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Assessment of crop water requirement and irrigation scheduling for selected crops in the Kohima district, Nagaland, India

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ABSTRACT

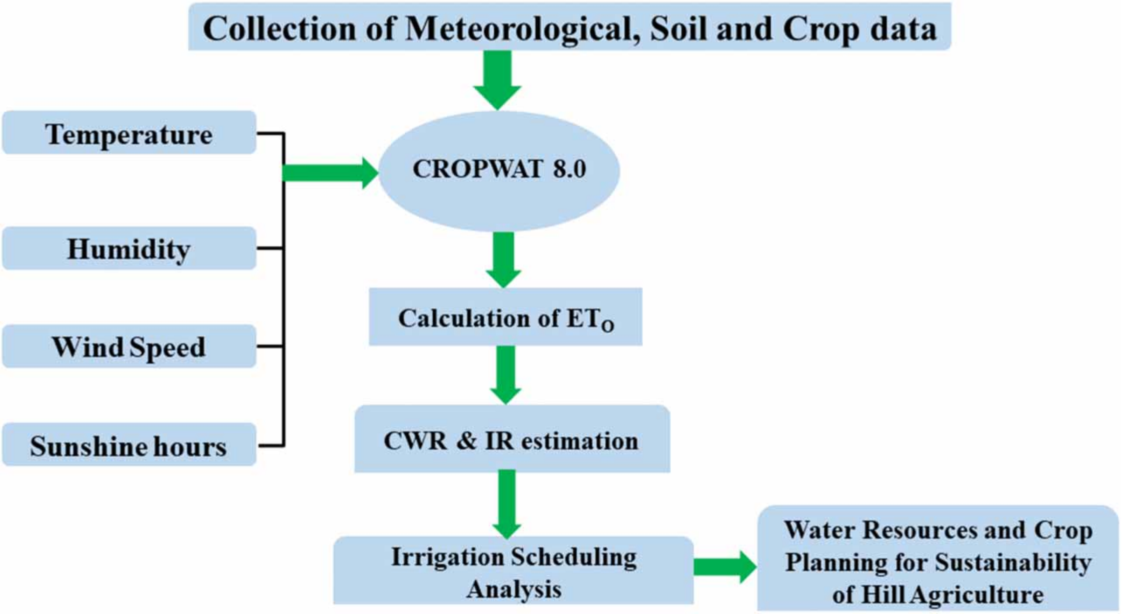
This study was done to examine agricultural water and irrigation schedules for key crops grown in Kohima area of Nagaland, India, which has a humid subtropical climate. Climatic data over 16 years (2006–2021) were used to estimate crop water requirements using CROPWAT 8.0 model. Rice, maize, soybean, potato, cabbage, dry bean, ginger, and naga chili are the most common crops. ET_0 was calculated using the FAO Penman–Monteith method and ranged from 1.41 to 3.65 mm/day. The USDA SCS approach calculated effective rainfall. The average annual ET_C for rice, maize, ginger, soybean, bean (dry), potato, cabbage, and naga chili were 537.1, 305.7, 342.7, 292.2, 288.1, 364.3, 190.6, and 141 mm, respectively. Rice, maize, ginger, soybean, bean (dry), potato, cabbage, and naga chili require an average of 251.7, 54.9, 26, 73.1, 21.3, 21.9, 121.9, and 14.5 mm of irrigation each year, respectively. The crop irrigation schedules were created with 70% efficiency. The study emphasizes that irrigation must be adjusted to each crop's individual needs, whether through strategic scheduling or modifying net and gross irrigation volumes, to enhance water management and maximize crop production in the region.

Key words: CROPWAT, crop water, ET_0, hilly terrain, irrigation scheduling

HIGHLIGHTS

- This study emphasizes water requirement and irrigation planning for the hilly district of Kohima.
- This study highlights individual crop demand through strategic scheduling to maximize production.
- Fulfilling Sustainable Development Goal 2 achieves food security and promotes sustainable agriculture in hilly regions of India.
- Efficient irrigation management maximizes yield and minimizes water stress.
- This study's findings will help in water resources planning in the Kohima region.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Water is a valuable natural resource that is used for a multitude of purposes throughout the world. However, inadequate distribution over the world, combined with rising demand, could have a significant impact on its availability, perhaps leading to severe freshwater scarcity in the near future (Tarjuelo *et al.* 2010). Agriculture consumes the most water in the world today, with evapotranspiration accounting for the vast bulk of water loss (Barrow 2016). Climatic variables such as evapotranspiration and unequal rainfall distribution, soil fertility, and soil features all have a significant impact on crop water requirements (CWR) and, hence, the country's development (Thimme Gowda *et al.* 2013). Thus, enhanced agricultural water productivity is crucial for meeting rising agricultural output demands and improving food security (Molden *et al.* 2010). Water management that is scientifically sound and wise is the only method to keep crops alive in dry, water-stressed areas. An accurate evapotranspiration calculation is required for scientifically sound irrigation water management practices. There are several approaches of calculating evapotranspiration. The Blaney–Criddle technique, for example, is based on the monthly percentage of total daylight hours and the monthly average temperature. The Thornthwaite technique assumes an exponential relationship between mean monthly temperature and consumption, whereas the Hargreaves method only considers potential evapotranspiration, average day temperature, and incident solar radiation (Michael 2009). The Penman–Monteith strategy combines the energy balancing approach with the mass transfer method and integrates the climatic influence on crop components to compute evapotranspiration (Ewaid *et al.* 2019; Kibret *et al.* 2021). The FAO-developed CROPWAT 8.0 software tool automates all of the calculations required to compute evapotranspiration. The Penman–Monteith technique serves as the foundation for future calculations, such as evapotranspiration, irrigation water requirements for various crops and crop rotations, irrigation schedule design, and so on. It is widely used to define agricultural water requirements throughout the world (Feng *et al.* 2007; Stancalie *et al.* 2010; Surendran *et al.* 2015). Several studies have been carried out to simulate evapotranspiration, CWRs, irrigation scheduling, and deficit irrigation for a variety of crops under different climatic conditions (Song *et al.* 2015; Surendran *et al.* 2015; Gabr 2023). Gabr & Fattouh (2021) state that crop water demand modeling methods calculate effective rainfall, reference evapotranspiration, crop evapotranspiration, net irrigation water requirement, gross irrigation water requirement, irrigation scheduling, and crop growth. Surendran *et al.* (2015) argued that irrigation schedule recommendations for different crops should be location-specific, taking into account soil types and agro-ecological conditions. Kar & Verma *et al.* (2005) found that proper irrigation scheduling can boost field crop water productivity by either matching crop evapotranspiration or delivering irrigation during important growth stages. Gabr (2022) discovered that improved water management should be designed to maximize irrigation efficiency and generate crops that demand less water.

Northeast India accounts for more than 40% of the country's total water resources or around 60 million hectares (Samuel & Satapathy 2008). Nagaland has an abundance of fertile land, different agroclimatic conditions, organic agriculture, and a rich biodiversity, including agro-biodiversity. In terms of employment and livelihood, the agricultural sector employs the vast majority of the state's rural population. However, as evidenced by the observations, natural resources are degrading, and climate change adds to the difficulty by making climate-dependent resources such as water, agriculture, and forests, as well as their output and linked livelihoods, more vulnerable. In Nagaland, altitude fluctuation is one of the most important variables influencing weather and climate conditions. The state is divided into four agroclimatic zones: high hills, low hills, foothills, and plains. Soils, crops, rainfall, and biodiversity all differ between these zones. Under such situations, efficient utilization of natural resources for maintaining agricultural sustainability to improve the livelihood of farmers in hilly regions becomes a challenging task. Sustainable Development Goal (SDG) 2 seeks long-term solutions to end all types of hunger by 2030 and ensure food security. This includes increasing small-scale farmers' productivity and incomes through equal access to land, technology, and markets, as well as supporting sustainable food production systems and resilient agricultural practices. The Nagaland State Government is implementing centrally sponsored development schemes such as the National Mission on Sustainable Agriculture and the National Food Security Mission, which aim to improve agricultural productivity, as well as schemes such as the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), which aims to improve water use efficiency, bring more area under cultivation, and provide assured irrigation to increase crop productivity and farmers' livelihoods. The government is playing an important role by taking all necessary steps to reduce poverty in all forms in the state, as well as to eliminate hunger and malnutrition. Climate change is increasing the frequency and intensity of extreme weather events, exacerbated water management issues, and reducing agricultural production and food security in the hilly state of Nagaland, drawing attention to SDG 13's call for urgent action to combat climate change and its effects on agriculture, water, and other sectors. Climate change has a substantial impact on water supplies in a particular place. Several studies have been conducted to determine the fluctuations in reference evapotranspiration and crop water demand values caused by changes in meteorological elements such as temperature and precipitation (El-Rawy *et al.* 2023; Gabr 2023). The state intends to fulfill its SDG by taking a path that allows it to conserve its natural resources while maintaining livelihood security, food security, and the state's long-term economic development.

The state of Nagaland receives 1,700–2,500 mm of rainfall on average per year; however, because of its extremely uneven temporal distribution, there is a 5–6-month dry season. The state's agricultural productivity depends heavily on rainfall. The absence of consistent precipitation throughout the arid months significantly restricts agricultural methods, leading to water stress in many crops and hindering their maximum development and yield. Efficient water management is essential for boosting crop productivity, encouraging agricultural development, enhancing the rural economy, and improving the quality of life because agriculture plays a significant role in the economy and the livelihoods of its people (Laouisset & Dellal 2016).

Given the existing knowledge gap in Nagaland about agricultural water requirements and irrigation scheduling, the current studies used agroclimatic data and the CROPWAT 8.0 model to project irrigation water demands and create irrigation schedules for major crops in Kohima, Nagaland. It is critical to calculate the water requirements of various farming systems across different locations and develop location-specific irrigation schedules for different crops while taking soil types and agro-ecological factors into account (Feng *et al.* 2007; Vozhehova *et al.* 2018; Aravind *et al.* 2021; Alotaibi *et al.* 2023). This research will encourage the sustainable use of water resources for agricultural growth in Nagaland, thereby contributing to food security and economic success in the region. The study's aims were to (a) estimate agricultural water requirements of chosen crops in Nagaland's Kohima district using the CROPWAT 8.0 model and (b) calculate irrigation requirements and produce an irrigation schedule for the selected crops in Kohima district.

2. MATERIALS AND METHODS

2.1. Study area

Kohima district, located in northeastern India between 25.67° North Latitude and 94.10° East Longitude, exemplifies Nagaland's rich cultural legacy and natural beauty in a humid subtropical climate. This 1,207 km^2 area is a fascinating combination of history, geography, and cultural significance. Kohima district's steep environment, at an elevation of 1,444 m above sea level, creates a distinct climate profile with obvious seasonal fluctuations. This unique terrain has had an impact on agricultural practices, local ecosystems, and the overall way of life.

Agriculture is essential to Kohima district's economy and survival due to its difficult terrain and changing environment. The district's largely steep terrain is ideal for terrace farming, a time-honored method that has evolved steadily over the years. Rice, an essential crop with cultural and nutritional value, flourishes as a result of precise hillside terracing. These practices not only provide food but also help prevent soil erosion and improve water management.

Aside from rice, the region grows a range of other crops such as maize, millet, and potatoes, demonstrating local farmers' adaptability to the area's changing microclimate. Despite these outstanding accomplishments, the district continues to face challenges. These include the constraints of limited agricultural land, the unpredictable nature of weather patterns, and the crucial need for ongoing modernization. The combination of these elements has the potential to cause major changes in land use and land cover (LULC), with severe consequences for the region's natural features. Furthermore, changes in LULC may increase the frequency and severity of environmental concerns such as landslides, soil erosion, floods, and land degradation, demanding smart land and water management methods, as well as sustainable farming practices. The information and locations of the site are shown in Figure 1.

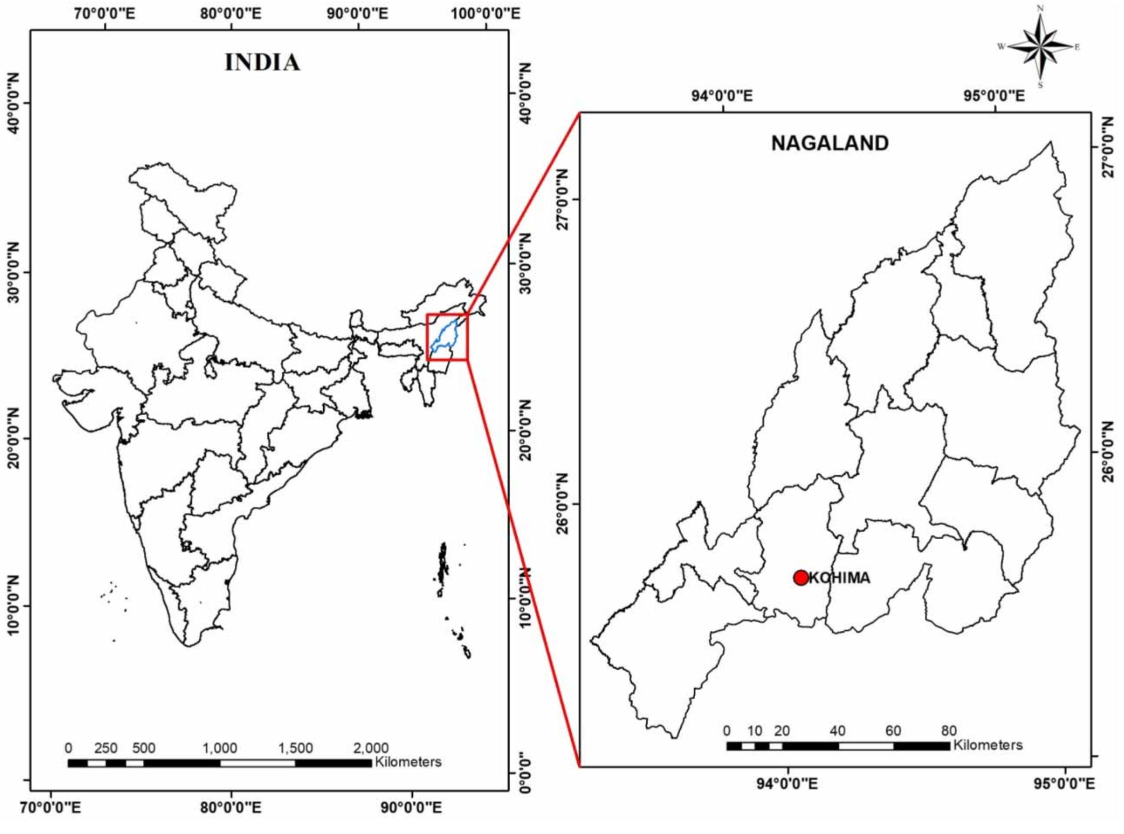


Figure 1 | Location map of the study area.

2.2. Data collection and analysis

The Directorate of Agriculture and Horticulture, Government of Nagaland, India, provided data on climate characteristics, soil and crop parameters, and cultivation practices to estimate CWRs. Daily meteorological parameters such as maximum temperature, minimum temperature, relative humidity, wind speed, sunshine hour, and rainfall were obtained over a 16-year period (2006–2021) and used to estimate daily ET_0 and effective rainfall using the CROPWAT 8.0 model. The CROPWAT 8.0 model was used to estimate CWRs and irrigation needs for the selected crops cultivated in the study area using soil and crop parameter input.

2.3. CROPWAT 8.0 model description

FAO's Land and Water Development Division in Italy developed CROPWAT 8.0 to aid with crop irrigation scheduling (Smith 1992). The model calculates ET_0, ET_C, and net irrigation requirement (NIR) to generate irrigation plans for various management scenarios. It can make irrigation recommendations, schedule irrigation, and assess productivity based on soil, meteorological, and crop data (Ewaid *et al.* 2019; Tewabe & Dessie 2020; Balan & Joseph 2021; Khaydar *et al.* 2021). CROPWAT 8.0 can also be used to evaluate farmers' irrigation methods and predict crop production in both wet and dry conditions.

2.4. Climate data

The Nagaland Directorate of Agriculture supplied climate data for the previous 16 years (2006–2021). Climate parameters include the daily minimum and maximum temperatures, relative humidity, wind speed, sunshine hours, and rainfall. The district experiences three distinct rainy seasons: pre-monsoon, southwest monsoon, and northeast monsoon. The pre-monsoon season runs from the last week of April until the end of May. The southwest monsoon season normally begins in the first week of June and lasts until September. The northeast monsoon occurs from the second half of October until the end of November. Between April and September, the majority of the rain falls in the 1,600 mm range. Normally, no rain falls in December; however, rainfall is quite low from January to March, and temperatures gradually drop from October onward. The lowest temperature is usually around 8 °C, and the highest is 26 °C.

2.5. Crop and soil data

The crop and soil characteristics were obtained from the Nagaland Directorate of Agriculture and Horticulture. Rice, maize, ginger, soybean, bean (dry), potato, cabbage, and naga chili were selected as essential crops for the study. Rooting depth, crop coefficient, and growth stage were all important considerations. Clay and loamy soils are widespread in the Kohima district of Nagaland. Table 1 shows crop coefficient (K_C) values, planting dates, growth stages, and root depth for important crops, while Table 2 lists the area under major crops and average production in the Kohima district.

Table 1 | Crop coefficient (K_C) values, planting date, growth stage, and root depth of major crops

		Crop coefficient (K_C)					
Sl. No.	**Crop name**	**Initial**	**Mid**	**Late**	**Planting date**	**Growth Stage (days)**	**Root depth (m)**
1	Rice	1.05	1.20	0.60	25/03	150	1
2	Maize	0.30	1.20	0.35	20/02	125	2.8
3	Ginger	0.40	0.60	0.90	10/02	245	0.025–0.038
4	Soybean	1	1.50	0.50	20/03	135	0.75–1.5
5	Bean (dry)	0.40	1.15	0.35	25/03	95	0.3–0.9
6	Potato	0.50	1.15	0.75	25/03	105	0.30
7	Cabbage	0.70	1.05	0.95	15/10	120	0.45–0.91
8	Naga chili	0.38	1.39	0.85	15/02	200	0.45–0.61

2.6. Crop water requirement

The FAO-approved Penman–Monteith approach was used in the CROPWAT model to determine reference crop evapotranspiration, and it has been widely recommended for predicting ET_0 (Smith 1991, 1992; Doria *et al.* 2006; Babu *et al.* 2015; Desta *et al.* 2015; Tewabe & Dessie 2020; Liu *et al.* 2022; Mohammed & Irmak 2022). The equation for computing reference evapotranspiration (ET_0) is given below:

$$\mathrm{ET}_0 = \frac{0.408\Delta(\mathrm{Rn} - G) + \gamma \dfrac{900}{T + 273} U_{2(e_s - e_a)}}{\Delta + \gamma(1 - 0.34U_2)} \tag{1}$$

where ET_0 is the reference evapotranspiration (mm day^{-1}), Rn is the net radiation at the crop surface (day^{-1}), G is the soil heat flux density (MJ m^2 day^{-1}), T is the mean daily air temperature at 2 m height (°C), U_2 is the wind

Table 2 | Crop-wise area, production, and average yield

Crop	Area (ha)	Production (Tons)	Avg. yield (kg/ha)
Rice	8,950	23,440	2,619
Maize	4,610	9,080	1,970
Ginger	275	4,792	1,7425
Soybean	2,040	2,610	1,279
Bean (dry)	340	460	1,352
Potato	1,510	15,250	10,099
Cabbage	778	15,137	19,456
Naga chili	120	873	7,275

speed at 2 m height (ms^{-1}), e_s is the saturation vapor pressure (kPa), e_a is the actual vapor pressure (kPa), $e_s - e_a$ is the saturation vapor pressure deficit (kPa), Δ is the slope vapor pressure curve (kPa °C^{-1}), and γ is the psychrometric constant (kPa °C^{-1}), which is considered as 0.0677 kPa °C^{-1}.

The K_C of the selected crops for specific growth stages and the Penman–Monteith equation were used to calculate the monthly ET_C of crops. The rate of evapotranspiration is calculated as

$$ET_C = K_C \times ET_0 \tag{2}$$

where ET_C is the Crop evapotranspiration in mm/day, K_C is the crop coefficient, dimensionless, and ET_0 is the reference crop evapotranspiration in mm/day.

2.7. Effective rainfall and NIR

The effective rainfall in the CROPWAT 8.0 model was calculated using the USDA SCA's suggested technique (Memon & Jamsa 2018). Using this method, Equations (3) and (4) were used to determine monthly effective rainfall.

1. When total rainfall is <250 mm, effective rainfall is given by

$$ER = \text{Total } R \times (125 - 0.2 \times TR)/125 \tag{3}$$

2. When total rainfall is >250 mm, effective rainfall is given by

$$ER = 125 + 0.1 \times \text{Total Rainfall} \tag{4}$$

Equations (5) and (6) were used to compute the monthly NIR and gross irrigation requirement (GIR), which includes the water losses from the irrigation system.

$$NIR = ET_C - P_e \tag{5}$$

$$GIR = NIR/Po \tag{6}$$

2.8. Irrigation scheduling

Irrigation scheduling involves determining how much and when to apply water to a field (Moseki *et al.* 2019). Only 40–60% of the water is used efficiently by the crop; the rest is lost in the system or on the farm due to evaporation, runoff, or percolation into groundwater (Thimme Gowda *et al.* 2013). Irrigation scheduling guarantees that water is always available to the plant and distributed in accordance with crop requirements (Soomro *et al.* 2023). To schedule irrigation using CROPWAT, consider irrigation time, irrigation at 100% critical depletion, irrigation at set intervals per stage, and irrigation application type, as well as refilling soil moisture content to 100% field capacity (Suryadi *et al.* 2019). To establish the irrigation schedule in this study, the NIR and GIR were determined using the CROPWAT model at 70% efficiency.

3. RESULTS AND DISCUSSION

3.1. Reference evapotranspiration (ET_0)

The mean monthly evapotranspiration (2006–2021) in mm was calculated using the daily scale ET_0 value, which is shown in Table 3. The region's ET_0 was found to be highest in July at a rate of 3.65 mm/day, followed by April at a rate of 3.64 mm/day. The lowest ET_0 occurred in January (1.41 mm/day).

Table 3 | Variation in mean monthly daily ET_0 due to different weather parameters at Kohima

Month	Min temp (°C)	Max temp (°C)	Humidity (%)	Wind (m/s)	Sun (h)	Rad (MJ/m²/day)	ET_0 (mm/day)
January	4.6	15.8	69	3	5.1	11.7	1.41
February	6.4	19.9	68	3	3.9	11.9	1.78
March	11	23.7	74	5	6.4	17.3	2.88
April	14.1	26.2	73	6	7.2	20.1	3.64
May	14.8	24.7	82	6	5.9	18.8	3.53
June	18	27.3	85	5	4.3	16.5	3.39
July	18.1	27.2	88	4	5.4	18.1	3.65
August	18	26	87	4	3	14	2.86
September	17.8	27.4	88	4	5.6	16.5	3.21
October	15.6	25.8	85	4	7.3	16.7	2.88
November	9.5	21.4	79	3	7.3	14.6	1.99
December	6.1	17.3	76	3	8.5	14.7	1.63
Annual	12.83	23.56	79.50	4.17	5.83	15.91	2.84

3.2. Rainfall and effective rainfall

The effective rainfall in December was the lowest (6.4 mm), indicating that a substantial amount of irrigation water will be required to refill the soil with moisture. The effective rainfall levels were determined to be adequate throughout the monsoon season. Figure 2 depicts the month-wise total and effective rainfall of the Kohima region. The month of July had the largest amount of effective rainfall (160.4 mm), followed by April (155.9 mm).

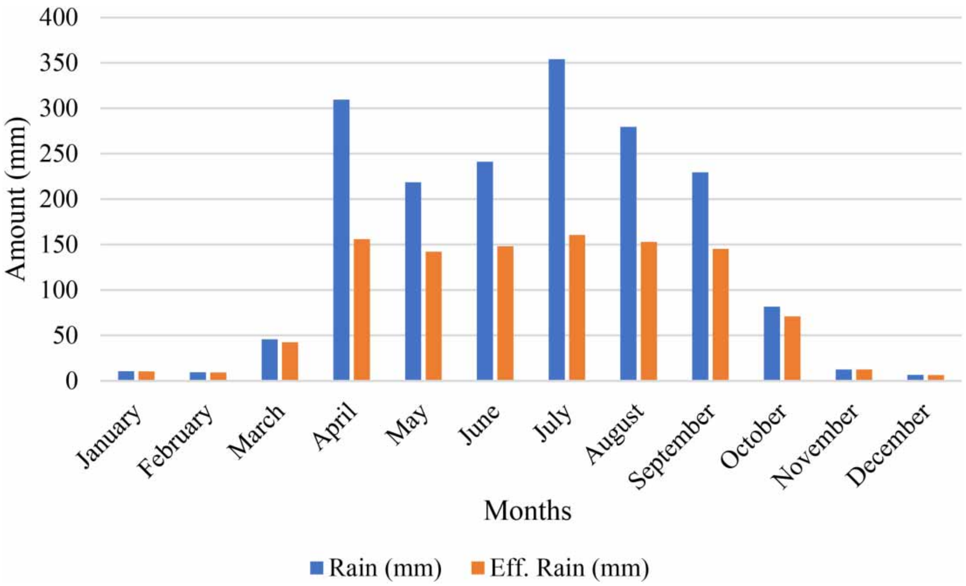


Figure 2 | Month-wise average total and effective rainfall at Kohima from 2006 to 2021.

3.3. Crop water and irrigation requirement

Table 4 shows the annual actual evapotranspiration (ET_C) and NIR of selected crops grown in Kohima district of Nagaland. The total CWR of rice, maize, ginger, soybean, bean (dry), potato, cabbage, and naga chili for the years 2006–2021 was calculated to be 537.1, 305.7, 342.7, 292.2, 288.1, 364.3, 190.6, and 141 mm, respectively, for total growth periods of 150, 125, 245, 135, 95, 105, 120, and 200 days. The total NIR of rice, maize, ginger, soybean, bean (dry), potato, cabbage, and naga chili was 251.7, 54.9, 26, 73.1, 21.3, 1.9, 121.9, and 14.5 mm respectively. The high CWR was caused by a lack of effective rainfall, which was necessary to restore the soil. Therefore, more irrigation water must be delivered to fulfill the crop's irrigation demands. Furthermore, CWRs vary depending on the stage of development. The CROPWAT data revealed that the amount of effective rainfall had a large influence on ET_0 value. As a result, ET_0 during the rainy season was lower than the predicted ET_0 during the dry or water deficiency season. Others have reached the same conclusion in their studies. The difference between GIR and NIR represents field irrigation losses. The variance in monthly water requirement is explained by differences in crop growth phases, crop coefficients, and cropping area (Djaman & Irmak 2013; Khaydar *et al.* 2021). Thus, it has been deemed essential to create a water management strategy based on agricultural requirements to maximize crop yields while protecting water supplies.

Table 4 | Actual evapotranspiration (ET_C) and NIR of selected crops grown at Kohima

Station	Crop	ET_C (mm)	NIR (mm)
Kohima	Rice	537.1	251.7
	Maize	305.7	54.9
	Ginger	342.7	26
	Soybean	292.2	73.1
	Bean (dry)	288.1	21.3
	Potato	364.3	21.9
	Cabbage	190.6	121.9
	Naga chili	141	14.5

In Figure 3, the graphs illustrate the dynamic interplay between actual crop evapotranspiration (ET_C), effective rainfall, and irrigation requirements for rice, maize, ginger, soybean, bean (dry), potato, cabbage, and naga chili cultivated in the region of Kohima during 2006–2021.

The x-axis of the graphs represents the time frame, while the y-axis quantifies the values of the parameters in mm. The ET_C bar shows the water needs of each crop over time, reflecting the amount of water lost through both evaporation and transpiration processes. Peaks in the ET_C correspond to periods of high water demand, typically aligning with the crop's critical growth stages. The effective rainfall bar demonstrates the contribution of natural precipitation to the crop's water requirements. The irrigation requirement bar signifies the gap between the ET_C and effective rainfall. Such insights empower farmers to allocate water resources judiciously, maximizing yield while conserving water.

3.4. Irrigation scheduling and gross water requirement

Table 5 shows the irrigation scheduling approach for rice, maize, ginger, soybean, bean (dry), potato, cabbage, and naga chili during their growth stages. Scheduling data provided the total count of irrigation applications required for each crop at each stage of growth. The timetable called for irrigating the crops at crucial moisture levels in the soil to fill them to field capacity.

For rice cultivation, a well-thought-out irrigation schedule involves watering on specific days. This includes irrigation events on 19, 9, and 5 days before planting, as well as 5 and 67 days after planting. The cumulative net irrigation for rice cultivation is estimated at 348.4 mm. Moving on to maize cultivation, the focus shifts to post-germination irrigation. Maize requires irrigation on 42, 52, 60, 70, 82, and 92 days after germination. This sequence corresponds to net irrigation amounts of 38.9, 36.5, 36.4, 37.2, 41.3, and 39.2 mm, respectively. The total gross irrigation for maize is estimated at 229.5 mm. For soybean crops, a well-timed irrigation approach involves watering on the 41 and 68 days after planting. This schedule ensures optimal growth with net irrigation amounts of 78.8 and 80.2 mm, respectively. The overall gross irrigation for soybean cultivation is estimated at

Figure 3 | ET_C, effective rainfall, and irrigation requirements of different crops grown at Kohima.

227.1 mm. Moving forward to dry bean cultivation, irrigation is focused on a single instance – specifically, 55 days after planting. This targeted approach entails a net irrigation of 59 mm and a gross irrigation of 84.3 mm. Potato cultivation, however, requires irrigation on multiple occasions after planting. The schedule includes irrigating on the 18, 39, 57, 70, 89, and 109 days. The net irrigation amounts for these intervals are 15.9, 22.1, 26.1, 26.3, 26, and 29.2 mm, respectively. The cumulative gross irrigation for potato cultivation is estimated at 208.1 mm.

Table 5 | Irrigation scheduling plan for selected crops grown at Kohima

Station	Crop	Date	Day	Stage	Depletion %	NIR (mm)	GIR (mm)
Kohima	Rice	05 March	−19	PrePu	1	24.7	0
		15 March	−9	Pudd1	4	74	0
		19 March	−5	Pudd1	0	54.6	0
		29 March	5	Init	0	96.2	0
		30 May	67	Mid	0	98.9	0
		11 August	End	End	0	0	0
	Maize	02 April	42	Dev	61	27.3	38.9
		12 April	52	Mid	57	25.5	36.5
		20 April	60	Mid	57	25.5	36.4
		30 April	70	Mid	58	26.0	37.2
		12 May	82	Mid	64	28.9	41.3
		22 May	92	End	61	27.4	39.2
		24 June	End	End	3		
	Soybean	29 April	41	Mid	62	78.8	112.6
		26 May	68	Mid	63	80.2	114.5
		12 June	End	End	20	0	0
	Bean (dry)	18 May	55	Mid	46	59	84.3
		12 July	End	End	40	0	0
	Potato	11 Apr	18	Init	27	15.9	22.7
		02 May	39	Dev	31	22.1	31.6
		20 May	57	Mid	33	26.1	37.3
		02 June	70	Mid	33	26.3	37.6
		21 June	89	End	32	26	37.1
		21 July	109	End	37	29.2	41.8
		01 August	End	End	17		
	Cabbage	05 November	22	Dev	47	27.8	39.7
		27 November	44	Dev	45	35.9	51.2
		23 December	70	Mid	46	36.8	52.6
		18 January	96	Mid	45	36.3	51.9
		11 February	End	End	42	0	0
	Naga chili	14 June		End	15	0	0

Moving to cabbage cultivation, a thoughtful irrigation strategy involves watering on the 22, 44, 70, and 96 days after planting. These irrigation events correspond to net irrigation amounts of 27.8, 35.9, 36.8, and 36.3 mm, respectively. The total gross irrigation for cabbage cultivation is estimated at 195.4 mm. It is important to note that naga chili crops do not necessitate extra irrigation due to the availability of effective rainfall.

Rice being the staple food in the region of Nagaland and requiring large amount of water, a few suggested water-saving rice cultivation techniques would be useful for increasing the water use efficiency and increasing productivity. The alternate wetting and drying (AWD) method, which allows the rice field to dry for a few days between irrigation operations, is the most extensively used water-saving approach in rice production. AWD methods are ones that lowland (paddy) rice farmers in the hilly area of Kohima can utilize to reduce water use in irrigated fields. The government is also supporting a system of rice intensification, in which fields are kept unflooded and the soil thoroughly aerated throughout the vegetative development phase, while just a small amount of water is retained on the field during the reproductive growth phase. Aerobic rice can also be practiced in areas where there is a high potential for water conservation. The CROPWAT 8.0 model did not assign any irrigation dates during September since there was enough effective water available to fulfill the crop's water demands.

4. CONCLUSION

Estimating crop water needs and understanding the irrigation schedule are critical for crop water planning and a region's agricultural sustainability. The CWR, NIR, and GIR of rice, maize, ginger, soybean, bean (dry), potato, cabbage, and naga chili were assessed using CROPWAT 8.0 in Nagaland's Kohima area. The model was also used to plan irrigation. Effective irrigation scheduling that is tailored to the growth stages of each crop is critical for generating maximum yields. Properly timed irrigation is critical to the overall success of these agricultural endeavors. The cropping pattern of the northeast hill region is distinct from the rest of the country's plain topography. Rice and maize are key foods for feeding people. The following crop combinations are suitable for the Nagaland region: rice, maize, and potato crop combinations; rice, maize, and vegetable crop combinations; and rice, maize, and oil seed crop combinations. The study's findings can be used to develop water-saving techniques like irrigation timing and efficient water use during times of scarcity. Using this knowledge, a thorough irrigation schedule plan may be developed to estimate the irrigation need for the other crops grown in the region, resulting in a higher productivity output.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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