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# COMPUTATION OF CROP WATER REQUIREMENT AND DEVELOP IRRIGATION SCHEDULE OF FIELD CROP IN THORDI VILLAGE, BHAVNAGAR, GUJARAT

[1]Gondaliya H. H., [2]Gohil K. B.,

[1]M.E. Student, [2]Assistant Professor

[1]Civil Engineering Department (Water Resources Engineering),

[1]Shantilal Shah Engineering College, Bhavnagar, Gujarat, India

*Abstract:* The overall usable amount of water on Earth is fixed and finite due to the continuing process of evaporation and precipitation across the hydrological cycle. Just 0.01% of this gross amount is usable as surface water in lakes and rivers. A significant amount of surface water is used in agriculture, and therefore good water usage will save more water on Earth. The aim of this research is to increase crop production by computing crop water and irrigation water demand, as well as developing an irrigation schedule in the Thordi village, which is located in Gujarat's semi-arid zone. The crops under consideration are groundnut, chickpea, wheat, sorghum, and millet, which are primarily grown in the Thordi village. The Cropwat, Penman-Monteith method developed by FAO is used to achieve the goal of this analysis. Irrigation scheduling is developed by integrating the timing option of irrigating at critical depletion with the operation option of refilling soil to field capability. This irrigation scheduling option results in the least amount of yield loss. ET0 has a cumulative value of 2054.95 mm/year. The analysis is carried out for five crops, with the maximum CWR and IR for winter wheat crop being 538.7 mm/dec and 522.6 mm/dec, respectively, and the minimum for sorghum being 348.1 mm/dec and 30.2 mm/dec. This research would undoubtedly improve crop production and save more water in the Bhavnagar district's Thordi village.

***Key words* - Evapotranspiration, FAO-Cropwat, Plant water requirement, Irrigation scheduling, Chickpea, Groundnut, Wheat, Sorghum, Millet.**

## I. INTRODUCTION

### 1.1 General

All plants require water to live, grow and provide a satisfactory yield to meet human needs. The relationship between crops, climate, soil, and water involves many biological, physical, and chemical processes. The maximum potential yield of a crop is determined primarily by the climate and the genetic potential of the crop. The irrigation system is to be designed and managed to meet the crop's water requirement in quantity and time to attain optimum yields.

### 1.2 Irrigation and Crop Water requirement

The estimation of the water requirements (WR) of crops is one of the basic needs for crop planning on the farm and for the planning of any irrigation projects. Demand of water is described as the amount of water needed by either a crop or diverse pattern of plants in such a specified period of time for healthy development under field trials at a location, regardless of origin. Water needs include evapotranspiration or consumptive usage losses, as well as losses during water application (unavoidable losses), and the amount of water required for special operations such as land preparing, pre-sowing irrigation, and transplanting.

#### 1.2.1 Water Needs of Crop

Water requirements include evapotranspiration and unavoidable losses of water like deep percolation. It also includes the requirement of pre-sowing irrigation and the leaching of salts, whenever required. Crop factors include types of crop, cultivar/species, growing stage, leaf area, root length, root density. Temperature, Radiation, Humidity, and wind speed affect the crop water requirement as a weather factor.

### 1.2.2 Irrigation Water Requirement

Irrigation water requirement is the quantity of water, exclusive of precipitation and contribution of soil moisture stored in the crop root zone and the upward flow of water to the root zone from a saturated zone below, that is required for normal crop production. The farm irrigation requirement depends on the irrigation needs of individual crops, their area, and the losses in the farm water distribution systems, mainly by way of seepage. The irrigation requirement of an outlet command area includes the irrigation requirement of individual farm holdings and the losses in the conveyance and distribution system.

### 1.3 Planning of Irrigation

The method of deciding when to irrigate as well as how much water to apply is known as irrigation scheduling. When creating an irrigation schedule, three parameters must be taken into account. These include the crop's daily water needs, the soil's gross usable moisture and the depth of the productive root zone.

### 1.4 Objectives

1. To Calculate reference evapotranspiration.
2. To calculate crop water requirements.
3. To develop an Irrigation schedule.

## II. STUDY AREA AND DATA COLLECTION

### 2.1 Study Location

The research area considered here is Thordi village in the Bhavnagar district, which is 17 kilometers away from the district. Thordi's coordinates are 21.64700 North (Latitude) and 72.19200 East (Longitude). Google Earth satellite imagery (Fig. 1) was used to create the study region. Cultivation accounts for 40% of total land area.


Figure 1 Google Earth Satellite Imagery Showing Study Area

### 2.2 Crop Data

Groundnut, wheat, millet, sorghum, and chickpea are the crops grown in the study region. The crop data collected were the crop’s planting date and its actual harvesting date, duration of growth stages, at various growth stages the value of $K_C$, $K_Y$, depletion level for allowable soil moisture and rooting depth of crop.

### 2.2 Meteorological Data

This study makes use of five years' collection of meteorological data (01/01/2015 to 01/01/2020). Table 1 shows the results of this data analysis. All of this data is obtained on a daily basis from the SWDC's (state water data center) closest weather station (Ghogha) and, based on latitude and longitude, from NASA's website, which is satellite-based (power.larc.nasa.gov).

| Month | maximum temperature (°C) | minimum temperature (°C) | humidity (%) | wind speed(m/s) | sunshine (hours) | Rainfall (mm) |
|---|---|---|---|---|---|---|
| January | 28.5 | 21.8 | 41 | 2.4 | 7 | 1 |
| February | 31.5 | 24.4 | 37 | 2.3 | 7.8 | 0 |
| March | 34.3 | 28.1 | 35 | 2.4 | 8.1 | 2 |
| April | 38.2 | 31.5 | 39 | 3 | 8.7 | 1 |
| May | 39.5 | 33.5 | 45 | 3.8 | 8.5 | 5 |
| June | 35.5 | 31.7 | 65 | 4.9 | 6.5 | 112 |
| July | 31.9 | 28.8 | 80 | 5 | 3.3 | 198 |
| August | 30.9 | 27.8 | 83 | 4.2 | 3.6 | 162 |
| September | 30.9 | 27.9 | 79 | 2.9 | 5.4 | 116 |
| October | 32.6 | 28 | 65 | 2 | 6.4 | 27 |
| November | 31.4 | 25.6 | 54 | 2.1 | 6.4 | 13 |
| December | 28.5 | 22 | 49 | 2.8 | 5 | 2 |

Table 1 Meteorological data analysis from 01/01/2015 to 31/12/2019

### 2.2 Soil Data

The rate of entry of water into the soil and its retention, movement, and availability to plant roots are all physical phenomena. hence, it is important to know the physical properties of soil in relation to water for the efficient management of irrigated agriculture. According to the survey of the district planning officer of Bhavnagar, Bhavnagar district is in Agro-climatic zone VI (south Saurashtra), VII (north Saurashtra), VII (Bhal and coastal area). Table 2 shows the collected soil parameters from the literature that are available for irrigation scheduling using the FAO CROPWAT software.

| PARAMETER | VALUE |
|---|---|
| Total usable soil moisture (FC - WP) | 200 mm/meter |
| Maximum rate of rain penetration | 30 mm/day |
| Maximum rooting depth | 900 cm |
| Initial soil moisture loss | 50% |
| Initial available soil moisture | 100 mm/meter |

Table 2 value of soil parameter

In the study region, medium black clay soil is available. This are formed by a variety of rocks. The texture varies from silty clay to clay, which is more productive and richer in lime, magnesium, and alumina while becoming deficient in phosphorus, nitrogen, and organic matter. They can hold a lot of moisture and are great for agriculture.

## III. METHODOLOGY

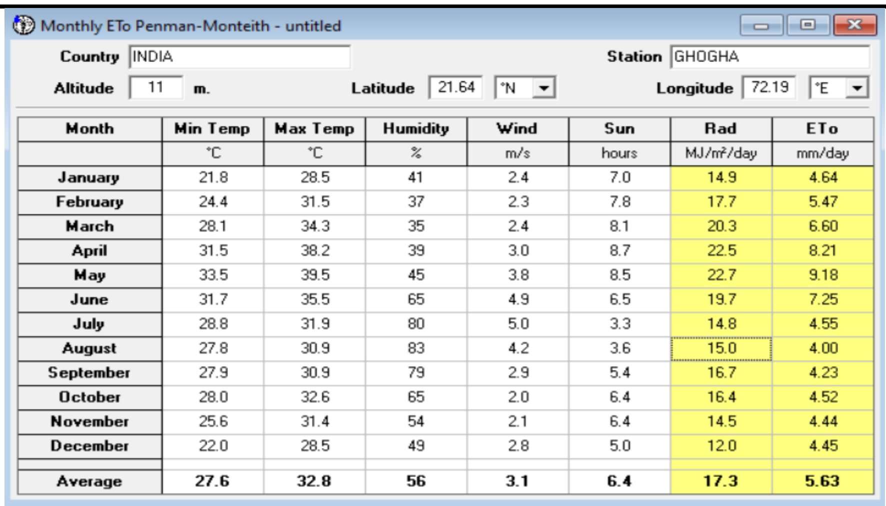
Manually calculating reference evapotranspiration is a time-consuming and labor-intensive process with a high chance of arithmetic error. When most irrigation engineers and practitioners need to estimate crop water requirements for several irrigation projects at the same time, the process will take a long time if done manually. As a result, computerization of the procedure is needed to speed up calculations and make the job less repetitive. FAO CROPWAT, a computer program for estimating ET0 and crop water needs, is one example of such software.

### 3.1 Reference Evapotranspiration and Effective rainfall

FAO penman-Monteith method is used for the calculation of reference evapotranspiration. In CROPWAT 8.0, irrigation schedules are produced using a daily soil-water balance. using various user-defined options for water supply and irrigation management conditions. The subsequent equation gives the penman-Monteith equation.

$$\mathbf{ET0} = \frac{0.408\,\Delta\,(Rn - G) + \Delta\,\frac{900}{T+273}u2\,(es - ea)}{\Delta + {}^{\gamma}(1 + 0.34\,u2)}$$

The approach was created by describing the reference surface as "a hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 sec/m, and an albedo of 0.23 (FAO, 1998a)". The comparison surface is similar to a large expanse of green grass that is uniform in height, actively rising, totally shading the field, and well-watered. We can calculate reference evapotranspiration and efficient rainfall by entering climatic data (temperature, relative humidity, wind speed, sunshine hours, and rainfall) into CROPWAT.




| Month | Min Temp | Max Temp | Humidity | Wind | Sun | Rad | ETo |
|---|---|---|---|---|---|---|---|
| | °C | °C | % | m/s | hours | MJ/m²/day | mm/day |
| January | 21.8 | 28.5 | 41 | 2.4 | 7.0 | 14.9 | 4.64 |
| February | 24.4 | 31.5 | 37 | 2.3 | 7.8 | 17.7 | 5.47 |
| March | 28.1 | 34.3 | 35 | 2.4 | 8.1 | 20.3 | 6.60 |
| April | 31.5 | 38.2 | 39 | 3.0 | 8.7 | 22.5 | 8.21 |
| May | 33.5 | 39.5 | 45 | 3.8 | 8.5 | 22.7 | 9.18 |
| June | 31.7 | 35.5 | 65 | 4.9 | 6.5 | 19.7 | 7.25 |
| July | 28.8 | 31.9 | 80 | 5.0 | 3.3 | 14.8 | 4.55 |
| August | 27.8 | 30.9 | 83 | 4.2 | 3.6 | 15.0 | 4.00 |
| September | 27.9 | 30.9 | 79 | 2.9 | 5.4 | 16.7 | 4.23 |
| October | 28.0 | 32.6 | 65 | 2.0 | 6.4 | 16.4 | 4.52 |
| November | 25.6 | 31.4 | 54 | 2.1 | 6.4 | 14.5 | 4.44 |
| December | 22.0 | 28.5 | 49 | 2.8 | 5.0 | 12.0 | 4.45 |
| Average | 27.6 | 32.8 | 56 | 3.1 | 6.4 | 17.3 | 5.63 |

Figure 2 Reference Evapotranspiration

The figure 3 depicts the formula that we want to use to measure effective rainfall in the software's choice collection module. The fourth method seen in the figure is used for further estimation because it produces more accurate results than the other methods.

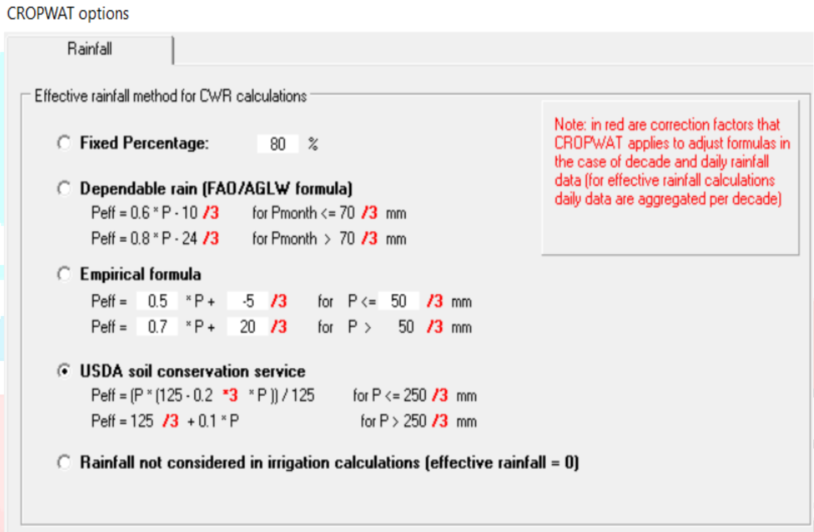



Figure 3 Effective rainfall method for CWR calculations

### 3.2 Crop Water and Irrigation Requirements

After the input of the crop data, CROPWAT proceeds to calculate the crop water and irrigation requirements of the given crop, using the entered crop data and $ET_0$ and effective rainfall values calculated earlier.

### 3.2 Irrigation Scheduling

To create an irrigation program, the program includes timing and application options. The timing option refers to WHEN irrigation will be applied. Irrigate at user specified intervals, at fixed depletion, at critical depletion, at fixed interval per point, at given yield reduction, below or above critical depletion, and completely rainfed (no irrigation required). Among the above timing options, we considered irrigate at critical depletion, which is the time when 100 percent depletion occurs. The Applications alternative is concerned with how much water is to be provided per irrigation. There are four options here: refill soil to field capacity, user specified application, refill soil below or above field capacity, and selecting set application depth.

Of both of these options, we chose or found the best alternative that would reduce yield loss as less as practicable, which is to irrigate at critical degradation as a timing choice and to refill soil to field potential as an application method.

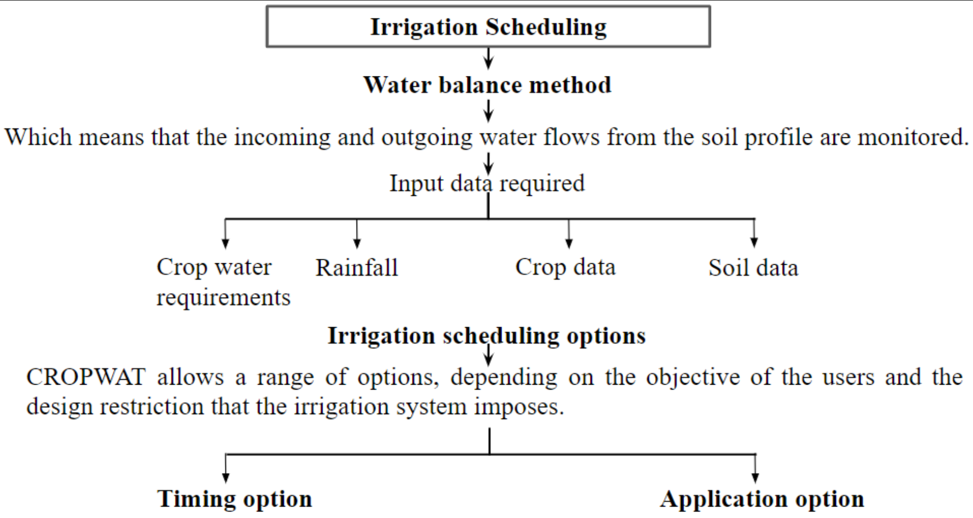



Figure 4 Input method flow chart for irrigation scheduling

## IV. RESULT AND DISCUSSION

### 4.2 Reference Evapotranspiration ($ET_0$)

Table 4.1 shows the result of the amount of reference ET in mm per day in Thordi village. For study location Reference Evapotranspiration varies between 4 mm/day to 9.18 mm/ day. The average value of $ET_0$ found out 5.63 mm/day. The monthly value of $ET_0$ shows in table 4.1. We got Annually 2054.95 mm total reference evapotranspiration.

| Month | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ETo(mm/day) | 4.64 | 5.47 | 6.6 | 8.21 | 9.18 | 7.25 | 4.55 | 4 | 4.23 | 4.52 | 4.44 | 4.46 | 5.63 |

Table 3 Monthly Result of evapotranspiration in mm per day

The highest value of $ET_0$ was found in May and the lowest in August. This shows clearly in figure 5. From this result, we say that $ET_0$ is at its peak in the summer season and lower in the monsoon.

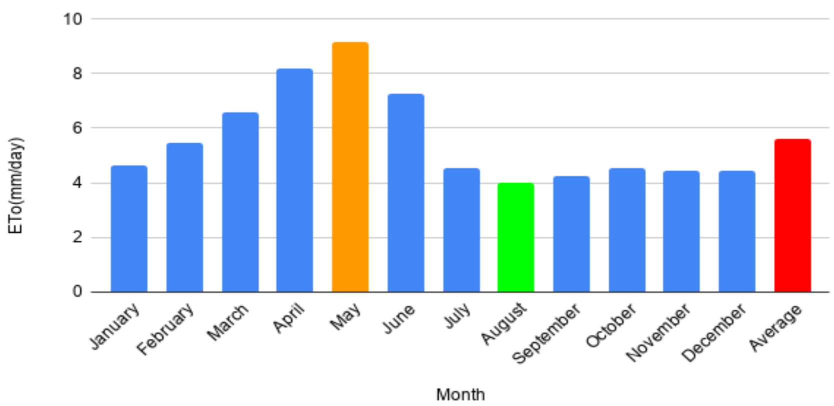



Figure 5 $ET_0$ Vs. month

### 4.2 Result of Efficient Rainfall

Figure 6 depicts the outcome of successful rainfall using all the approaches at the same time. We used the USDA SCS process, which yields a more accurate effective rainfall value of 491.2 mm gross annual rainfall. As a result, we will take this result into account for future calculations.

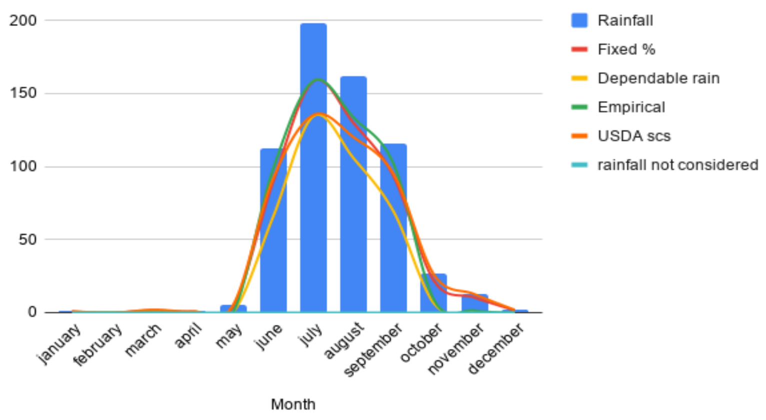



Figure 6 Rainfalls in mm vs. month

### 4.3 Crop Water Requirement

We calculated crop water requirements for all crops using reference evapotranspiration and crop info. Figure 7 depicts the results of crops such as groundnut, sorghum, wheat, millet, and chickpea. We calculated the overall crop water demand in millimeter per decade. In this case, the decade refers to a 10-day era.

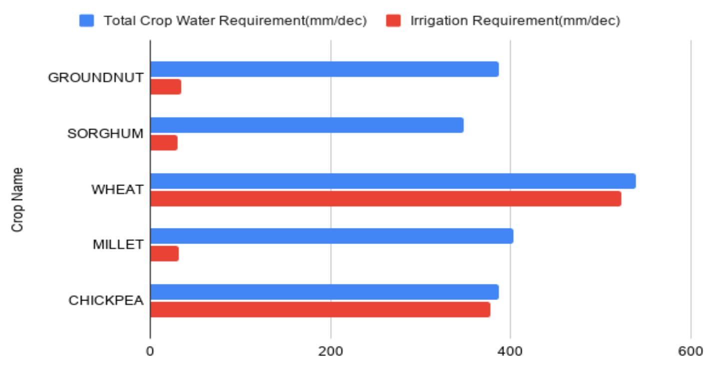



Figure 7 Bar chart of CWR and IR

We obtained the highest water demand for wheat crop and the lowest for sorghum, as seen in the table below. The output file is summarized in Table 4.

| Crop Name | Total Crop Water Requirement(mm/dec) | Irrigation Requirement(mm/dec) |
|---|---|---|
| GROUNDNUT | 386.6 | 34.4 |
| SORGHUM | 348.1 | 30.2 |
| WHEAT | 538.7 | 522.6 |
| MILLET | 403.5 | 31.8 |
| CHICKPEA | 386.2 | 377.9 |

Table 4 Summary of output of CWR and IR

### 4.4 Irrigation Scheduling

Output of Irrigation scheduling and yield reduction for individual crops is seen in the following section. which is summarized in table 5 Cropwat develops an irrigation demand plan based on water demand and production. This schedule indicates that no significant irrigation is needed for the sorghum farm. The crop's yield loss is kept to a minimum. Irrigation efficiency around 70% is taken into account here.

| Crop Name | Date | Day | Stage | Depletion % | Net Irr mm | Gr. Irr mm | Flow l/s/ha |
|---|---|---|---|---|---|---|---|
| GROUNDNUT | 15 Jun | 1 | Init | 54 | 33.7 | 48.1 | 5.56 |
| | 2 Oct | End | End | 9 | | | |
| | | | | | | | |
| MILLET | 15 Jun | 1 | Init | 57 | 35.9 | 51.3 | 5.93 |
| | 27 Sep | End | End | 0 | | | |
| | | | | | | | |
| WHEAT | 4 Nov | 4 | Init | 62 | 50.9 | 72.7 | 2.1 |
| | 25 Nov | 25 | Dev | 61 | 121.4 | 173.4 | 0.96 |
| | 23 Dec | 53 | Mid | 61 | 170.2 | 243.1 | 1.01 |
| | 24 Jan | 85 | Mid | 60 | 169.1 | 241.6 | 0.87 |
| | 28 Feb | End | End | 53 | | | |
| | | | | | | | |
| CHICKPEA | 15 Nov | 1 | Init | 51 | 62.5 | 89.3 | 10.34 |
| | 13 Dec | 29 | Dev | 46 | 78.7 | 112.4 | 0.46 |
| | 2 Jan | 49 | Mid | 46 | 91.7 | 130.9 | 0.76 |
| | 22 Jan | 69 | Mid | 46 | 92.4 | 132 | 0.76 |
| | 10 Feb | 88 | End | 48 | 95 | 135.8 | 0.83 |
| | 27 Feb | End | End | 28 | | | |

Table 5 Summary of Irrigation Plan

### 4.5 Comparison of actual harvesting date and software output date

| Sr. No | Crop Name | Planting Date | (actual)Harvesting Date | (in output)Harvesting Date |
|---|---|---|---|---|
| 1 | Groundnut | 15/06/2020 | 01/10/2020 | 02/10/2020 |
| 2 | Millet | 15/06/2020 | 15/09/2020 | 12/10/2020 |
| 3 | Sorghum | 15/06/2020 | 15/09/2020 | 27/09/2020 |
| 4 | wheat | 01/11/2020 | 10/02/2021 | 28/02/2021 |
| 5 | Gram | 15/11/2020 | 17/02/2021 | 27/02/2021 |

Table 6 Comparison of actual and output harvesting date

## V. CONCLUSION

The aim of this research was to increase crop production in the Bhavnagar district village of Thordi, which was accomplished by achieving the objectives of my study. The total annual Reference evapotranspiration was discovered to be 2054.95 mm. A schedule of irrigation was established for each crop considered in the current study by computing crop water requirements and irrigation demand. The crop water demand in millimeter per dec was found to be 386.6 for groundnut, 348.7 for sorghum, 538.7 for wheat, 403.5 for millet, and 386.2 for chickpea (Gram). When we consider the actual scenario of crop harvesting date and date in output file, we see only minor differences, indicating that Cropwat provides us with accurate results that can be used for any crop production prediction in Thordi village. In terms of limitations, we discovered that if we adjust the method of efficient rainfall, there is no change in crop water demand, and if we change the duration of growth stages, the date of harvesting changes in the crop data input module. The harvesting date does not change when the other characteristics are changed. Overall yield can be used to forecast crop water demand and irrigation demand by comparing it to the current scenario Cropwat. We will use the results of this analysis to plan irrigation canal projects in Thordi Village.

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