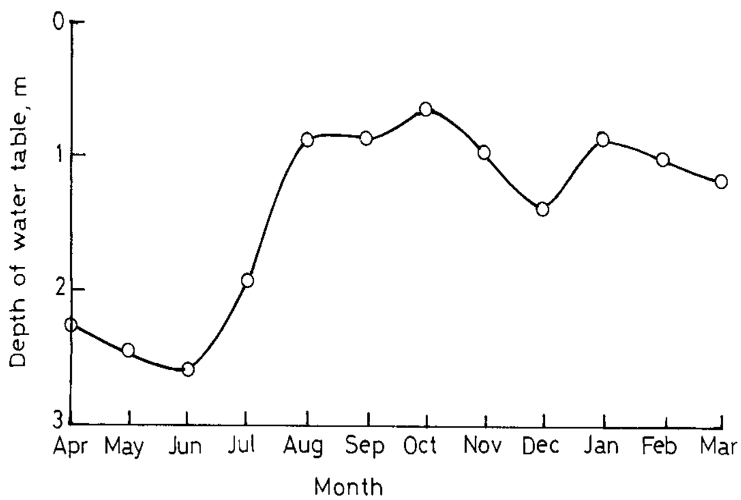

Figure 8. Ground water fluctuations in the project

For simulation, De Zeeuw- Hellinga equation was used keeping in view of the recharge a effective rainfall (m) average water table depth and the drain discharge (m/day) for the 3 consecutive years from 1998-2000. Rainfall data for study are was obtained from meteorological laboratory and the average values for 3 years i.e. 1998-2000 were worked in month wise and the program was prepared C++ version and ultimately the average water table values and drain discharge values were worked out. The reference drainable porosity in kept at 10 per cent.

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