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Drought Analysis based on LGP under Changing Climate

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ABSTRACT
Quantification of impact of climate change on crop production is necessary for finalizing the strategy for crop diversification in particular area. Drought has impact on crop production. Length of Growing Period (LGP) was determined for the period 1998-2017. Based on LGP and mean annual rainfall, drought analysis was carried out. Under average rainfall condition, the LGP could be as high as 182 days extending from 24 to 50 standard meteorological week (SMW). On an average LGP for Yavatmal taluka is estimated as 23 weeks (162 days). Based on LGP and mean annual rainfall, mild drought is common in Yavatmal taluka. Thus crop planning should be prepared considering mild drought condition and LGP OF 162 days.
Keywords: crop planning, drought, Yavatmal, LGP, water balance

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INTRODUCTION

India stands to face major challenges in many fronts so far as the impact of climate change is concerned. As a large part of the arable land in India is rainfed, the productivity of agriculture depends on the rainfall and its pattern. As a result of climate change, increase in temperature and significant changes in rainfall pattern have been observed during the 20th century. Successful agriculture is not possible without rainfall and hence water security is one of the most important threats in this regard. At present, available statistics on water demand shows that the agriculture sector is the largest consumer of water in India [1-3].

The vulnerability to climate change was greater in developing countries like India which are mostly located in lower warmer latitudes [8]. The long spells of rainfall show a significant decreasing trend over India as a whole while short and dry spells indicated an increasing tendency with 5% significance [4] as an effect of climate change [3].

Potential evapotranspiration (PET) is a crucial indicator of hydrologic regime of a region. It is an important variable in estimation of actual evapotranspiration (AET) in hydrological and ecosystem modeling [1]. Actual evapotranspiration is actual water requirement of crop. There are several models recommended by FAO for estimation of PET.

The success or failure of rainfed farming is depend on the availability of rainwater and its distribution over crop growth period. There is no real control on the weather, but it is possible to optimize the rainfed crop production by adjusting the cropping patterns, crop plans and agronomic practices in accordance with the probable weather conditions. Similarly, rainwater management can be made accordingly for making it available for supplemental irrigation during water stress periods especially at critical growth stage of the crops. This study was undertaken to assess the suitability of rainfed cropping in Yavatmal taluka in Vidarbha region based on length of growing period (LGP) and water balance approach.

MATERIAL AND METHODS

Data Collection

The study area was Yavatmal taluka (latitudes: 20.24 N, longitudes : 78.8 E, altitude:445 mamsl) of Vidarbha region. Meteorological data viz. daily rainfall and daily maximum and minimum temperature was collected from All India Coordinated Research Project on Agro-meteorology, Dr. PDKV Akola for period of 20 years *i.e.*1998 to 2017, for Yavatmal station. Daily rainfall data were summed up to obtain weekly total rainfall for each standard meteorological week (SMW).

Potential Evapotranspiration

The Hargreaves-Samani [6] model is one of the more represents versions and one of the older evapotranspiration estimation models [7]. The model is computationally simple and applicable to a variety of climates using commonly available meteorological data. The Hargreaves-Samani model was adopted for use by FAO for areas where air temperature is the only available variable [2, 7]. As only temperature data is available, Hargreaves-Samani [6] model was selected for estimation of potential evapotranspiration in this study. It is given by following relationship.

$ET_o = 0.0023 (T_{mean}+17.8)(T_{max}-T_{min})^{0.5} R_a$

where,

ET_o = Reference evapotranspiration, (mm/day)
T_{mean} = Mean air temperature, (°C)
T_{max} = Daily maximum temperature, (°C)
T_{min} = Daily minimum temperature, (°C) and
R_a = Daily extraterrestrial radiation ($MJ/m^2/day$)

Weekly total potential evapotranspiration (PET) was calculated for each SMW.

Water Balance Parameters

The average PET, AET, water surplus, water deficit, soil moisture index (SMI) and index of moisture adequacy (IMA) for the period of 1998-2017 were calculated as described below.

Actual evapotranspiration (AET)

The water balance method considered that when rainfall is greater than potential evapotranspiration, actual evapotranspiration is taken as equal to potential evapotranspiration and when rainfall is below the potential evapotranspiration, the actual evapotranspiration is calculated as the sum of rainfall and change in soil moisture storage between two successive weeks. The weekly actual evapotranspiration was calculated using weekly precipitation and changes in weekly soil moisture storage data (ΔSTOR) in following way.

a) When P > PET, then AET= PET
b) When P < PET, then AET = P+ ΔSTOR

The potential evapotranspiration (ET_o) and the crop coefficient (K_c), were used to determine the crop evapotranspiration ET_c under normal condition as below.

$$ET_c = K_c \times ET_o$$

The values of crop coefficient (K_c) for existing crops in Yavatmal taluka viz. cotton, soybean, pigeon pea, sorghum, green gram and black gram for initial, development, mid-season and late growth stages were referred from FAO Irrigation and Drainage Paper No. 56.

Soil moisture storage

Soil moisture storage during different months was estimated using following equation involving monthly precipitation and monthly potential evapotranspiration values under two different conditions.

Soil storage = (P - PET)

a) If (P-PET) ≤ 0, then soil storage = 0
b) If (P-PET) > 0 but < AHWC, then soil storage = (P-PET)

where,

AWHC = Available water holding capacity of soil in mm per meter depth.

The field capacity, permanent wilting point and average water holding capacity for clay loam soil is considered as 30%, 15% and 15% (150mm/m).

Water deficit (WD)

Water deficit was calculated as the difference between potential evapotranspiration and actual evapotranspiration.

Water Deficit = PET - AET

Index of moisture adequacy (IMA)

The index of moisture adequacy (I_{ma}) is the ratio between AET and PET

$$I_m = \frac{AET}{PET}$$

Soil moisture index (SMI)

Soil moisture index (SMI) is the ratio between soil moisture storage (SMS) and available water holding capacity (AWHC).

$$SMI = \frac{SMS}{AWHC}$$

Effective rainfall (ER)

The term effective rainfall is used to define the fraction of the total amount of rainwater useful for meeting the water need of the crops. The effective rainfall is the total rainfall excluding runoff, evaporation and deep percolation. It is the only water retained in the root zone that can be used by the plants, and represents as the effective part of the rainwater. The effective rainfall (ER) was computed by subtracting water surplus from rainfall.

For determination of water balance component on weekly basis 'Weather Crop software' developed by All India Coordinated Research Project on Agrometeorology. Central Research Institute for Dryland Agriculture Hyderabad was used.

Determination of length of growing period

The length of growing period (LGP) is based on the concept of index of moisture adequacy (IMA). IMA is the ratio between AET and PET. Since the study area falls under dry sub humid climatic condition, the onset of growing season was considered at a week when IMA was greater than or equal to 0.75 [5], which is considered as the minimum moisture level for starting the sowing of rainfed crops. The termination of growing period was taken at a week from where IMA is less than 0.25.

Identification of Drought Type Based on Length of Growing Period

Drought prone area analysis was carried out using annual rainfall data and soil type. Length of growing period was taken as basis for different kinds of drought. LGP is the duration during which rainfall meets 50% of PET requirement during vegetative phase till soil moisture storage meet 25% PET during maturity or harvesting stage of the crop (Higgins and Kassam, 1981). The drought analysis was carried out based on LGP and average annual rainfall for the location, based on criterion described in Table 2.

Table 2 Classes of drought type based on LGP

Sr. No.	Length of growing period (days)	Type of Drought	Mean annual rainfall (mm)
1.	< 90	Chronic	430 – 630
2.	90 – 120	Sever	622 – 679
3	120 – 150	Moderate	603 – 875
4.	150 – 180	Mild	740 – 992
5.	180 >	Rarely drought prone	More than 992

(Source: Naidu and Srinivas; 2014)

RESULTS AND DISCUSSION

Water Balance Parameters

The variation in average rainfall, PET, AET, water surplus (WS), water deficit (WD) and soil moisture storage (SMS) for the period 1998-2017 is depicted in Fig. 1.

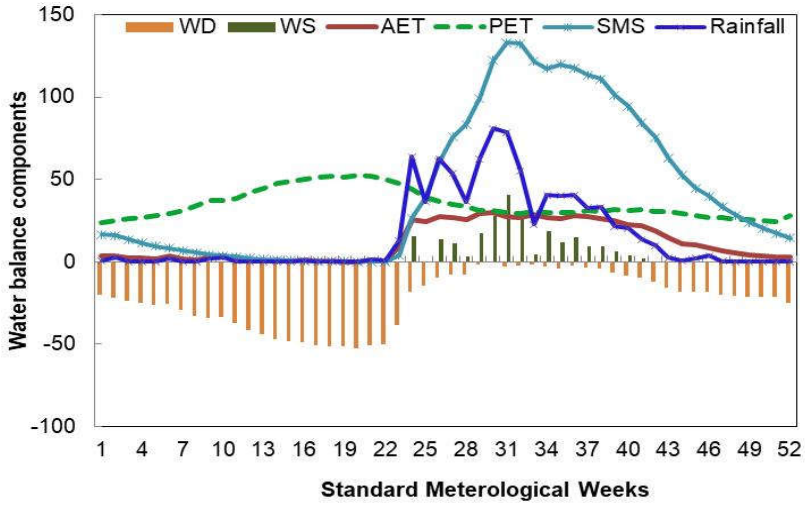

Fig. 1 Variation in average weekly water balance parameters

The average rainfall over study period was found more than 50 mm during 24-32 SMW while it was more than 30 mm during 33 SMW to 38 SMW. The highest average weekly rainfall (80.94 mm) was found to occur in 30 SMW. However, there were 12 SMWs without rainfall.

Average weekly total PET was less than 30 mm during the period from 1 to 6 SMW, whereas it was greater than 30 mm week during 7- 43 except 32, 34 and 36 SMW.

Water surplus, which includes runoff and deep drainage, was found to prevail from 24 to 41 SMW. The total annual surplus was computed as 237.90 mm during 24 to 41 SMW as against the total water deficit as 109.07 mm during the corresponding period. However, annual deficit was estimated as 1206.67 mm.

The 50% of AWHC value prevailed during the period from 27 SMW to 42 SMW, indicating that under average rainfall condition, crops growing during this period would be able to produce at potential level. Similar variation was also observed in soil moisture index, where SMI>0.5 was found to occur during the period from 27- 42 SMW.

Length of Growing Period

Understanding of rainfall amount, distribution, start and end of the season is essential for altering the crop production system. Year wise start week and end week based on I_{ma} values are presented in Table 1.

Table 1 Start, end and duration of length of growing period (LGP) at Yavatmal during 1998-2017

Year	Start Week ($I_{ma} \geq 0.75$)	End Week ($I_{ma} \leq 0.25$)	LGP (Weeks)	LGP (Days)	Total Rainfall (mm)
1998	24	50	27	189	767.5
1999	24	50	27	189	1103.3
2000	25	44	20	140	562.6
2001	23	50	28	196	1106.2
2002	24	49	26	182	1155
2003	24	50	27	189	1084.8
2004	28	50	23	161	604.3
2005	26	48	23	161	609.5
2006	26	48	23	161	1224.7
2007	26	47	22	154	826.6
2008	26	46	21	147	601
2009	26	51	26	182	539
2010	24	50	27	189	1044.4
2011	24	45	22	154	824.9
2012	24	49	26	182	1083.5
2013	23	50	28	196	1067.8
2014	29	44	16	112	462.1
2015	30	46	17	119	389.7
2016	25	45	21	147	618.5
2017	29	41	13	91	261.2
		Average	**23.15**	**162.05**	**796.83**

From Table 1 it is cleared that the average growing period ranges from 13 to 28 weeks (91 to 169 days) in Yavatmal taluka. Highest LGP was found in 2001 and 2013, while lowest was found in year 2017. On an average LGP for Yavatmal taluka is 23 weeks (162 days).

Drought type based on length of growing period

The drought prone area analysis for Yavatmal during 1970-2016 revealed that the region was subjected to mild type of drought since the region received mean annual rainfall 796.83 mm and LGP is more than 150 days and less than 180 days..

Inference

The drought prone area analysis for Yavatmal during 1970-2016 revealed that the region was subjected to mild type of drought. Mean length of growing period was estimated as 162 days. Therefore crops tolerant to mild drought and having crop period less than 150 days should be planned for Yavatmal station during kharif season.

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