**Effectiveness of Rainfall for major crops grown under the canal command areas of Musi Irrigation Project in Telangana, India**

**ABSTRACT**

Rainwater is an essential source for agriculture as well as human beings and animals which falls on the earth’s surface. In the present study, the USDA-SCS method was used to estimate the effectiveness of rainfall for various crops grown in the command areas of Musi irrigation project in the Telangana state of the southern Agro-climatic zone of southern India. Rainfall data of these Musi irrigation project was collected and analyzed to know its effectiveness on different crops grown during *Kharif* and *Rabi* seasons. The results revealed that the Paddy crop has the highest effectiveness of rainfall percent in all cases. On an average, effectiveness of rainfall of the Paddy crop in *Kharif* and *Rabi* season were 34% and 57% respectively. The effectiveness of rainfall was more during below the normal annual rainfall year than the normal and above normal annual rainfall year. During the below, normal and above normal annual rainfall year, it was found that the Paddy crop had the effectiveness of rainfall 62, 21 and 12% under the command area of RFMC of Musi medium irrigation project. Whereas, 25, 23 and 11% under the command area of LFMC of Musi medium irrigation project respectively. This study will enable us to make necessary plans for more efficient utilization of water resources and proper irrigation scheduling.

**Key words:** Canal water, Command area, Consumptive use, Crop coefficient, Rainwater, Effective rainfall, Effectiveness of rainfall, Reference evapotranspiration (ET0).

**1. Introduction**

Rainwater is an important and essential source for agriculture and horticulture as well as human beings and animals which falls on the earth’s surface (Adnan and Khan, 2009). The average annual rainfall of India is 1257 mm, which is 108% of its long period average (LPA) of 1160 mm (IMD Annual Report, 2022). About 75-80% of annual is received from the South-West monsoon (June to September).

The primary source of water supply for agriculture in most places of the world is rainfall and characteristics of this rainfall may vary from place to place and time to time. The actual and normal annual rainfall of Telangana is about 1270. 6 mm and 938.7 mm, respectively (IMD Annual Report, 2022). Groundwater either well or bore well has become the major source of irrigation water along with canal water (Jadhav *et al.,* 2025).

India, as a developing country, continues to invest in improving its irrigation infrastructure. Significant efforts are being made to convert rainfed areas into irrigated farmland to ensure sustainable food production. To achieve this, it is essential to regularly assess the performance and utilization of existing irrigation projects and their potential (Krishna *et al.,* 2022).

Water used for irrigation in the crop production is mainly depends upon the interaction between the climatic parameters that determines the crop evapotranspiration and water supply from the rainfall (Ali and Mubarak, 2017). Effective rainfall may be defined as the portion of the rainfall that is useful directly or indirectly for crop production at the site where it falls (Dastane, 1974). Effective rainfall is the function of crop type, soil type, land preparation type needed and climatic factors. The effective rainfall is used in computing irrigation requirement of crops, irrigation scheduling and planning of agriculture in rainfed areas (Mishra *et al.,* 1999; Panigrahi and Panda, 2001). Several researchers for estimating crop water requirements, have used the effective rainfall method of United States Department of Agriculture- Soil Conservation Service (USDA-SCS) (Gulati, 1987). Effective rainfall is used for planning the cropping patterns in the canal commands and to estimating crop water requirements; it is also used for preparing schedules in agriculture and efficient operation of irrigation projects (Rao and Rajput, 2008). Most of the studies were done at distributary level, planning of efficient management of water resources and supplying of water at field level is not possible with utmost accuracy. So, there is a need to estimate the effectiveness of rainfall at project level in order to manage and distribute the water resources more accurately.

**2. Materials & Methods**

The present study was conducted at the canal command area of Musi irrigation project in the Telangana state of southern India. These canal command area falls in the southern Agro-climatic zones of Telangana. The average annual rainfall of Southern Telangana zone is 606-853 mm, respectively. The major crops growing in the command area were considered in this study.

Musi medium irrigation project was constructed across the Musi River near *Solipet* village and *Suryapet* mandal and district of Telangana state in Krishna basin of *Southern* Telangana zone (Fig. 1). The Musi medium irrigation project is designed with a live storage of 4.60 T.M.C. for providing irrigation to 16915.86 ha in *Kharif* under both canals covering 41 villages of 6 Mandals of Nalgonda district. The command area of the project lies in between both the right and left canals of the project. The length of the right flank main canal (RFMC) is 33.80 km which irrigates a total ayacut of 6141.10 ha covering 19 villages in 4 mandals namely *Kethepally*, *Madugulapally,* *Thipparthy* and *Vemulapally* of *Nalgonda* constituency. The length of the left flank main canal (LFMC) is 41.75 km which irrigates a total ayacut of 6,944.99 ha covering 22 villages in 3 mandals namely *Suryapet*, *Chivvemla* and *Penpahad* of *Suryapet* constituency and district. The total ayacut to be irrigated is nearly of 13,556.97 ha. But, at present, the ayacut has been reduced to 12,140.57 ha due to non-availability of canal water to the tail reaches and also due to urbanization of the tail end of the canals. Geographically the Musi medium irrigation project is located at a latitude of 17 ̊ 15' °N and longitude of 79 ̊ 33' °E at an elevation of about 216.37 m above mean sea level (MSL). Paddy is the major crop grown in the command area (i.e. both RFMC and LFMC) of Musi in both seasons.



**Fig. 1: Location map of the Musi irrigation project**

In the present study, the effectiveness of rainfall for the crop was calculated by using a slight modification in the USDA-SCS method and incorporated as suggested by Gulati (1987). The weekly rainfall and weekly water requirement of the crop were used to calculate the weekly effective rainfall for various crops growing in the command area. Six years (2017-2022) rainfall data of Musi irrigation project taken from the Nasa Power were used.

The crop coefficients (kc) for the crop were selected from the FAO manual (FAO, 1998). The multiplication of reference evapotranspiration (ET0) with the kc during that period were given the crop consumptive use/crop evapotranspiration (ETc).

In addition to the crop evapotranspiration (consumptive use), crops needed special water at different stages, depending upon the crop type, water quality and characteristics of the soil. *Kharif* crops were sown using the moisture from rainfall. So, there is no requirement for pre-sowing irrigation for crops grown in the *Kharif* season. Special water needs includes land preparation, percolation losses and leaching in the paddy. Percolation losses from the paddy fields were assumed as 3 mm day-1 in the current study. Land preparation was required for paddy fields about 10 days. For flooding and land preparation, water requirement for paddy fields during these 10 days were 200 mm (Rao, 2005).

After calculating the weekly total rainfall, total crop water requirement, effective rainfall of each crop and total effectiveness of rainfall were estimated by summing the corresponding weekly values during the crop duration. After that the ratio of effective rainfall and rainfall and then percentage of rainfall effectiveness were calculated. A sample calculation for Paddy crop is shown in Table: 1.

**Table 1: Sample calculation of weekly crop water requirement for paddy *Kharif***

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Week No** | **Rainfall** | **ET0** | **kc** | **ETc** | **Special Needs** | **WR** | **ER** | **NIR** | **GIR** | **GIR** |
| **LP** | **P** |
| **mm** | **mm** |  | **mm** | **mm** | **mm** | **mm** | **mm** | **Mm** | **mm** | **m³** |
| 28 | 26.90 | 38.20 |  |  | 200 | 21 | 221.00 | 20.41 | 200.59 | 266.64 | 41364.63 |
| 29 | 148.85 | 33.37 |  |  | 200 | 21 | 221.00 | 0.00 | 221.00 | 293.77 | 45573.38 |
| 30 | 8.57 | 41.87 | 1.14 | 47.73 | 200 | 21 | 268.73 | 7.69 | 261.04 | 346.99 | 53829.56 |
| 31 | 18.37 | 38.85 | 1.14 | 44.29 |  | 21 | 65.29 | 15.24 | 50.05 | 66.53 | 30962.97 |
| 32 | 79.73 | 27.84 | 1.14 | 31.74 |  | 21 | 52.74 | 0.00 | 52.74 | 70.11 | 32629.10 |
| 33 | 30.63 | 24.92 | 1.14 | 28.41 |  | 21 | 49.41 | 21.28 | 28.13 | 37.39 | 17401.25 |
| 34 | 52.57 | 27.01 | 1.16 | 31.33 |  | 21 | 52.33 | 30.28 | 22.05 | 29.31 | 13640.83 |
| 35 | 25.62 | 27.79 | 1.18 | 32.79 |  | 21 | 53.79 | 18.79 | 35.00 | 46.52 | 21650.34 |
| 36 | 37.53 | 28.51 | 1.2 | 34.21 |  | 21 | 55.21 | 26.38 | 28.83 | 38.32 | 17834.08 |
| 37 | 40.86 | 31.47 | 1.21 | 38.08 |  | 21 | 59.08 | 29.33 | 29.75 | 39.55 | 18406.52 |
| 38 | 6.24 | 23.29 | 1.22 | 28.41 |  | 21 | 49.41 | 4.60 | 44.81 | 59.56 | 27719.14 |
| 39 | 87.78 | 24.91 | 1.22 | 30.39 |  | 21 | 51.39 | 0.00 | 51.39 | 68.31 | 31791.38 |
| 40 | 50.66 | 20.56 | 1.22 | 25.08 |  | 21 | 46.08 | 0.00 | 46.08 | 61.25 | 28505.67 |
| 41 | 19.13 | 24.04 | 1.22 | 29.33 |  | 21 | 50.33 | 14.04 | 36.29 | 48.24 | 22450.83 |
| 42 | 2.60 | 27.74 | 1.21 | 33.57 |  | 21 | 54.57 | 0.00 | 54.57 | 72.54 | 33760.02 |
| 43 | 0.45 | 26.96 | 1.16 | 31.27 |  | 21 | 52.27 | 0.00 | 52.27 | 69.48 | 32335.90 |
| 44 | 0.14 | 27.73 | 1.07 | 29.67 |  | 21 | 50.67 | 0.00 | 50.67 | 67.35 | 31344.60 |
| 45 | 0.01 | 26.30 | 0.90 | 23.67 |  | 21 | 44.67 | 0.00 | 44.67 | 59.38 | 27635.37 |
|  | **636.64** |  |  | **519.97** |  | **378** | **1497.97** | **188.04** | **1309.93** | **1741.24** | **528835.56** |

Note: ET0: Reference Evapotranspiration; kc: crop coefficient: ETc: Crop evapotranspiration; LP: Land Preparation; P: Percolation; WR: Water Requirement; ER: Effective Rainfall and RE: Rainfall Effectiveness.

**3. Results and Discussion**

The total rainfall, water requirement, effective rainfall and effectiveness of rainfall values for major crops growing in the command area of Musi irrigation project was calculated and the averages of five years rainfall, effective rainfall, water requirement and effectiveness of rainfall values for major crops growing in the command area of Musi irrigation project.

**Rainfall (R), Effective Rainfall (ER) and Water requirement (WR) under Musi project**

The major crop grown under the command area of Musi medium irrigation project is Paddy. The total rainfall, water requirement, effective rainfall and effectiveness of rainfall values for Paddy crop growing in the command area of Musi were presented in Table 2. The averages of five years rainfall (R), effective rainfall (ER) and water requirement (WR) for the paddy crop during *Kharif* season were found to be 601, 185 and 1860 mm under the command area of RFMC; and 602, 184 and 1841 mm under the command area of LFMC of Musi irrigation project (Table 2). Also, during *Rabi* season, the five years average rainfall (R), effective rainfall (ER) and water requirement (WR) were 35, 24 and 1980 mm, respectively found to be under the command area of RFMC and 35, 24 and 1942 mm, respectively found to be under the command area of Musi irrigation project (Table 2).

**Table 2: Effectiveness of rainfall for Paddy under RFMC of Musi project**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Canal** | **Year** | **Annual Rainfall (mm)** | **Kharif** | ***Rabi*** |
| **R (mm)** | **ER (mm)** | **WR (mm)** | **RE (%)** | **R (mm)** | **ER (mm)** | **WR (mm)** | **RE (%)** |
| **RFMC** | 2017-18 | 847 | 638 | 189 | 1831 | 30 | 25 | 18 | 1999 | 72 |
| 2018-19 | 585 | 317 | 141 | 2099 | 44 | 65 | 43 | 2047 | 66 |
| 2019-20 | 707 | 545 | 296 | 1705 | 54 | 37 | 29 | 2002 | 80 |
| 2020-21 | 1199 | 842 | 149 | 1794 | 18 | 3 | 0 | 1940 | 0 |
| 2021-22 | 931 | 662 | 148 | 1871 | 22 | 45 | 30 | 1911 | 66 |
| **Average** | **854** | **601** | **185** | **1860** | **34** | **35** | **24** | **1980** | **57** |
| **LFMC** | 2017-18 | 847 | 637 | 189 | 1811 | 30 | 25 | 18 | 2004 | 71 |
| 2018-19 | 585 | 317 | 141 | 2071 | 44 | 65 | 43 | 1999 | 67 |
| 2019-20 | 707 | 545 | 296 | 1699 | 54 | 37 | 30 | 1954 | 79 |
| 2020-21 | 1199 | 849 | 149 | 1777 | 18 | 3 | 0 | 1892 | 0 |
| 2021-22 | 931 | 660 | 147 | 1847 | 22 | 45 | 30 | 1861 | 66 |
| **Average** | **854** | **602** | **184** | **1841** | **34** | **35** | **24** | **1942** | **57** |

Note: R: Rainfall; WR: Water Requirement; ER: Effective Rainfall and RE: Rainfall Effectiveness.

Fig. 2: Average Rainfall (R), Effective Rainfall (ER) and Water Requirement (WR) of major crop growing in the commands of Musi.

Five years averages of Rainfall (R), Water Requirement (WR) & Effective Rainfall (ER) of major crop growing in the commands of Musi (mm) are shown in Fig.2. The five years (2017-22) average annual rainfall of Musi irrigation project was calculated from the Nasa Power and provided as 854 mm (Table. 2). These values were more than the normal annual rainfall. Paddy crop (*Kharif* and *Rabi* season) receives 74-75% of the five years average annual rainfall in the command area (RFMC & LFMC) of Musi irrigation project. Therefore, the contribution of the rainfall or rainwater use efficiency was found to be depending upon the crop, season and location. The results obtained were in line with the results of Adnan and Khan (2009), Hasan *et al.,* (2019) and Vekaria *et al.,* (2020). The water requirement of a crop depends upon the reference evapotranspiration (ET0), crop characteristics (Crop coefficient, crop stage and crop consumptive use (ETc)), effective rainfall and an application efficiency. In case of Paddy crop, water requirement accounts for special needs including land preparation and percolation. So, that the Paddy crop requires more water than the cotton and chillies. Also, Laghari *et al.,* (2014), Djaman *et al.,* (2017) and Babu *et al.,* (2015) were found similar results in their studies.

**Effectiveness of Rainfall under Musi project**

The Effectiveness of Rainfall (RE) for major crops growing in the command areas of Musi (%) was calculated and shown in Fig.3. It can be visualized that the five years averages effectiveness of rainfall for Paddy crop in *Kharif* and *Rabi* season was 34% and 57% respectively under the command area of RFMC and LFMC of Musi medium irrigation project (Fig. 3). Similar results also matched with the Hasan *et al.,* (2019) and Babu *et al.,* (2015).

**Effectiveness of Rainfall for below, normal and above normal annual rainfall**

The average annual rainfall of Musi irrigation project was taken from the Nasa Power and provided in Table.2. From the Table. 2, rainfall received at the Musi medium irrigation project during 2017-18 and 2019-20 was normal annual rainfall. While, during 2018-19 received was below the normal annual rainfall and remaining 2020-22 received above the normal annual rainfall. During the below, normal and above normal annual rainfall year, it was found that the Paddy crop had the effectiveness of rainfall 62, 21 and 12% under the command area of RFMC of Musi medium irrigation project. Whereas, 25, 23 and 11% under the command area of LFMC of Musi medium irrigation project respectively.

From the study, the results revealed that the effectiveness of rainfall was more during below the normal annual rainfall year due to the crop utilizes more rainwater for its growth. Whereas, less rainwater was utilized during normal and above normal annual rainfall year. So, that the effectiveness of rainfall was more during below the normal annual rainfall year than the normal and above normal annual rainfall year. Also, the Paddy crop had the highest effectiveness of rainfall (RE). In *Kharif* season, the Paddy crop has effectiveness of rainfall of 28% and 60% in *Rabi* season in the commands of Musi project. Also, the Paddy crop has the highest effectiveness of rainfall percent in all cases due to the heavy rainfall (i.e. above the normal annual rainfall) during all the years in all the command areas (i.e. 20% for most of the years). This is because Paddy crop required standing water for longer period. And, the effectiveness of rainfall for Paddy was higher in *Rabi* due to the soil is very dry in this season than *Kharif* season (i.e. soil is wet). So that, it can starts storing of water in the root zone from the rainfall; which, will be results in more water utilized and causes less runoff. Similar findings inferred with Hasan *et al.,* (2019) and Rao and Rajput (2008).

Fig. 3: Effectiveness of Rainfall (RE) for major crops growing in the command of Musi (%)

**4. Conclusions**

On the basis of results it can be concluded that the effectiveness of rainfall was more during below the normal annual rainfall year due to the crop utilizes more rainwater for its growth, whereas, less rainwater was utilized during normal and above normal annual rainfall year. So, that the effectiveness of rainfall was more during below the normal annual rainfall year than the normal and above normal annual rainfall year. Also, the results revealed that the effectiveness of rainfall for Paddy was higher than the other crops i.e. 20% for most of the years. In *Kharif* season, the Paddy crop has effectiveness of rainfall of 21% where as it was 30% in *Rabi* season in the command areas of Musi project. Also, the results revealed that the Paddy crop has the highest effectiveness of rainfall percent in all cases due to standing water for longer period. The effectiveness of rainfall was varied due to the variation of rainfall of Agro-climatic zones of Telangana.

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**Disclaimer**

Authors hereby declare that NO generate AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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