Hydrological Simulation Of A Rainfed Minor Irrigation Tank

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Abstract

Minor irrigation schemes play an important role in the rural livelihoods and economy of Andhra Pradesh state. The state has 12,351 MI tanks with an individual ayacut exceeding 40 ha commanding a total ayacut of 12.5 lakh hectares. The majority of these tanks are non-system fed tanks receiving inflows entirely from rainfall. In this paper it is attempted to study the assessment of physical benefits of one such non-system fed tank viz. Chittivalasa MI tank located in Bheemunipatnam mandal in Visakhapatnam district of Andhra Pradesh, India through hydrological simulation for 30 years. Strange's runoff model is used to compute inflows in to the tank. Modified penman method is used to compute crop water requirements. Such studies become necessary for the design of new MI tanks or for taking up rehabilitation of existing MI tanks for carrying out techno-economic feasibility to examine whether sufficient inflows are available from the upstream catchment areas for the prevailing spatial and temporal distribution of rainfall.

***Keywords** - Minor irrigation tanks, Hydrological Simulation, Assessment of physical benefits, Strange's runoff model, Modified penman method for computing crop water requirement*

1. Introduction

Minor irrigation schemes have been the backbone of agriculture in Andhra Pradesh as is the case with India as a whole. The importance of these schemes in the Indian agriculture sector was highlighted by the First Irrigation Commission (1901-03) and the Royal commission of Agriculture (1928). The crucial role that minor irrigation could play in augmenting food production with in a short time was specially recognized in the "Growmore" food campaign launched in 1943.

The planning commission, since its inception, has been stressing the importance of minor irrigation schemes in increasing food production. Page 251 of first five year plan says that "they (minor irrigation schemes) provide large amount of dispersal employment. They involve smaller outlay and can be executed in a comparatively shorter period. Being spread all over the country they confer widespread benefit and it is therefore easier to mobilize public cooperation in their construction". The food grain enquiry committee (1952) also reiterated the need for paying greater attention to the MI works for the purpose of encouraging food production.

1.1 Description about Andhra Pradesh

Andhra Pradesh state ranked fifth in both area and population of the country. About 75 percent of the state's population lives in rural areas and they largely depend on agriculture for their sustenance. The state has a geographical area of 274.4 lakhs ha.

1.2 Agriculture Sector in Andhra Pradesh

The state cultivates a net sown area of 106.4 lakhs ha accounting for 38.8% of the total geographical area of the state. The share of agriculture sector in the gross state domestic product (GSDP) stands at 28.3%. The average annual growth rate of agriculture sector during the last five year period stands at 3.9 percent. Negative growth rate was observed in the years 1994-95 and 1997-98.

1.3 Irrigation Sector in Andhra Pradesh

Aided by 40% of net sown area under irrigation, AP has a cropping intensity of 122 percent. The net irrigated area of 44.5 lakhs ha is contributed from canals (38%) and tanks (17%); and the balance by wells, tube wells and other wells (45%). In the last three decades, net irrigated area has increased from 29.6 lakhs ha to 41.5 lakhs ha. Canal irrigated area has gone up from 13.02 lakhs ha to 15.7 lakhs ha during this period but its share in net irrigated area has come down from 45 to 38%. Tanks with a net irrigated area of 10.7 lakhs ha accounted for 36% of the net irrigated area in triennium ending 1968. But in triennium ending 1998, tanks irrigated only 7.2 lakhs ha accounting for only 17% of the net irrigated area.

"Tanks as a source of irrigation in 1960s through 1990s have therefore, depressed the overall growth in net irrigated area"

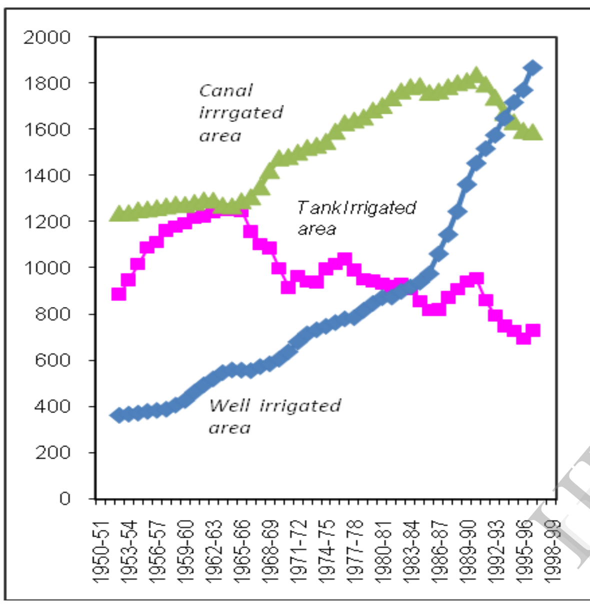


Figure 1. Declining trend in area irrigated by tanks in AP, 5-year moving average ('000 ha)

1.4 Minor Irrigation Sector in Andhra Pradesh

Minor Irrigation schemes occupy a prominent place in the history of irrigation development in the state of Andhra Pradesh. The state has 12,351 MI sources as of now commanding a total ayacut of 12.5 lakh hectares which is maintained by Irrigation department. In addition to these, there are small tanks commanding an ayacut of less than 40 ha. About 70, 474 such small tanks commanding a total ayacut of over 6 lakh ha is maintained by Panchayat Raj department. During the last decade, only 9,147 MI sources out of the total of 12,351 MI sources were actually functioning in the state indicating that nearly one-fourth of the MI tanks failed to irrigate any area during this period.

1.5 Degeneration of MI Tanks

Degeneration in tank irrigation system is an established trend. This is because of deterioration in the components of these tank systems from the originally designed standards. The affected components are feeder channels, bunds, revetment of bund, sluices, shutters, irrigation canals and surplus courses. As a consequence, they have become inefficient in receiving the due share of waters from the upstream catchment areas, in holding the storage at designed levels at different stages of irrigation or in distributing the waters in the envisaged command areas. To study the performance of these tanks, it is necessary to examine whether the designed inflows are available from the upstream catchment areas for the prevailing spatial and temporal distribution of rainfall. Further it is necessary to examine even in case adequate flows are forthcoming, whether the tanks with ideal conditions of the components, will be able to alter the inflow hydrology to the desired outflow patterns.

1.6 Identification of Problem

In the above context, it is proposed to take up hydrological analysis of a typical minor irrigation tank located in a rainfed area to study its inflow hydrology and desired outflow patterns.

1.7 Problem Definition

For studying the inflow hydrology and desired outflow patterns of an MI tank, it is necessary to carryout hydrological simulation using appropriate model for runoff computation. In the present study, Strange's runoff model is identified and adopted for this purpose.

1.8 Study Area

One minor irrigation tank known as Large tank (Pedda Cheruvu in Telugu) existing in the Chittivalasa village (Latitude – 17° 26' 10", Longitude – 83° 26' 10") of Bheemunipatnam mandal in Visakhapatnam district of Andhra Pradesh state, India is selected as the study area. The tank is maintained by Irrigation and Command area development department of Government of Andhra Pradesh.

The climate in the study area is normally hot and humid. The temperature ranges from 18^{o}C in December to 37^{o}C in May. Sandy loamy soils are present in the study area. The study area is influenced by South-West and North-East monsoons. The study area experiences drought conditions often, as no major irrigation system exists to cushion the vagaries of the monsoon. Hence farmers here mostly depend on the rainfed MI tanks for irrigating their fields.

1.9 Objective of the Study

The objective of the present study is to carryout hydrological simulation for the assessment of physical benefits of a typical rainfed minor irrigation tank located in Chittivalasa village of Bheemunipatnam mandal in Visakhapatnam district of Andhra Pradesh, India.

1.10 Scope and Limitations of the Study

The scope and limitations of the present study are given below.

1. To carryout hydrological simulation for the assessment of physical benefits of MI tank at Chittivalasa for 30 years from 1978-79 to 2007-08.
2. The MI tank is assumed to be in ideal conditions
3. Bheemunipatnam raingauge station is assumed to be the only available influencing raingauge station in the catchment area.
4. 30 years monthly rainfall data recorded at Bheemunipatnam raingauge station is considered as the basic input
5. The effective catchment area is calculated by considered 100% of free catchment area and 50% of intercepted catchment area
6. Strange's runoff model is selected for computing runoff yields.
7. Two cropping seasons kharif and rabi are considered for assessing benefits
8. Paddy is the only identified cropping pattern in the study area
9. Modified penman method is used to calculate the crop water requirement
10. Appropriate agronomical inputs have been assumed.

1.11 Significance of the Study

The study assumed special significance in the context of assessing the benefits of an MI tank which will be carried out in a systematic manner. For the design of new MI tanks or for taking up rehabilitation measures for the existing MI tanks, it is necessary to study he techno-economic feasibility of the projects before making investments. For carrying out such techno-economic feasibility studies, it is necessary to examine whether sufficient inflows are available in the upstream catchment areas for the prevailing spatial and temporal distribution of rainfall. Further it becomes necessary to examine even incase adequate flows are forthcoming, whether the tanks with ideal conditions of the components will be able to alter the inflow hydrology to the desired outflow patterns.

2. Review of Literature

Hydrological simulation model may be defined as generalization of an organized methodology based on standard techniques which are repetitive and iterative in nature. A hierarchical scheme for the systematic testing of hydrological simulation models was proposed by V. Klemes [1] in the early 1986.

Shu-Li Huang and John D. Keenan [2] have developed a deterministic hydrological model by integrating the integral empirical relationships and applied to the Brandywine basin located in south eastern Pennsylvania and northern Delaware in the year 1987.

Krishna Moan M et al. [3] was the first to devise a hydrological simulation model in the year 1999 for MI tanks based on 75% and 50% dependability rainfall and applied the model for assessing the simulated physical benefits of 384 MI tanks located in various districts of Andhra Pradesh.

The hydrological simulation model was applied to assess the simulated physical benefits of 2,596 other MI tanks in Andhra Pradesh under APERP in the year 2000 [4].

During the year 2001, the simulated physical benefits of various MI tanks proposed under APIII were assessed using this hydrological simulation model [5].

In the present hydrological simulation model, it is proposed to assess the actual year wise simulated physical benefits of MI tanks rather than considering the 75% and 50% dependability rainfall and in that it is an improvement over the previous model developed and applied by Krishna Mohan M et. al. [3], [4], [5].

3. Data Inputs

Data is collected on Tank Geometry, Rainfall, Pan Evaporation, Potential evapotranspiration values of the study area from various agencies. The collected data is analysed using standard techniques and the inputs for the model were prepared.

3.1 Tank Geometry

The Chittivalasa MI tank is situated in the latitude of 17° 56’ 10” and longitude of 83°26’ 10” has the following dimensions. The tank bund is of homogeneous embankment type. The bund has a length of 643 metres. The top width of the bund is 1.2 metres and bottom width is 8 metres. The capacity of the tank at FTL is 0.165 M.cu.m. The waterspread area of the tank at FTL is 0.1020 M. sq.m.

Table 1: Tank Geometry of Chittivalasa MI tank

Basin	Gosthani
Sub basin	IX
Catchment area - Free	2.3175 Sq.km.
Intercepted area	1.420 Sq.km
Effective Catchment area	2.5175 + 20% (1.42) = 2.8015 Sq.C10km
Effective Catchment area considered for simulation	2.5175 + 50% (1.42) = 3.2275 Sq.km.
Water spread Area	10.2 hectares = 0.102 M.sq.m
Live Storage of Tank	5.3 Mcft = 0.145 M.Cum
Gross Storage of Tank	0.145 * 1.1 = 0.165 M.cum.
Registered Ayacut	40 hectares
Tank Bund length	643 m
Bund top width	1.2 m
Bund bottom width	8 m
Slopes	1.5 : 1 - Water front side 2:1 - Rear side
Full Tank Level-FTL	15.85 m
Maximum Water Level - MWL	16.45 m
Tank Bund Level - TBL	17.04 m
Length of Surplus Weir	15.30 m
Number of sluices	3, +8.75 m, +8.52 m, + 8.33 m

Figure 2. A view of waterspread area of Chittivalasa MI tank

3.2 Catchment Area

The MI tank is identified on the SOI toposheet No 65 O/5 and the catchment area is marked with greater accuracy duly verifying the contour values along the ridges and valleys. The free as well as intercepted catchment areas were marked accordingly.

The catchment area is measured with the help of planimeter. The free catchment area of the tank is measured as 2.5175 sq.km and intercepted catchment area is found to be 1.42 sq.km. The effective catchment area is worked out using the following formula.

Effective catchment area = Free catchment area + (20% * Intercepted catchment area)

The effective catchment area comes to around 2.8015 sq. km.

3.3 Command Area

The Registered ayacut of the tank is 40 ha. Usual cropping pattern in the command area is Paddy in both Kharif and Rabi. A part of the command area of the MI tank is shown below.

Figure 3. A view of command area of Chittivalasa MI tank

3.4 Rainfall

The monthly rainfall data recorded at Bheemunipatnam raingauge station has been collected for 30 years from 1978-79 to 2007-08. The data is arranged in sequence from June to May as the hydrological year starts from June in the study area. Annual rainfall is computed and presented in the following tables. It is observed that highest annual rainfall is recorded during 1985-86 with a magnitude of 2470.9 mm and the lowest annual rainfall is recorded during 2002-03 with a magnitude of 473.4 mm. The annual rainfall of above 1000 mm is recorded in another 10 years during 1986-87 (1776.6 mm), 1989-99 (1429.3 mm), 1989-90 (1375.8 mm), 2005-06 (1307.7 mm), 1992-93 (1190.2 mm), 1987-88 (1152.2 mm), 1994-95 (1145.6 mm)1982-83 (1142.7 mm), 1996-97 (1128.2 mm), 2006-07 (1014.5 mm).. Below normal rainfall of less than 800 mm is recorded in another 5 years during 2001-02 (776.6 mm), 1993-94 (693.8), 1999-00 (648.2),1984-85 (628 mm), 2007-08 (605.4 mm.).

Mean monthly rainfall distribution shows that the study area is receiving most of the rainfall during 5 months starting from June to October in any year. Maximum amount of mean monthly rainfall is observed highest in October followed by August, September, June and July. But the standard deviation is fluctuating from 64.47 in July to 258.13 in August while the coefficient of variation is fluctuating from 0.53 in July to 1.28 in August.

The 3-year moving average shows a maximum value of 1799.9 mm and a minimum value of 701.8 mm, and 5-year moving average shows a maximum value of 1545.94 mm and 836.6 mm. According to Weibull's plotting position, the 75% dependability rainfall works out to be 628 mm and 50% dependability rainfall works out to be 940.6 mm.

Table 2. Monthly and annual rainfall data in mm

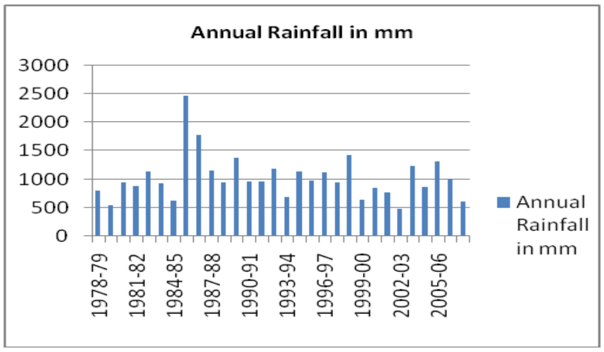
MONTHLY RAIN FALL DATA FROM 1978-79 TO 2007-08

DISTRICT : Visakhapatnam   Raingauge Station: Bheemunipatnam

Note : This rainguage Station Influences the Catchment area of the Chittivalasa MI tank.

All units are in mm

Year	June	July	August	September	October	November	December	January	February	March	April	May	Total Annual Rainfall
1978-79	93.3	184.4	154.4	63	46.8	86.2	0	0	39.2	0	0	139.7	807
1979-80	190	60	70.2	153.7	0	0	0	0	0	0	18.6	59.2	551.7
1980-81	123	129	139.8	74.6	317	16.6	1.8	7.8	3.2	30.6	22	87.7	953.1
1981-82	50.6	94.8	143.9	413.4	32	55.7	0	0	0	0	76.2	17	883.6
1982-83	93.8	159	60.3	92.8	600.6	42.2	0	0	18.6	0	0	75.4	1142.7
1983-84	186.6	158.4	160.6	70.4	310.2	0	22.2	9.2	15.2	0	0	2	934.8
1984-85	27.4	124.6	252.7	93.6	42	15.5	2	44.2	0	0	0	26	628
1985-86	88.6	103.1	1469.8	116.6	349.2	126.2	0	0	18.4	3.2	58.4	137.4	2470.9
1986-87	74.6	70	594.4	168	383.4	354.9	26.5	25	0	3.6	22.8	53.4	1776.6
1987-88	28.7	30.4	148.5	169.6	287	414.6	1	0	0	0	27	45.4	1152.2
1988-89	57.2	228.3	170.2	232.4	96.9	6.2	3.6	0	0	28.8	43	87.6	954.2
1989-90	96.8	253.2	122	94.2	56.8	0	0	18.4	102.8	175.8	39.6	416.2	1375.8
1990-91	61.8	150.8	219.6	122.6	218.8	121.4	6	42.4	0	0	12	7.4	962.8
1991-92	217.4	111.2	31	208.2	224.8	138.8	0	0	0	0	0	31.4	962.8
1992-93	104	83.2	165.2	93.6	160	334.2	0	0	0	0	19	231	1190.2
1993-94	104.4	46.6	52.0	150.6	225.8	8.2	0.0	26.0	0.0	0.0	5.6	74.6	693.8
1994-95	27.6	154.2	126.8	116.8	281.0	74.8	0.0	61.2	0.0	4.8	0.0	298.4	1145.6
1995-96	74.0	159.0	109.8	110.5	391.8	117.6	7.2	0.0	5.8	0.0	0.0	7.0	982.7
1996-97	471.4	35.4	223.8	160.6	208.6	15.8	12.6	0.0	0.0	0.0	0.0	0.0	1128.2
1997-98	62.8	207.2	261.8	238.0	0.0	0.0	0.0	60.4	82.4	0.0	14.0	14.0	940.6
1998-99	146.4	220.8	196.4	292.2	427.2	70.5	0.0	0.0	0.0	0.0	0.0	75.8	1429.3
1999-00	166.8	62.4	73.4	76.0	95.6	24.6	0.0	0.0	98.6	0.0	19.8	31.0	648.2
2000-01	305.8	69.9	219.0	103.6	84.6	5.6	0.0	3.0	0.0	10.6	11.0	42.4	855.5
2001-02	56.8	97.6	91.4	97.6	269.6	0.0	0.0	17.2	0.0	0.0	115.2	31.2	776.6
2002-03	123.4	42.2	105.0	72.8	63.4	0.0	0.0	8.2	12.8	8.2	0.0	37.4	473.4
2003-04	34.4	221.6	123.6	174.0	399.4	0.0	66.8	106.6	2.4	0.0	77.6	30.6	1237
2004-05	194.0	188.4	83.6	104.2	235.0	0.0	0.0	14.4	17.8	0.0	21.3	5.6	864.3
2005-06	39.2	52.6	123.6	397.6	508.7	65.8	0.0	0.0	0.0	21.0	36.8	62.4	1307.7
2006-07	194.4	131.4	326.6	102.2	103.2	95.0	0.0	0.0	0.0	0.0	0.0	62.0	1014.8
2007-08	283.6	44.6	46.6	170.6	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	605.4
MEAN	125.96	122.48	202.20	151.13	215.98	73.01	4.99	14.80	13.91	9.55	21.33	72.97	1028.32
S.D	97.08	64.47	258.13	87.22	157.18	108.18	13.14	24.70	28.44	31.94	27.93	91.49	386.50
C.V	0.77	0.53	1.28	0.58	0.73	1.48	2.63	1.67	2.04	3.34	1.31	1.25	0.38
ANNUAL RAINFALL AT 75% EXCEEDANCE PROBABILITY LEVEL =							628.00	mm					
ANNUAL RAINFALL AT 50% EXCEEDANCE PROBABILITY LEVEL =							940.60	mm					



Figuare 4. Annual Rainfall in mm

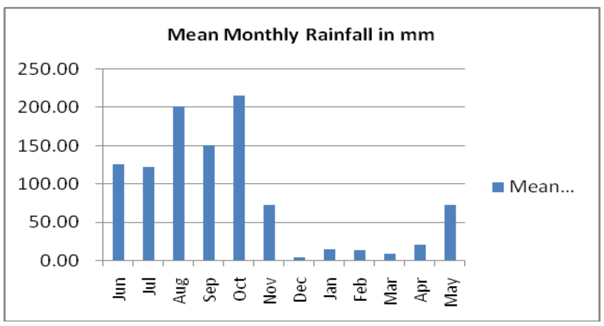


Figure 6. Mean monthly rainfall distribution

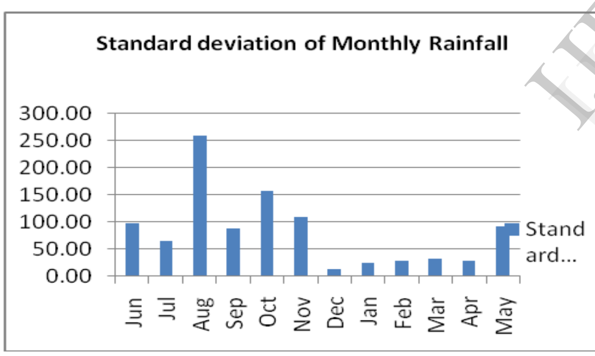


Figure 7. Standard deviation of monthly rainfall

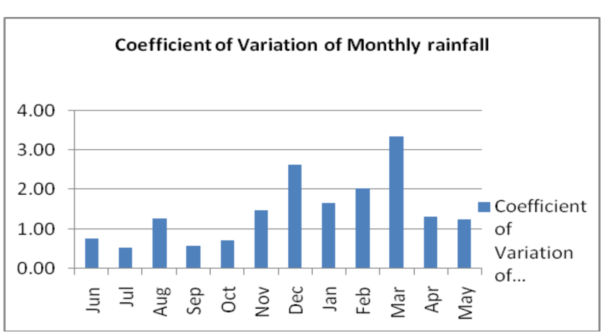


Figure 8. Coefficient of variation of monthly rainfall

Table 3. 3-year and 5-year Moving Average

Year	Annual Rainfall in mm	3- year Moving Average	5-year Moving Average
1978-79	807		
1979-80	551.7	770.6	
1980-81	953.1	796.1	867.62
1981-82	883.6	993.1	893.18
1982-83	1142.7	987.0	908.44
1983-84	934.8	901.8	1212
1984-85	628	1344.6	1390.6
1985-86	2470.9	1625.2	1392.5
1986-87	1776.6	1799.9	1396.38
1987-88	1152.2	1294.3	1545.94
1988-89	954.2	1160.7	1244.32
1989-90	1375.8	1097.6	1081.56
1990-91	962.8	1100.5	1089.16
1991-92	962.8	1038.6	1037.08
1992-93	1190.2	948.9	991.04
1993-94	693.8	1009.9	995.02
1994-95	1145.6	940.7	1028.1
1995-96	982.7	1085.5	978.18
1996-97	1128.2	1017.2	1125.28
1997-98	940.6	1166.0	1025.8
1998-99	1429.3	1006.0	1000.36
1999-00	648.2	977.7	930.04
2000-01	855.5	760.1	836.6
2001-02	776.6	701.8	798.14
2002-03	473.4	829.0	841.36
2003-04	1237	858.2	931.8
2004-05	864.3	1136.3	979.44
2005-06	1307.7	1062.3	1005.84
2006-07	1014.8	976.0	
2007-08	605.4		

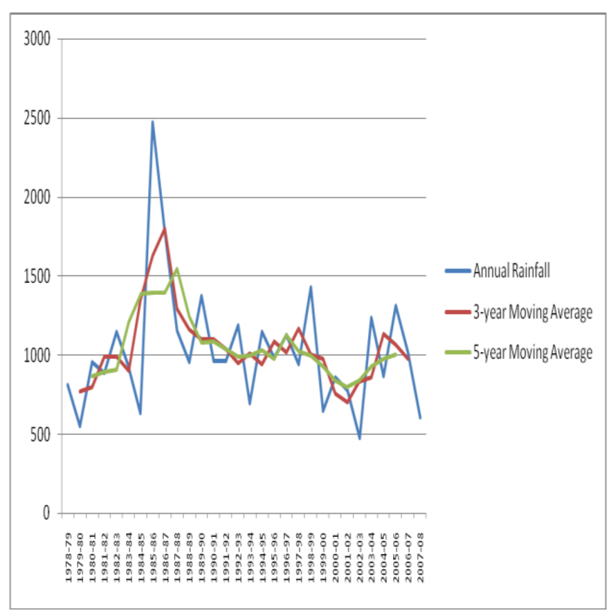


Figure 5. 3- year and 5-year moving average

Table 4. Weibull's Plotting Position

Year	Annual Rainfall	Ann. RF in D.O.	Rank m	m/n+1
1978-79	1336.3	2470.9	1	0.028
1979-80	853.4	1776.6	2	0.056
1980-81	1654.2	1429.3	3	0.083
1981-82	1621.8	1375.8	4	0.111
1982-83	2032.6	1307.7	5	0.139
1983-84	1524.6	1237	6	0.167
1984-85	1104	1190.2	7	0.194
1985-86	4750.1	1152.2	8	0.222
1986-87	3408.6	1145.6	9	0.250
1987-88	2245.3	1142.7	10	0.278
1988-89	1622.9	1128.2	11	0.306
1989-90	2401.6	1014.8	12	0.333
1990-91	1713	982.7	13	0.361
1991-92	1597	962.8	14	0.389
1992-93	2193.2	962.8	15	0.417
1993-94	1236.6	954.2	16	0.444
1994-95	2109.4	953.1	17	0.472
1995-96	1732.4	940.6	18	0.500
1996-97	1749.6	934.8	19	0.528
1997-98	1611.2	883.6	20	0.556
1998-99	2491.4	864.3	21	0.583
1999-00	1067.2	855.5	22	0.611
2000-01	1335.3	807	23	0.639
2001-02	1398.8	776.6	24	0.667
2002-03	781.2	693.8	25	0.694
2003-04	2218	648.2	26	0.722
2004-05	1346.2	628	27	0.750
2005-06	2523.6	605.4	28	0.778
2006-07	1703.8	551.7	29	0.806
2007-08	882.6	473.4	30	0.833

4. Methodology and its Application

Runoff has been computed from the catchment using Strange's runoff table. Crop water requirements were calculated using Modified penman method. Evaporation losses have been appropriately assumed and the Hydrological Simulation has been carried out for 30 years.

4.1 Runoff

Mr. W. L. Strange carried out investigations on catchments in South India and worked out Runoff yields for given rainfall events according to the nature of the catchments. The catchments prone to producing higher yields were categorised as good catchments. The catchments producing low yields are categorized as bad catchments. The intermediate type were called as average catchments. The values of rainfall events and the corresponding runoff events were given in table. The strange's rainfall events and runoff yields were plotted for Good, Average and Bad catchments as shown in figure and an average polynomial relationship of order 2 is approximately established as given below with in the acceptable range of mean square distance. The polynomial relationship of order 2 established between Rainfall in mm to Runoff in M.cu.m for various types of catchments are shown in figures 9 to 13.

Strange's relationship for good catchments is given by

$$y = 5E\text{-}07x^2 - 1E\text{-}04x + 0.006, \quad R^2 = 0.998$$

Strange's relationship for average catchments is given by

$$y = 3E\text{-}07x^2 - 6E\text{-}05x + 0.002, \quad R^2 = 0.999$$

Strange's relationship for bad catchments is given by

$$y = 2E\text{-}07x^2 - 4E\text{-}05x + 0.002, \quad R^2 = 0.999$$

Strange's relationship for catchments with 50% Good and 50% Average conditions is given by

$$y = 4E\text{-}07x^2 - 8E\text{-}05x + 0.004, \quad R^2 = 0.999$$

Strange's relationship for catchments with 50% Average and 50% Bad conditions is given by

$$y = 3E\text{-}07x^2 - 5E\text{-}05x + 0.002, \quad R^2 = 0.999$$

The yield rate per sq. km is estimated using the strange's method for the given nature of catchment.

The yield rates multiplied by the effective catchment area will give rise to inflows during that month.

Table 5. Strange's runoff yield per sq. km of catchments which are good, average, bad etc.

STRANGE'S TABLE

Undernoted table extracted from Strange's Indian storage reservoirs is suitable for estimating runoff from rainfall in the plains of the South India

Table of total monsoon rainfall and estimated runoff and yield per square mile from cathcment

Total Rainfall in a month in mm	Good Yield of runoff from catchment per sq.km in M.Cum	Average Yield of runoff from catchment per sq.km in M.Cum	Bad Yield of runoff from catchment per sqkm in M.Cum	(Good+Avg)/2 Yield of runoff from catchment per sqkm in M.Cum	(Avg+Bad)/2 Yield of runoff from catchment per sqkm in M.Cum
25.4	2.21192E-05	1.10596E-05	1.10596E-05	1.65894E-05	1.10596E-05
50.8	9.95364E-05	3.31788E-05	4.42384E-05	6.63576E-05	3.87086E-05
76.2	0.000221192	0.000232252	0.000165894	0.000226722	0.000199073
101.6	0.000696755	0.000530861	0.000353907	0.000613808	0.000442384
127	0.001282913	0.000962185	0.000652516	0.001122549	0.000807351
152.4	0.002311456	0.00165894	0.001150198	0.001985198	0.001404569
177.8	0.003439535	0.002820197	0.001880132	0.003129866	0.002350165
203.2	0.005750991	0.004313243	0.002875495	0.005032117	0.003594369
228.6	0.008095626	0.006071719	0.004047813	0.007083672	0.005059766
254	0.011048538	0.008283639	0.005518739	0.009666089	0.006901189
279.4	0.014698206	0.01101536	0.007343573	0.012856783	0.009179466
304.8	0.019088866	0.014266881	0.009555493	0.016677874	0.011911187
330.2	0.024043566	0.018027145	0.012021783	0.021035355	0.015024464
355.6	0.029849855	0.022384626	0.01458761	0.026117241	0.018486118
381	0.036231243	0.027173432	0.018115621	0.031702338	0.022644527
406.4	0.043165611	0.032371443	0.021577276	0.037768527	0.026974359
431.8	0.050664018	0.037989719	0.024331116	0.044326869	0.031160417
457.2	0.059202028	0.044393226	0.031741046	0.051797627	0.038067136
482.6	0.067850633	0.050918389	0.033919787	0.059384511	0.042419088
508	0.077085398	0.057808519	0.038553758	0.067446958	0.048181139
533.4	0.086873142	0.07289381	0.043431041	0.079883476	0.058162426
558.8	0.095245258	0.073336194	0.049558058	0.084290726	0.061447126
584.2	0.108737967	0.081553475	0.054302626	0.095145721	0.067928051
609.6	0.11800591	0.090036187	0.061159577	0.104021049	0.075597882
635	0.1221422	0.099237773	0.066711495	0.110689986	0.082974634
660.4	0.145577488	0.10590671	0.073889174	0.125742099	0.089897942
685.8	0.163693109	0.119145049	0.079430033	0.141419079	0.099287541
711.2	0.172662443	0.129496833	0.086331222	0.151079638	0.107914027
736.6	0.187028861	0.139926033	0.090312677	0.163477447	0.115119355
762	0.202722431	0.152036293	0.101582407	0.177379362	0.12680935
787.4	0.218239047	0.162675626	0.10838406	0.190457336	0.135529843
812.8	0.234341821	0.186807669	0.117165381	0.210574745	0.151986525
838.2	0.244339698	0.188455549	0.125415841	0.216397624	0.156935695
863.6	0.268969422	0.201461636	0.133821135	0.235215529	0.167641386
889	0.286775375	0.211802361	0.142668814	0.249288868	0.177235587
914.4	0.298609145	0.228933678	0.148198613	0.263771411	0.188566145
939.8	0.330814694	0.243101023	0.155387351	0.286957859	0.199244187
965.2	0.343986675	0.258484924	0.172319596	0.301235799	0.21540226
990.6	0.354902499	0.273570215	0.18237277	0.314236357	0.227971493
1016	0.385073082	0.292371532	0.192669256	0.338722307	0.242520394
1041.4	0.339607075	0.304968414	0.203308589	0.322287744	0.254138502
1066.8	0.440559085	0.322055493	0.214744214	0.381307289	0.268399853
1092.2	0.446354314	0.338567472	0.22585911	0.392460893	0.282213291
1117.6	0.464868081	0.356107995	0.23739427	0.410488038	0.296751133
1143	0.476204169	0.373736994	0.249062146	0.424970581	0.31139957
1168.4	0.519933819	0.392682085	0.255155985	0.456307952	0.323919035
1193.8	0.54824639	0.403443074	0.274123195	0.475844732	0.338783135
1219.2	0.573594989	0.430107765	0.286742196	0.501851377	0.358424981
1244.6	0.598987826	0.449451002	0.298642324	0.524219414	0.374046663
1270	0.626858012	0.470187748	0.313130397	0.54852288	0.391659072
1295.4	0.65387661	0.495934492	0.326932775	0.574905551	0.411433634
1320.8	0.68139289	0.511041903	0.340690915	0.596217396	0.425866409
1346.2	0.709484269	0.532497523	0.354736605	0.620990896	0.443617064
1371.6	0.739511077	0.554528242	0.369755539	0.64701966	0.46214189
1397	0.768752654	0.576558961	0.384376327	0.672655808	0.480467644
1422.4	0.798558271	0.598910408	0.399273606	0.69873434	0.499092007
1447.8	0.828927927	0.62169318	0.414458434	0.725310554	0.518075807
1473.2	0.861354668	0.646013236	0.430671804	0.753683952	0.53834252
1498.6	0.892852403	0.669658657	0.446663983	0.78125553	0.55816132
1524	0.924969476	0.693724342	0.462479208	0.809346909	0.578101775

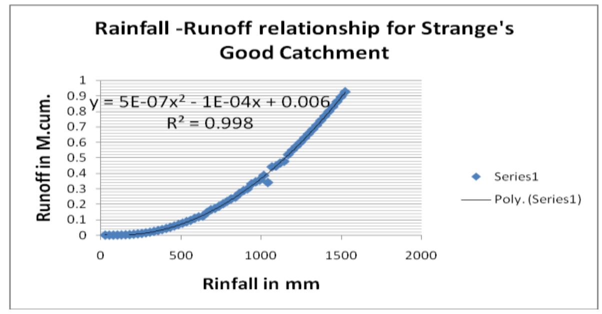


Figure 9. Rainfall – Runoff yield relationship for Strange's good catchment

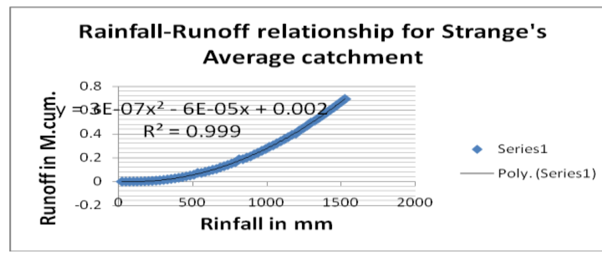


Figure 10. Rainfall – Runoff yield relationship for Strange's average catchment

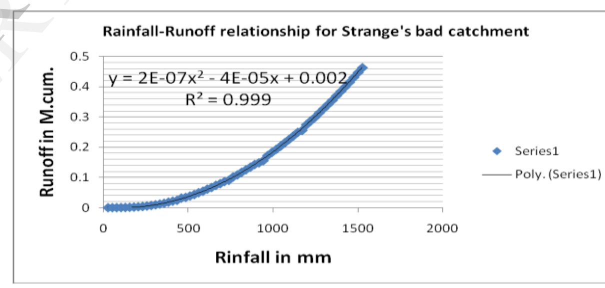


Figure 11. Rainfall – Runoff yield relationship for Strange' bad catchment

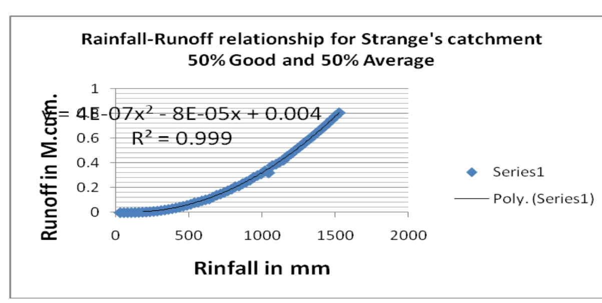


Figure 12. Rainfall – Runoff yield relationship for Strange's catchment 50% good and 50% average

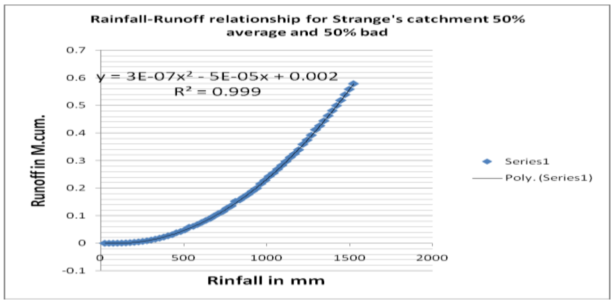


Figure 13. Rainfall – Runoff yield relationship for Strange's catchment 50% average and 50% bad

4.2 Validation of Runoff Yield Rates

Observed flows are not available for any period during the last 30 years. Hence it is attempted to validate the runoff yield rates obtained from the strange's runoff model with the inflows per sq km of a near by major irrigation project. The variation of computed and observed yield rates is found to be within ±5%.

4.3 Crop water requirements

Two crop seasons are identified in the study area viz. kharif and rabi. The identified cropping pattern in the study area is Paddy only. The modified penman method is used to compute the crop water requirements. The Potential Evapotranspiration values of Ranga Reddy district are collected from the IMD through Irrigation department. The values are given in the following table 6.

Table 6. Potential Evapotranspiration values of Visakhapatnam district

S.No	Month	PET value in mm
Kharif		
1	July	140.4
2	August	135.5
3	September	119.3
4	October	123.6
Rabi		
5	December	98.6
6	January	109.8
7	February	129.5
8	March	181.5

The modified penman method is used to compute the crop water requirements. The crop coefficient for paddy is taken as 1.1 for first 3 months and 0.95 for the fourth month in both kharif and rabi. Monthly water requirement in mm is obtained by multiplying the PET value with crop coefficient. A provision of 40 mm for nursery is made during the first month in both kharif and rabi. An allowance of 90 mm for land preparation during the first month is considered in both kharif and rabi. An allowance of 90 mm for four months in both kharif and rabi is provided for deep percolation at the rate of 3 mm per day. An allowance of 50 mm for 2 months is provided for minimum depth in kharif and rabi. After making all the above allowances the gross monthly water requirement is found out in mm. Considering 50% of actual rainfall during the corresponding month as effective rainfall, it is subtracted from the gross monthly water requirement to obtain net irrigation requirement. Assuming 80% field efficiency and 90% conveyance efficiency, the total crop water requirement is found out in mm and subsequently the total requirement per ha in cu.m. is found out. The model calculation of crop water requirements are shown in table 7 and 8 for kharif and rabi respectively.

Table 7. Model calculation of crop water requirement for the year 1978-79, kharif

CROP WATER REQUIREMENT 78-79						
	KHARIF			Kharif	Paddy	
S.No.	Description of the item	July	August	Septembe	October	Total
1	E.T. Value in mm	118	120	110	116	
2	Kc (Crop coefficiant) value	1.1	1.1	1.1	0.95	
3	Monthly Water Requirement	129.8	132	121	110.2	
4	Add for Nursery	40	0	0	0	
5	Add for Land Preparation	160	0	0	0	
6	Add for deep percolation(3 mm per day)	90	90	90	90	
7	Add for minimum depth	50	0	50	0	
8	Gross total monthly requirement in mm	469.8	222	261	200.2	1153
9	Monthly Rainfall during 1978-79	184.4	154.4	63	46.8	
10	Effective Rainfall 50% of rainfall during 1978-79	92.2	77.2	31.5	23.4	224.3
11	Net Irrigation Requirement	377.6	144.8	229.5	176.8	928.7
12	Requirement @ 80% Field efficiency	472	181	286.875	221	1160.875
13	Monthly requirement @ Canal Head @ 90% conveyance efficiency	524.4444	201.1111	318.75	245.5556	1289.861
14	Total Requirement in mm	524.4444	201.1111	318.75	245.5556	1289.861
15	**Total Requirement per Ha in Cubic Metres**	**5244.444**	**2011.111**	**3187.5**	**2455.556**	**12898.61**

Table 8. Model calculation of crop water requirement for the year 1978-79, rabi

CROP WATER REQUIREMENT 78-79						
	RABI			Rabi	Paddy	
S.No.	Description of the item	Decembe	January	Febraury	March	Total
1	E.T. Value in mm	94.4	95.2	109.3	154.7	
2	Kc (Crop coefficiant) value	1.1	1.1	1.1	0.95	
3	Monthly Water Requirement	103.84	104.72	120.23	146.965	
4	Add for Nursery	40	0	0	0	
5	Add for Land Preparation	160	0	0	0	
6	Add for deep percolation(3 mm per day)	90	90	90	90	
7	Add for minimum depth	50	0	50	0	
8	Gross total monthly requirement in mm	443.84	194.72	260.23	236.965	1135.755
9	Monthly rainfall during 1978-79	0	0	39.2	0	
10	Effective Rainfall 50% of rainfall during 1978-79	0	0	19.6	0	19.6
11	Net Irrigation Requirement	443.84	194.72	240.63	236.965	1116.155
12	Requirement @ 80% Field efficiency	554.8	243.4	300.7875	296.2063	1395.194
13	Monthly requirement @ Canal Head @ 90% conveyance efficiency	616.4444	270.4444	334.20833	329.1181	1550.215
14	Total Requirement in mm	616.4444	270.4444	334.20833	329.1181	1550.215
15	**Total Requirement per Ha in Cubic Metres**	**6164.444**	**2704.444**	**3342.0833**	**3291.181**	**15502.15**

The crop water requirement for 30 years for both kharif and rabi were computed and presented in table 9 given below.

Crop water requirement is dependant on various factors like rainfall, crop coefficient and potential evapotranspiration values. The crop water requirement will be high during first month of any season compared to other months due to additional requirement for nursery and land preparation during first month. The crop water requirements are found to be higher in Rabi compared to Kharif due to scanty rainfall during Rabi.

The maximum value of mean monthly crop water requirement is found during first month of Kharif with a magnitude of 5680 cubic metres per hectare while the lowest value is found during fourth month with a magnitude of 1361 cubic metres per hectares. The standard deviation fluctuated from 966 to during fourth month to 451 during first month of Kharif while the coefficient of variation fluctuated from 0.71 during fourth month to 0.08 during first month.

The mean monthly crop water requirement is found to be maximum in rabi during the first month with a magnitude of 6130 cubic metres per hectare. The crop water requirement is found to be lowest during second month in Rabi with a magnitude of 2602 cubic metres per hectare. However, the standard deviation fluctuated from 92 during first month to 173 during second month while the coefficient of variation fluctuated from 0.01 during first month to 0.07 during second month of Rabi.

Table 9. Computed monthly crop water requirement for 30 years from 1978-79 to 2007-08, kharif and rabi

CROP WATER REQUIREMENT											
S.No.	Year	Kharif					Rabi				
		July	August	September	October	Total	December	January	February	March	Total
1	1978-79	5244	2011	3188	2456	12899	6164	2704	3342	3291	15501
2	1979-80	6108	2597	2563	2781	14049	6164	2704	3614	3291	15773
3	1980-81	5629	2118	3111	579	11437	6152	2650	3592	3079	15473
4	1981-82	5867	2090	757	2558	11272	6164	2704	3614	3291	15773
5	1982-83	5420	2667	2986	0	11073	6164	2704	3485	3291	15644
6	1983-84	5428	1972	3139	628	11167	6010	2641	3509	3291	15451
7	1984-85	5664	1333	2979	2489	12465	6151	2399	3614	3291	15455
8	1985-86	5810	0	2819	357	8986	6164	2704	3489	3270	15627
9	1986-87	6039	0	2458	121	8618	5984	2531	3614	3266	15395
10	1987-88	6317	2056	2451	788	11612	6158	2704	3614	3291	15767
11	1988-89	4942	1903	2014	2114	10973	6139	2704	3614	3097	15554
12	1989-90	4768	2236	2972	2392	12368	6164	2579	2906	2770	14419
13	1990-91	5483	1563	2778	1267	11091	6123	2413	3614	3291	15441
14	1991-92	5754	2868	2181	1225	12028	6164	2704	3614	3291	15773
15	1992-93	5949	1938	2975	1669	12531	6164	2704	3614	3291	15773
16	1993-94	6206	2722	2583	1218	12729	6164	2524	3614	3291	15593
17	1994-95	5456	2208	2819	829	11312	6164	2281	3614	3258	15317
18	1995-96	5421	2326	2861	65	10673	6114	2704	3574	3291	15683
19	1996-97	6282	1535	2514	1336	11667	6077	2704	3614	3291	15686
20	1997-98	5088	1271	1972	2781	11112	6164	2288	3045	3291	14788
21	1998-99	5088	1722	1597	0	8407	6164	2704	3614	3291	15773
22	1999-00	6094	2576	3097	2121	13888	6164	2704	2934	3291	15093
23	2000-01	6046	1563	2910	2197	12716	6164	2684	3614	3222	15684
24	2001-02	5851	2451	2951	913	12166	6164	2586	3614	3291	15655
25	2002-03	6233	2354	3125	2343	14055	6164	2649	3531	3236	15580
26	2003-04	4990	2229	2417	10	9646	5706	1968	3597	3291	14562
27	2004-05	5219	2507	2903	1149	11778	6164	2607	3496	3291	15558
28	2005-06	6164	2229	868	0	9261	6164	2704	3614	3145	15627
29	2006-07	5615	819	2917	2065	11416	6164	2704	3614	3291	15773
30	2007-08	6219	2764	2444	2364	13791	6164	2704	3614	3291	15773
	Mean	5680	1954	2578	1361	11573	6130	2602	3518	3248	15499
	Std. Deviati	451	717	616	966	1516	92	173	199	107	351
	CV	0.08	0.37	0.24	0.71	0.13	0.01	0.07	0.06	0.03	0.02

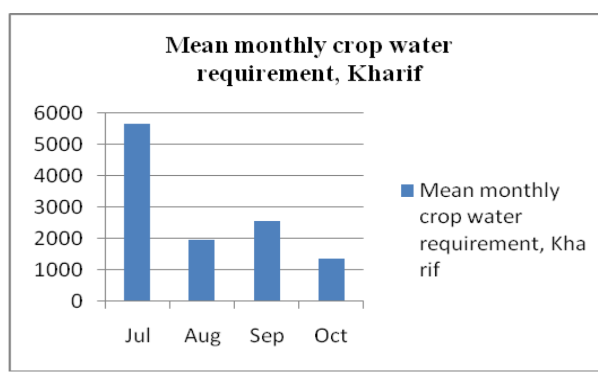


Figure 14. Mean monthly crop water requirement, kharif

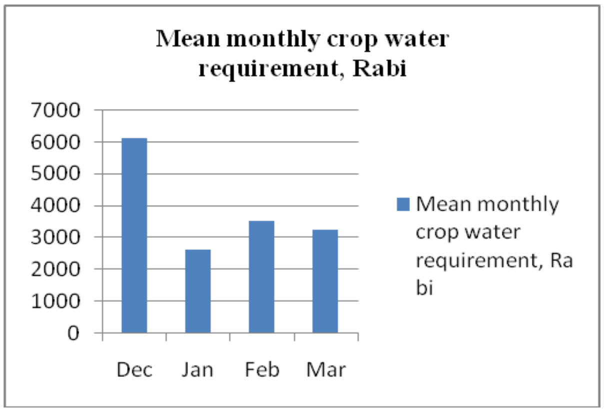


Figure 15. Mean monthly crop water requirement, rabi

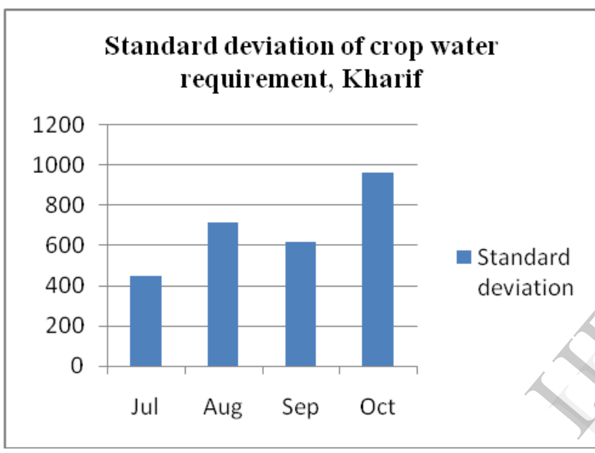


Figure 16. Standard deviation of crop water requirement, kharif

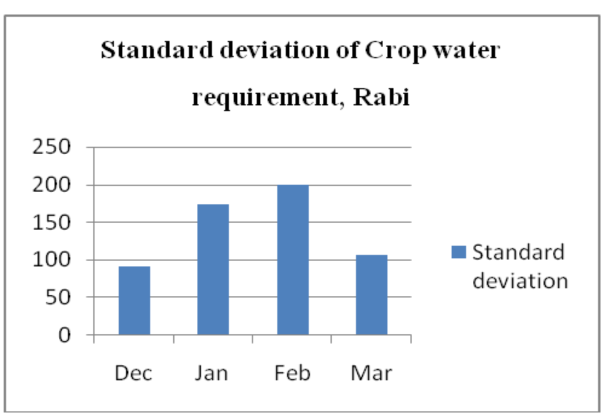


Figure 17. Standard deviation of crop water requirement, rabi

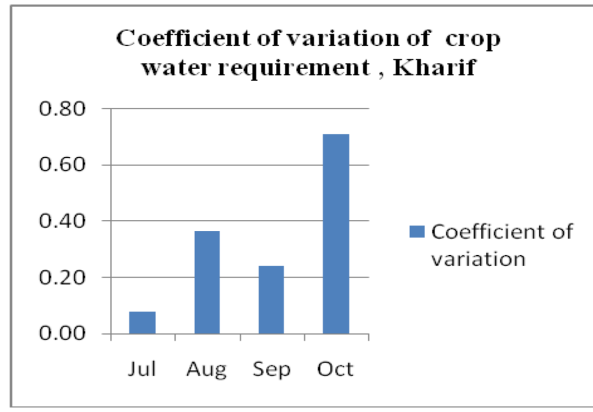


Figure 18. Coefficient of variation of crop water requirement, kharif

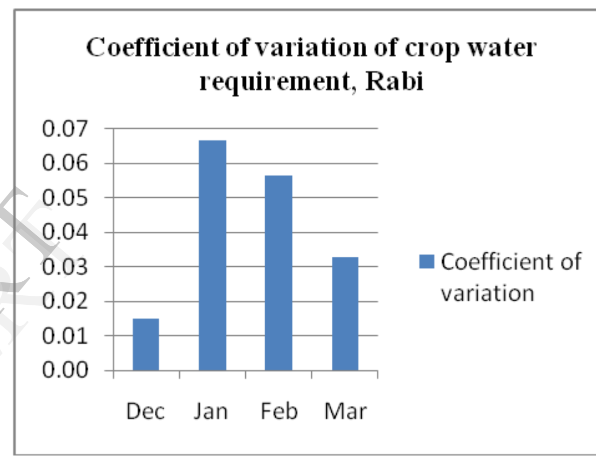


Figure 19. Coefficient of variation of crop water requirement, rabi

4.4 Evaporation losses

The monthly pan evaporation data pertaining to Visakhapatnam district is collected from IMD and are presented here. The losses are calculated using the formula given below.

Average Monthly evaporation losses = (Average Storage / Gross Storage) * Water Spread Area * Pan Evaporation.

Only 50% of the inflows of June month every year are considered as inflows for June.

Table 10. Monthly pan evaporation data of Visakhapatnam district

Month	Pan evaporation in m
June	0.187
July	0.156
August	0.136
Septembei	0.129
October	0.143
November	0.126
December	0.127
January	0.149
Febraury	0.169
March	0.246
April	0.238
May	0.239

4.5 Hydrological Simulation

After computing the month-wise inflows, the crop water requirements and losses, the end storage during any month is calculated by adding the inflows to the initial storage and subtracting from it the crop water requirement and the losses. If the end storage is greater than the gross capacity of the tank at FTL, then the tank will retain the water up to its gross capacity and the remaining water goes as surplus. If the sum of crop water requirement and losses during any month exceeds the sum of initial storage and inflows, then the difference of two sums will represent deficit for that particular month.

It is with this mechanism in mind, a simulation exercise has been carried out in MS-Excel package to compute the maximum possible cropping area for each year under kharif and rabi seasons in such a way that there is no deficit and no surplus (or minimum surplus). The model run of the hydrological simulation for one year during 1978-79 is presented in table 11. It is observed from the simulation run that the tank could irrigate 1 hectare during kharif and 0 hectares during rabi. The end storage of 0.0088 M.cu.m during May of hydrological year 1978-79 will be carry forwarded as e initial storage for the next hydrological year starting with June 1979-80.

The simulation exercise has been continued for the subsequent 29 hydrological years and each year the simulated irrigated area details are found out and tabulated in table 12 given under results.

Table 11. Model run of the hydrological simulation for the year 1978-79

HYDROLOGICAL SIMULATION FOR THE YEAR 1978-79

Free	2.5175 sqkm	Gross Capacity of the tank@	0.165 Mcum	Waterspread area	0.102 M.Sq.m
Intercepted	1.42 sqkm				
Effective ca	3.2275 sqkm				

Month	Ini Storage in Mcum	Rainfall in mm	Strange's yield rate	Inflow in Mcum	Paddy CWR/ha in Cum	Paddy Area in ha	Total CWR in MCum	Mon evap in metres	Losses in MCum	End Storage in Mcum	Surplus in Mcum	Deficit in Mcum
June	0.0000	93.3	0.0005	0.0009	0	0	0	0.187	0.0001	0.0008	0.0000	0.0000
July	0.0008	184.4	0.0040	0.0130	5244	1	0.0052	0.156	0.0005	0.0082	0.0000	0.0000
August	0.0082	154.4	0.0024	0.0077	2011	1	0.0020	0.136	0.0009	0.0130	0.0000	0.0000
September	0.0130	63.0	0.0002	0.0005	3188	1	0.0032	0.129	0.0009	0.0094	0.0000	0.0000
October	0.0094	46.8	0.0001	0.0003	2456	1	0.0025	0.143	0.0007	0.0065	0.0000	0.0000
November	0.0065	86.2	0.0004	0.0013	0	0	0.0000	0.126	0.0006	0.0072	0.0000	0.0000
December	0.0072	0.0	0.0000	0.0000	6164	0	0.0000	0.127	0.0006	0.0067	0.0000	0.0000
January	0.0067	0.0	0.0000	0.0000	2704	0	0.0000	0.149	0.0006	0.0060	0.0000	0.0000
Febraury	0.0060	39.2	0.0001	0.0002	3342	0	0.0000	0.169	0.0006	0.0056	0.0000	0.0000
March	0.0056	0.0	0.0000	0.0000	3291	0	0.0000	0.246	0.0009	0.0048	0.0000	0.0000
April	0.0048	0.0	0.0000	0.0000	0	0	0	0.238	0.0007	0.0041	0.0000	0.0000
May	0.0041	139.7	0.0018	0.0058	0	0	0	0.239	0.0010	0.0088	0.0000	0.0000

5. Results

The results of the simulation are presented in table 12. The surplus history of the MI tank is presented in table 13.

Table 12. Results of hydrological simulation of Chittivalasa MI tank

Year	Regd. Ayacut in ha	Simulated Ayacut in ha Kharif	Rabi
1978-79	40	1	0
1979-80	40	1	0
1980-81	40	1	3
1981-82	40	4	5
1982-83	40	1	8
1983-84	40	2	3
1984-85	40	4	0
1985-86	40	40	5
1986-87	40	40	8
1987-88	40	3	8
1988-89	40	6	0
1989-90	40	3	0
1990-91	40	15	0
1991-92	40	1	1
1992-93	40	2	4
1993-94	40	2	1
1994-95	40	2	2
1995-96	40	5	6
1996-97	40	12	0
1997-98	40	10	0
1998-99	40	9	8
1999-00	40	0	0
2000-01	40	4	0
2001-02	40	0	2
2002-03	40	0	0
2003-04	40	3	6
2004-05	40	2	1
2005-06	40	1	8
2006-07	40	12	0
2007-08	40	2	0

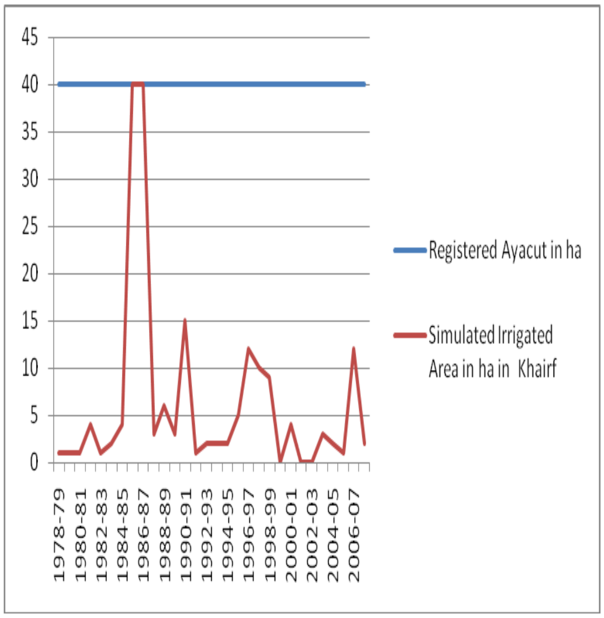


Figure 20 Registered ayacut and simulated ayacut, kharif

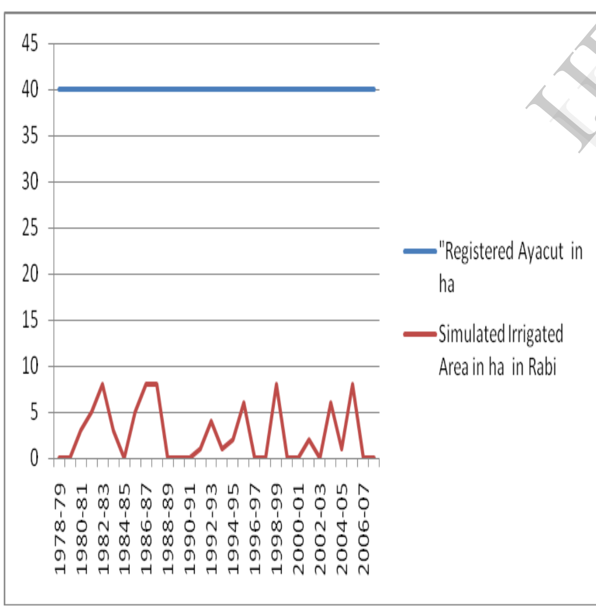


Figure 21 Registered ayacut and simulated ayacut, rabi

Table 13. Surplus history of Chittivalasa MI Tank

Year	Month	Surplus Quantity in M.Cum.
1982-83	October	0.2016
1985-86	August	2.5941
1986-87	August	0.191
	October	0.057
	November	0.083
1987-88	November	0.0238
1998-99	October	0.0247
2005-06	October	0.1987

6. Conclusions

The results indicated that the MI tank has received sufficient inflows only for 2 years during 1985-86 and 1986-87 to irrigate the entire registered ayacut of 40 ha in kharif. However in rabi, the tank has received inflows to irrigate an ayacut of 8 ha during 186-87 and 5 ha during 1985-86. Except these 2 years, the tank has under performed and the tank has not irrigated more than15 hectares in the remaining 28 years. The tank has received inflows only for 4 years which are sufficient to irrigate an ayacut of 10 to 15 ha during 1990-91 (20 ha), 1996-97 (12 ha), 2006-07 (12 ha) and 1997-98 (10 ha).

The tank has not received sufficient inflows even to irrigate 1 ha during 2002-03 either in kharif or rabi. The tank failed to irrigate even 1 ha during kharif of 2001-02 but it could irrigate just 1 ha during 2001-02. The tank has received inflows to irrigate just 1 ha only for 2 years during 1978-79 and 1979-80 and 2 ha only for 3 years during 1991-92, 2001-02 and 2007-08.

The results indicate that the living conditions of the people whose livelihoods are linked to this Chittivalasa MI tank were pathetic since many years owing to the vagaries of monsoon. It is because of the good efforts and timely intervention of the successive governments in Andhra Pradesh state in terms of providing various drought relief measures and welfare schemes to these people that made them keep going in their routine life.

Out of the 30 years from 1978-79 to 2007-08, the tank has surplused only on few occasions. The tank has surplused for 8 months during these 30 years. The quantity of surplus water ranges from a low of 0.057 M.cu.m during October, 1986-87 to 2.5941 M.cu.m. during August, 1985-86. The surplus history of the MI tank shows that there exists scope for additional storage if de-silting operations are taken up to increase the capacity of the tank.

It is always advisable to convert such a rainfed tank in to a system-fed tank by constructing a feeder channel to the tank from a near by major irrigation project.

7. References

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