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# Assessment of Crop-Water Requirement of Alfalfa Using FAO-CROPWAT Model-8.0

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*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

The current study was conducted at the Farming System Research Station, situated within the Department of Agronomy at the College of Agriculture, Junagadh Agricultural University in Junagadh, Gujarat, India. This research took place during the winter cycle (*Rabi* season) 2021 to 2022 and 2022 to 2023. In this study, the CROPWAT crop irrigation schedule provides an overall Evapotranspiration (ETc) value of 549.6 millimeters as the optimal water requirement for achieving maximum crop production with sufficient water supply. The actual water use by the crop during its growth period amounted to 544.2 millimeters and total net irrigation applied was 507.9 millimeters, while the gross irrigation amounted to 725.6 millimeters. The irrigation efficiency was 100%. Comparing this approach to irrigation scheduling based on the Irrigation Water to Crop Potential

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Evapotranspiration (IW/CPE) ratio, using CROPWAT enabled the precise management of irrigation water. It ensured that the alfalfa crop received the appropriate amount of water according to its specific growth stage requirements. The CROPWAT model data indicates that there was no yield reduction, even with a 100% critical depletion of available soil moisture. Additionally, the seasonal yield response factor was calculated to be 0.80%. These findings emphasize the effectiveness of the irrigation strategy employed, resulting in optimal crop yields without yield losses due to critical soil moisture depletion.

*Keywords: Cropwat; irrigation schedule; alfalfa; crop evapotranspiration and CWR.*

## 1. INTRODUCTION

The water requirements of crops play a pivotal role in determining their yield and overall productivity. Several factors influence crop water needs, including climatic conditions, crop type and acreage, soil composition, growing seasons, and the frequency of crop cultivation [1]. To ensure a bountiful harvest, it is crucial to provide adequate water to crops at critical growth stages. Unfortunately, traditional irrigation methods, such as surface water irrigation, have led to water shortages exacerbated by climate-related factors. This has resulted in reduced agricultural productivity and inefficient water use, primarily attributed to conventional flooding irrigation techniques and the inadequate adoption of scientific water management practices [2].

Globally, there is a noticeable decline in irrigation water supplies, and water scarcity is increasingly prevalent. In India, agriculture is the largest consumer of water resources, necessitating significant efforts towards efficient water utilization (Surendran *et al.*, 2013). With India recently surpassing a population of 1.4 billion, it is apparent that the water demands of such a vast populace are on the rise. Consequently, the implementation of intelligent water management strategies is essential to address water shortages. The growing population's increased food demands pose a substantial challenge, especially as resources become scarcer. One of the core issues is the inefficient utilization of water resources, with water use efficiency in conventional irrigation methods at a mere 50 to 60 percent [2]. Efficient water management hinges on two critical factors: precise irrigation scheduling and the effective use of irrigation water. Enhancing water use efficiency in irrigated agriculture can also optimize the benefits derived from other agricultural inputs, such as fertilizers, high-quality seeds, tillage, energy, and machinery (Sharma *et al.*, 2015). Given that water is both invaluable and limited, studies on irrigation scheduling, water use efficiency, consumptive water use, and soil moisture distribution patterns are of paramount importance for achieving maximum crop yields.

Alfalfa, an ancient crop with its origins in South-Central Asia, has remarkably spread across regions, including the Mediterranean Basin, South America, and North America. This versatile crop can thrive in both rainfed and irrigated conditions, and its harvest frequency varies throughout the year depending on climate and management practices. It's worth noting that how alfalfa is harvested has a substantial impact on its yields, as demonstrated in studies by Orloff and Putnam [3] and Teixeira *et al.* [4]. Alfalfa holds a crucial position in the global animal husbandry food chain, serving as fodder in various forms such as hay, silage, or pellets. Consequently, it is traded worldwide as a valuable commodity [5]. One noteworthy characteristic of alfalfa is its relatively high transpiration ratio [6]. Given its significant water requirements, efficient irrigation management becomes paramount. To ensure optimal yields and prevent adverse effects on soil properties, it is essential to adopt irrigation scheduling, which involves applying the right amount of water precisely when the crop needs it, as recommended by Rockstorm and Barron [7]. Effective irrigation not only boosts both green and dry fodder yields but also enhances the quality of the fodder itself, as highlighted by Kumar [8]. These findings underscore the critical role of water scheduling and prudent water consumption in the cultivation of alfalfa.

Recognizing the critical importance of irrigation scheduling, several computer models have been developed to enhance the efficiency of irrigation water usage. These models represent an emerging trend in the realm of water use efficiency. Among them, the CROPWAT software stands out as a notable example. It serves as a decision support system for estimating irrigation scheduling and crop water requirements, and it has gained widespread adoption in the field of water management worldwide. CROPWAT was developed by Smith [9] under the auspices of the Food and Agricultural Organization (FAO). One noteworthy application of CROPWAT is the determination of crop water requirements for major crops in the North coastal districts of Andhra Pradesh, achieved through the analysis of long-term climatic data using the CROPWAT 8.0 model [10]. This software tool facilitates the calculation of crop evapotranspiration, crop water requirements, and irrigation schedules for various cropping patterns, aiding in efficient irrigation planning, as demonstrated by Gowda et al. [11]. The CROPWAT model excels in two primary functions:

1. **Estimation of Crop Evapotranspiration:** It accurately calculates the water lost from crops through both evaporation from the soil and transpiration from plant leaves. This information is essential for determining how much water a crop requires for optimal growth.
2. **Irrigation Scheduling:** CROPWAT helps in devising precise irrigation schedules, ensuring that crops receive the right amount of water at the right times, thereby maximizing water use efficiency and crop productivity.

These capabilities make CROPWAT a valuable tool in the effective management of water resources in agriculture, aligning with the broader goals of sustainable and efficient farming practices.

## 2. MATERIALS AND METHODS

### 2.1 Study Location

The current study was conducted at the Farming System Research Station, situated within the Department of Agronomy at the College of Agriculture, Junagadh Agricultural University in Junagadh, Gujarat, India. This research took place during the winter cycle, specifically the Rabi season, spanning from 2021 to 2022 and continuing into 2022 to 2023. The geographical location of the farm is noteworthy, as it is positioned at an elevation of 60 meters above sea level, with coordinates at 21.50 degrees North latitude and 70.50 degrees East longitude. The region experiences its rainy season, which typically begins in the second half of June and concludes in September, characterized by an average annual rainfall of approximately 1088.55 millimeters.

### 2.2 Crop Water Requirement

The crop water requirement is the amount of water equal to what is lost from a cropped field by ET and is expressed by the rate of ET in mm/day. Estimation of CWR is derived from crop evapotranspiration (ETc) which can be calculated by the following equation.

$$ET_c = K_c * ET_0$$

Where, Kc is the crop coefficient.

It is the ratio of the crop ETc to the ET0, and it represents an integration of the effects of four essential qualities that differentiate the crop from reference grass, and it covers albedo (reflectance) of the crop–soil surface, crop height, canopy resistance, and evaporation from the soil. Due to the ET differences during the growth stages, the Kc for the crop will vary over the developing period which can be divided into four distinct stages: initial, crop development, mid-season, and late season. The reference evapotranspiration $ET_0$ is calculated by FAO Penman- Monteith method, using decision support software –CROPWAT 8.0 developed by FAO, based on FAO Irrigation and Drainage Paper 56 [12]. The FAO CROPWAT program [10] incorporates procedures for reference crop evapotranspiration and crop water requirements and allows the simulation of crop water use under various climate, crop and soil conditions (www.FAO.org).

### 2.3 Meteorological Data

Meteorological data of ten years was collected from meteorological station located near the experimental sites. Meteorological parameters used for calculation of $ET_0$ are latitude, longitude and altitude of the station, maximum and minimum temperature (°C), maximum and minimum relative humidity (%), wind speed (m/s) and sunshine hours which were collected and the average values have been fed to the model. Rainfall data collected from the same station is also fed to the software which would generate the effective rainfall data (Table 1).

### 2.4 Crop Data

Groundnut is the major crop in this region during rainy cycle and groundnut – wheat being the most popular cropping system. CROPWAT software needs certain information like crop coefficient, Kc values (initial, mid and late growth stages), depth of root, crop duration time, critical depletion and yield response factor which have been taken from FAO Irrigation and drainage paper 56. The yield response factor ($K_y$) is the ratio of relative yield reduction to relative evapo-transpiration deficit that integrates the weather, crop and soil conditions which make crop yield less than its potential yield in the face of deficit evapo-transpiration. Sowing and harvesting date were taken according to the guide from agricultural operations over this area. Sowing dates were taken at 15 days interval starting from December 15th.

## 2.5 Soil Data

Soil type in this area is medium black clay. The software needs some general information about the soil *viz.* total available soil moisture, maximum rain infiltration rate, maximum rooting depth, initial soil moisture depletion and initial available soil moisture.

## 2.6 Irrigation Schedule

Irrigation scheduling determines the correct measure of water to irrigate and the correct time for irrigation. The CROPWAT model calculates the $ET_0$, crop water requirement and irrigation requirements to develop the irrigation schedules under different administration conditions and water supply plans.

# 3. RESULTS AND DISCUSION

## 3.1 Climatic Data

The climatic data and potential evapotranspiration during the investigation period are summarized in Table 1. Throughout the crop cycle, the reference evapotranspiration ($ET_0$) ranged from 3.11 to 6.54 mm. Wind speeds fluctuated between 0.8 to 2.4 meters per second, indicating a moderate breeze during this time. Sunshine hours were relatively low, varying from 1.6 to 9.6, suggesting predominantly overcast skies throughout the day. The maximum and minimum temperatures recorded during this period were 40.76°C and 11.43°C, respectively. These temperature ranges are considered optimal for the growth of alfalfa crops in semi-arid regions, providing favorable conditions for cultivation. In terms of effective precipitation, the area received an average of 651.7 mm of rainfall throughout the year in 2021-22 and 2022-23, as detailed in Table 1. Most notably, the effective precipitation was highest from July to September, indicating a significant rainy season during these months. However, from November to May, effective rainfall was negligible, suggesting a dry period during this period. This climatic information is essential for understanding the water availability and requirements for alfalfa cultivation in the region.

Throughout the growth of the alfalfa crop, there was a noticeable absence of rainfall, necessitating the use of irrigation to meet the crop's water requirements. The patterns of irrigation water requirement and the availability of water in the field deviated from the expected trends due to variations in temperature. This deviation from observed trends is quite understandable in this study, as the lack of rainfall meant that the crop relied heavily on irrigation to sustain its water needs. The temperature fluctuations likely played a significant role in driving the increased demand for irrigation, highlighting the importance of efficient water management in response to changing climate conditions.

In Table 2, the crop water requirements for alfalfa in a semi-arid region during the short rains are outlined. During the initiation stage, the Crop Coefficient (Kc) was observed to be 0.50. Evapotranspiration (ETc) was calculated to be 1.62 and 12.86 millimeters per day and per decade, respectively. Notably, there was no effective rainfall recorded during this stage. This is attributed to the fact that the crop was in its initial growth phase, characterized by minimal leaf area and predominantly soil evaporation-driven actual evapotranspiration. The low Kc value reflects the crop's early establishment with limited canopy and ground cover, resulting in a minimal water requirement. This phenomenon can be attributed to the inverse relationship between evaporative demand from the atmosphere and Kc values, as explained by Van Ranst and Verdoodt (2005). Moving into the vegetative stage, there was a progressive increase in Kc values. In the third decade (December), Kc was 0.56, followed by 0.70, 0.82, and 0.95 in the first, second, and third decades of January, respectively. Correspondingly, ETc increased, ranging from 1.57 to 6.13 millimeters per day over the course of the crop cycle. These trends indicate the growing water requirements of the alfalfa crop as it progressed through its vegetative stage.

The rapid growth and development of the crop during the vegetative stage demand a substantial amount of water, making irrigation a necessity at this critical phase of crop growth. Water depletion during this stage was notably rapid, and it increased as the crop continued to develop, as depicted in Fig. 2. The rate of water depletion exceeded the level of Readily Available Moisture (RAM) in the soil, indicating that additional water, through irrigation, was required to meet the crop's increasing water needs. In Table 2, it is evident that both the Crop Coefficient (Kc) and Evapotranspiration (ETc) reached their maximum values during the vegetative stage. Kc peaked at 1.11, reflecting the high water demand of the rapidly growing crop canopy. Meanwhile, ETc reached a maximum value of 67.4 millimeters per decade, underlining the substantial daily water requirement of the crop during this growth phase. These findings emphasize the critical need for irrigation during the vegetative stage to ensure adequate water supply to support the crop's vigorous development.

**Table 1. Climate characteristics, rainfalls, and $ET_0$ of experiment area (average of 2021-22 and 2022-23 period) obtained using CROPWAT software**

| Month | Temperature | | Humidity % | Wind speed (m/s) | BSS | Rainfall (mm) | ET (mm/day) | Rad (MJ/m$^2$/day) | ETo |
|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | | | | | | | |
| Jan | 11.43 | 27.75 | 54.31 | 1.3 | 6.7 | 0.1 | 4.3 | 16.6 | 3.11 |
| Feb | 14.18 | 32.01 | 49.71 | 1.1 | 8.9 | 0 | 5.4 | 19.2 | 3.84 |
| March | 20.17 | 38.00 | 38.64 | 1.4 | 9.6 | 0 | 8.3 | 22.4 | 5.57 |
| April | 23.23 | 40.76 | 46.03 | 1.5 | 9.3 | 4.8 | 8.8 | 23.5 | 6.42 |
| May | 25.82 | 38.76 | 56.92 | 2.4 | 7.6 | 26.55 | 8.8 | 21.4 | 6.65 |
| June | 26.33 | 36.70 | 67.66 | 2.4 | 4.2 | 92.65 | 6.8 | 16.2 | 5.21 |
| July | 24.77 | 31.51 | 82.78 | 2.3 | 1.6 | 461.25 | 3.0 | 12.3 | 3.34 |
| August | 24.02 | 31.71 | 80.10 | 1.9 | 2.4 | 213.45 | 3.2 | 13.2 | 3.43 |
| September | 23.80 | 31.38 | 81.48 | 1.3 | 4.0 | 480.15 | 3.0 | 14.7 | 3.39 |
| October | 21.60 | 34.40 | 59.07 | 0.9 | 8.6 | 64.4 | 4.4 | 19.4 | 4.26 |
| November | 16.71 | 33.61 | 49.88 | 0.8 | 7.9 | 0 | 4.3 | 16.4 | 3.47 |
| December | 15.11 | 29.87 | 52.80 | 1.1 | 6.8 | 0 | 4.3 | 14.1 | 3.13 |

**Table 2. Daily and decadal crop water requirement of alfalfa at the experimental site (average of 2021-22 and 2022-23)**

| ETo station | | Junagadh | | | | Crop | Alfalfa |
|---|---|---|---|---|---|---|---|
| **Rain station** | | **Junagadh** | | | | **Planting date** | **27/11** |
| **Month** | **Decade** | **Stage** | **Kc (coefficient)** | **ETc (mm/day)** | **ETc (mm/decade)** | **Eff. Rain (mm/decade)** | **Irr. Req. (mm/decade)** |
| Nov. | 3 | Init. | 0.50 | 1.68 | 6.7 | 0.0 | 6.7 |
| Dec. | 1 | Init. | 0.50 | 1.62 | 16.2 | 0.0 | 16.2 |
| Dec. | 2 | Init. | 0.50 | 1.57 | 15.7 | 0.0 | 15.7 |
| Dec. | 3 | Devp. | 0.56 | 1.76 | 19.4 | 0.0 | 19.4 |
| Jan. | 1 | Devp. | 0.70 | 2.17 | 21.7 | 0.0 | 21.7 |
| Jan. | 2 | Devp. | 0.82 | 2.55 | 25.5 | 0.0 | 25.5 |
| Jan. | 3 | Devp. | 0.95 | 3.20 | 35.2 | 0.0 | 35.2 |
| Feb. | 1 | Mid. | 1.08 | 3.81 | 38.1 | 0.0 | 38.1 |
| Feb. | 2 | Mid. | 1.11 | 4.14 | 41.4 | 0.0 | 41.4 |
| Feb. | 3 | Mid. | 1.11 | 4.82 | 38.5 | 0.0 | 38.5 |
| Mar. | 1 | Mid. | 1.11 | 5.53 | 55.3 | 0.0 | 55.3 |
| Mar. | 2 | Mid. | 1.11 | 6.17 | 61.7 | 0.0 | 61.7 |
| Mar. | 3 | Late | 1.05 | 6.13 | 67.4 | 0.1 | 67.3 |
| Apr. | 1 | Late | 0.94 | 5.78 | 57.8 | 0.6 | 57.2 |
| Apr. | 2 | Late | 0.85 | 5.44 | 49.0 | 0.8 | 48.1 |
| Total | | | | | 549.6 | 1.6 | 547.9 |

**Table 3. Irrigation schedules for alfalfa crop during the study period as per the Cropwat model**

| Date | Day | Stage | Rain (mm) | Ks fraction | ETa (%) | Depletion (%) | Net irrigation (mm) | Deficit (mm) | Loss (mm) | Gross irrigation | Flow (l/s/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **29 Nov.** | 3 | Initial | 0.0 | 1.00 | 100 | 32 | 17.3 | 0.0 | 0.0 | 24.8 | 0.96 |
| **10 Dec.** | 14 | Initial | 0.0 | 1.00 | 100 | 32 | 20.0 | 0.0 | 0.0 | 28.6 | 0.30 |
| **24 Dec.** | 28 | Dev. | 0.0 | 1.00 | 100 | 34 | 25.4 | 0.0 | 0.0 | 36.2 | 0.30 |
| **18 Jan.** | 53 | Dev. | 0.0 | 1.00 | 100 | 63 | 59.1 | 0.0 | 0.0 | 84.5 | 0.39 |
| **13 Feb.** | 79 | Mid. | 0.0 | 1.00 | 100 | 85 | 94.4 | 0.0 | 0.0 | 134.9 | 0.60 |
| **5 Mar.** | 99 | Mid. | 0.0 | 1.00 | 100 | 86 | 95.1 | 0.0 | 0.0 | 135.9 | 0.79 |
| **21 Mar.** | 115 | End | 0.0 | 1.00 | 100 | 86 | 95.5 | 0.0 | 0.0 | 136.4 | 0.99 |
| **7 Apr.** | 132 | End | 0.3 | 1.00 | 100 | 91 | 101.1 | 0.0 | 0.0 | 144.4 | 0.98 |
| **19 Apr.** | End | End | 0.0 | 1.00 | 0 | 54 | | | | | |

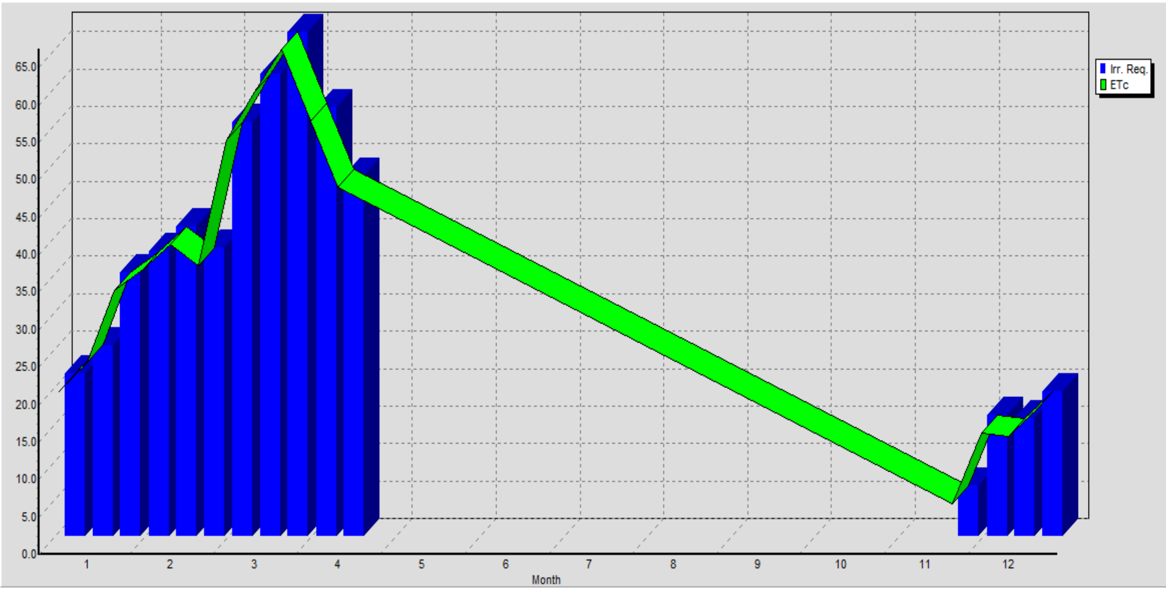


**Fig. 1. Crop water requirement of the alfalfa crop during crop cycle period (2021-22 and 2022-23)**

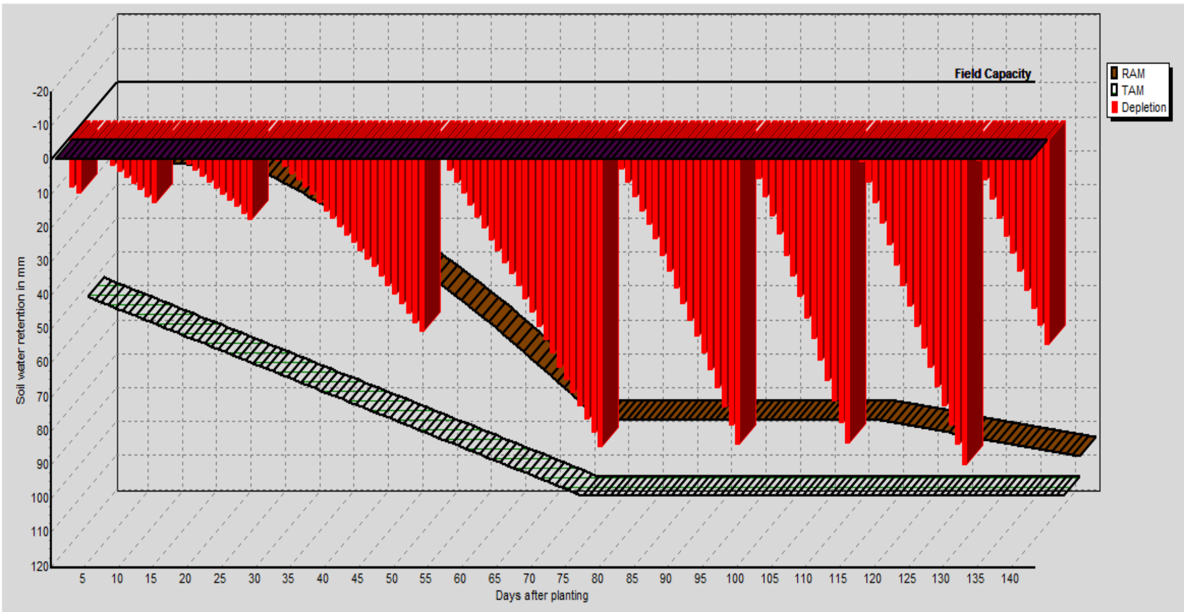


**Fig. 2. Irrigation scheduling graph for alfalfa crop during crop cycle**

In this study, the CROPWAT crop irrigation schedule provides an overall Evapotranspiration (ETc) value of 549.6 millimeters as the optimal water requirement for achieving maximum crop production with sufficient water supply, as shown in Table 2. The actual water use by the crop during its growth period amounted to 544.2 millimeters, as detailed in Table 3. The total net irrigation applied was 507.9 millimeters, while the gross irrigation amounted to 725.6 millimeters. Notably, the irrigation efficiency was 100%, indicating that there were no losses in the irrigation process. This high efficiency demonstrates that irrigation was effectively managed, delivering the precise amount of water needed by the alfalfa crop at different growth stages. Comparing this approach to irrigation scheduling based on the Irrigation Water to Crop Potential Evapotranspiration (IW/CPE) ratio, using CROPWAT enabled the precise management of irrigation water. It ensured that the alfalfa crop received the appropriate amount of water according to its specific growth stage requirements. Remarkably, the CROPWAT model data indicates that there was no yield reduction, even with a 100% critical depletion of available soil moisture, as illustrated in Table 5. Additionally, the seasonal yield response factor was calculated to be 0.80%. These findings emphasize the effectiveness of the irrigation strategy employed, resulting in optimal crop yields without yield losses due to critical soil moisture depletion.

Fig. 1 provides a visual representation of the predicted irrigation water requirements for alfalfa in the study area, spanning from the initiation stage to the maturity stage. At the initiation stage, the irrigation requirement was relatively low, reflecting the early growth phase of the alfalfa crop. However, as the crop progressed through its development and vegetative stages, the irrigation requirement steadily increased, reaching its peak during these growth phases. It's important to note that the most critical periods for alfalfa in terms of sensitivity to water deficit are when the actual evapotranspiration (ETa) falls below the maximum crop evapotranspiration (ETm), denoted as ETa < ETm. These sensitive periods are particularly pronounced during and just after transplanting. In order of sensitivity, these critical growth periods are ranked as vegetative > development > initiation, emphasizing the heightened importance of ensuring adequate water availability during these stages. This information aligns with the insights provided by Doorenbos and Kassam [13] regarding the sensitivity of alfalfa to water deficit at various growth phases.

Fig. 2 illustrates the available soil moisture levels throughout the crop growth period. At its maximum, the total available moisture in the soil reached 97 millimeters. In contrast, the readily available moisture (RAM) was approximately 77 millimeters. This suggests that there was an additional 20 millimeters of moisture beyond the RAM, indicating a relatively good water reserve in the soil. However, it's noteworthy that the moisture depletion levels in March were notably high compared to other developmental stages. This suggests that the crop had a particularly high water demand during March, likely due to its rapid growth during this phase. Importantly, this depletion surpassed the RAM during the vegetative development stage, indicating that the crop's water requirements were exceeding the readily available moisture in the soil. The combination of rapid growth and relatively poor ground cover, despite sufficient irrigation, might have contributed to an elevated atmospheric water demand. This resulted in actual evapotranspiration (ETa) levels falling below 100%, leading to higher irrigation water requirements compared to other growth stages. However, the reduction in ETa is considered negligible and may not significantly impact the overall recommendations for water management in this context.

### 3.2 Irrigation Scheduling for Optimal Alfalfa Growth

The results indicate that the alfalfa crop required higher net irrigation water from February to April compared to December and January, as summarized in Table 3. Implementing supplementary irrigation during this growth stage has the potential to significantly increase alfalfa fodder yield. After performing the calculations for Crop Water Requirements (CWR) and inputting soil data based on the previously collected information in Table 1, it is noteworthy that there was an overall negligible reduction in yield, with the reduction rate estimated at 0%. This suggests that the proposed irrigation schedule would lead to optimal yields without compromising crop productivity. These findings underscore the critical importance of providing adequate water during these specific growth stages, namely, February to April. Ensuring sufficient water availability during these periods

**Table 4. Total gross irrigation, total net irrigation and efficiency of rain**

| Totals | | | |
|---|---|---|---|
| Total gross irrigation | 725.6 mm | Total rainfall | 1.6 mm |
| Total net irrigation | 507.9 mm | Effective rainfall | 1.6 mm |
| Total irrigation losses | 0.0 mm | Total rain loss | 0.0 mm |
| Actual water use by crop | 544.2 mm | Moist deficit at harvest | 60.0 mm |
| Potential water use by crop | 544.2 mm | Actual irrigation requirement | 542.5 mm |
| Efficiency irrigation schedule | 100 % | Efficiency rain | 100 % |
| Deficiency irrigation schedule | 0.0 % | | |

**Table 5. Yield reduction at 100% of critical depletion**

| | Yield reductions | | | | |
|---|---|---|---|---|---|
| **Stage label** | **A** | **B** | **C** | **D** | **Season** |
| Reduction in ETc | 0.0 % | 0.0 % | 0.0 % | 0.0 % | 0.0 % |
| Yield response factor | 0.45 | 0.60 | 1.20 | 1.10 | 0.80 |
| Yield reduction | 0.0 % | 0.0 % | 0.0 % | 0.0 % | 0.0 % |
| Cumulative yield reduction | 0.0 % | 0.0 % | 0.0 % | 0.0 % | 0.0 % |

aligns with the research insights of Nurrudrin and Madramootoo (2001), Obreza et al. [14], Patanè and Cosentino [15], who emphasize the significance of proper water management to achieve optimal yields during these critical stages of alfalfa growth [16-19].

## 4. CONCLUSION

The study in the Saurashtra region of Gujarat utilized the CROPWAT 8.0 model, developed by the Food and Agricultural Organization (FAO), to compute the crop water requirements for alfalfa. This approach allowed for precise and optimal irrigation scheduling, resulting in efficient water utilization. The Penman-Monteith method, integrated into the model, was employed to calculate evapotranspiration. The study considered up to 91% of critical soil moisture depletion as the threshold for irrigation. The CROPWAT 8.0 model provided predictions for daily, decadal, and monthly crop water requirements at various growth stages of the alfalfa crop. In particular, the crop water requirement was determined to be 544.2 millimeters, while the irrigation requirement was estimated at 542.5 millimeters. These results underscore the critical importance of efficient water management, especially in normal or deficit rainfall years. The findings also highlight the potential of the CROPWAT 8.0 model in accurately predicting crop water requirements for different crops. Additionally, the model can offer valuable insights for crop patterns and rotation strategies, making it a useful tool for farmers seeking to optimize their agricultural practices. Overall, the study suggests that the CROPWAT 8.0 model can be a valuable resource for enhancing water management and agricultural productivity in the region.

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## COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## REFERENCES

1. George B, Shende S. Raghuwanshi N. Development and testing of an irrigation scheduling model. -Agricultural Water Management. 2000;46(2):121–136.
2. Dhayal D, Lal K, Sudhishri S, Khanna M, Singh M, Rosin KG., Bhattacharya R. Chakraborty D. Irrigation scheduling in drip fertigated maize (*Zea mays*) using FAO-CROPWAT model. The Pharma Innovation Journal. 2023;12(3):1422-1428.
3. Orloff SB, Putnam DH. Harvest strategies for alfalfa. In “Irrigated alfalfa management for Mediterranean and Desert zones”. Chapter 13. University of California Agriculture Nat. Resour. Publ. 8299;2007.
4. Teixeira EI, Moot DJ, Brown HE. Defoliation frequency and season affected radiation use efficiency and dry matter partitioning to roots of lucerne (*Medicago sativa*, L.) crops. Eur.opian Journal of Agronomy. 2008;28(2):103–111.
5. FAOSTAT. FAOSTAT Database. FAO, Rome, Italy; 2022.
   Available:http://FAOstat.FAOorg/
   accessed on: 23 2022).
6. Michel. Irrigation theory and practices, 2nd Edition; 2007.
7. Rockström J. Barron J. Water Productivity in Rainfed Systems: Overview of Challenges and Analysis of Opportunities in Water Scarcity Prone Savannahs. Irrigation Science. 2007;25(3):299-311.

8. Kumar AS. Effect of Different Cutting Intervals and Moisture Regimes on Yield and Quality of Lucerne (Medicago sativa L.). Mysore Journal of Agricultural Sciences. 1979;13(3):228-229.
9. Smith Martin. CROPWAT: Manual and Guidelines. FAO of UN, Rome; 1991.
10. FAO. CROPWAT Software, Food and Agriculture Organization, Land and Water Division; 2009. Available:http://www.FAO.org/nr/water/infores_databases_cropwat.html.
11. Gowda TP, Manjunaththa SB, Yogesh TC, Satyareddim SA. Study on Water Requirement of Maize (Zea mays L.) using CROPWAT Model in Northern Transitional Zone of Karnataka. Journal of Environmental Science, Computer Science and Engineering & Technology, 2013;2(1):105-113.
12. FAO. Crop evapotranspiration guidelines for computing crop water requirement. Irrigation and Drainage. 2002;56.
13. Doorenbos J. Kassam AH. Yield response to water. FAO Irrigation and Drainage Paper 33, FAO, Rome. 1979;193.
14. Obreza TA., Pitts DJ, McGovern RJ. Spreen TH. Deficit Irrigation of Micro-Irrigated Tomato Affects Yield, Fruit Quality, and Disease Severity No. 4626; 2010.
15. Patanè C, Cosentino SL. Effects of soil water deficit on yield and quality of processing tomato under a Mediterranean climate. Agriculture Water Management. 2010;97(1):131-138.
16. FAO-AGL. Crop description and climate. land and water development division. Agriculture. 2002;21.
17. Nuruddin M. Md, Madramootoo CA, Dodds GT. Effects of water stress on tomato at different growth stages. Journal of Horticulture Science. 2003;38(7):1389-1393
18. Sharma B, Molden D, Cook S. Water use efficiency in agriculture: Measurement, current situation and trends. Managing water and fertilizer for sustainable agricultural intensification. 2005;39.
19. Surendran U, Sushanth CM, Mammen G. Joseph EJ. Modelling the crop water requirement using FAO-CROPWAT and assessment of water resources for sustainable water resource management: A case study in Palakkad district of humid tropical Kerala, India. ICWRCOE: 2015: 1211-1219.



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