Hydrological Simulation of a Minor Irrigation Tank in Yerra Mandala, Krishna District, A.P

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ABSTRACT- Hydrological simulation plays a vital role in understanding and managing water resources of minor irrigation tanks, which are crucial for agricultural sustainability, especially in semi-arid and rural regions. This study focuses on the simulation of hydrological processes governing a minor irrigation tank, including rainfall, runoff, inflow, evaporation, seepage, storage, and irrigation releases. The simulation model integrates meteorological data, catchment characteristics, and tank operational parameters to estimate water availability and storage behavior over time.

The study utilizes long-term rainfall and climatic data to analyze seasonal and annual variations in water availability. Runoff estimation is carried out using standard hydrological methods, while crop water requirements are determined based on evapotranspiration principles. The model continuously updates the storage levels of the tank by considering inflows and deducting losses such as evaporation and seepage, along with irrigation demands. This dynamic approach helps in understanding the temporal variation of water storage and availability.

By analyzing inflow–outflow relationships, the model evaluates the performance of the tank under different climatic scenarios and irrigation conditions. It also helps in identifying surplus and deficit periods, which are critical for effective water resource planning. The results provide insights into the adequacy of water supply for the command area and assist in optimizing irrigation scheduling for different cropping seasons.

Furthermore, the study highlights the impact of rainfall variability and catchment response on tank performance. It emphasizes the importance of proper management and maintenance of tank components to ensure efficient water utilization. The findings of this study are useful for improving the operational efficiency of existing tanks and for planning rehabilitation measures where necessary.

Hydrological simulation thus serves as an effective decision-support tool for engineers and planners in optimizing water use, enhancing crop productivity, and ensuring sustainable management of minor irrigation systems. It also contributes to better understanding of water balance components, thereby aiding in the development of strategies for long-term water resource sustainability.

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 within a short time was specially recognized in the "Grow more" food campaign launched in1943.

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.

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 rain fed 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

The yerra Minor Irrigation (MI) Tank, located in yerra village of krishna district, lies within the Krishna River basin and forms part of the Krishna sub-basin. Geographically, the tank is positioned at a latitude of 16.8363° and a longitude of 80.9407°. It serves as an important water resource structure supporting irrigation in the region. The tank has a total storage capacity of 124.19 Mcft, with a current storage level of 97.58 Mcft. The registered command (transplantation) area of the tank is 369.35 acres, while the presently utilized irrigation area is about 118 acres. The tank has a top bund level (TBL) of 69.07 m. Hydrologically, it is supported by a catchment area of 9.5 square kilometers, which contributes runoff during rainfall events. The tank's full tank level (FTL) spread area extends to 87.16 square kilometers, indicating its capacity to store and distribute water effectively. Overall, the yerra MI Tank plays a crucial role in sustaining agricultural activities and managing local water resources within the basin.

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 rain fed minor irrigation tank located in yerra village of krishna 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 yerra for 10 years from 2015-16 to 2024-25.
2. The MI tank is assumed to be in ideal conditions
3. Amaravathi rain gauge station is assumed to be the only available influencing rain gauge station in the catchment area.
4. 10 year's monthly rainfall data recorded at Amaravathi rain gauge 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.

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 THEORY AND LITERATURE REVIEW

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 in the early1986.

Shu-Li Huang and John D. Keenan 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. 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. During the year 2001, the simulated physical benefits of various MI tanks proposed under APIII were assessed using this hydrological simulation model.

2.1 Rainfall:

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. The monthly rainfall data recorded at Amaravathi rain gauge station has been collected for 10 years from 2015-16 to 2024-2025. The data is arranged in sequence from June to May as the hydrological year starts from June in the study area.

Annual rainfall for the study area was computed from the recorded monthly rainfall data and the results are presented in the tables above. It is observed that the highest annual rainfall during the study period occurred in 2021–22 with a magnitude of 1658.8 mm, while the lowest annual rainfall occurred in 2015–16 with a magnitude of 799.6 mm.

Annual rainfall greater than 1000 mm was recorded in several years such as 2017–18 (1025.2 mm), 2018–19 (1210.2 mm), 2019–20 (1263.3 mm), 2020–21 (1493.8 mm), 2021–22 (1658.8 mm), 2023–24 (1131.5 mm), and 2024–25 (1072 mm). These years indicate relatively wet conditions in the study area.

On the other hand, below normal rainfall (less than 1000 mm) was observed in 2015–16 (799.6 mm), 2016–17 (880 mm), and 2022–23 (957.9 mm), indicating comparatively dry years.
The mean annual rainfall for the study period is 1149.23 mm. Analysis of the mean monthly rainfall distribution indicates that the study area receives the majority of rainfall during the monsoon months from June to October. Among these months, July records the highest mean monthly rainfall (297.46 mm) followed by August (214.79 mm), June (162.64 mm), September (175.26 mm), and October (119.56 mm).

The standard deviation varies from 11.21 mm in February to 132.31 mm in July, indicating significant variability in rainfall during the monsoon season. Similarly, the coefficient of variation ranges from 0.42 in July to 2.43 in February, showing that rainfall variability is relatively high in the non-monsoon months compared to the monsoon months.

Overall, the rainfall analysis indicates that the study area experiences strong seasonal rainfall concentration during the southwest monsoon period, which plays a crucial role in influencing surface runoff, tank storage, and irrigation availability in the region.

2.2 Run-off:

Surface runoff (also known as overland flow) is the flow of water that occurs when excess storm water, meltwater, or other sources flow over the Earth's surface. This can occur when the soil is saturated to full capacity, and rain arrives more quickly than soil can absorb it. Surface runoff often occurs because impervious areas (such as roofs and pavement) do not allow water to soak into the ground. Surface runoff is a major component of the water cycle. It is the primary agent of water. The land area producing runoff that drains to a common point is called a drainage basin.

Runoff that occurs on the ground surface before reaching a channel can be a nonpoint source of pollution, as it can carry man-made contaminants or natural forms of pollution (such as rotting leaves). Man-made contaminants in runoff include petroleum, pesticides, fertilizers and others.

In addition to causing water erosion and pollution, surface runoff in urban areas is a primary cause of urban flooding, which can result in property damage, damp and mold in basements, and street flooding.

2.3 Crop Water-Requirement:

Prediction methods for crop water requirements are used owing to the difficulty of obtaining accurate field measurements. The methods often need to be applied under climatic and agronomic conditions very different from those under which they were originally developed. Testing the accuracy of the methods under a new set of conditions is laborious, time-consuming and costly, and yet crop water requirement data are frequently needed at short notice for project planning. To meet this need, guidelines are presented to calculate water requirements of crops under different climatic and agronomic conditions, based on the recommendations formulated by the FAO Group on Crop Water Requirements during its meetin.gs held in Lebanon (1971) and Rome (1972). Crop water requirements are defined here as "the depth of water needed to meet the water loss through evapotranspiration (ET_{crop}) of a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment

2.4 Evapo-Transpiration

Evaporation is the process whereby liquid water is converted to water vapor (vaporization) and removed from the evaporating surface (vapor removal). Water evaporates from a variety of surfaces, such as lakes, rivers, pavements, soils and wet vegetation. Transpiration consists of the vaporization of liquid water contained in plant tissues and the vapor removal to the atmosphere. Crops predominately lose their water through stomata. These are small openings on the plant leaf through which gases and water vapor pass. The combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration is referred to as evapotranspiration (ET). Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. Apart from the water availability in the topsoil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area. When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process. At sowing nearly 100% of ET comes from evaporation, while at full crop cover more than 90% of ET comes from transpiration. The evapotranspiration rate is normally expressed in millimeters (mm) per unit time. The rate expresses the amount of water lost from a cropped surface in units of water depth. The time unit can be an hour, day, decade, month or an entire growing period or year.

2.5 Crop Coefficient (K_C):

These coefficients represent the water need of a crop growth under optimum conditions to produce maximum yield. The K_c values are same for any given crop period and change with the stage of the crop. Crop characteristics like variety, duration, growing season, stage of crop growth, depth of routing, method of irrigation, plant population, fertilization, plant protection, and weed control etc. on crop water requirements is accounted by crop coefficients. For a selected crop based on time of sowing, stage of development and the preventive climatic conditions, crop coefficients can be determined using field experiments. The crop coefficient values are low during the early stages of crop growth and increase as the plant approaches grand period of growth and are constant for some time and then decline gradually. Selection of crop coefficient is most important in determining the irrigation needs of a particular place. The crop coefficient gives relationship between the Reference evapotranspiration and crop water requirement of specific crops.

2.6 Effective Rainfall

Not all rainfall is effective and a part may be lost by surface runoff, deep percolation or evaporation. Only the portion of rainfall, which contributes to the crop water needs, is the effective rainfall.

22.7 Evaporation Losses

Water losses by evaporation. The water that is lost to the air from the surface of the pond is called evaporation. The amount of water lost by evaporation depends largely on local climate conditions. Low air temperatures, high humidity, rainfall and cloud cover will decrease evaporation.

2.8 Hydrological Simulation

Hydrological simulation represents the movement and storage of water in a catchment–tank system using mathematical relationships.

- Rainfall over the catchment generates runoff based on soil type, land use, slope, and rainfall intensity, while part of the rainfall infiltrates into the soil.
- The generated runoff along with direct rainfall enters the minor irrigation tank as inflow The tank storage is simulated over time by applying the water balance principle, where inflows are added and outflows and losses are deducted.
- Outflows include irrigation releases and overflow through the spillway during excess rainfall.
- Losses mainly occur due to evaporation from the water surface and seepage through the tank bed and bund.
- By continuously updating storage for each time step, the hydrological simulation helps in estimating water availability, evaluating tank performance, planning irrigation releases, and supporting sustainable management of minor irrigation.

2.9 Literature Review

Though exhaustive literature review is available on various aspects related to irrigation, only the review of most limited and relevant literature to the present work is furnished below. The literature review is presented under suitable headlines, here under.

2.9.1 Irrigation Indices:

Evapotranspiration (ET) equations such as the theoretically based Penman combination are available to account for the effects of solar radiation, temperature, dryness and movement of the air environment on the evapotranspiration process by considering energy and aerodynamic transfer. The lack of availability of climatological data in many areas and during the historical periods necessitates the use of approaches which incorporate the effects of temperature and day length only. The FAO Blaney-Criddle method (FAO-BC) is unique from the original and in a study conducted by Richard G .Allen. (1986), practical procedures and necessary conditions for obtaining a reasonable estimate of consumptive use with the FAO Blaney-Criddle formula are discussed. Richard G. Allen (1948) suggested that soil moisture may have considerable effect on evapotranspiration & potential evapotranspiration was equal to actual evapotranspiration that would occur when there was an adequate supply of soil moisture at all times.

Richard G. Allen, In the calculation of crop water requirements an important factor contributing is rainfall occurring in the study area. The amount of rainfall which can be depended upon in one out four or five years corresponding to a 75% or 80% probability of exceedance and representing a dry year. The dependable rainfall (80%) is used for design of irrigation system capacity. The rainfall with 20%, 50%, 80% probability of exceedance representing a wet, normal and dry year is useful for the programming of irrigation supply and simulation of irrigation management conditions as per the document per FAO irrigation and drainage paper No:56 (1998). Eric Harmsen[2](1966) defined potential evapotranspiration as "the evapotranspiration that occurs when the vapor pressure at the evaporating surface is at the saturating point".

The widely-used Penman-Monteith equation to estimate crop evapotranspiration (ET) has limited utility in many areas of the world due to its requirement for full meteorological data. Legal and engineering water agencies commonly use the original Blaney-Criddle method (1962) in their efforts to manage competing water demands in mountain basins, both for its long-time familiarity and minimal data requirements. The original Blaney-Criddle equation predicts crop ET based solely on readily available mean monthly air temperature, t, and percentage of daylight hours.
However, in semi-arid, high-elevation environments, Blaney-Criddle underestimates crop ET. Keeping this in view Darcy G[1] et al. (2011), evaluated three modifications of the Blaney-Criddle temperature expression against the original equation with mean t, and another temperature method, Hargreaves, using lysimeter measurements from nine irrigated grass meadow sites in the upper Gunnison River basin of Colorado (1999–2003). Two of the modified temperature expressions resulted in improved correlation of Blaney-Criddle estimated crop ET with lysimeter ET. Similar improvements were observed when estimating with Hargreaves, which incorporates an additional term, T_{diff}, the difference between maximum and minimum daily temperature. It was opined that, these modifications to the original Blaney-Criddle can be applied successfully throughout Colorado mountain basins, and may be globally applicable to high-elevation areas.

3. METHODOLOGY

3.1 Data Collection

The data w.r.t. various parameters are collected from the relevant government agencies the following text includes the details of the different parameters and the respective governmental agencies from which they are collected.

3.1.1 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 analyzed using standard techniques and the inputs for the model were prepared.

3.1.2 Tank Geometry

Table 3.1.2.1: Tank Geometry of yerra MI tank

Parameter	**Details**
External ID	M1010946
Unique Tank ID	6.80225E+14
Name of the Basin	KRISHNA
Sub-Basin	Krishna
Name of the Tank	yerra MI Tank
Latitude	16.8363
Longitude	80.9407
Village, Mandal, District	yerra (V,M), krishna District
Current Storage (MCFT)	97.58
Registered Transplantation Area (Acres)	369.35
Current Transplantation Area (Acres)	118
TBL (m)	69.07
Capacity (MCFT)	124.19
Catchment Area (Sq.Km)	9.5
Tank Spread Area at FTL (Sq.Km)	87.16

The yerra Minor Irrigation (MI) Tank, located in yerra village of krishna district, lies within the Krishna River basin and forms part of the Krishna sub-basin. Geographically, the tank is positioned at a latitude of 16.8363° and a longitude of 80.9407°. It serves as an important water resource structure supporting irrigation in the region. The tank has a total storage capacity of 124.19 Mcft, with a current storage level of 97.58 Mcft. The registered command (transplantation) area of the tank is 369.35 acres, while the presently utilized irrigation area is about 118 acres. The tank has a top bund level (TBL) of 69.07 m. Hydrologically, it is supported by a catchment area of 9.5 square kilometers, which contributes runoff during rainfall events. The tank's full tank level (FTL) spread area extends to 87.16 square kilometers, indicating its capacity to store and distribute water effectively. Overall, the yerra MI Tank plays a crucial role in sustaining agricultural activities and managing local water resources within the basin.

3.1.3 Catchment Area

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 9.5 sq.km and intercepted catchment area is found to be 8.3 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 11.16 sq. km.

3.1.4 Command Area

The Registered ayacut of the tank is 149.47 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.

3.2 Rainfall Data

The monthly rainfall data both normal and actual is obtained from The Directorate of Economics and Statistics, Government of Andhra Pradesh, from 2015 to 2024.

The effective monthly rainfall values (dependable rain) for the period 2015 to 2024 are calculated using, Food and Agriculture Organization (FAO/AGLW) (AGLW is a Water management and irrigation systems group) formula which is an empirical formula based on analysis carried out for different climatic data to determine the dependable effective rainfall i.e. dependable rainfall at 80% probability corrected for assumed losses due to runoff and percolation. (CROPWAT8.0 Software) as stated below.

$P_{eff} = 0.6 \times P - 10/3$ for Pmonth $\leq 70/3$ mm
$P_{eff} = 0.8 \times P - 24/3$ for Pmonth$>70/3$ mm
Where:
P_{eff} = effective rainfall (mm),
Pmonth= monthly rainfall (mm)

Table 3.2.1: Monthly and 10 Years Rainfall data

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
2015-16	4.8	0	0	2.2	0	209.3	187.2	111.9	175.9	41.8	66.5	0	799.6
2016-17	4.5	0	0	0	108.2	355.4	60.6	191.7	71.8	81.3	2.8	3.7	880
2017-18	0	0	3.1		13.9	220.4	344	166	80.8	96.2	100.8	0	1025.2
2018-19	0	0	0		58.2	169.3	276.5	454.6	81.5	2.8	23.2	144.1	1210.2
2019-20	9.1	35.4	32.3	0	25.2	109.6	412.2	275.3	248.1	116.1	0	0	1263.3
2020-21	16.6	8.3	5.2	62.4	0	131.2	411.5	203.1	156.4	346.2	152.9	0	1493.8
2021-22	0	0	0	61.8	131.7	124.9	517.9	231.8	285.9	180.1	124.7	0	1658.8
2022-23	56.7	0	0	0	19.3	87.9	222	168.9	126.1	240.6	14.3	22.1	957.9
2023-24	0	0	17.5	84.9	80.3	48.4	320.7	74.6	331.1	15.5	6.9	151.6	1131.5
2024-25	6	0	3	30	35	170	222	270	195	75	66	0	1072
Mean	9.77	4.37	6.11	30.162	47.18	162.64	297.46	214.79	175.26	119.56	55.81	32.15	1149.23
Std Dev	17.3141592	11.210515	10.65556193	34.9441161	46.01168451	86.04338957	132.3118891	105.3583984	90.31615089	107.5982982	55.2951766	61.38516379	268.3519126
C.V	1.68123374	2.4336908	1.654460496	1.083704187	0.925191111	0.501893302	0.421979693	0.465346398	0.488881798	0.853769726	0.9399321	1.81135551	0.221523087

Graphical Representation

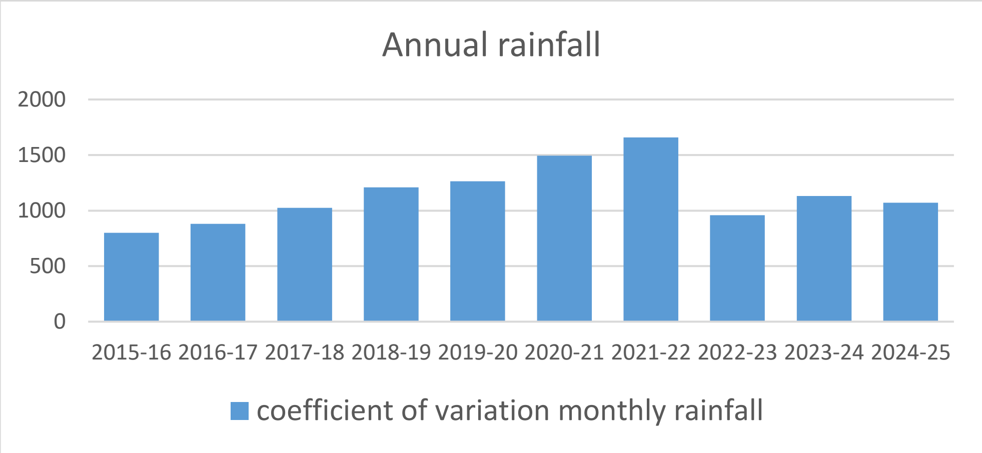


Figure 3.2.1: Annual rainfall

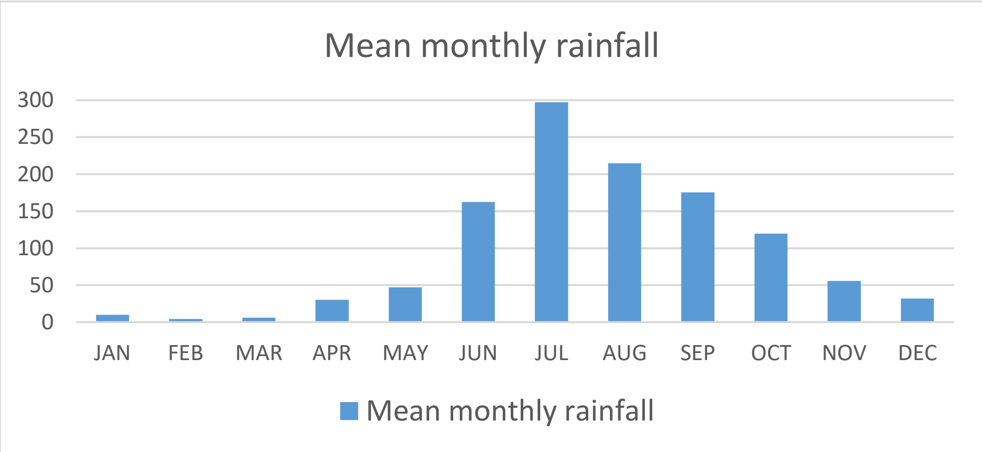


Figure 3.2.2: Mean monthly rainfall

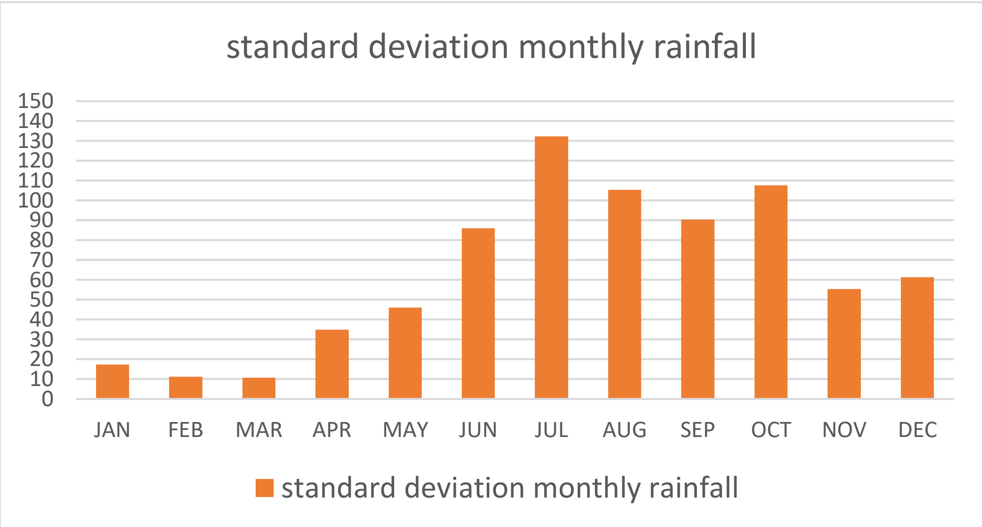


Figure 3.2.3: Std Dev of monthly rainfall

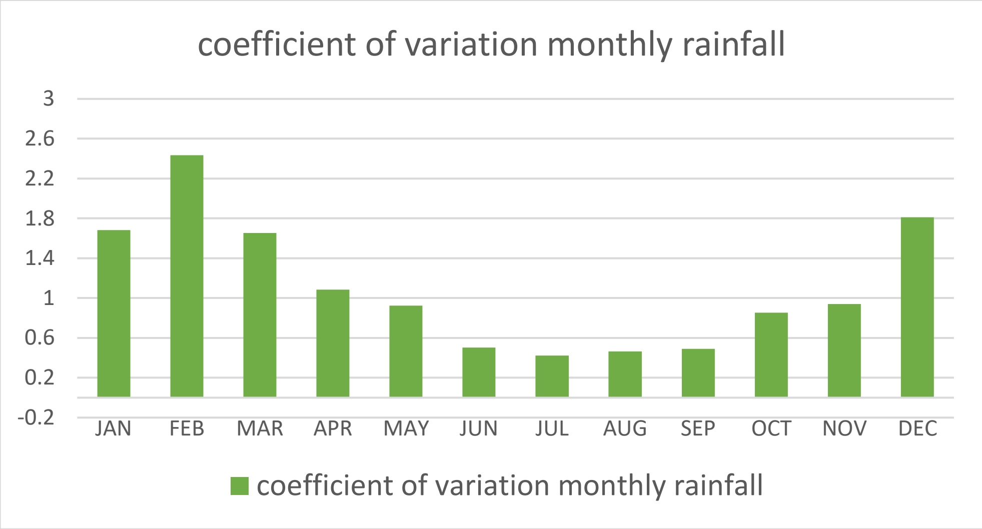


Figure 3.2.4: C.V of monthly rainfall

3.2.1 Meteorological Data:

The meteorological data is obtained from the meteorological centers located at Hyderabad and Machilipatnam.
The temperature data is obtained as monthly minimum, and maximum from 2015 to 2024. The data w.r.t. sunshine hours, wind speed and relative humidity are also collected for the period 2015 to 2025.

3.2.2 Crop Coefficient:

The crop coefficient Kc and crop periods for all the principle crops are obtained at different growth stages of crops i.e. initial, crop development, mid-season and late season/harvest stages from FAO Irrigation.

3.3 Analysis of Data and Calculation of Irrigation Indices:

The Data collected on various parameters as depicted above, is analyzed and various indices w.r.t. to irrigation potential in the study area are calculated as given below.

3.3.1 Calculation of Runoff Using Strange Table

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 categorized as good catchments. The catchments producing low yields are categorized as bad catchments. The intermediate type was 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.
Strange's relationship for good catchments is given by
$y = 5E\text{-}07x^2 - 1E\text{-}04x + 0.006$, $R^2 = 0.998$
Strange's relationship for average catchments is given by
$y = 3E\text{-}07x^2 - 6E\text{-}05x + 0.002$, $R^2 = 0.999$
Strange's relationship for bad catchments is given by
$y = 2E\text{-}07x^2 - 4E\text{-}05x + 0.002$, $R^2 = 0.999$
Strange's relationship for catchments with 50% Good and 50% Average conditions is given by
$y = 4E\text{-}07x^2 - 8E\text{-}05x + 0.004$, $R^2 = 0.999$
Strange's relationship for catchments with 50% Average and 50% Bad conditions is given by

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

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.

3.3.2 Crop Water Requirement

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.

3.3.3 Calculation of ETo and Effective Rainfall using CROPWAT 8.0

CROPWAT 8.0 is a computer model for the calculation of crop water and irrigation requirements from the existing climatic and crop data and using the reference evapotranspiration (ETo). The ETo to be used in this CROPWAT is to be evaluated using Penman-Monteith formula. One such work was done at Amaravathi in Visakhapatnam as the study area. Effective Rainfall is calculated by using Constant Percentage Method.

3.4 Evaporation Losses

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.

3.5 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.

4. CROPWATER REQUIREMENT

4.1 Crop water-requirements:

Table 4.1.1: Model calculation of crop water requirement for the year 2015-16, kharif

S.No	Description of Item	July	August	September	October	Total
1	E.T. Value (mm)	233.74	189.9	156.86	162	—
2	Kc (Crop Coefficient) Value	1.1	1.1	1.1	0.95	—
3	Monthly Water Requirement	257.11	208.89	172.59	153.9	—
4	Add for Nursery	40	0	0	0	—
5	Add for Land Preparation	150	0	0	0	—

6	Add for Deep Percolation (3 mm/day)	90	90	90	90	—
7	Gross Total Monthly Requirement (mm)	537.11	298.89	262.59	243.9	**1342.44**
8	Monthly Rainfall (2015-16)	187.2	111.9	175.9	41.8	—
9	Effective Rainfall (50%)	93.6	55.95	87.95	20.91	**258.4**
10	Net Irrigation Requirement	443.51	242.94	174.59	223	**1084.04**
11	Requirement @ 80% Field Efficiency	554.38	303.67	218.23	278.75	**1335.05**
12	Monthly Requirement @ Canal Head (80% Conveyance Efficiency)	692.97	378.58	272.78	348.43	**1693.81**
13	Total Requirement (mm)	692.97	378.58	272.78	348.43	**1693.81**
14	Total Requirement per ha (m^3)	6929.7	3785.8	2727.8	3484.3	**16938.1**

Table 4.1.2 : Model calculation of crop water requirement for the year 2015-16, Rabi

S.No	**Description of Item**	**December**	**January**	**February**	**March**	**Total**
1	E.T. Value (mm)	163.37	128.37	145.88	199.64	**-**
2	Kc (Crop Coefficient) Value	1.1	1.1	1.1	0.95	**-**
3	Monthly Water Requirement	179.7	141.2	160.46	189.65	**-**
4	Add for Nursery	40	0	0	0	**-**
5	Add for Land Preparation	150	0	0	0	**-**
6	Add for Deep Percolation (3 mm/day)	90	90	90	90	**-**
7	Add for minimum depth	50	0	50	0	**-**
8	Gross Total Monthly Requirement (mm)	509.7	231.2	300.46	279.61	**1321.01**
9	Monthly Rainfall (2015-16)	0	4.8	0	0	**-**
10	Effective Rainfall (50%)	0	2.4	0	0	**2.7**
11	Net Irrigation Requirement	509.7	228.8	300.46	279.65	**1318.31**
12	Requirement @ 80% Field Efficiency	637.125	286	375.57	349.5	**1647.88**
13	Monthly Requirement @ Canal Head (80% Conveyance Efficiency)	796.4	357.5	469.46	436.87	**2059.85**
14	Total Requirement (mm)	796.4	357.5	469.46	436.87	**2059.85**
15	Total Requirement per ha (m^3)	7964	3575	4694.6	4368.7	**20598.5**

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 are given below

Table 5.1: Model run of the hydrological simulation for the year 2015-16

Month	Initial Storage (Mcum)	Rainfall (mm)	Storage Yield Rate	Inflow (Mcum)	Paddy CWR (Cum)	Paddy Area (ha)	Total CWR (Mcum)	Evaporation (m)	Losses (Mcum)	End Storage (Mcum)	Surplus (Mcum)	Deficit (Mcum)
Jun	0	209.3	0.00631	0.06	0	0	0	0.117	0.0117	0.178	0	0
Jul	0.0424	187.2	0.00419	0.046	6911.7	1	0.00692	0.156	0.0143	0.6037	0	0
Aug	0.0519	11.9	0.00094	0.0088	3795.68	1	0.00379	0.136	0.0142	0.0637	0	0
Sep	0.045	75	0.00335	0.0338	2727.8	1	0.00272	0.129	0.0121	0.0334	0	0
Oct	0.0334	41.8	0.000111	0.00855	3862.3	1	0.00348	0.143	0.0135	0.0181	0	0
Nov	0.017	6.5	0.000073	0.00185	0	0	0	0.112	0.0119	0.00668	0	0
Dec	0.00668	0	0	0	7964	0	0	0.117	0.0119	1.137	0	0
Jan	2.132	4.9	0.000215	0	3975	0	0	0.166	0.014	2.118	0	0
Feb	2.118	0	0	0	4694.6	0	0	0.169	0.0159	2.107	0	0
Mar	2.102	0	0	0	4368.7	0	0	0.246	0.0232	2.078	0	0
Apr	2.078	0	0	0	0	0	0	0.238	0.021	2.076	0	0
May	2.056	0	0	0	0	0	0	0.259	0.014	2.084	0	0

6. RESULTS

6.1 Run-off:

Table 6.1.1: 10 years Run-off

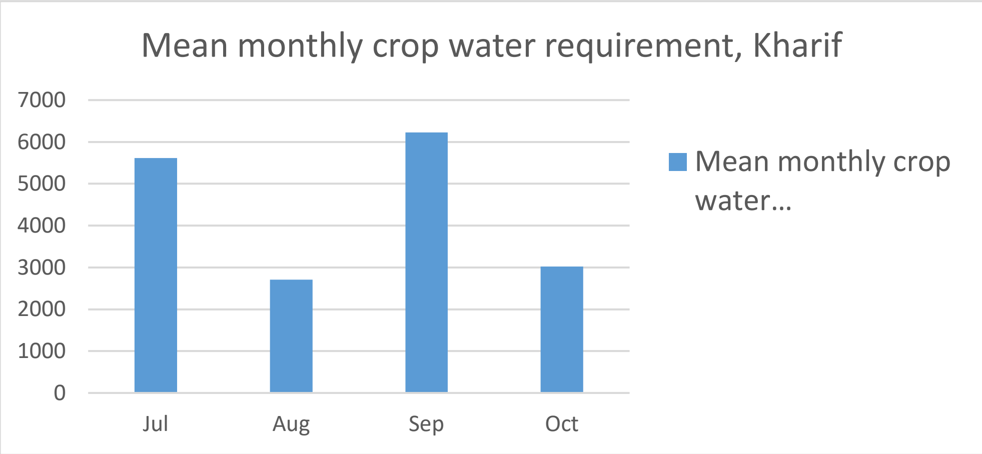
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
2015-16	4.8	0	0	2.2	0	209.3	187.2	111.9	175.9	41.8	66.5	0	799.6
2016-17	4.5	0	0	0	108.2	355.4	60.6	191.7	71.8	81.3	2.8	3.7	880
2017-18	0	0	3.1	0	13.9	220.4	344	166	80.8	96.2	100.8	0	1025.2
2018-19	0	0	0	0	58.2	169.3	276.5	454.6	81.5	2.8	23.2	144.1	1210.2
2019-20	9.1	35.4	32.3	0	25.2	109.6	412.2	275.3	248.1	116.1	0	0	1263.3
2020-21	16.6	8.3	5.2	62.4	0	131.2	411.5	203.1	156.4	346.2	152.9	0	1493.8
2021-22	0	0	0	61.8	131.7	124.9	517.9	231.8	285.9	180.1	124.7	0	1658.8
2022-23	56.7	0	0	0	19.3	87.9	222	168.9	126.1	240.6	14.3	22.1	957.9
2023-24	0	0	17.5	84.9	80.3	48.4	320.7	74.6	331.1	15.5	6.9	151.6	1131.5
2024-25	6	0	3	30	35	170	222	270	195	75	66	0	1072
Mean	9.77	4.37	6.11	30.1625	47.18	162.64	297.46	214.79	175.26	119.56	55.81	32.15	1149.23
Std Dev	17.31415927	11.2105159	10.65556193	34.9441161	46.01168451	86.04338957	132.3118891	105.3583984	90.31615089	107.5982982	55.2951766	61.38516379	268.3519126
C.V	1.68123	2.433690891	1.654460496	1.083704187	0.925191111	0.501893302	0.421979693	0.465346398	0.488881798	0.853769726	0.9399321	1.81135551	0.221523087

6.2 Crop Water Coefficient:

Table 6.2.1: Computed monthly crop water requirement for 10 years from 2015-16 to 2024-25, kharif and rabi

S.No	Year	kharif					Rabi				
		Jul	**Aug**	**Sep**	**Oct**	**Total**	**Dec**	**Jan**	**Feb**	**Mar**	**Total**
1	2015-16	6929.7	3785.8	2727.8	3484.3	**16938.1**	7964	3575	4694.6	4368.7	**20598.5**
2	2016-17	7412.6	3281.2	3402.7	3614.7	**17711.2**	6288.5	3356	4258.1	3584	**17486.6**
3	2017-18	4799	2842.6	36477	2801	**14089.6**	7894.8	4192.8	5108.5	4483.4	**21679.5**
4	2018-19	5443.5	385.3	3987	4588.1	**14403.4**	6167	4198.1	5224	4360.3	**19949.4**
5	2019-20	4266.2	2628.1	2685.4	2984	**12563**	7900.1	4159	4947.5	4255.3	**21261.9**
6	2020-21	5178	2350.5	3432.8	1186.4	**12147**	789.48	348.23	5043.7	4946	**21366.8**
7	2021-22	4346	2968	1781.7	2484	**11579.8**	7964	3612	4694.6	4369.5	**20640.1**
8	2022-23	6151.7	3459.3	2978.5	2370.3	**14959.8**	7716.8	3787.1	5322.6	4480	**21306.5**
9	2023-24	4981	3556.7	1691.5	3431.5	**13660.7**	6710.4	4192.8	5108.5	4370.9	**20382.6**
10	2024-25	6657.9	1827.6	3131.2	3305.1	**14921.8**	7894.8	3565.1	5108.5	4963.2	**21531.6**
11	Mean	5616.56	2708.51	6229.56	3024.94	14297.44	6728.988	3498.613	4951.06	4418.13	20620.35
12	Std Dev	1108.215809	1009.119458	10651.65492	906.721963	1970.152082	2208.669317	1151.847434	317.4957819	382.4636164	1234.670744
13	C.V	0.19731	0.372573	1.7098567	0.2997487	0.1377975	0.3282320	0.329229	0.0641268	0.086566	0.0598763

Figure 6.2.1: Mean monthly CWR, kharif



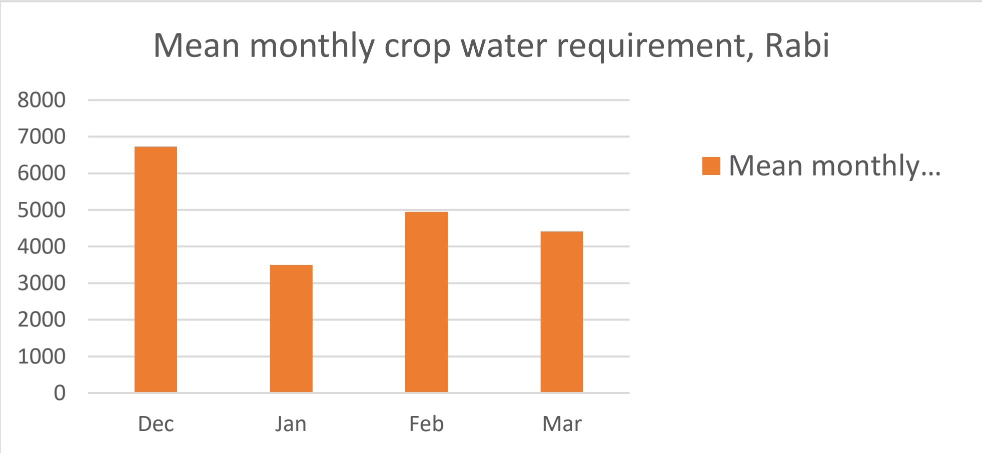


Figure 6.2.2: Mean monthly CWR, Rabi

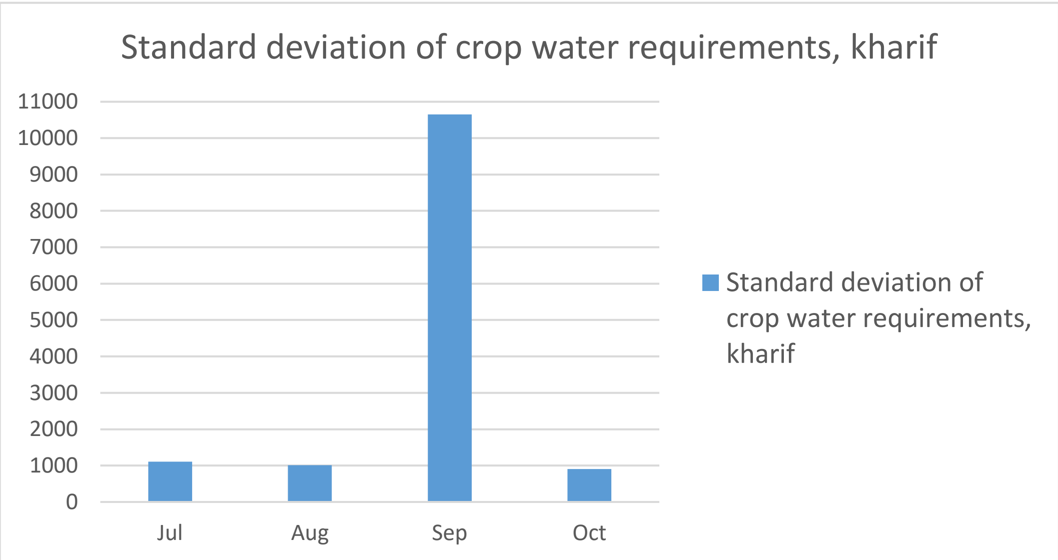


Figure 6.2.3: Std Dev of CWR, kharif

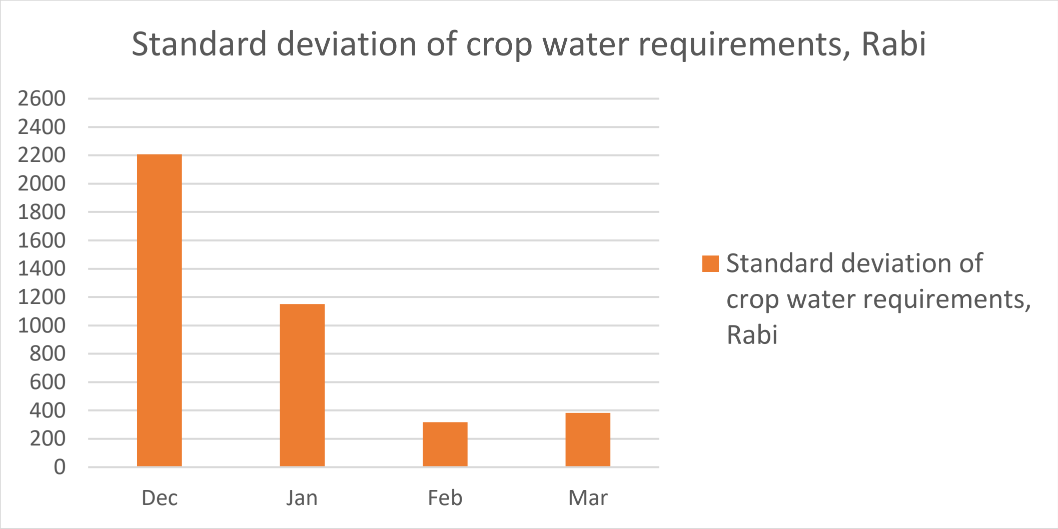


Figure 6.2.4: Std Dev of CWR, Rabi

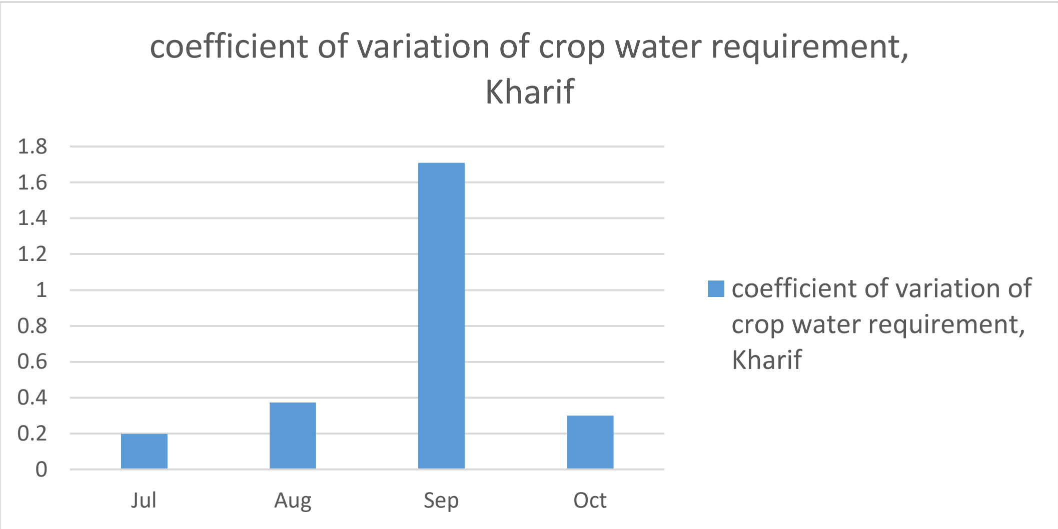


Figure 6.2.5: C.V of CWR, kharif

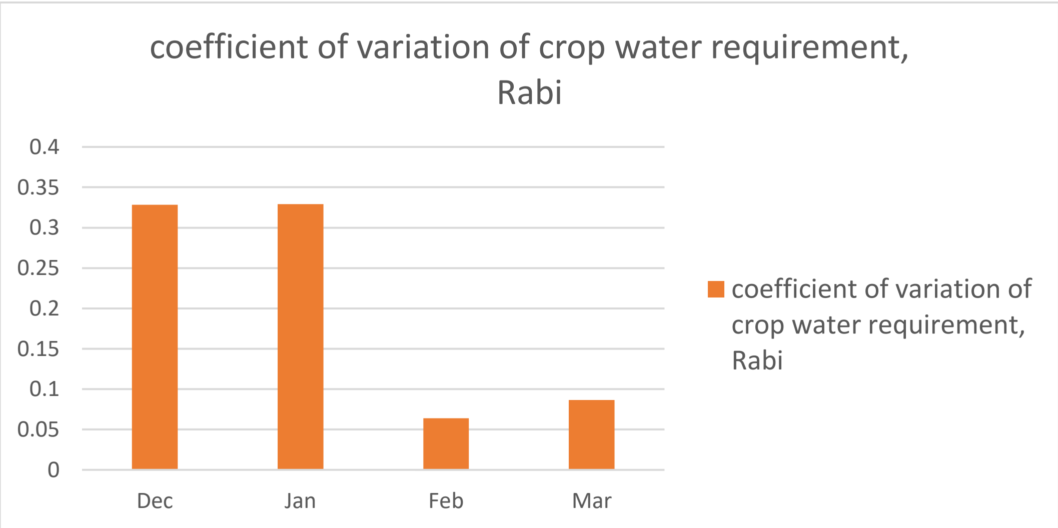


Figure 6.2.6: C.V of CWR, Rabi

6.3 Surplus History of MI tank

The surplus history of the MI tank is presented in following table:

Table 6.3.1: The results of the simulation of 10 years

Results of hydrological simulation of Yerra MI tank				
Sl. NO	**Year**	**Registered Ayacut (ha)**	**Simulated irrigated area**	
			Kharif (ha)	**Rabi (ha)**
1	2015–16	148	3	0
2	2016–17	148	15	9
3	2017–18	148	65	38
4	2018–19	148	48	29
5	2019–20	148	50	24
6	2020–21	148	38	29
7	2021–22	148	83	43
8	2022–23	148	5	2
9	2023–24	148	30	14
10	2024–25	148	16	5

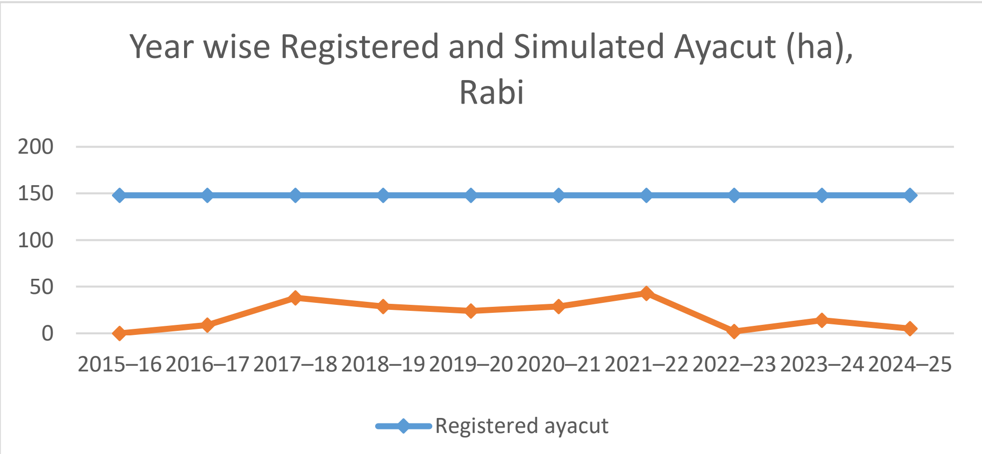


Figure 6.3.1: year wise registered & simulated Ayacut (ha), Rabi

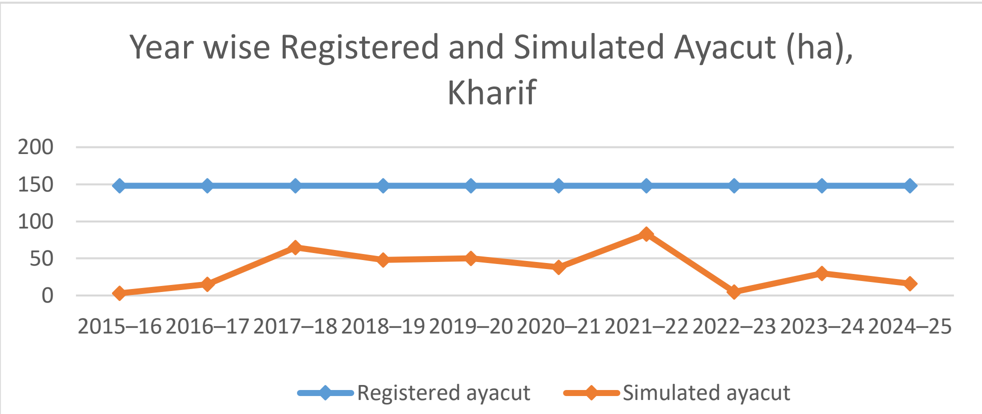


Figure 6.3.2: year wise registered & simulated Ayacut (ha), Kharif

7. CONLUSIONS

1. The results of the tank simulation indicate that the yerra MI Tank has received sufficient inflows only in a few years to support irrigation close to the registered ayacut area. In particular, years with higher rainfall such as 2019–20, 2020–21 and 2021–22 showed comparatively better storage and inflow conditions, enabling irrigation over a larger area during the Kharif season.
2. During the Rabi season, the availability of water was relatively limited. Only a small portion of the ayacut area could be irrigated, as the tank storage was mainly dependent on monsoon inflows received during the Kharif period.
3. In some years with relatively higher rainfall and runoff, the tank was able to irrigate a moderately larger area, though still not reaching the full registered ayacut. These years demonstrate that adequate monsoon rainfall significantly influences tank performance and irrigation potential.
4. In several years, the tank underperformed due to insufficient rainfall and inflow, resulting in irrigation of only a small portion of the ayacut area. This clearly indicates that the performance of the tank is highly dependent on the variability of monsoon rainfall.
5. The analysis suggests that the livelihood of farmers depending on the yerra MI Tank is strongly affected by rainfall variability and water availability. In years of poor rainfall, agricultural productivity and irrigation potential are significantly reduced.
6. The support of government programs, drought relief measures, and agricultural welfare schemes plays an important role in helping farmers manage during periods of water scarcity and maintaining their livelihood.
7. To improve the long-term sustainability of irrigation from the yerra MI Tank, it is recommended to strengthen the tank system through measures such as feeder channel construction, catchment treatment, desiltation, and improved water management practices. Converting the tank into a system-fed tank connected to nearby irrigation sources could significantly enhance water availability and irrigation reliability.

8. REFERENCE

[1] V. Klemes. "Operational testing of hydrological simulation models", Journal of Hydrological Sciences, Vol. 31, Issue 1, pp 13-24, 1986.

[2] Shu-Li Huang, John D. Keenan. "Hydrological simulation of the Brandywine basin" , Journal of the American Water Resources Association, JAWRA, Vol. 23, Issue 3 pp 403-421, 1987.

[3] Krishna Mohan M, Sethurathinam S, Selvarajan S."Techno-Economic Feasibility Study of APERP -Minimum Rehabilitation of 384 selected Minor Irrigation Schemes in Andhra Pradesh" I & CAD department, GoAP and AFC Ltd., 1999.

[4] Krishna Mohan M et al. "Techno-Economic Feasibility Study of APERP - Minimum Rehabilitation of 2,596 Minor Irrigation Schemes in Andhra Pradesh" I & CAD department, GoAP and AFC Ltd., 2000.

[5] Krishna Mohan M et al. "Techno-Economic Feasibility Study of APIII- Minimum Rehabilitation of Minor Irrigationn Schemes in Andhra Pradesh" I & CAD department, GoAP and WAPCOS(I) Ltd., 2001.

[6] Krishna Mohan M "Hydrological Simulation of a Rainfed Minor Irrigation Tank" International Journal of Engineering Research & Technology (IJERT), Vol. 2, Issue 4, pp 1493-1506, 2013.