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Assessment of Crop water requirement using FAO CROPWAT 8.0 for Groundnut in South Odisha

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Abstract

Water has a major impact on crop growth, output, and quality and increased production with less water consumption is crucial due to increased demand from domestic and industrial sectors. With evaporative demand-based irrigation scheduling the water consumption gets reduced and improves water productivity. The type of soil, growing season, weather, and crop type affect specific crops' water needs. To compute crop water requirement, irrigation requirement, and its schedule for groundnut cultivated during the rabi season in south Odisha, India, the FAO CROPWAT 8 program was used, with the meteorological data of Centurion University, Paralakhemundi, and NASA power. The water requirement for groundnut was 362.1 mm, the irrigation requirement for groundnut crops was 323.7 mm, and crop evapotranspiration (ETc) was 373.4 mm during *rabi* season. At 50% critical depletion of soil moisture and soil replenishment to field capacity, the yield did not decrease. These results indicate that irrigation schedules can be practiced for different regions' crops without experimental results by estimating crop water requirements and irrigation schedules obtained through the FAO CROPWAT 8 model.

Keywords

crop evapotranspiration; FAO CROPWAT 8; Irrigation scheduling; water requirement

Introduction

At the global level, groundnut is an important oil seed crop that provides oil, nutrition, and income security. India is the second-largest producer of groundnuts in the world. Odisha is one of the leading groundnut-growing states in India. In Odisha, the crop is cultivated as rainfed *kharif* as well as irrigated *rabi*. In India, *rabi* groundnut is cultivated in an area of 49.13 lakh ha with a production and productivity of 83.69 lakh tons and 1758 kg/ha, respectively. In Odisha, it is cultivated in 0.77 lakh ha with a productivity of 806 kg /ha (1,2)

Like other places in Odisha, the availability of fresh water and its share for irrigation is showing a continuous decreasing trend. Therefore, the challenge in an irrigated ecosystem is to produce maximum yield with minimum water input. To do so, we have to assess the status of weather variables and the nature of the soil of any location. As per the soil-plant-atmospheric-continuum concept, weather variables are the driving force for the transpiration rate of any crop at any location. Besides, the physiological characteristics of any crop also regulate the transpiration rate, which, in turn, is termed the crop coefficient (K_c) factor (3). Soil is the source of water supply to plants; thus, its hydro-physical properties also regulate soil moisture availability at the root zone. Thus, scheduling of irrigation on the basis of evaporative demand results not only in efficient utilization of water but also in considerable saving of water (4). Before the yield reduction level, irrigation is necessary to restore the soil moisture deficit in the root zone (4). Crop water requirements are influenced by soil type, growing seasons, crop area and type, climate, and crop production frequencies (5,6). Successful irrigation planning requires accurate information about crop water needs and water withdrawals depending on crop type, soil type, and climate (7,8). The Food and Agriculture Organization (FAO) developed CROPWAT 8.0 is a decision support computer program that uses soil, crop, and weather data to determine evapotranspiration (ET_o), crop water, irrigation schedules, and water requirements.

The amount of crop water required for groundnut grown in Odisha's south-eastern region is not available. Thus, the water requirement for groundnuts grown during rabi season must be calculated. An attempt has been made to find out the amount of water required for groundnuts during *rabi* in southern Odisha, India.

Materials and Methods

Experimental site

The study was carried out at Bagusala, which is in the southern part of Odisha during November month of 2023. The study site is located at 19.1912° N, 84.1857° E°, at an altitude of 850 meters above sea level.

Crop Water Requirement

The decision support software CROPWAT 8.0, developed by FAO to calculate actual evapotranspiration (ET_O), was used to estimate the groundnut-grown water requirement during rabi. It uses soil, crop, and weather data to determine actual evapotranspiration (ET_O), crop water, and irrigation requirements and provides a guide for irrigation scheduling (3).

Climate data

The climate data recorded for 10 years from the National Aeronautics and Space Administration (NASA) Langley Research Center (LaRC) Prediction of Worldwide Energy Resource (POWER) Project funded through the NASA Earth Science/Applied Science Program of Centurion University located at Paralakhemundi in Gajapati district of Odisha, located at an altitude of 850 meters, coordinates 18.7807° North and latitude and longitude 84.0916° E, was used for calculation of ET_O (Table 1). Maximum and minimum temperature (°C), wind speed (km/day), sunshine duration, altitude maximum and minimum relative humidity (%), latitude, longitude, and altitude are the climate variables used to calculate Eto. The average of this data was collected and fed into the model. Additionally, rainfall data was collected and used in the CROPWAT 8.0 model, which provides useful rainfall information. Evaporation of the planted area (expressed in ml/day) is used to calculate the amount of water that should be used for planting. The basis for estimating CWR is crop evaporation (ETc), which can be calculated using the following formula (Eqn. 1).

ETc = Kc x Eto ……………….. (Eqn. 1)

Crop information

The groundnut crop is sown in November during the Rabi season and in January during the summer season. The sowing date of the groundnut is taken as November 15, and the harvesting date as March 4, having 120 days duration. Crop coefficient, Kc value (early, mid, and late growth), rooting depth, and yield factor (Ky), which is the ratio of relative yield reduction to relative evapotranspiration deficit, which takes into account crop, weather, and soil factors that cause crop loss to be less than present, are taken from Irrigation and drainage paper, FAO 56 and from FAO 56 manual as required by CROPWAT.

Soil information

The soil type in which groundnuts are cultivated in the region is sandy loam (9,10). The soil information, including total soil moisture, maximum rainfall infiltration rate, maximum root depth, initial soil moisture depletion, and initial soil moisture corresponding to sandy loam soil, was taken from the FAO publication 56 (3).

Irrigation Schedule

The eleven year normalized weather data from NASA POWER of Paralakhemundi, Gajapati district (Table 2) was used to estimate the amount of water required and provide irrigation schedules for groundnut crops grown during the *rabi* season. It also provided the time and amount of water used for irrigation.

Results and Discussion

Details pertaining to the climatic station (Paralakhemundi), crop, cultivation date, and soil type (sandy loam) data were submitted to the CROPWAT program. The model estimated the crop water requirements for *rabi* groundnut at various growth stages on a daily, decadal, and total growing period. As per the model output, the *rabi* groundnut crop required 517.3 mm of gross irrigation, 362.1 mm of net irrigation, and 369.5 mm of potential and actual water use by the crop (Table 3 and Table 4). The above quantity of water is scheduled through nine irrigations (Table 5). It has been observed from the estimated values that groundnut crop yield did

Table 1. Crop input parameters for FAO CROPWAT 8 model

Crop Name	Planting Date	Harvesting date	Critical moisture depletion (%)	Rooting depth (m)	Crop growth periods				
					Initial	Development	Mid	Late	Total
Rabi Groundnut	15 November	4 March	0.50	0.90	20	30	35	25	110

Table 2. 11 years normalized mean weather data of the study site used as input in CROPWAT model

Month	Min Temp	Max Temp	Mean relative Humidity (%)	Wind speed km/day	Bright sun shine hours	Radiation MJ/m³/day	ET_o mm/ day	Precipitation (mm/day)
January	12.4	29.6	68	147	8.6	17.7	3.56	0.09
February	15.4	34.7	61	173	8.8	19.8	4.84	0.03
March	19.6	38.4	60	216	9.2	22.3	6.28	0.00
April	23.5	39.9	61	302	8.8	22.9	7.45	0.55
May	24.5	39.9	67	302	8.3	22.4	7.12	2.04
June	24.8	37.1	77	268	6.8	20.0	5.64	5.84
July	23.9	32.4	86	268	5.8	18.5	4.32	8.07
August	23.6	31.3	87	233	5.9	18.5	4.06	7.49
September	23.6	30.9	87	190	6.3	18.3	3.95	8.17
October	19.1	30.7	83	181	7.0	17.7	3.84	6.36
November	15.2	28.4	80	190	8.0	17.3	3.49	2.06
December	12.0	27.4	75	173	8.5	16.9	3.27	0.16
Average	19.8	33.4	74	220	7.7	19.3	4.82	3.4

ET_o - Reference Evapotranspiration, Crop season – November 15 to March 4

Table 3. Model outputs on decadal basis during the *rabi* groundnut growing period

Month	Decade	Stage	Kc Coeff	ETc mm/dec	Effective rain mm/dec	Irrigation Requirement mm/dec
November	2	Initial	0.40	8.4	10.6	0.0
November	3	Initial	0.40	13.6	12.4	1.2
December	1	Development	0.45	15.2	5.9	9.3
December	2	Development	0.69	22.7	0.0	22.7
December	3	Development	0.96	35.6	0.2	35.4
January	1	Mid-season	1.16	39.4	0.5	38.9
January	2	Mid-season	1.17	40.4	0.0	40.4
January	3	Mid-season	1.17	50.4	1.6	48.8
February	1	Late season	1.16	51.0	4.5	46.5
February	2	Late season	0.99	47.7	6.4	41.3
February	3	Late season	0.79	33.7	6.4	27.3
March	1	Late season	0.66	15.4	2.6	12.1
				373.4	51.3	323.7

Kc – Crop coefficient, ETc- Crop Evapotranspiration

Table 4. Components of water balance for *rabi* groundnut

Components of water balance	In mm
Total gross irrigation	517.3
Total net irrigation	362.1
Actual water uses by the crop	369.5
Total rainfall	51.9
Effective rainfall	48.8
Moisture deficit at harvest	8.1

Table 5: Irrigation Schedules for *rabi* groundnut based on CROPWAT 8.0 model

Date	Day	Stage	Rain mm	Ks fraction	ETa %	Depletion %	Net irrigation, mm	Deficit mm	Loss mm	Gross Irrigation mm
15 November	1	Initial	0.0	1.00	100	54	18.6	0.0	0.0	26.5
13 December	29	Development	0.0	1.00	100	51	36.3	0.0	0.0	51.9
27 December	43	Development	0.1	1.00	100	51	45.6	0.0	0.0	65.2
9 January	56	Mid-season	0.0	1.00	100	52	51.0	0.0	0.0	72.9
22 January	69	Mid-season	0.0	1.00	100	54	53.5	0.0	0.0	76.4
2 February	80	Mid-season	0.0	1.00	100	51	50.6	0.0	0.0	72.3
14 February	92	End	0.0	1.00	100	55	54.2	0.0	0.0	77.4
28 February	106	End	0.0	1.00	100	53	52.3	0.0	0.0	74.7
4 March	End	End	0.0	1.00	0	8				

Ks – Stress coefficienct , Eta – Actual Evapotranspiration not decrease when the crop is grown with maximum rainfall efficiency at 50% critical depletion and soil replenishment to field capacity.

Maintaining adequate accessible soil moisture in the root zone has coincided with crop development phases for efficient water absorption and nutrient utilization and positively influences growth and yield components, resulting in higher pod yields in groundnut crops. (11-14). Estimating the irrigation schedule using CROPWAT 8.0 with 50% soil moisture depletion has no deleterious influence on yield where CWR and irrigation requirement was 362.1 mm and 323.7 mm respectively. It indicates that the schedule has met the crop water requirement. Further, these results collaborate with that where comparable yield was obtained with scheduling of irrigation at lower frequency i.e. either at 0.5 or 0.7 ratio from planting to flowering followed by 0.9 ratio during pegging to pod formation or 0.7 and 0.9 ratio during pod formation to maturity where crop received 517.3 mm of gross and 362.1 mm of net irrigation (15). There are reports that with increase in moisture regime there was better crop performance (16-19). However, our studies showed that there may not be a decrease in yield where irrigation scheduling was done at 50% moisture depletion. As noted by previous approaches, the estimate using CROPWAT 8 is indicative. Hence the model can be utilized for estimating CWR and scheduling of irrigation in various climatic condition.

The total accessible moisture (TAM) is the quantity of water held in soil for plant use, measured as the difference between soil water content at field capacity (FC) and permanent wilting point (PWP). TAM is mostly developed in two phases. In the first phase, the soil water retention slowly increases from 35 mm to 100 mm in a time span from sowing to 50 days after sowing, and the second phase includes a phase of stabilizing where soil water retention does not change till the harvesting (Fig. 1). The amount of moisture that the plant can get from the root zone without experiencing water stress is known as readily accessible water (RAW), or readily available moisture (RAM). It is critical for irrigation scheduling since it dictates how much water can be applied without producing waterlogging or leaching. The quantity of accessible water varies depending on soil type, crop, rooting depth, and irrigation method. It is critical for irrigation management because it determines the most effective quantity and time of water distribution to crops. Irrigation scheduling seeks to keep soil water content within the RAM range to minimize waterlogging or stress under sandy loam soil condition with 50% soil moisture depletion. These results demonstrate that when irrigation is provided at 50% critical depletion and soil is recovered to the field capacity at each irrigation, yield reduction does not occur.

Conclusion

An attempt has been made to determine the crop water requirements of *rabi* groundnut of Southern Odisha using the FAO's CROPWAT 8.0 model. The crop water and irrigation requirements for rabi groundnut are 373.4 mm and 323.7 mm, respectively, at 50% critical soil moisture depletion. Wherever the crop water requirement data is unavailable, using the CROPWAT 8 model, the crop water needs for various crops can be estimated, and recommendations can be provided for different crops in a region.

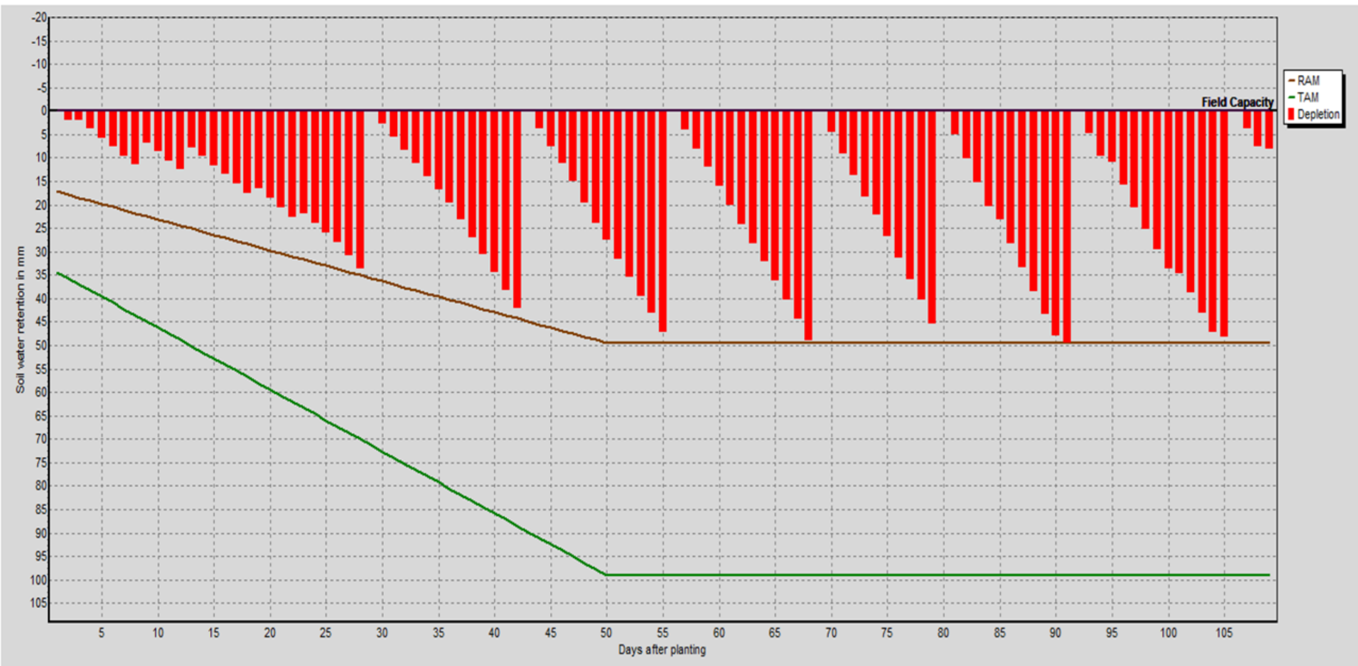

Fig. 1 – Irrigation scheduling for *rabi* groundnut

TAM- Total available moisture, RAM – Readily available moisture

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Authors' contributions

SR and MDR had conceptualized the research; Methodology, SR, LS and MDR had done the validation, SR, MDR,SS and BRB had done the analysis, SR, SM and AS had curated the data, MDR,SS,BRM,LS and SR had writing-original draft paper, SR,MDR,SS and LS participated in writing- review and editing, the total research has been done under the supervision of MDR and SS. . All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors of this paper declare that they have no conflicts of interests associated with this paper .

Ethical issues: None.

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