RESEARCH PAPER

Assessment of Total Available Moisture (TAM) and Readily Available Moisture (RAM) for the Cultivation of Soybean in Saraikela Kharsawan District of Jharkhand

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ABSTRACT

In this research, the impact of climate on soybean cultivation has been studied for Saraikela Kharsawan district of Jharkhand using the Food and Agriculture Organization (FAO) CROPWAT model. The work tries to look at crop water needs, evapotranspiration, effective rainfall and the amount of irrigation demanded under the arid climatic situation that already exists. Climatic information like rainfall, temperature, humidity, wind speed and sunshine duration have been gathered from the FAO CLIMWAT database. Agricultural details connected with soybean cultivation, cropping system patterns, irrigation methods, and soil attributes have also been taken from the same database. The FAO Penman-Monteith approach, which is built into the CROPWAT model, has been used to estimate reference evapotranspiration (ET0), crop water requirement (CWR), effective rainfall and irrigation requirement for soybean cultivation. The results show that soybean cultivation in Saraikela Kharsawan is very tied to monsoonal rainfall and it is rather vulnerable to climatic irregularities like a delayed monsoon onset, long dry spells, and uneven rainfall distribution. Also rising temperature along with increasing evapotranspiration seems to raise crop water demand during the key growth stages. Overall these findings underline the need for climate-resilient farm planning plus scientifically minded irrigation management within the district.

Keywords: Climate variability, soybean cultivation, CROPWAT model, crop water requirement, evapotranspiration, irrigation requirement.

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1. Introduction

Agriculture has always been intrinsically linked with climate, because climatic elements like temperature, rainfall, humidity, sunshine duration, wind velocity and seasonal changes directly steer crop growth, output, and agricultural sustainability (Adams et al., 1998; Asha latha et al., 2012; Birthal et al., 2014; Babar et al., 2015; Boudad et al., 2018; Arora, 2019). In largely agrarian economies such as India, climate works as both a sort of resource and constraint, it controls agricultural calendars, cropping arrangements, irrigation needs, soil fertility, and also food security (Adhikari, 2018). And over the last few decades, the increasing variability of climatic conditions has made people worry more about agricultural vulnerability, particularly in rainfed and tribal dominated pockets, where cultivation stays very dependent on natural environmental states (Das et al., 2003; Dash et al., 2007; Deshmukh et al., 2014; Carrão et al., 2015; Cavalieri et al., 2021). Climate variability and climate change have now turned into some of the critical global concerns affecting ecological systems, economic stability and human livelihoods (Porter et al., 2014; Pathak et al., 2018; Diffloth et al., 2020; Perkins-Kirkpatrick & Lewis, 2020). The Intergovernmental Panel on Climate Change (IPCC) has underlined that higher temperatures, uneven rainfall, more frequent droughts, floods, heat waves, along with the shifting monsoonal behavior are affecting agricultural productivity across the globe (Agada & Obi, 2015). Developing countries in particular feel the pressure harder because agriculture still dominates, adaptive capacity is relatively low, and socio-economic constraints remain strong (Zarafshani et al., 2016; Singh, 2018; Zemp et al., 2019). India, with its monsoon dependent agricultural setup, is counted among the countries that are most exposed to climatic uncertainties (Singh and Kumar, 2014; Singh et al., 2015; Singh et al., 2020). Differences in the southwest monsoon, rising temperature tendencies and the arrival of extreme weather events are already influencing crop yields, water availability and rural livelihoods across different agro- climatic zones (Aggarwal, 2013). The eastern Indian state of Jharkhand represents one of those climatically sensitive and agriculturally vulnerable regions of India. It has undulating topography, hard rock terrain, forested landscapes and also a sizable tribal population. So, mostly Jharkhand depends on rainfed agriculture. In the state, farming is largely subsistence oriented and it is dominated by small and marginal farmers. Most agricultural work happens in the kharif season, which depends strongly on the southwest monsoon. Because of that, when rainfall fluctuates in amount, or the monsoon arrives late, then crop failures become common, productivity drops and economic distress follows, especially for farming communities. Climate induced agricultural instability has therefore turned into a real developmental issue there. Now, among the districts of Jharkhand, Saraikela Kharsawan holds a slightly distinctive geographical and socio-economic place. It is in the southern portion of the state, and it lies within the Chotanagpur plateau region. The district shows rugged terrain with lateritic and red soils, seasonal rivers and a fair amount of forest cover. It also shares boundaries with East Singhbhum and West Singhbhum, neighboring districts of Odisha and West Bengal. The study area represents transitional climatic and cultural features in practice. Agriculture is the backbone of the rural economy of Saraikela Kharsawan, and it employs a large share of the population, either directly or indirectly. The agricultural system of the district is really quite sensitive to climatic fluctuations, mainly because it leans on monsoonal rainfall, irrigation facilities that are not adequate, fragmented landholdings and also a rather limited level of technological advancement. The climate is mostly tropical monsoonal, with very hot summers, a rainy monsoon spell, and winters that feel comparatively cool. The study area notices strong seasonal swings in temperature and rainfall. The southwest monsoon brings most of the yearly rainfall, usually from June to September. Yet, over the last few decades, irregular monsoonal behavior has been seen more often, since it is not following the expected pattern. These sorts of climate irregularities seem to affect farm activities, including sowing time, crop growth phases, moisture availability, pest pressure and the whole agricultural output.

Rice is the key crop grown in Saraikela Kharsawan district, especially during the kharif season. Besides paddy cultivation, farmers also manage to grow pulses, oilseeds, maize, vegetables, and minor millets, depending on local environmental conditions along with water availability. Since most fields are rainfed, people depend heavily on getting timely monsoon rainfall, otherwise expected agricultural output will become much less than the actual output. If there is any break from normal to near normal climatic conditions, crop yield and farm income get affected immediately. Climate variability also affects irrigation potential, the demand for agricultural labor, cropping intensity, and even livestock management. When temperatures keep rising, evapotranspiration goes higher, so soil moisture tends to slip away faster. It will create more demand for the irrigational water. At the same time, rainfall that comes irregularly can speed up soil erosion and nutrient depletion, leading to land degradation especially in upland stretches and the sloping zones of the district. Changing climatic conditions can make pests and diseases more comfortable, so agricultural risks rise and production costs for farmers also climb.

A large share of farmers come from tribal communities and their way of life is closely tied to agriculture, forests and natural resources. These groups often have low adaptive capacity when climatic stress hits, largely because of economic marginalization and missing infrastructure. Hence, the idea of climate-resilient agriculture is getting more attention. The whole purpose is to boost productivity, build stronger adaptation capacity, cut down vulnerability and still keep agricultural development on a sustainable path even when climatic conditions keep shifting. People have been proposing a bunch of adaptation approaches like drought-resistant crop varieties, crop diversification, water harvesting, micro-irrigation, agroforestry, soil conservation measures, and better weather forecasting, which are generally seen as ways to lessen the climatic pressure on farming. Because of that, it becomes really necessary to carry out region-specific studies, so local climatic issues can be understood properly and adaptation strategies can be set in a more matching way.

The study of climate-agriculture interaction in Saraikela Kharsawan district has become especially relevant, for a few reasons that are hard to ignore. First, the district is mostly rural, and it depends a lot on agriculture. So the issue of climatic variability cannot be ignored. Second, the area has a geographical setup that includes plateau-type topography, rainfed farming and noticeable socio-economic fragility, which together makes it quite exposed to climate-related stress.

Most existing studies on climate change and agriculture in India are carried out at a national level or sometimes at the state level, and the previous researches can miss the little local differences, like micro regional dynamics. So, a more concentrated inquiry on Saraikela Kharsawan could still bring in very useful, more localized insights about climate and farming, relationship between them. From a geographical viewpoint, climate affects farming systems through complicated links that mix physical elements, biological processes, and socio-economic pathways. At the same time, temperature patterns shape crop phenology and the length of the growing season. Therefore, farming output cannot be seen alone, without considering environmental settings and climatic conditions. For that reason, regional geographic studies become important for judging agricultural vulnerability, and for thinking through sustainable resource management.

This study has assessed the impact of climate on agriculture in the Saraikela Kharsawan district with special reference to soybean cultivation through the computation of CWR and irrigation water requirement (IWR). This study feels more relevant now especially as people are getting more concerned about food security and sustainable development. The importance of localized climate studies has gone up a lot in recent years, because climatic impacts are not the same everywhere across regions. Even inside the same state, districts can show different climatic trends, different levels of agricultural vulnerability, and also different adaptation capacities. So district-level studies become necessary for framing climate adaptation policies that actually fit the local situation and for planning sustainable agriculture in a more practical way. Saraikela Kharsawan, because of its particular geographical arrangement and the way agriculture supports livelihoods, gives a useful chance to look at how climate variability plays out in rural agricultural systems.

2. Methodology

The present study adopts an integrated geographical and agro-climatic approach, to assess the impact of climate on soybean cultivation in Saraikela Kharsawan district of Jharkhand. Here we sort of combined climatic data examination, agricultural appraisal, and crop water requirement estimation, using the Food and Agriculture Organization (FAO) software packages CROPWAT and CLIMWAT. The work leans on secondary data exclusively, as it uses quantitative model-based techniques to assess the CWR and IWR for the soybean cultivation.

2.1 Study area

Saraikela Kharsawan district is positioned in the southern belt of Jharkhand, under the Chotanagpur plateau region (Fig. 1). The district usually gets a tropical monsoon climate, with hot summers, moderate to heavy monsoonal rainfall, and then cool winter. Farming is mostly rainfed, and it is strongly tied to monsoon rainfall. Paddy cultivation dominates the agricultural land, while pulses, oilseeds, vegetables and maize are also grown in various zones of the district. Because of this climate sensitivity and this reliance on natural precipitation, the district becomes a reasonable place for examining climate agriculture interactions.

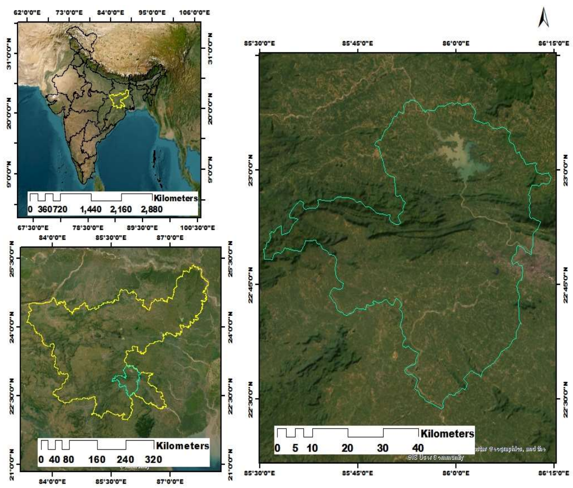

Fig. 1 Location map of the study area

2.2 Sources of data

2.2.1 Use of CLIMWAT database

The CLIMWAT database, worked out by the Food and Agriculture Organization (FAO) has been used to retrieve the weather related inputs needed for estimating crop water requirement. CLIMWAT actually gives long-term monthly climatic values for many meteorological stations around the world and it is meant specifically for use with the CROPWAT model, not as a stand-alone model.

In this study, the climatic parameters like air temperature, rainfall, humidity, solar radiation are fed into CROPWAT. These are then used to compute reference evapotranspiration, effective rainfall, irrigation requirement, and crop water demand for different climatic settings. So, the model takes those factors first, then translates them into water related outcomes. For the climatic representation, the meteorological station closest to the Saraikela Kharsawan district has been picked to stand in for the regional climatic condition. The monthly averages obtained from CLIMWAT have also been checked against whatever meteorological observations are available from India Meteorological Department (IMD) and some local or regional sources, just to keep the results reliable and consistent. After that, the FAO CROPWAT model has been applied to estimate crop water needs and irrigation demand under the existing climatic conditions. CROPWAT is basically a decision-support type software from FAO, meant for irrigation planning and crop water management, using both climate inputs and crop parameters together. Finally, the same model has been used to see how climatic variability affects agricultural water demand for soybean cultivation in Saraikela Kharsawan district.

2.2.2 Estimation of reference evapotranspiration (ET_0)

Reference evapotranspiration (ET_0) is estimated using the FAO Penman-Monteith equation incorporated within the CROPWAT model.

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

ET_0 = Reference evapotranspiration (mm/day)

Δ = Slope of saturation vapor pressure curve (kP

R_n = Net radiation at crop surface (MJ m^{-2} day

G = Soil heat flux density (MJ m^{-2} day^{-1})

γ = Psychrometric constant (kPa $°C^{-1}$)

T = Mean daily air temperature at 2 m height (°C

u_2 = Wind speed at 2 m height (m/s)

e_s = Saturation vapor pressure (kPa)

e_a = Actual vapor pressure (kPa)

$(e_s - e_a)$ = Vapor pressure deficit (kPa)

This method is widely accepted for estimating evapotranspiration and agricultural water demand under different climatic conditions.

2.2.3 Crop water requirement estimation

Crop water requirement (CWR) has been estimated by multiplying reference evapotranspiration with crop coefficient values.

CWR = ET_0 X Kc

Where:

CWR = Crop water requirement

ET_0 = Reference evapotranspiration

Kc = Crop coefficient

Different crop growth stages such as initial stage, crop development stage, mid-season stage, and late-season stage have been considered while assigning Kc values.

2.2.4 Effective rainfall estimation

Effective rainfall has been estimated inside the CROPWAT environment, to figure out the proportion of rainfall that is really available for crop use. The United States Department of Agriculture (USDA) soil conservation method that is integrated in CROPWAT has been used for the calculation of effective rainfall. Then the comparison between crop water requirement and that effective rainfall has helped to spot the times when water deficit is happening, and also when irrigation becomes necessary during the crop growing season.

2.2.5 Irrigation requirement assessment

Net irrigation requirement has been estimated by subtracting effective rainfall from crop water requirement.

IR = CWR - ER

Where:

IR = Irrigation requirement

CWR = Crop water requirement

ER = Effective rainfall

The analysis helps in understanding seasonal irrigation demand when climatic conditions are changing, and also in finding where agriculture is vulnerable to rainfall variability. Soybean cultivation vulnerability has been assessed by combining climatic variability, the crop water requirement and rainfall dependency.

3. Results and discussion

The CROPWAT analysis for soybean growing in Saraikela Kharsawan district indicates that the crop water requirement keeps changing depending on growth stages and also the local prevailing weather conditions. In the start phase from 13 June to 27 June (15 days), the estimated crop evapotranspiration (ETc) comes around 30.6 mm. At the same time, the effective rainfall is found to be 63.16 mm. From the soil moisture balance, it is seen that the rainfall is good enough during this phase, still the irrigation need is calculated as 32.56 mm when we use the standard crop water demand. If we total it, the water requirement for the early stage is found to be 124.57 mm. Then during the crop development phase from 28 June to 12 July (15 days), crop evapotranspiration rises up to 34.05 mm as vegetative growth has strengthened and the atmosphere has demanded more moisture (Fig. 2 & Table 1). The effective rainfall in this period is estimated as 70.52 mm, so it is encountered to be more in comparison to the crop water requirement. Because of that, no extra irrigation requirement is seen in the development stage. This simply suggests that monsoon rain during this time is sufficient to cover the water demand of soybeans. The difference between total available moisture (TAM) and readily available moisture (RAM) is found to be higher after 30 days of planting. This indicates the presence of ample amount of moisture in the soil after 30 days of planting the crop. Now the plants will find it easier to absorb moisture from the soil, thus no irrigation is suggested after 30 days of planting (Fig. 2). The balance between TAM and RAM is found to be in an unfavourable condition after 80 days of planting since the RAM values have substantially increased due to higher need of moisture by the plants. The study shows that soybean cultivation in Saraikela Kharsawan is quite reliant on how monsoon rainfall is timed and distributed. When early growth stages receive enough rainfall, it reduces the dependence on irrigation and also helps the crop establish properly. However, if rainfall fluctuates in timing or pattern, there can be short term water stress, which may reduce crop performance and yield potential. So, sensible water management along with a plan for supplemental irrigation is still important, especially when climate conditions keep changing.

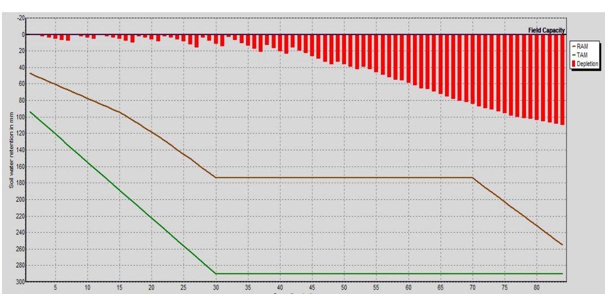

Fig. 2 Difference between TAM and RAM for soybean

Table 1 CWR and IWR for soybeans

Crop	Stage	Time	Days	ETc (mm/day)	ETc total	Effective Rain (mm)	DIFFERENCE (EFFECTIVE RAIN - ETc TOTAL)	Irrigation requirement (mm) of individual crop	Excess water of individual crop (mm)
SOYBEAN	Initial	13 JUN - 27 JUN	15	2.04	30.6	63.16	32.56		124.57

4. Conclusion

The present study looked at how climate affects soybean cultivation in Saraikela Kharsawan district, Jharkhand, using the FAO CROPWAT model. It has shown a close link between climatic variability and farm output in an area that is mostly rainfed. Weather related factors like rainfall, temperature, humidity and evapotranspiration are seen to be very important for working out crop water demand, the irrigation need, and the longer term steadiness of soybean farming in the district. From the results it becomes clear that soybean cultivation in Saraikela Kharsawan is really dependent on monsoonal rainfall. Changes in rainfall pattern, a late start of the monsoon, long dry spells, increasing temperatures, all of them noticeably affect crop development and the final productivity. Even though the district gets a moderate amount of annual rainfall, the timing of precipitation is irregular. The estimation of reference evapotranspiration with the FAO Penman-Monteith method has shown a steady increase in the atmospheric water need. As temperature goes up and evapotranspiration becomes stronger, soil moisture is drained faster and crop water needs rise, so agricultural vulnerability becomes more serious, especially in rainfed farming systems. The analysis also suggested that in some development phases, the effective rainfall is enough to cover the crop water demand, so irrigation demand has stayed low. Still, relying only on monsoonal rainfall can leave soybean cultivation with a notable amount of climate risk, since rainfall comes irregularly and climatic behavior is getting less predictable. Overall, the results imply that the distribution of rainfall matters more for soybean productivity than the total rainfall over the year. Rainfall that is uneven during sowing and vegetative growth can hurt crop establishment, while too much rain during reproductive stages might lower yield quality and also raise the chance of crop damage. For that reason, careful water management, along with timely agricultural planning is essential, if productivity has to remain stable under changing climatic conditions.

The application of the CROPWAT model turned out to be quite effective for estimating crop water requirement, effective rainfall, and irrigation demand for soybean cultivation. The model has delivered a scientific ground for understanding agricultural water stress, and for evaluating climatic impacts on crop output. When climatic data has been combined with crop and soil parameters, it became easier to spot critical windows where water deficit occurs, and where irrigation becomes necessary. Therefore, the study shows the usefulness of CROPWAT as a supportive instrument for agro-climatic assessment, irrigation scheduling and sustainable agricultural planning in rainfed agricultural regions. Based on these findings, the study recommends adopting climate-resilient agricultural practices to reduce vulnerability and raise soybean productivity in Saraikela Kharsawan district. Expansion of minor irrigation facilities, rainwater harvesting, watershed management, crop diversification, drought-tolerant soybean varieties, soil moisture conservation practices and scientific irrigation scheduling can collectively improve agricultural resilience under shifting climatic conditions. The study concludes that climate variability has become a significant challenge for sustainable soybean cultivation in Saraikela Kharsawan district. Increasing climatic uncertainty, rising evapotranspiration, and rainfall irregularity are likely to intensify agricultural stress in the future, if proper adaptation measures are not implemented. So, integrated climate sensitive agricultural planning and sustainable management of water resources are essential to keep agricultural sustainability, livelihood security and broader rural development on track in the district.

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