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Simulation of current soil moisture status for green gram sowing practices

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Abstract
The present study was conducted in Budelkani watershed in Sundargarh district of Odisha. The water balance model is used to simulate soil moisture status. Irrigation scheduling based on threshold value of soil moisture status i.e. below 75 percentage of allowable soil moisture (ASM). During this period only 50 mm of water would be applied to crop for each irrigation. The result shows that 6 out of 23 years there was not enough water in the soil before planting winter crops. The years that require pre-sowing irrigation (PSI) were 1997, 2002, 2003, 2004, 2006 and 2014. Therefore, there is a need to provide PSI for the winter crop.

Keywords: ASM, current soil moisture, critical growth period, PSI

1. Introduction

Soil moisture refers to the amount of moisture that is contained in soil pores. It is essential for all major ecological processes and has a major impact on all physiological functions. Water scarcity is a growing issue around the world that needs to be resolved in order to maintain agricultural expansion (Rajan and Ram., 2021) [17]. Surface soil moisture content is a critical hydrologic component of the water balance that stimulates not only runoff and other hydrologic components (Sinshaw *et al*., 2022, Thesis, O'Neill, *et al*., 2017, Cosh, *et al*., 2021) [21, 15, 6] but also water availability and its distribution (Liu *et al*., 2020) [22]. It is considered a "fundamental climate variable". It supports the processes of infiltration, evaporation and runoff. Moreover, it is a major parameter in vegetation and crop growth (Lei *et al*., 2022) [13]. Reliable soil moisture assessment can support weather forecasts, help with agricultural production monitoring, and assist in predicting floods and droughts. (Dandridge *et al*., 2020) [8]. It affects temperature, relative humidity, and precipitation on a regional scale, which controls the rate of evapotranspiration. For this reason, precise measurement of the spatiotemporal variability of soil moisture is essential for a number of hydro meteorological researches including drought monitoring (Fang *et al*., 2021; Jung *et al*., 2020) [9, 14].

Soil moisture is the primary limiting factor in dry cultivation and dry land farming scenarios. For regular processes like nutrient absorption, transpiration, and metabolic activities that result in growth, development, and yield, plants need to absorb water. (Singh *et al*., 2021) [20]. It is of considerable importance during the critical period of crop growth (Das and Maity, 2012) [18]. It is a crucial hydrological parameter related to irrigation scheduling, plant stress and crop yield improvement. Sustainable agriculture and water management needs accurate information on surface soil moisture. Low soil moisture for an extended period of time can lead to plant water scarcity (Abate *et al*., 2015) [1]. Improved soil can help control the amount of water used for agriculture. (Jonathan, *et al*., Book Chapter).

A lack of soil moisture (SM) during the plant-growing season is the basis for assessing agricultural droughts. (Chatterjee *et al*., 2022) [4]. Moisture deficit information quantification of available water resources is one of the most important tasks of hydrologists to improve water and crop management. Many terrain techniques are available including; gravimetric, strain measurement, neutron probe, time domain reflectometry (TDR) and capacitance measurement (Cao *et al*., 2015) [3]. Measuring soil moisture using the above method requires special skills and knowledge that may not be available locally. Therefore, methodologies for estimating soil surface moisture need to be developed, especially in data-poor areas.

2. Methodology

2.1 Field water balance model of kharif crop

The inflow to the field consists of the total water supplied from precipitation, and the runoff from the field consists of its own evapotranspiration, seepage, and percolation. A generalized water balance model of a rain-flooded upland rice field in the drying phase is:

$$SMC_i = SMC_{i-1} + P_i - AET_i - SP_i \quad \text{......(1)}$$

Where, SMC = Soil moisture content, mm; P = Rainfall, mm; SP = Seepage and percolation loss, mm; AET = Actual evapotranspiration, mm; and i = time index taken as 1 day in the study.

2.2 Actual evapotranspiration

The actual evapotranspiration on any day i (AET_i) under moisture stress condition is given (Idike *et al*., 1982) [11] as:

$$AET_i = Kc_i . Ks_i . ET_{0i} \quad \text{......(2)}$$

Where, K_c = Dimensionless crop coefficient that depends on the growth stage of the crop; K_s = Dimensionless crop stress coefficient and ET_0 = Reference crop evapotranspiration in mm/day.

In the present study, Ks_i in the field under the unsaturated condition as:

$$Ks_i = \frac{SMC_i}{SAT} \quad \text{......(3)}$$

The SP model for the present simulation study expressed (Panigrahi and Panda, 2001) [16] as:

$$SP_i = -16.45 + 0.145\ SMB_i \ (R^2 = 0.87) \quad \text{......(4)}$$

Where, SMB = Soil moisture balance in the effective root zone, mm.

Under the rainfed upland condition, SMB for unsaturated and ponding depth case in the field is given by equations (5) and (6), respectively as:

$$SMB_i = SMC_{i-1} + P_i - AET_i \quad \text{......(5)}$$

$$SMB_i = D_{i-1} + SAT + P_i - AET_i \quad \text{......(6)}$$

The SP value in the model is calculated at the end of each day, while P and AET are assumed to occur at the beginning of the day. If the SMB on any day is less than or equal to the field capacity moisture content, then the SP is zero. The average value of wilting point (WP), field capacity (FC) and saturation (SAT) of paddy fields in the study area within the effective root zone depth was found to be 40.5, 85.5 and 170 mm, respectively.

2.3 Bare soil evaporation

Initially, when the seed is sown in the field, SMC_{i-1} is assumed to be at WP. During the germination period, there is no crop in the field and bare soil evaporation (E_i) is computed from reference crop evapotranspiration (ET_{0i}) subjected to the rainfall (P_i) condition of the day (**Srivastava, 2001**) [19] as:

$$E_i = 0.1\ ET_{0i} \qquad if\ P_i = 0 \quad \text{......(7)}$$

$$E_i = ET_{0i} \qquad if\ P_i > ET_{0i} \quad \text{......(8)}$$

$$E_i = P_i \qquad if\ 0 < P_i > ET_{0i} \quad \text{......(9)}$$

2.4 Bare soil evaporation during the turn-in period

During the last 15 days of simulation (turn-in period- after the harvest of rice till the sowing of a green gram), the soil is under bare conditions. The bare soil evaporation Et_i occurs at a potential rate of ET_{oi} as:

$$Et_i = ET_{0i} \qquad if\ SMC_i \geq FC \quad \text{......(10)}$$

$$Et_i = ET_{0i} . \frac{SMC_i}{FC} \qquad if\ SMC_i < FC \quad \text{......(11)}$$

For the computation of different water balance parameters, AET_i is replaced by bare soil evaporation E_i using equation (7) to (9) during the germination period and Et_i by using equation (10) to (11) during the turn-in period.

2.5 Model application

For simulation purposes, 23 years (1993-2015) of the required meteorological data were taken from the study site. The simulation started from the occurrence date of OEM (Onset of Effective Monsoon) every year. The occurrence of OEM and WM (Withdrawal Monsoon) in the simulated years was predicted along with the determination of the average duration of the rainy season in the study area (102) (Ganachari *et al*., 2022) [10]. This winter crop can be grown as a purely rainfed crop provided residual soil moisture after rice harvest is available for seed germination (Dash and Rautaray, 2017) [7]. After the rice harvest, 15 days are needed as a period for sowing the next winter crop. In this study, simulation is carried out within 15 days after rice harvest to estimate the soil moisture available in the top 15 cm soil layer to determine the germination potential of green gram. Thus, for each year, the simulation continues for 119 days, with 3 days for germination, 101 days for rice growth, and 15 days as the handover period. If the current available SMC is more than 75 percentage of the allowable soil moisture (ASM) in the top 15 cm soil depth, green gram can germinate without the need for pre-sowing irrigation (PSI).

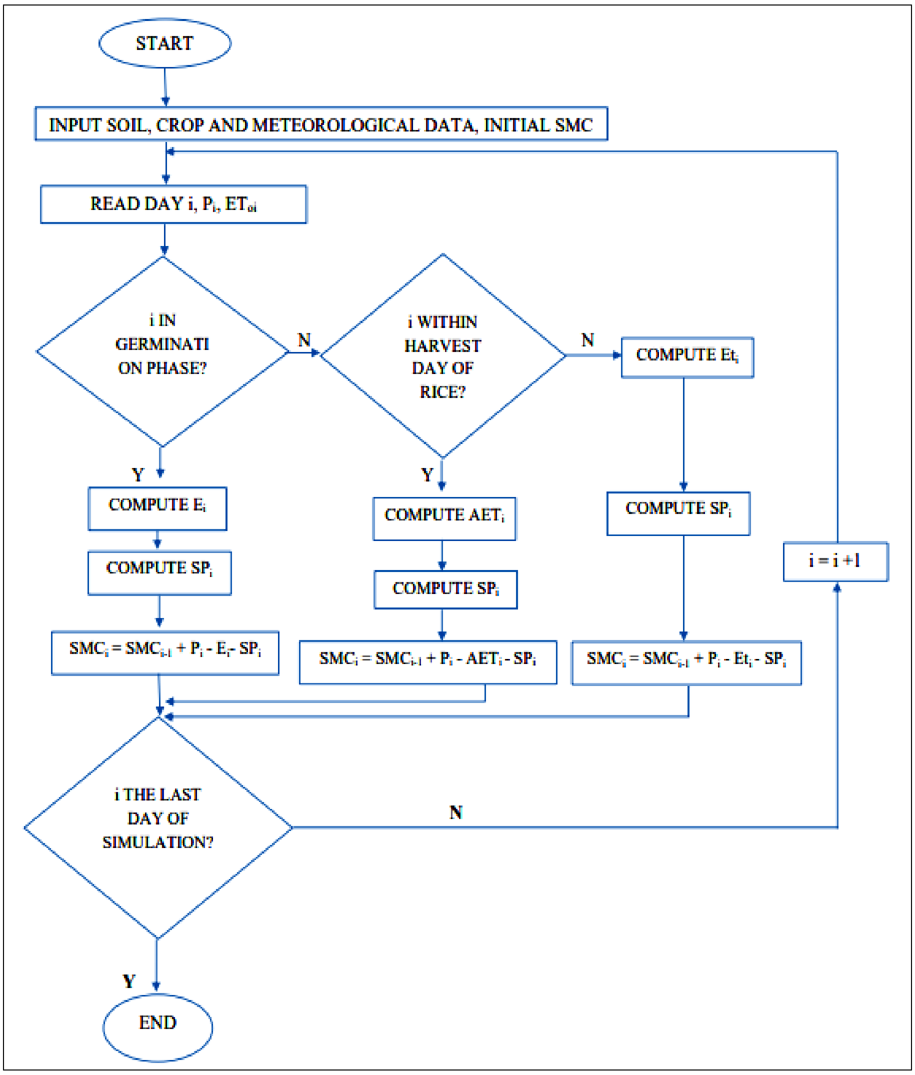

Fig 1: Flowchart prediction of current soil moisture status of soil

3. Results and Discussion

Soil moisture content in rainfed riceland

From Fig. 2, it was observed that out of 23 years of records, it is not possible to sow winter crop in 6 years because the soil moisture required for crop seed germination is below the optimum level. The years that require PSI were 1997, 2002, 2003, 2004, 2006 and 2014.

4. Conclusion

It was also observed that in 6 out of 23 years, residual soil moisture after rice harvest is not sufficient for growing winter crops in the region. Thus, the study shows that there is a need to organize PSI in the region.

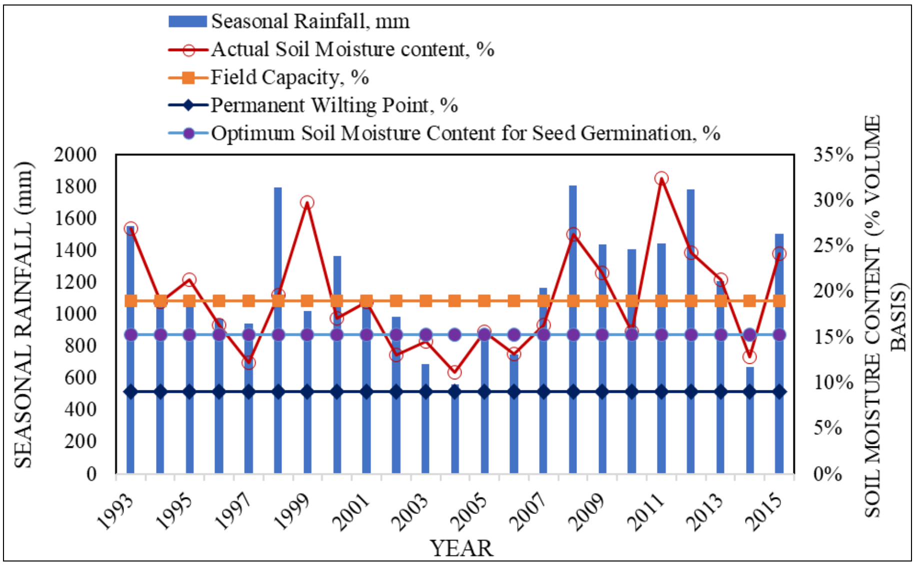

Fig 2: Variation of soil moisture content at the time of sowing of green gram and seasonal rainfall in different years

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