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Research Article

PRE-DRAINAGE INVESTIGATIONS OF WATERLOGGED RICE FIELDS IN BAPATLA REGION

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Abstract: The excessive application of irrigation water combined with high rainfall led to rapid rise of water table, resulting into development of waterlogging and salinity in Krishna western delta farmer's fields. To test and demonstrate the need for control of soil salinity and waterlogging, pre drainage investigations were carried out at one of the farmer's field near Bapatla, Guntur district, Andhra Pradesh. The results of physical and chemical analysis of soil samples showed that the type of soil is alkali in nature with high content of ESP. The N, P, K values were found to be 130, 18, 760 kg ha^{-1} respectively. The texture of the soil is clay loam with hydraulic conductivity value of 0.709 m/day and drainable porosity of 2.98%. Rainfall data of ten years (2008-2017) was analyzed to determine expected rainfall of different durations for one to ten years recurrence interval (RI). The drainage coefficient (dc) was estimated as 2.96 mm/day for the design of drainage system in the study location.

Keywords: *Waterlogging, Salinity, Hydraulic Conductivity, Drainable Porosity, RI and Dc*

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Introduction

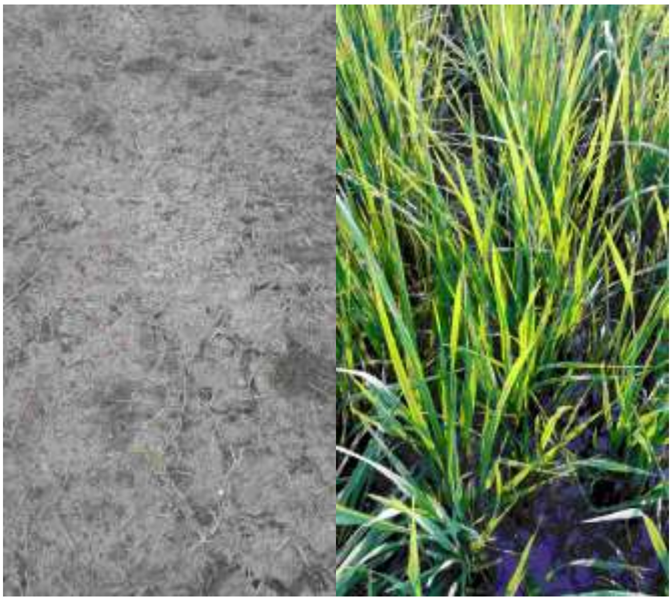
In India, an estimated 2.46 million hectares of land is reported to be suffering from waterlogging and the area containing salt-affected soils was estimated to be 7.0 million hectares. Waterlogging, closely associated with salinization and alkalization, continues to be a threat to sustained irrigated agriculture, affecting an estimated 6 million hectares of fertile land in India. About 4.5 million hectares of land have already become barren and more lands are being encroached upon by these problems every year, depending on the climate, topographic, geohydrologic and groundwater conditions. India is estimated to have about 58.2 million hectares of wetlands [1]. India is mainly dependent on agriculture sector and thus loss of agricultural production poses serious threats to the economy [2]. Waterlogging and salinity are the potentially serious problems for the agricultural industry and can reduce the potential yield by as much as 30-80% for many crops. Waterlogging in low lying areas is created by seepage of water from irrigated uplands and from canal systems. Continued irrigation with excess water induces rising of the groundwater table. The salinity problem in irrigated agriculture is frequently associated with groundwater table within one to two meters below the ground surface. Area with saline soils associated with a high-water table conditions promote unfavorable growth conditions for green vegetation [3]. Drainage is a prerequisite for intensive cropping on soils with restricted internal drainage caused by low permeable subsoils, and extensive installations were taken place over the past two decades. The productivity of soils suffering from excess soil moisture can be improved by reducing or controlling their moisture level. The traditional consideration of drainage is to provide adequate root depth free from the submergence in the water table. The primary objective of subsurface drainage in soils with excess water and perched water table is to remove a depth of approximately 30-50 cm from the surface. It is generally accepted that drains should be installed as deep as possible in homogenous permeable material [4,5] above any impermeable layers. Generally, an impermeable layer is defined as a layer that has a hydraulic conductivity less than one tenth of the conductivity of the layer above it.

Traditionally, subsurface drainage has not been recommended for soils with shallow impermeable layers because the drain would be placed within or below the layer, reducing the water that moves to the drains. Drains installed at shallow depths and small diameter pipes are not structurally damaged by normal field operations and are hydraulically effective. Placing drains at shallow depths and putting them in a permeable material will directly affects the rate of water table fall besides reducing cost of trench digging. Controlled drainage has been practiced for many years, but may not always have been referred to as "controlled drainage". It is the principle of restricting free flow from drains, such that they only discharge when it is necessary, based on pre-determined water management criteria [6]. The prime reasons for water table management from a drainage perspective is the removal of excess water to permit farming on poorly drained soils. This includes improving trafficability during certain times of the growing season (especially planting and harvesting time). Salinity control is another typical drainage objective. An extension of controlled drainage is the use of the drainage system for sub-irrigation. This was first reported in 1956 when experienced with sub-irrigation in California, Idaho, Utah and Colorado were described [7]. In the drainage system, water level is controlled by a weir or gate. Water may be pumped into the drainage system through the manholes or in the open drain beyond the subsurface outlet. The weir that controls the water level is usually in the open drain. Early experiences with subirrigation are on the light textured soils. It was found that sub-irrigation requires only 5–25% of the energy required by sprinkler irrigation. There are at present no accepted design criteria for controlled or managed drainage systems in either humid or arid zones. In this research article, the Pre-Drainage Investigations of Waterlogged Rice Fields in Bapatla Region taken up are described firstly the physical and chemical properties of soil, canal water and drain water secondly, the frequency analysis of rainfall data for different durations and finally the estimation of drainage co-efficient on different criteria.

Material and Methods

Selection and Description of the Pilot Area

In order to suggest suitable reclamation technology for combating the twin problems of water logging and salinity [Fig-1] in Bapatla region, one of the farmer's field was selected to design and install controlled and sub irrigation system. The study area as shown in [Fig-2] which is located besides Bapatla-Pedanandipadu road, which is 6 km distance from Bapatla. The extent of the farmer's land is 1.75 acres. A natural drain exits at bottom of the field in eastern side and flows towards north. The water table is generally observed to remain below 1m from ground surface during monsoon season and falls to below 2.5m depth during post monsoon season. The average annual rainfall in the study area is 1160.41 mm.



a) Identification of salinity problem b) Identification of water logging problem

Fig-1 Twin problems of drainage

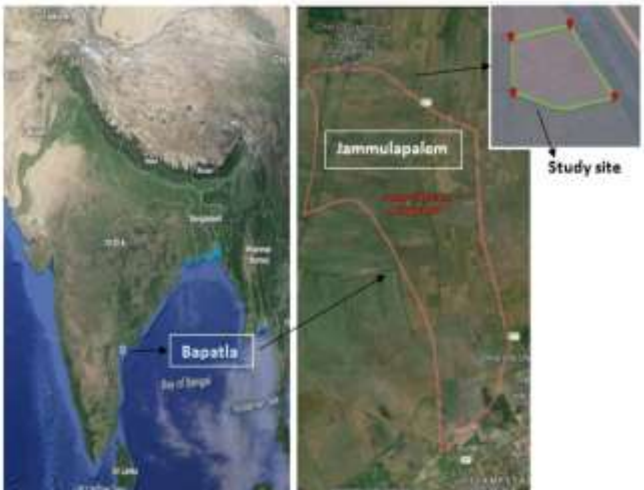


Fig-2 Location map of experimental study area

Topography and Climate

The pilot area is located in the latitude of 15º.97502 N and longitude of 80º.43684 E. The monthly maximum and minimum temperatures may from 34.46ºC to 30.07ºC and 26.06ºC to 17.85ºC respectively in August to January, whereas, monthly maximum and minimum temperatures may vary from 38.57ºC to 33.14ºC and 27.78ºC to 22.41ºC respectively in March to July. The maximum and minimum relative humidity is 92% and 56.5% respectively. The maximum and minimum wind speeds are 9.39 and 4.26 kmph respectively. The grid survey was carried out with a grid size of 10 x 10m. Based on the levels obtained in survey, contour map was prepared for the design.

Irrigation Practices

Irrigation water is received from field channels and flooding method of irrigation is adopted during the entire crop period. The number of irrigations required during the cropping period is 10 to 12. There is an open natural drain on the eastern side.

Cropping Pattern

The cropping pattern mainly followed by the farmers during pre-drainage is rice as a single crop during monsoon period. There was no cultivation of any crop during pre and post monsoon seasons mainly due to soil salinity and lack of irrigation facilities. Rice was being sown in the field with seed drill during August month. During the preliminary survey, most of the farmers were using few salt tolerant varieties like NLR 145, NLR 523, NLR 92. Some farmers used long duration (150 days) rice varieties also, which are available locally such as BPT 5204, BPT 2270, BPT 2595.

Hydraulic Conductivity of Soil

The design and functioning of sub-surface drainage system depends to a great extent on the soil saturated hydraulic conductivity. All drain spacing equations make use of this important parameter to design drainage system. The in-situ measurement of hydraulic conductivity (K) by auger hole method was taken up at selected locations in the study area, Eijkel Kamp Agri-search make standard kit as shown in [Fig-3]. The 'K' value for the study area was found to be 0.709 m/day from Equation (1).

$$K = \frac{C(H_0 - H_t)}{t} \qquad (1)$$

$$C = \frac{4000\frac{r}{h'}}{\left(20+\frac{D_2}{r}\right)\left(2-\frac{h'}{D_2}\right)} \qquad (2)$$

Where, D_1 = Depth of water table below reference line (m)

D_2 = Depth of bottom of bore below the water table (m)

D = Depth of impermeable layer from the from the bottom of the bore (m)

D' = Depth of bore from the reference line (m)

H_0 = Depth of water depressing level from the bottom (m)

H_t = Depth of water re-quicked back in time't' (m)

Δht = Depth of water raised in time't' (m)

r = Radius of the bore (m)

h' = Average depth (m)

Fig-3 a) Making an Auger hole

Fig-3 b) Measurement of hydraulic conductivity

Depth to Water Table

For monitoring the ground water table fluctuations, 10 no. of observation wells were installed to a depth of 3 m in the study area in the month of August, 2018 as shown in [Fig-4]. The depth to water table was measured at weekly intervals. The water table was observed to remain almost at the ground surface during the crop season because of irrigation and rainfall and went down to 2.65m depth during the summer.

Fig-4 Installation of observation well

Soil Properties

To study the physical characteristics of soils at pilot area, soil samples were collected at different points from the field and analyzed. Bulk density, drainable porosity, field capacity, particle size analysis is shown in [Fig-5] and soil colour were analyzed. Soil colour was measured using Munsell colour chart and expressed in terms of Hue, Value and Chroma. Hue denotes the dominant spectral colour. Value denotes the intensity of colour. Chroma denotes the purity of colour.

Fig-5 Conducting mechanical sieve analysis

Drainable Porosity

Drainable porosity is one of the basic input parameters for predicting the water table fluctuations and fro the computation of drain spacing. The importance of the soil drainable porosity in subsurface drainage design results from its effect on the drainage flow rate (drainage coefficient). High drainable porosity means more water could be drained when the water table is lowered by a specific depth. Chossat (1987)[8], carried out extensive studies on correlation between hydraulic conductivity and drainable porosity and developed certain equations. For soils with clay contents between 15% to 30% is as follows:

$$f = 0.033K_{sat}^{0.289} \quad (3)$$

Where, f is drainable porosity in fraction and Ksat is saturated hydraulic conductivity in m/day.

Analysis of Rainfall Data

Rainfall data of ten years (from 2008 to 2017) for the study area was collected and analyzed. It was observed from the data that the daily rainfall is found to be very high in the month of September. Weibull's technique was adopted to carry out the rainfall probability analysis. The rainfall data are analyzed for one, two three, four and five consecutive day's storms. The relationship between depth, duration and frequency was established for the location which will be helpful in deciding the design rainfall for any number of consecutive days from one to five and for any recurrence interval (R.I), *i.e.* from one to ten years. Analysis was carried out as follows, to get the depth, duration and frequency relationship.

1. Recorded one day, two days, three days, four days and five days consecutive rainfalls were calculated for the 10 years duration.
2. The rainfall depth in descending order was allotted for each number of consecutive days, separately.
3. Top 10 sets of rainfall in each case of 1 to 5 days consecutively were taken and ranked them for 1 to 10.
4. Frequency of exceedance was determined which gives unbiased plotting position which is given by r/(n+1), where, r = rank of storm, n = total number of observations i.e. 10.
5. The percentage chances were found for occurrence of a given storm = plotting position x 100.
6. A recurrence interval (RI) was allotted to each storm which is equal to 1/percentage chance x 100.
7. With help of above analysis, graphs were drawn for recurrence interval of different storms of various durations.

Depth Duration Frequency Relationship

After plotting graphs between depths of rainfall expected in 1 to 10 years, R.I. in one, two, three, four and five consecutive day's period, the rainfall for any duration of R.I and any number of consecutive days was calculated. Combining all these graphs, a single graph was prepared to present the relationship between depth of rainfall to number of consecutive days and various recurrence intervals.

Estimation of Drainage co-efficient

The drainage discharge rate (drainage coefficient) is the important parameter for the design of subsurface drainage system. The drain discharge rate is observed by computing water balance equation for crop season on the basis of rainfall analysis, leaching requirement during the irrigation season and lowering water table below root zone in any season. The practically feasible value of drainage coefficient among the estimated values has been considered for the design purposes.

Basis I

As an attempt towards finding the leaching requirement, a simple water balance approach was adopted. Firstly, the 10-year monthly rainfall were arranged in a descending order table for each of 12 months. The 75% probable value of monthly rainfall were worked out by ranking method and the cumulative monthly rainfall at 75% probability level of being equaled or exceeded have been plotted. The cumulative monthly evapotranspiration was also plotted in the same graph. Leaching requirement is given by formula [9].

$$LR = \frac{(E-P)C_i}{F(Cf_c-C_i)} \qquad (4)$$

Where, LR = leaching requirement, mm

E = evapotranspiration, mm

P = effective precipitation, mm

Ci = average irrigation water salt concentration, meq/l

F = leaching efficiency

Cfc = average salt concentration of soil at field capacity, meq/l

Concentration in meq/l = 12 x concentration in dS/m

Concentration at field capacity = 2 x concentration of 1:2 saturation extract

Basis II

Taking the average salinity of irrigation water from canals as 1 dS/m, additional water to be supplied to meet the leaching requirement for maintaining proper long-term salt balance in the profile was calculated by using the following formula [10]:

$$R^* = \frac{(E-P)EC_i}{f(2EC_e-EC_i)} \qquad (5)$$

Where, R* = leaching requirement, mm

E = evapotranspiration, mm

P = effective precipitation, mm

F = leaching efficiency coefficient

ECi = mean salinity of irrigation water, dS/m

ECe = desired salinity of soil saturation extract, dS/m

Basis III

To prevent any damage to crops, the water table needs to be lowered below root zone within the critical duration. The drainage coefficient for such situations is computed using formula as follows [10]

$$q = \frac{d_r \times n}{t} \qquad (6)$$

Where, q = drainage coefficient, mm

dr = depth of root zone, mm

n = drainable pore space (on volume basis)

t = critical time for commonly grown crops

Results and Discussion

Drainage measures [Table-1] are generally location specific and vary according to soil, climate, irrigation and cropping pattern, etc. Information on hydraulic conductivity, rainfall probability, ESP, EC, pH, quality of irrigation water and N, P, K of the soil, *etc* are very much required to design the drainage systems. It is advisable to foresee the minimum data requirement and plan for obtaining these data for a specific project to design and execution of drainage systems.

Table-1 *Design parameters after drainage investigations*

Parameter	Average value
pH of soil	8.32
EC of soil	3.18 dS m^{-1}
ESP	30.5%
pH of canal water	7.18
pH of drain water	7.30
EC of canal water	1.50 dS m^{-1}
EC of drain water	2.43 dS m^{-1}
N	130 kg ha^{-1}
P	18 kg ha^{-1}
K	760 kg ha^{-1}

Table-2 *Soil physical properties*

Physical property	Value
Bulk density	1.38 g cm^{-3}
Drainable porosity	2.98 %
Field capacity	30.6 %
Particle size distribution	Clay loam
1. Sand	45 %
2. Silt	25 %
3. Clay	30 %
Soil colour	Dark grey (7.5 YR 4/1) Hue: 7.5 YR, Value: 4, Chroma: 1

The contour map was prepared for the study area with a contour interval of 0.02m as shown in [Fig-6]. The map shows that the area is sloping in west-east direction by about 0.3% slope. The elevation difference between the highest and lowest points is about 1.24m. Physical properties of the soil analyzed are shown in [Table-2].

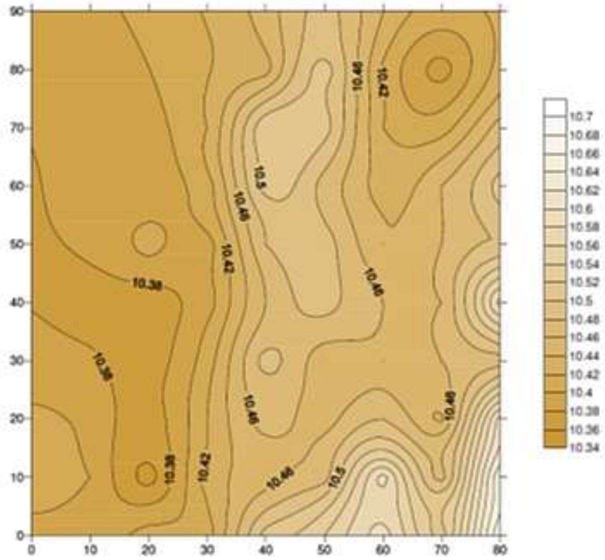


Fig-6 Contour map of experimental field

Analysis of Rainfall Data

The ten years (2008-2017) data analyzed shows that there is much variation in the annual rainfall. The minimum annual rainfall recorded as low as 714.8 mm whereas the maximum value was 2254.8 mm. The average annual rainfall is computed as 1160.41 mm. The variation in annual rainfall was shown in [Fig-7]. Daily rainfall data from 2008 to 2017 were analysed to find out maximum one, two, three, four and five consecutive days rainfall at different recurrence interval. [Table-3 to 7] presents the frequency analysis of 1, 2, 3, 4 and 5 consecutive day's rainfall respectively. The trend between rainfall and its recurrence interval is shown in [Fig-8].

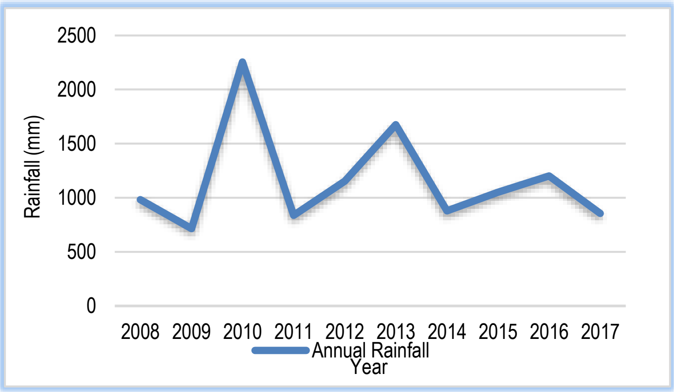


Fig-7 Fluctuation of annual rainfall at Bapatla region (2008-2017)

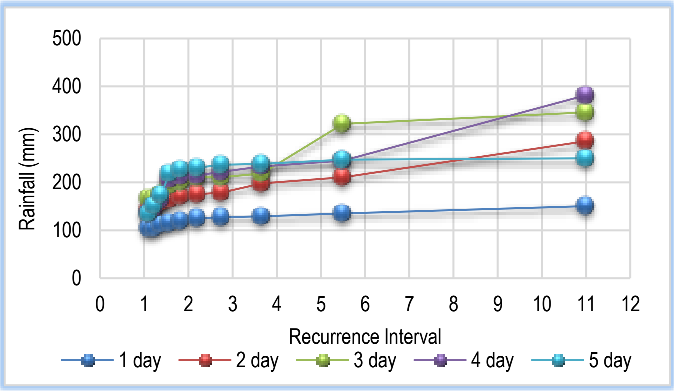


Fig-8 Rainfall depth for various recurrence intervals and for 1,2,3,4 and 5 consecutive days

Table-3 *Frequency analysis for one - day duration rainfall from 2008 -2017*

SN	Date	Rainfall	Total rainfall	Rank	Plotting position	% chance	RI
1	2/11/2012	150.5	150.5	1	0.09	9.09	11.00
2	3/11/2012	135.5	135.5	2	0.18	18.18	5.50
3	3/11/2010	129.5	129.5	3	0.27	27.27	3.67
4	30/8/2010	127	127	4	0.36	36.36	2.75
5	17/7/2010	125.4	125.4	5	0.45	45.45	2.20
6	15/11/2010	120	120	6	0.54	54.54	1.83
7	29/9/2009	116.2	116.2	7	0.63	63.64	1.57
8	22/9/2016	112.5	112.5	8	0.72	72.73	1.37
9	14/11/2014	105.4	105.4	9	0.81	81.82	1.22
10	19/5/2016	105	105	10	0.90	90.91	1.1

Table-4 *Frequency analysis for two - day duration rainfall from 2008 -2017*

SN	Date	Rainfall	Total rainfall	Rank	Plotting position	% chance	RI
1	2/11/2012	150.5	150.5	1	0.09	9.09	11.00
2	3/11/2012	135.5	135.5	2	0.18	18.18	5.50
3	3/11/2010	129.5	129.5	3	0.27	27.27	3.67
4	30/8/2010	127	127	4	0.36	36.36	2.75
5	17/7/2010	125.4	125.4	5	0.45	45.45	2.20
6	15/11/2010	120	120	6	0.54	54.54	1.83
7	29/9/2009	116.2	116.2	7	0.63	63.64	1.57
8	22/9/2016	112.5	112.5	8	0.72	72.73	1.37
9	14/11/2014	105.4	105.4	9	0.81	81.82	1.22
10	19/5/2016	105	105	10	0.90	90.91	1.1

Table-5 *Frequency analysis for three - day duration rainfall from 2008 -2017*

SN	Date	Rainfall	Total rainfall	Rank	Plotting position	% chance	RI
1	1/11/2012	60.0	346.0	1	0.09	9.09	11.00
	2/11/2012	150.5					
	3/11/2012	135.5					
2	2/11/2012	150.5	321.8	2	0.18	18.18	5.5
	3/11/2012	135.5					
	4/11/2012	35.8					
3	27/8/2016	20.4	218.4	3	0.27	27.27	3.67
	28/8/2016	95.2					
	29/8/2016	102.8					
4	22/10/2013	35.2	210.7	4	0.36	36.36	2.75
	23/10/2013	85.0					
	24/10/2013	90.5					
5	23/10/2013	85.0	210.5	5	0.45	45.45	2.2
	24/10/2013	90.5					
	25/10/2013	35.0					
6	28/8/2016	95.2	201.5	6	0.54	54.55	1.83
	29/8/2016	102.8					
	30/8/2016	3.5					
7	20/5/2010	81.2	193.6	7	0.63	63.64	1.57
	21/5/2010	97.4					
	22/5/2010	15.0					
8	29/8/2010	37.4	174.4	8	0.72	72.73	1.375
	30/8/2010	127					
	31/8/2010	10.0					
9	28/11/2008	60.0	166.4	9	0.81	81.82	1.22
	29/11/2008	90.4					
	30/11/2008	16.0					
10	15/8/2009	100.0	166.4	10	0.90	90.91	1.1
	16/8/2009	40.2					
	17/8/2009	26.2					

Values of rainfall at 1, 2, 3, 4, 5, 6, 7, 8, 9- and 10-years recurrence interval are interpolated from [Fig-8] and plotted against number of consecutive days and is shown in [Fig-9]. The values of depth, duration and frequency of different rainfall are given in [Table-8]. The corresponding graph could be used to determine the designed rainfall of any duration ranging from one to five days at recurrence interval varying from one to ten years. The analysis of rainfall was used in estimation of drainage coefficient as one of the parameters.

Estimation of drainage coefficient

Basis I

The graphical relationship between cumulative ETo and cumulative rainfall was shown in [Fig-10]. The maximum deficit of rainfall of 1554.09mm was found in December [Fig-10]. The following values are substituted in the Equation 3 & 4 and the results are as follows.

E-P = 1554.04 mm

F = 0.4

Ci = 12 x 1 = 12 meq/l

Cfc = 2 x 12 x 3.14 = 75.36 meq/l

$$LR = \frac{(1554.04)12}{0.4(75.36-12)} = 735.81\ mm$$

Dividing this by 31 (No. of days in December), the drainage coefficient is obtained as 23.73 mm/day, which is considered to be very high for all practical purposes for the design of subsurface drainage system and not considered.

Table-6 Frequency analysis for four - day duration rainfall from 2008 -2017

S	Date	Rainfall	Total rainfall	Rank	Plotting position	% chance	RI
1	1/11/2012	60.0	381.8	1	0.09	9.09	11
	2/11/2012	150.5					
	3/11/2012	135.5					
	4/11/2012	35.8					
2	22/10/2013	35.2	245.7	2	0.18	18.18	5.5
	23/10/2013	85.0					
	24/10/2013	90.5					
	25/10/2013	35.0					
3	26/8/2016	15.0	233.4	3	0.27	27.27	3.67
	27/8/2016	20.4					
	28/8/2016	95.2					
	29/8/2016	102.8					
4	27/8/2016	20.4	221.9	4	0.36	36.36	2.75
	28/8/2016	95.2					
	29/8/2016	102.2					
	30/8/2016	3.5					
5	23/10/2013	85.0	215.0	5	0.45	45.45	2.2
	24/10/2013	90.5					
	25/10/2013	35.0					
	26/10/2013	4.5					
6	21/10/2013	2.0	212.7	6	0.54	54.55	1.83
	22/10/2013	35.2					
	23/10/2013	85.0					
	24/10/2013	90.5					
7	28/8/2016	95.2	206.0	7	0.63	63.64	1.57
	29/8/2016	102.2					
	30/8/2016	3.5					
	31/8/2016	4.5					
8	16/7/2013	50.1	164.0	8	0.72	72.73	1.38
	17/7/2013	35.0					
	18/7/2013	50.5					
	19/7/2013	28.4					
9	24/10/2013	90.5	145.5	9	0.81	81.82	1.22
	25/10/2013	35.0					
	26/10/2013	4.5					
	27/10/2013	15.5					
10	25/8/2016	5.2	135.8	10	0.90	90.91	1.1
	26/8/2016	15					
	27/8/2016	20.4					
	28/8/2016	95.2					

Basis II

For the months of August to January (*Kharif*) period, the P and E values are as presented in Table 9 and 10.

P = 449.31 mm

E = 943.72 mm (10-year average weather data 2008-2017)

F = 0.4

ECi = 1 dS/m

ECe = 3.27 dS/m

$$R^* = \frac{(943.72 - 449.31)1}{0.4(2(3.27) - 1)} = 222.44\ mm$$

Table-7 *Frequency analysis for five - day duration rainfall from 2008 -2017*

S	Date	Rainfall	Total rainfall	Rank	Plotting position	% chance	RI
1	22/10/2013	35.2	250.2	1	0.09	9.09	11
	23/10/2013	85.0					
	24/10/2013	90.5					
	25/10/2013	35.0					
	26/10/2013	4.5.0					
2	21/10/2013	2.0	247.7	2	0.18	18.18	5.5
	22/10/2013	35.2					
	23/10/2013	85.0					
	24/10/2013	90.5					
	25/10/2013	35.0					
3	25/8/2016	5.2	238.6	3	0.27	27.27	3.67
	26/8/2016	15.0					
	27/8/2016	20.4					
	28/8/2016	95.2					
	29/8/2016	102.8					
4	26/8/2016	15.0	236.9	4	0.36	36.36	2.75
	27/8/2016	20.4					
	28/8/2016	95.2					
	29/8/2016	102.8					
	30/8/2016	3.5					
5	23/10/2013	85.0	230.5	5	0.45	45.45	2.2
	24/10/2013	90.5					
	25/10/2013	35.0					
	26/10/2013	4.5					
	27/10/2013	15.5					
6	27/8/2016	20.4	226.4	6	0.54	54.55	1.83
	28/8/2016	95.2					
	29/8/2016	102.8					
	30/8/2016	3.5					
	31/8/2016	4.5					
7	28/8/2016	95.2	219	7	0.63	63.64	1.57
	29/8/2016	102.8					
	30/8/2016	3.5					
	31/8/2016	4.5					
	1/9/2016	13.0					
8	16/7/2013	50.1	174.2	8	0.72	72.73	1.375
	17/7/2013	35.0					
	18/7/2013	50.5					
	19/7/2013	28.4					
	20/7/2013	10.2					
9	18/7/2013	50.5	152.1	9	0.81	81.82	1.22
	19/7/2013	28.4					
	20/7/2013	10.2					
	21/7/2013	3.0					
	22/7/2013	60.0					
10	29/8/2016	102.8	135.4	10	0.90	90.91	1.1
	30/8/2016	3.5					
	31/8/2016	4.5					
	1/9/2016	13.0					
	2/9/2016	11.6					

Table-8 *Depth, duration and frequency of different rainfall (in mm)*

No. of consecutive	Recurrence Interval in years									
days	1	2	3	4	5	6	7	8	9	10
1	105	122	128	131	134	137	140	142	145	148
2	138	173	184	200	207	217	231	245	259	272
3	163	206	213	238	294	324	328	333	337	342
4	128	215	225	236	242	258	283	308	332	357
5	121	228	237	240	245	248	248	249	249	250

Assuming leaching can be done in once in 2 days. For the months of August to January, total 75 days it should be leached.

$$d_c = \frac{222.44}{75} = 2.96\ mm/day$$

Basis III

In this case, by considering crop as rice and water table is to be lowered to 30 cm in three days period and substituting the values of drainable porosity as 3.1%, the q value was worked out as 3.1 mm. Lowering of water table by 30 cm in three days means, on an average 10 cm depth of lowe1ing of water table from the soil surface in a day. Therefore, the drainage coefficient is equivalent to 1.03 mm/day (for crops other than rice). As the estimated drainage coefficient varied from 1.03 to 2.96 mm. A higher value of 2.96 mm/day was taken as the drainage coefficient to meet the drainage needs of all the situations. Calculation of drainage co-efficient on the above three criteria is given in the following [Table-11].

Table-9 *Monthly rainfall and cumulative values from 2008-2017*

Month	Rainfall	Cum. Rainfall
January	8.9	8.9
February	9.43	18.33
March	1.0	19.33
April	11.93	31.26
May	5.5	36.76
June	35.2	71.96
July	98.2	170.16
August	176	346.16
September	156.1	502.26
October	60.4	562.66
November	32.5	595.16
December	15.41	610.57

Table-10 *Monthly ETo and Cumulative values for the period of 2008-2017.*

Days	Month	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Avg.	Cum. Et_o
31	Jan	121.8	122.7	122.4	114.9	118.2	121.5	121.8	124.8	120	121.8	120.9	120.99
29,28	Feb	133.4	131.0	129.0	129.3	131.0	148.4	130.7	130.4	137.7	130.4	133.1	254.17
31	Mar	171.4	174.5	174.5	172.0	171.4	180.7	175.4	178.5	175.4	179.8	175.4	429.57
30	Apr	186.9	204.9	199.5	183.9	192.6	200.1	201.6	203.4	200.7	200.7	197.4	627.00
31	May	287.6	236.2	237.4	243.9	248.9	241.1	249.5	276.8	230.6	237.1	248.9	875.96
30	June	238.5	281.1	228	257.4	257.1	234.6	268.8	204.9	201	211.5	238.2	1114.25
31	July	220.1	283.6	194.3	223.8	215.4	209.8	246.1	248.6	218.2	216.0	227.6	1341.89
31	Aug	187.2	228.1	179.1	205.8	204.2	204.6	215.1	200.8	220.7	189.4	203.5	1545.43
30	Sept	192	195.3	176.7	195.6	181.8	181.2	192	184.8	181.5	180.6	186.1	1731.58
31	Oct	172.3	178.2	167.4	164.9	168.9	162.1	175.7	172.3	169.2	166.7	169.8	1901.40
30	Nov	138	135.9	135.3	139.8	135	134.7	134.1	140.4	138.3	137.4	136.8	2038.29
31	Dec	125.5	128.6	123.0	130.8	126.4	124.6	125.5	128.6	125.5	124.3	126.3	2164.61

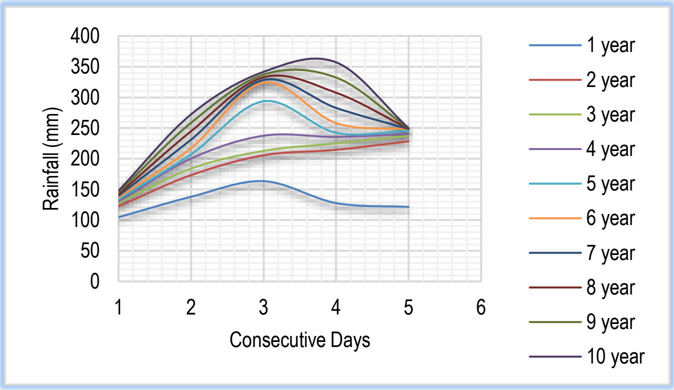


Fig-9 Depth, duration and frequency relationship of rainfall at Bapatla region

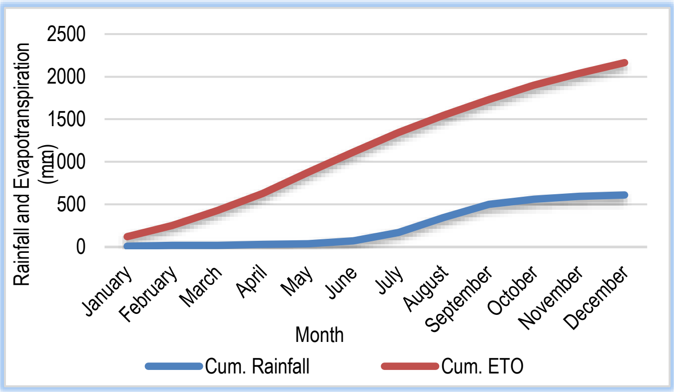


Fig-10 Simple water balance of the study area

Table-11 *Estimation of drainage co-efficient on the Basis I, II, III*

Basis	Drainage co-efficient
I	23.73 mm/day
II	2.96 mm/day
III	1.03 mm/day

Conclusion

For the reclamation of waterlogged fields near Bapatla region, pre drainage investigations were carried out. Based on the auger hole method, hydraulic conductivity value was found to be 0.709 m/day. To identify the nature of soil and the nutrients present in the soil, physical and chemical tests have been executed. Rainfall data for ten-year period was analyzed and plotted depth, duration and frequency curves. Drainage coefficient for the study area was estimated as 2.96 mm/day based on water balance equation and leaching requirements. From all the above results, it is concluded that the soil is affected by twin problems of salinity and waterlogging. Hence, reclamation measures are highly required for enhancing the productivity.

Application of research: This article has been prepared with the objective of giving information's on waterlogging and soil salinity problems. The investigations into the problem resulted in a recommendation that drainage should be planned for long term benefits of irrigation field.

Research category: Agricultural Engineering

Abbreviations: dc- Drainage coefficient, EC- Electrical conductivity, ETo- Reference evapotranspiration, RI- Recurrence interval.

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University: Acharya N.G. Ranga Agricultural University, Guntur, 522034
Research project name or number: PhD Thesis

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Bapatla region

Cultivar / Variety / Breed name: Rice

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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