Soil Moisture Based Estimation of Length of Growing Period for Efficient Crop Planning in Micro Landforms of Chaka Watershed, Purulia, India

Srabanti Ghosh*

*Assistant Professor, Department of Geography, Mankar College, Mankar, West Bengal

***Corresponding Author:** Srabanti Ghosh
*Mail: srabanti73@gmail.com

Abstract
Estimation of length of growing period (LGP) is essential in any cropping system as it determines crop selection, yield potential, different farming practices and has direct impact on agricultural productivity and sustainability. Considering this, an agro-topo pedological study has been carried out for Chaka watershed, Purulia, West Bengal, India, to assess length of growing period based on soil moisture availability. It is observed that along with the influence of climatic parameters length of growing period varies with change of micro landform depending on available water holding capacity (AWC) and actual soil moisture storage (ASMS). Soil samples from different landforms have been collected at regular incremental depth to get values of available water holding capacity and actual soil moisture storage. Soil moisture storage is observed to increase sequentially from the undulating ridge top to back slope, foot slope, and finally the valley fill, which are locally referred to as tarn, baid, kanali, and bahal respectively. Accordingly, length of growing period varies in different topographical situation from 158 to 184 days. The span of growing period is 150-160 days in tarn, 160-170 days in baid, 170-180 days in kanali and 180-190 days in bahal. Based on this aspect, a cropping system with alternate crops and a cropping pattern suited to the actual growing period in different micro-landforms has been suggested.

Key words: Length of growing period (LGP), Available water holding capacity (AWC), Actual soil moisture storage (ASMS), Micro landform.

1. Introduction

The productivity of agricultural crops significantly relies on the timely availability of optimal amount of water, supported by effective agronomic practices. The duration of water availability period plays a crucial role in determining crop selection, cropping pattern, and yield potential within an agro-climatic region. Rainfed agriculture in India faces numerous challenges due to the unpredictability of rainfall and occurrence of crop failure and low yield (Mishra,2005). The growing period of crop should align with the duration of moisture availability to satisfy its evapotranspiration needs, reducing climatic risks and enhancing productivity. Length of growing period in rainfed farming is influenced by seasonal pattern of rainfall and evapotranspiration (FAO 1978, Higgins and Kassam,1981). Except climatic factors, duration of water availability period also varies from soil to soil ((Ramana Rao et al., 1979). Considerable variation exists in length of growing period within same climatic zone depending on water holding capacity and soil moisture storage of different soils occurring in varying slope and altitude in an undulating landform. Geomorphologically Chaka basin of Purulia district, West Bengal is a part of eastern extension of dissected Chhotonagpur plateau. Undulating landform with varying slope and different types of soil occur throughout the watershed which belongs to same agroclimatic region. Across the watershed, rainfed agriculture predominates, with rice grown as a monocrop on 80% of the land in both upland and lowland areas, though productivity remains low. A large portion of land remains uncultivated during the rabi season due to a lack of irrigation water. Productivity of crop depends on the availability of soil moisture storage in the profile (Singh et.al.,1979; Dutta et .al,2012). In this context precise estimation of length of growing period is an important pre-requisite for crop planning under rainfed condition.

Several studies have been conducted on duration of suitable period of farming to increase productivity. Climatic water balance method has been used to determine length of growing period for micro regional planning by agro-topo climatological approach (Kumari et.al.2019). Local variation of climate according to landform is considered for efficient land resource management and higher crop productivity (Richards, 1999). Climatic and hydrological variation in different topographic situation has been studied considering climatic parameters for selection of suitable crops and cropping pattern (Sudhishri et.al., 2020; Ekka et.al, 2007). Precipitation and potential evapotranspiration ratio has been used to find critical benchmark of moisture availability and length of growing period for crop planning (Mahadevaswamy et.al. 2016). Soil moisture storage and its variation in different topographic situation has been used for calculation of length of growing period (Dutta et.al.2012). In few studies evapotranspiration based soil moisture index has been considered in determining length of growing period for crop planning (Sattar et.al 2016; Sattar et.al. 2022).

In all studies, climatic parameters have been emphasized in determining the length of the growing period. It has been noted that the rugged and uneven landform of the Chaka watershed can be classified into micro-landform units based on

differences in slope and altitude. Soil moisture availability and actual soil moisture storage vary across these micro landforms. Thus need of precise calculation of length of moisture availability of soil in micro level is felt for suitable selection of crop and cropping pattern to maximize yield.

2. Materials and Method

The study was conducted in Akarbad village ($23^0 10' 29''$N, $86^0 24' 52''$E) in Chaka watershed, Purulia district. The Chaka watershed ($23^0 3'$N to $23^0 13' 12''$N and $86^0 19' 48''$ E to $86^0 33' 36''$E) is a part of Kasai catchment (Fig1). As per National bureau of Soil Survey,1996 the area belongs to agro-ecological subregion of 12.3 characterized by hot, dry subhumid climate. Daily rainfall data has been collected from Indian Meteorological department from 2002-2021 for further analysis. PET has been calculated following Blaney-Criddle method. The Length of Growing Period (LGP), as defined by the Agro-Ecological Zones project (FAO, 1978), refers to the number of days in a year when precipitation surpasses half of the potential evapotranspiration (PET), plus a period required to evapotranspire stored moisture usually 100-125mm for deep soil (>1m) and actual soil moisture storage for shallow soil (<1m).

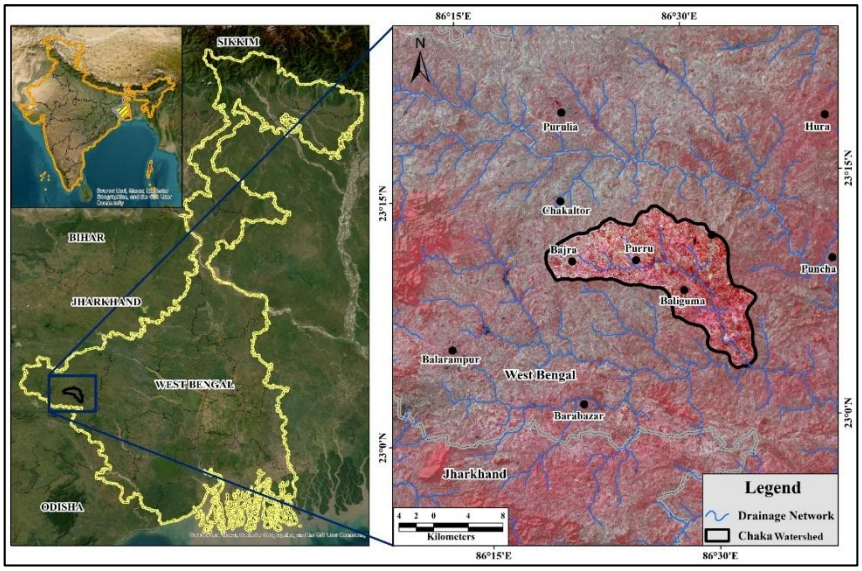

Fig 1 Location Map

According to water balance model (FAO,1978) a typical growing period consists of three phases: a humid period (when precipitation exceeds potential evapotranspiration, P>PET), a moist period (when precipitation is at least half of PET, P ≥ 0.5 PET), and a moderately dry to dry period (when precipitation falls below 0.5 PET). The onset of the growing season depends on both the quantity and frequency of pre-season rainfall. For seed germination and early crop development, precipitation equal to or greater than 0.5 PET is considered adequate to meet the initial water needs of crops. The humid period occurs when precipitation surpasses PET, ensuring that crops receive sufficient water while also replenishing any soil moisture deficit. As this phase transitions to the post-humid period, PET begins to exceed precipitation, forcing crops to rely on stored soil moisture to meet their water requirements. Over time, as soil moisture depletes, water scarcity increases, causing crops to experience wilting. The end of the growing season is marked by precipitation dropping below 0.5 PET, and the time required to evapotranpire the stored soil moisture reserve. Therefore, if adequate soil moisture remains, the growing period can extend beyond the moist phase (Fig 2).

It is observed that soil moisture storage varies in different micro landforms. Therefore, to estimate length of growing period precisely four micro landforms have been selected in Akarbad village in Purulia I block. The micro landforms are ridge land or tanr ($>6^0$ slope), back slope or baid ($3\text{-}6^0$ slope), toe slope or kanali ($1\text{-}3^0$ slope), valley fill or bahal ($< 1^0$ slope). Tanr, baid, kanali and bahal are local name of the mentioned micro landforms. For detail study soil samples have been collected from four micro landforms at regular incremental depth of 20 cm in the soil profile in 2nd week of November, 2021. From the collected soil samples moisture content as percentage of dry weight basis, bulk density, field capacity and permanent wilting point have been measured following standard measurement procedure. Bulk density(gm/cc) of soil is closely correlated with porosity, infiltration capacity and degree of aeration and thereby helps in determination of moisture content. The field capacity of soil is the moisture content in percentage of a soil on oven dry basis when it has been completely saturated and downward movement of excess water has practically ceased. The field capacity is the upper limit of available soil moisture range to the plant. The soil moisture tension at field capacity varies from soil to soil, but it generally ranges from 1/10th to 1/3rd atmosphere. Permanent wilting point is the moisture content in percentage at which nearly all plants wilt unless water is added from an outside source. This is the lower limit of available water range for plant growth. Moisture content at field capacity (-33k Pa) and permanent wilting point (-1500k Pa) have been estimated to determine available water holding capacity of the soil samples. Available water holding capacity (AWC) has been calculated using the following formula.

$AWC = \sum_{i=0}^{n} \frac{Fci - PWP_i \times bd_i \times D_i}{100}$ (Mishra & Ahmed,1987)

Where, Fci = Field capacity (%) at the ^{i}th soil layer, PWP_i = Permanent wilting percentage on dry weight basis of ^{i}th layer, bd_i =Bulk density (gm/cc) of ^{i}th layer, D_i = Depth of layer in cm., n = no. of layer in the profile.

Soil moisture percentage at dry basis has been measured in laboratory and that has been multiplied with bulk density to get the moisture content on volumetric basis. Actual soil moisture storage (ASMS) has been calculated using this volumetric moisture percentage for the required depth of the profile. From weekly PET data average rate of evapotranspiration per day has been calculated which helps to determine the day required to evaporate stored soil moisture. To determine the specific weeks suitable for growing crops, moisture availability was assessed for each standard week by analyzing weekly precipitation and PET data. Moisture availability was calculated using the P/PET ratio (Challa et al., 1999), categorizing the weeks into four groups: dry (P/PET < 0.25), moderately dry (P/PET 0.25–0.5), moist (P/PET 0.5–0.99), and humid (P/PET ≥ 1.0) (Table 2).

3.Result and Discussion

3.1 *Water Balance Model and Length of Growing Period*

Following the water balance model referred by FAO (1978) the growing period has been estimated using climatic parameters. The length of growing period of Purulia meteorological station has been calculated as 150 days which comprises the period beginning from the onset of growing period upto the end of rainy season. Considering the monthly rainfall and PET value (Table 1) it is observed that moist period starts at the end of May when rainfall exceeds 0.5 PET and humid season starts at first week of June when rainfall exceeds PET. Humid and moist period ends at the 1st week and 4th week of October respectively. The length of growing period determined by this method is 150 days (Fig 2).

Table 1 Average Monthly Climatic Data of Purulia

Month	Rainfall (mm)	PET (mm)	0.5 PET (mm)
January	11.07	88.89	44.44
February	17.79	95.37	47.68
March	27.14	152.14	76.07
April	34.74	201.76	100.88
May	53.84	223.55	111.77
June	205.69	162.73	81.36
July	305.13	143.09	71.54
August	298.82	144.37	72.18
September	192.56	136.6	68.3
October	98.5	128.77	64.38
November	12.87	105.73	52.86
December	9.03	93.19	46.59

Source: Indian Meteorological Department *PET calculated by Author*

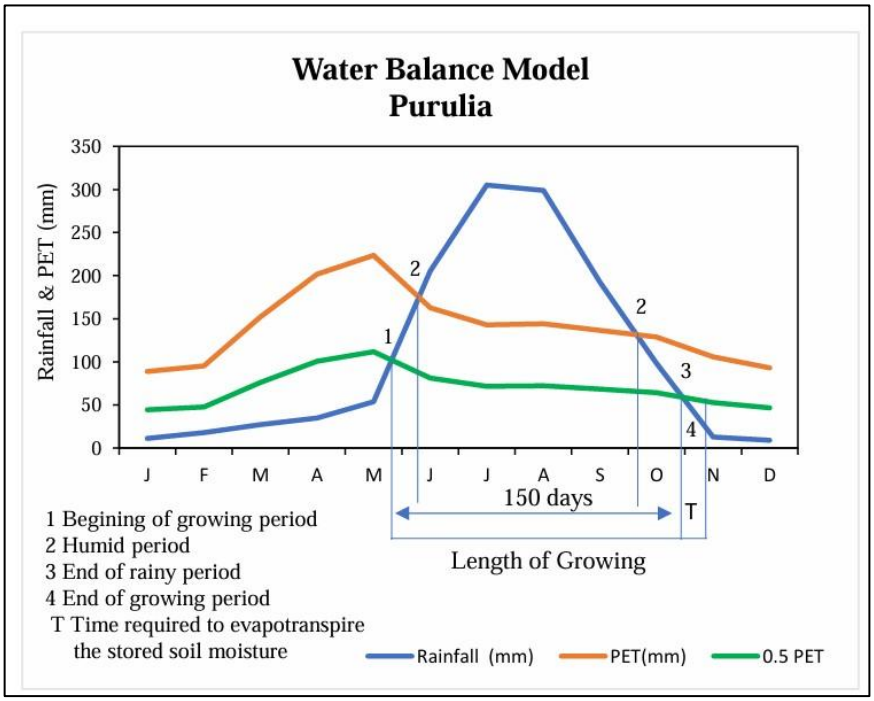

Fig 2

Considering the weekly rainfall (P) and PET data, P/PET ratio has been determined (Challa et al., 1999) and shown in table 2. The weekly moisture availability period (Table 3) shows that the total number of dry weeks (including dry and moderately dry weeks, where P/PET < 0.5) was found to be 31 in Purulia. Number of weeks indicating growing period are 21 which includes 17 humid weeks (when P/PET ≥ 1.0) and 4 moist weeks (when P/PET 0.5–0.99).

Table 2- Weekly Rainfall and PET data of Purulia

No. of Week	Rainfall (P in mm)	PET (mm)	P/PET	No. of Week	Rainfall (P in mm)	PET (mm)	P/PET
1	0.5	16.8	0.03	27	61.7	34.6	1.78
2	0.8	18.7	0.04	28	69.8	30.5	2.29
3	4.5	20.9	0.22	29	60.24	34.3	1.76
4	3.9	23.24	0.17	30	82.3	30.1	2.73
5	3.2	21.6	0.15	31	72.3	29.8	2.43
6	3.1	23.7	0.13	32	70.88	31.2	2.27
7	2.6	21.8	0.12	33	67.05	35.4	1.89
8	6.89	24.5	0.28	34	59.4	33.1	1.79
9	7.9	30.45	0.26	35	69.8	32.79	2.13
10	1.5	31.4	0.05	36	59.4	30.94	1.92
11	6.07	36.7	0.17	37	46.7	30.1	1.55
12	4.24	38.78	0.11	38	31.72	32.6	0.97
13	12.66	32.6	0.39	39	34.8	33.6	1.04
14	5.6	48.7	0.11	40	34.5	33.1	1.04
15	7.38	45.56	0.16	41	26.64	29.8	0.89
16	6.4	44.67	0.14	42	17.01	27.54	0.62
17	11.9	50.8	0.23	43	16.6	26.9	0.62
18	11.65	51.66	0.23	44	8.75	26.67	0.33
19	7.45	55.3	0.13	45	1.8	25.29	0.07
20	16.2	53.4	0.30	46	3.68	24.9	0.15
21	12.23	45.6	0.27	47	1.41	23.8	0.06
22	13.98	43.7	0.32	48	1.28	23.1	0.06
23	42.3	38.5	1.10	49	3.01	23.8	0.13
24	42.9	36.5	1.18	50	2.83	22.4	0.13
25	52.3	38.5	1.36	51	1.5	22.1	0.07
26	72.6	35.6	2.04	52	1.33	18.1	0.07

Data Source: Indian Meteorological Department *Calculated by the Author*

Table 3 Weekly Moisture Availability Period in Purulia

Moisture Availability Period	No. of Standard week	Total Period (week)
Dry Period (P/PET= <0.25)	1st to 7th, 10th to 12t, 14th to 19th , 19th, 45th to 52nd	24
Moderately Dry Period (P/PET=.25- 0.5)	8th, 9th, 13th , 20th , 21st , 22nd , 44th	7
Moist Period (P/PET=0.5-0.99)	38th ,41st to 43rd	4
Humid Period (P/PET ≥ 1.0)	23rd to 37th , 39th ,40th	17
Growing Period		(4+17) = 21

Data Source: Indian Meteorological Department *Calculated by the Author*

3.2 *Variation of Soil Moisture Content and Length of Growing Period in Micro Landforms*

Different parameters of soil have been tested in laboratory (field capacity % (FC), permanent wilting point % (PWP), bulk density (gm/cc), % of moisture content on dry weight basis), to estimate available moisture capacity (AWC) and actual soil moisture storage (ASMS). The soil moisture parameters of different micro landforms have been presented in table 4.

Table 4 Soil Moisture Parameters in Different Micro Landforms in Chaka Watershed

Profile No (Landform)	Depth (m)	FC(%)	PWP (%)	Moisture Content on Dry Weight Basis (%)	Bulk Density (gm/cc)	AWC (cm)	ASMS (cm)	Avg. PET (mm/day)	LGP 150+T
P1(Tanr)	0.2	16.5	5.1	2.1	1.33	3.03	0.55	3.4	150+8 =158 (150-160)
	0.4	15.9	7.1	3.1	1.36	2.39	.84		
	0.6	18.2	5.3	5.8	1.28	3.3	1.48		
						∑ 8.72	∑ 2.87		
P2 (Baid)	0.2	16.3	7.8	5.4	1.53	2.6	1.65	3.4	150+17 = 167 (160-170)
	0.4	17.3	6.8	3.8	1.44	3.02	1.09		
	0.6	18.8	10.6	5.6	1.65	2.7	1.84		
	0.8	19.2	8.8	4.8	1.38	2.87	1.32		
						∑ 11.19	∑5.9		
P3 (Kanali)	0.2	18.6	10.4	6.7	1.36	2.23	1.82	3.4	150+29 =179 (170-180)
	0.4	21.4	12.2	6.8	1.5	2.76	2.04		
	0.6	20.1	12.4	7.2	1.44	2.21	2.07		
	0.8	21.4	14.2	6.9	1.45	2.08	2.00		
	1.0	20.5	11.2	6.7	1.42	2.64	1.9		
						∑ 11.78	∑ 9.83		
P4(Bahal)	0.2	23.8	12.4	9.4	1.35	2.23	2.53	3.4	150+34 =184 (180-190)
	0.4	21.8	10.8	8.6	1.33	2.92	2.28		
	0.6	26.3	16.6	8.9	1.29	2.5	2.29		
	0.8	28.1	16.3	8.5	1.32	3.11	2.24		
	1.0	26.3	16.2	8.4	1.35	2.72	2.26		
						∑ 13.48	∑ 11.6		

Source: Primary Survey

It is observed that soil moisture contents regarding FC, PWP, AWC and ASMS vary in different micro landforms. Moisture content on dry weight basis (%) per meter is observed as 18.33 %, 24.5%, 34.3%, and 43.8% in Tarn, baid, kanali and bahal respectively. Regarding soil taxonomy soil of tarn land is loamy skeletal lithic ustorthent, soil of baid land is coarse loamy mixed hyperthermic typic haplustepts, soil of kanali land is mixed hyperthermic typic ustipsamments, and soil of bahal is fine loamy typic endoaquept. The available water holding capacity (AWC) and actual soil moisture storage vary, gradually increasing in the order of tarn < baid < kanali < bahal. In this context length of growing period has to be considered for each micro landform. From water balance diagram (fig 2) the growing period has been estimated as 150 days. Now time (T) required for evapotranspiration of actual soil moisture storage is to be considered. After the end of moist period average PET/day has been calculated as 3.4 mm/day (table 2). The time taken to evapotranspire the stored soil moisture is calculated. Since actual soil moisture storage (ASMS) differs across micro-landforms, the time (T) needed for stored soil moisture to be lost through evapotranspiration also varies. Data represents that for deep soils of kanali (P3) and bahal(P4) the values of T are 29 days and 34 days respectively, while for shallow to moderately shallow soil of tarn(P1) and baid(P2) the values of T are 8 and 17 days respectively. Thus the actual length of growing period in tarn land (P1) would be 150+8=158 days, in baid land (P2) 150+17= 167 days, in kanali land (P3) 150+29=179days, and in bahal land (P4) 150+34=184 days. Thus moisture availability period of four micro landforms has been considered as 150-160 days for tarn, 160-170 days for baid, 170-180 days for kanali and 180-190 days for bahal.

4. Moisture Availability and Cropping Pattern

Most part of the watershed is dominated by monocropping of kharif paddy. The main cropping pattern includes fallow-paddy-fallow. In few cases paddy is replaced by maize or pulse and followed by fallow. Few farmers utilize the stored moisture after rainy season to cultivate mustard and vegetable. In rainfed agriculture paddy always dominate as staple cereal. For limitation of rainfall during non monsoon season and lack of irrigation facilities farming is difficult throughout the year. In rainfed farming, crops should be chosen in a way that their water needs at various growth stages align with the available soil moisture. It has been observed that in deep soils of kanali and bahal land moisture is available for more days than tarn and baid. Therefore, different crops may be selected in different micro landforms depending on varying length of growing period. In addition to crop selection agronomic practices and irrigation practices may also be changed to get higher yield.

Considering the land suitability of crops in four micro landforms alternate crops and cropping system may be suggested. In tarn land with shallow soil depth and coarse soil texture, short duration paddy may be grown. Except paddy maize may be grown as sole crop. Intercropping may be done with maize and pigeon pea or cowpea, maize and pulse like khesari mung, cowpea and groundnut. Baid land having LGP of 160-170 days may adopt pulses like pigeon pea, cowpea, and oilseed like sunflower, sesame, mustard. For cultivation sprinkler irrigation may be adopted to increase water use

efficiency. Considering the LGP of baid land crop with 140-150 days growth cycle should be selected for better productivity. In kanali paddy is the most suitable kharif crop considering the slope. As it has higher LGP ranging 170-180 days crop diversity may be adopted by introducing linseed, sunflower, mustard, barley, horse gram, lentil etc. as all of these require minimum water. The bahal land having LGP of 180-190 days is suitable for long duration kharif paddy. As in this landform soil moisture storage is higher, paddy may be followed by pulses like lentil, mung, vegetables, mustard and spices like coriander, fenugreek etc.

Regarding cropping pattern instead of solo cropping crop rotation, intercropping and strip cropping are recommended. Arhar (Tur) can be rotated with short-duration, drought-resistant wheat, as they have different root zone depths of water availability. Kharif pulse or maize instead of paddy may be adopted followed by mustard or rapeseed in baid land.

5. Conclusion

The study reveals that within same agro- climatic zone moisture availability period and length of growing period vary with different micro landforms of different soil characteristics. The agro-topo pedological study indicates variable stored moisture availability in different micro landforms after the end of climatic growing period. Considering actual soil moisture storage and the time to evapotranspiration of that moisture, length of growing period has been calculated. The estimated range of LGP in different micro landforms are 150-160 days in ridge land or tarn, 160-170 days in back slope or baid, 170-180 days in in toe slope or kanali, 180-190 days in valley fill or bahal. This variable moisture availability may be utilized in proper selection of crop and adopting suitable cropping pattern. The current cropping pattern is largely dominated by kharif paddy, often followed by fallow, which not only results in low productivity but also increases the risk of soil erosion. Depending on available moisture after the end of rainy season rabi crops like different pulses, oilseeds may be recommended to increase crop diversity reducing dependency on mono cropping of paddy. Lac production can be promoted in highland areas as a part of climate-resilient agriculture. This agro-topo pedological study, considering local variations in soil moisture availability and the resulting length of the growing period across different micro-landforms, holds significant potential for optimal land resource management and sustainable crop productivity.

Reference:

1. Challa,O., Reddy,R.S.,Shiva Prashad, C.R.(1999).Assessment of quality of growing periods in arid and semi arid ecosystem for crop production. Agropedology, 9 (1): 63-70
2. Dutta,D., Banerjee,T., Sarkar,D. (2012). Length of growing period Assessment in Bankura district For Micro level crop planning. Agropedology, 22(2),80-87
3. Ekka, A.P., Kumari,P., Kumar,S., Wadood,A. (2020). Estimation of the Water Balance and Length of Growing Period under Gumla District of Jharkhand for Efficient Crop Planning. Agricultural Science Digest, Volume 40 Issue 3: 234-241.
4. FAO, (1978). Report on the Agro Ecological Zones Project, Vol.1, Methodology and Research for Africa , Rome, 15p.
5. Higgins, G.M., Kassam, A.H. (1981). The FAO agrological Approach for Determination of Land Potential, Pedologie,31, 147-168.
6. Kumari,P., Balmuchu,S.A., Tirkey,D.A., Wadood,A. (2019). Climatic water balance and length of growing period for efficient crop planning under different agrotopo-climate in Ranchi, Jharkhand. Journal of Soil and Water Conservation 18(1): 59-63, January-March DOI: 10.5958/2455-7145.2019.00007.9.
7. Mahadevaswamy, M., Ramesh,S., Sreenivas, S.S.(2016). Determining the Length of Growing Period (LGP) for efficient crop planning and sustaining farm productivity in the rainfed STZ of Karnataka . Tob. Res. 42, No. 1: 20-23, June, 2016.
8. Misra, A.K. (2005). Contingency planning for feeding and management of livestock during drought. In: Drought Management, eds: K.D. Sharma and K.S. Ramasastri, Allied Publishers Pvt. Ltd., New Delhi. pp. 276-286.
9. Mishra, R.D., and Ahmed, M.(1987). Manual on irrigation agronomy. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi.
10. Ramana Rao, B.V., Biradar, B.R., Surpur, S.S. and Rao, M.G. (1979). A climatological study on water avialbility to crops in different types of soils in Gulbarga region. J. Indian Soc. Soil Sci. 27:441-445.
11. Richards, K. (1999). Topoclimate South: Land and climate information for a sustainable future. Environmental Perspectives 22:2-4.
12. Sattar,A., Khan,S.A. (2016). AE/PE versus crop planning in Bihar. Journal of Agrometeorology 18 (2) : 270-276
13. Sattar,A., Singh,G., Khan,S.A., Jha,R.K., Kumar,S.(2022). Estimation of evaporation and soil moisture index based length of growing period for enhanced agricultural production in Bihar MAUSAM, 73, 2 (April 2022), 389-404. DOI : https://doi.org/10.54302/mausam.v73i2.5482.
14. Singh,N.T., Singh,R., Mahajan, P.S., Vig,A.C.(1979) Influence of supplemental irrigation and pre sowing soil water storage. Agronomic journal 71, 483-486.
15. Sudhishri, S., Dass, A. and Paikaray, N.K. (2007). Water balance studies and strategies for combating water deficit in upper kolab catchment of Orissa. Hydrology Journal 30:103-116.