A JOURNAL OF THE ASSOCIATION OF PUNJAB GEOGRAPHERS, INDIA

punjab geographer

VOLUME 9 OCTOBER 2013

IDENTIFICATION OF IDEAL LENGTH OF GROWING PERIOD FOR RAIN-FED CROPS: A CASE STUDY OF AMHARA NATIONAL REGIONAL STATE - ETHIOPIA

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Abstract

Under rain-fed conditions food crops are produced in areas where climatic and other conditions prevail for their successful growth. The length of time in a year in which these ideal climatic conditions prevail is called length of growing period. Of all these ideal conditions, it is moisture which is more variable in the tropics. Amhara National Region State has been selected as a case study from Ethiopia which is one of the drought prone and food insecurity areas of the country. By employing Thornthwaite's 1955 water balance method of computations, length of growing period(LGP) of the study area was assessed. Index of Moisture Adequacy (Ima), a derivative index of water balance, serves as the most important parameter for the identification of LGPs in the study area. By using the values of Ima, degrees of soil moisture dependability are assessed. Furthermore, the shortest length of growing period for the quick maturing crops in the study area is taken as a threshold to determine LGPs. It is found that the study area is having 150 days (five months) of single length of growing period. The five months of growing period of the study area are further categorized into highly and marginally suitable for crop growth.

Introduction

Availability of moisture in soil determines the success of crop production. Moisture, in rain-fed crop production system, depends on the amount of rainfall which varies over space and time. Though rainfall is the prime source of moisture yet, it is the relationship between potential evapotranspiration (PE) and actual evapotranspiration (AE) that determines soil moisture availability at a given time (Hema Malini and Pampa Chaundri, 2010). The length of crop farming season is determined by the duration of retained water in the soil (Narasimha Raju, 1985). Length of growing season is a period in which sufficient moisture is available in a particular area to produce crops (Ayoade, 1983).

The revised water balance method of Thornthwaite and Mather (1955) is employed in this study (Thornthwaite and Mather, 1957). Index of Moisture Adequacy (Ima), a derived variable of water balance elements as demonstrated by Subrahmanyam, et al in 1963, is used to determine the status of soil moisture of the study area (Hema Malini and Pampa

Chaundri, 2010).

The rural households around Kombolcha station entirely depend on rain-fed crop cultivation, and are frequently affected by drought. As the station is located at the heart of drought prone and food insecure areas of the country, such a study is of paramount importance. Therefore in this study an attempt is made to assess whether there is sufficient moisture in the soil to support crop growth or not. Crop growing months of the study area are finally categorized into different suitability classes for growth of crops.

Study Area

Kombolcha, the station chosen for the present study, is located in the Amhara National Regional State of Ethiopia. Geographically, it is located on 11°05' N latitude and 39°44' E longitude. The station is located at a height of 1903 metre above sea level.Topographically, it is a plain area surrounded by plateaus in almost all directions. Farmers are mostly settled on the piedmont plateaus. A perennial river called Borkena is passing through the study area, but farmers rarely irrigate their farms. The dominant soil type of the study area as per ANRS, BoFED (2006) is cambisols, the texture of which range from clay-loam to sandy-clay-loam.

Methods of the Study

The use of appropriate methods is critical for scientific investigations. The following techniques are employed in this particular study.

Water Balance Assessment

Water Balance technique (1955) of Thornthwaite and Mather is employed for the present study. Monthly temperature and rainfall data of the station were collected from the records of National Meteorological Agency (NMSA) of Ethiopia for a period of 1968-2010. In the computation of water balance, potential evapotranspiration and precipitation were compared and the balance determines the status of soil moisture storage after meeting the demands of atmosphere in the form of actual evapotranspiration. If there is sufficient availability of moisture in the form of precipitation and in the soil reservoir to meet the demands of the atmosphere, actual evapotranspiration is equal to potential evapotranspiration and there will be no water scarcity conditions. On the other hand, if the precipitation and soil moisture fail to meet the water need of the atmosphere, actual evapotranspiration is less than potential evapotranspiration and water deficit conditions do exist. The percentage ratio of actual evapotranspiration to potential evapotranspiration provides information of water potential of the region.

Assessment of Moisture Adequacy

Index of moisture adequacy (Ima) is one of the indices derived from the water balance analysis. Ima is worked out as a percentage ratio of AE to PE (Ima=AE/PE x 100) to estimate soil moisture availability at a given time in a given locality as demonstrated by Subrahmanyam (Hema Malini, 1996). Ima is considered as the best index, because it clearly indicates the amount of moisture in the soil at a time and its temporal fluctuation ((Hema Malini and Pampa Chaundri, 2010, Sarma and Lakshimi Kumar, 2006). The following AE/PE indices (Ima values) are used as indicators to estimate length of growing periods and to identify degree of their suitability for crop culture based on the work of Subrahmanyam as presented in Hema Malini (1996).

i. **Highly Suitable (Ima >80%):** This class signifies months having high amounts of moisture for the successful growth of different types of crops including wetland crops like rice. Moisture stress conditions are almost non-existent during these months.

ii. **Moderately Suitable (Ima 60-80%):** This class consists of months in which there is sufficient moisture in the soil to grow even wetland crops like rice, but yields may be comparatively lower than the highly suitable range.

iii. **Marginally Suitable (Ima 40-60%):** As the name implies, this category is not as such promising for wide variety of crops since only those crops which can withstand dry conditions can thrive.

iv. **Not Suitable (Ima <40%):** Due to low moisture potential of the soil, cultivation of crops is not possible.

Based on these indices, months of the year are categorized into different suitability classes for the study period in the study area.

Assessment of Moisture Stability

Stability here refers to the dependability of moisture for crop production. Months of the year vary in their moisture content and the moisture content of a month may differ from one year to another. Moisture content in soil must be reliably sufficient within LGPs to grow crop. Chandrasekran, et al., (2010) defined length of growing period as the period when the soil water, resulting mainly from rainfall, is freely available to the crop. According to Ram Babu (2010), even though rainfall is the primary source of moisture for plants, it is the available soil moisture at the root zone of crops which is more important for the performance of crops. Therefore, the knowledge of soil moisture availability is of paramount importance for crop production. However, categorization and demarcation of length of growing period, in reality, is not found as simple as it appears. Assessment of the length of growing season is a crucial task because of the variations in the rainfall (Ayoade. 1983). It is therefore very imperative to identify which months vary significantly and which months remain stable over the study period.

To assess the moisture stability conditions, each month's index of moisture adequacy is separately analyzed for the study period. Based on the results of this Ima stability analysis, months of the year are categorized as months of stable conditions (Ima consistent in one suitability class throughout), months with moderate fluctuation (Ima between 40-100%), and months of high fluctuation (Ima between 10-100%) as follows:

I. **Stable Months:** these months are those in which Ima values are constant over the study period. The suitability class of a month could be highly suitable, moderately suitable, marginally suitable, or unsuitable, but remains the same during the study period.

II. **Moderately Fluctuating Months:** These are the months in which their Ima values fluctuate from 40% to 100% throughout the study period. The Ima values for these months may cross over two or three suitability classes above 40%.

III. **Highly Fluctuating Months:** These are the months whose Ima values fluctuate from below 40% to 100%. Moisture supply is highly unreliable during these months entailing imminent risk of drought.

The stable months, moderately fluctuating and highly fluctuating months are identified on the basis of moisture adequacy works of Subrahmanyam (1963) as presented in Hema Malini and Pampa Chaundri (2010).

Demarcation of LGPs

LGP can be defined as the period when soil moisture content is freely available at the root zone of crops (Chandrasekran, et al., 2010, Ram Babu, 2010). When seen from climatic point of view, soil moisture above 50% of the AE/PE ratio is considered as suitable for crop growth; and the period is called LGP (Narasimha Raju, 1985). However, the process of the identification and demarcation of LGPs is a difficult and even a risky task due to the variability nature of moisture (Ayoade, 1983). Ayoade further emphasized that the number of months with sufficient moisture to fulfill the demand of crops is the fundamental parameter for the identification of LGPs. Therefore, to identify and demarcate LGPs, two important issues must get special consideration: (i) the duration in which sufficient moisture must be available for Growth of crops and (ii) the stability or degree of dependability of moisture within the LGP. In the first case, fluctuations of monthly Ima are apparent. This means that Ima values of a month may distribute over different suitability classes during the study period and this results in the problem of classifying a given month into a specific suitability class. Secondly, the LGP when seen from climatic perspective, it may mean soil moisture above the minimum level to support crop growth as long as the ratio of AE/PE (or P/AE) is ≥ 0.5 (Narasimha Raju, 1985). Such quantitative measurement has little significance when it comes to practice, unless the number of days in which retained moisture in soil is known. Therefore, it is very important to know the ideal duration of soil moisture above the minimum value to identify LGPs.

The following parameters are, therefore, used in this study for the identification of LGPs.

1. AE/PE > 0.5;
2. Shortest growing period to produce crops in the study area, which is 90 days, is taken as a threshold for the purpose. According to FAO (1996), 95 days for over 75% of the study period is considered as dependable growing period.
3. FAO (1996) accepted less than 25% of variability below the minimum moisture amount during the study period. Though this seems acceptable, such an extent of tolerance may result in frequent disasters and starvations of farmers in the study area with no food reserve at all. Hence, considering the hand to mouth economy of the farmers of the study area, a 10% variation below 40% of Ima is tolerated in this study. This means that over 90% of months of the study period must have Ima values of over 40% to be regarded as LGP.

Based on the above three parameters, the overall growing periods of the study area are identified and months of the growing period are classified as highly suitable, moderately suitable, and marginally suitable.

Results and Discussion

Potential Evapotranspiration and Actual Evapotranspiration of Kombolcha

Fig.1 shows that the actual evapotranspiration of Kombolcha is almost equivalent to atmospheric demand (PE) during March, April, and from July to October.

Average Ima of Kombolcha

As reviewed in Fig. 2, March, April, July, August, September and October are highly suitable, whereas January, February, May, November, and December are moderately suitable for rain-fed crop culture. The month of June, at this station, is the only month with

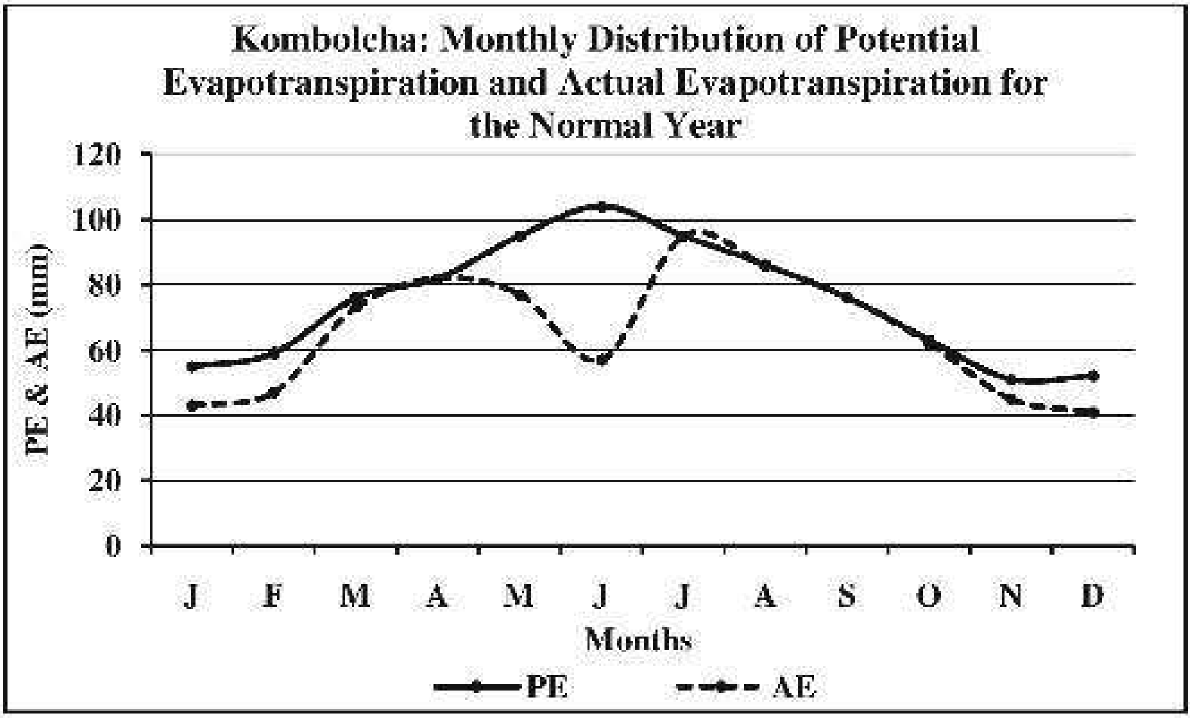
Kombolcha: Monthly Distribution of Potential Evapotranspiration and Actual Evapotranspiration for the Normal Year
PE & AE (mm)
120
100
80
60
40
20
0
J F M A M J J A S O N D
Months
PE
AE

Fig. 1

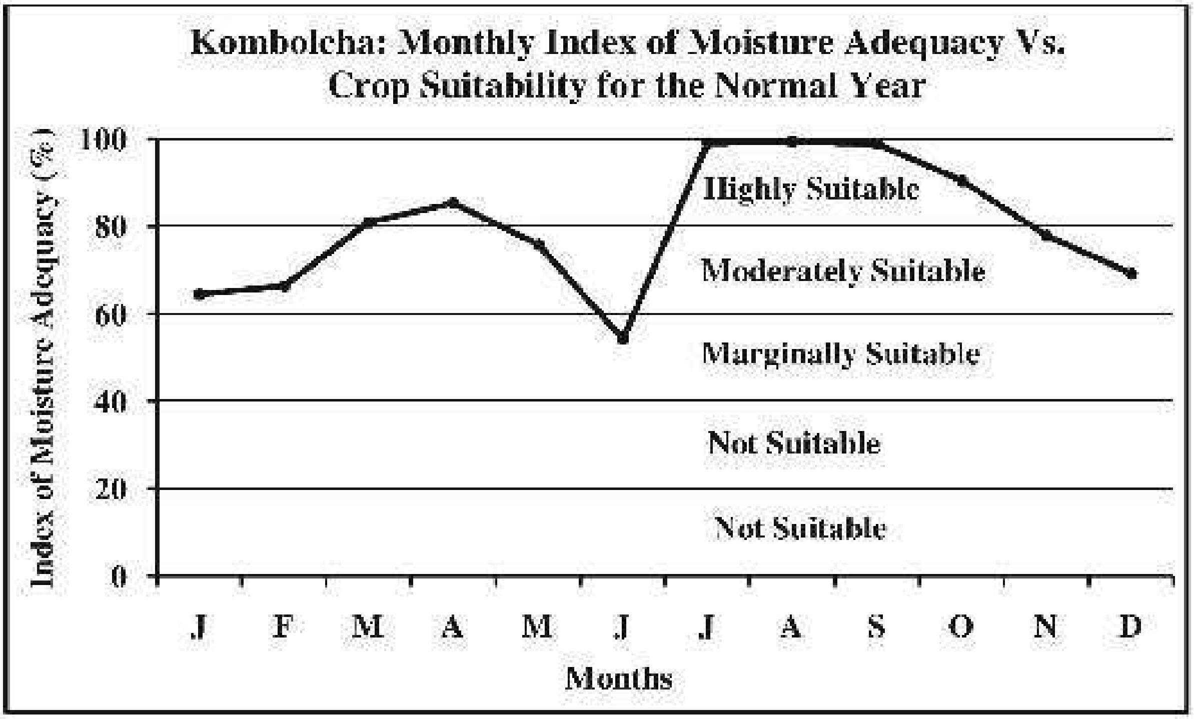
Kombolcha: Monthly Index of Moisture Adequacy Vs. Crop Suitability for the Normal Year
Index of Moisture Adequacy (%)
100
80
60
40
20
0
Highly Suitable
Moderately Suitable
Marginally Suitable
Not Suitable
Not Suitable
J F M A M J J A S O N D
Months

Fig. 2

Table 1
Kombolcha: Occurrences of Suitability Classes by Months

Stability Class	No. Months	Months	No. of occurrences				
			Highly	Moderately	Marginally	Not	Total
Stable	1	September	43				43
Moderately fluctuating	4	July	42	1			43
		August	42	1			43
		October	38	4	1		43
		November	20	16	7		43
Highly Fluctuating	7	January	13	6	13	11	43
		February	16	11	6	10	43
		March	25	13	2	3	43
		April	32	3	3	5	43
		May	22	10	6	5	43
		June	7	7	14	15	43
		December	14	13	14	2	43

marginal suitability for rain-fed cultivation of crops. It is interesting to note that at this station no month has been found as unsuitable for crop culture, as far as the average Ima monthly values are concerned.

Stability Analysis

Moisture stability of Kombolcha station is presented in Table 1.

Table 1 revealed that September is the only month found stable in which its Ima values remain constant at one suitability class throughout the study period. Fig 3(i) displayed that the Ima value of September is the highest and constantly belong to a highly suitable range throughout the study period. Four months of the year (July, August, October, and November) are found to be moderately stable. Fig. 3 (g, h, j, and k) indicated that their Ima values cover the highly, moderately and marginally suitable ranges. Table 1 further showed that seven months of the year (January, February, March, April, May, June, and December) are highly fluctuating as they constitute years of unsuitable Ima ranges below 40% (Fig. 3 - a, b, c, d, e, f, and l).

Identification and Delineation of Length of Growing Period

The LGPs of the study area are identified on the basis of the parameters discussed above. The identified growing months of Kombolcha station are further classified in to different suitability classes.

As shown in Table 2, the study area has 180 days of growing period in a year out of

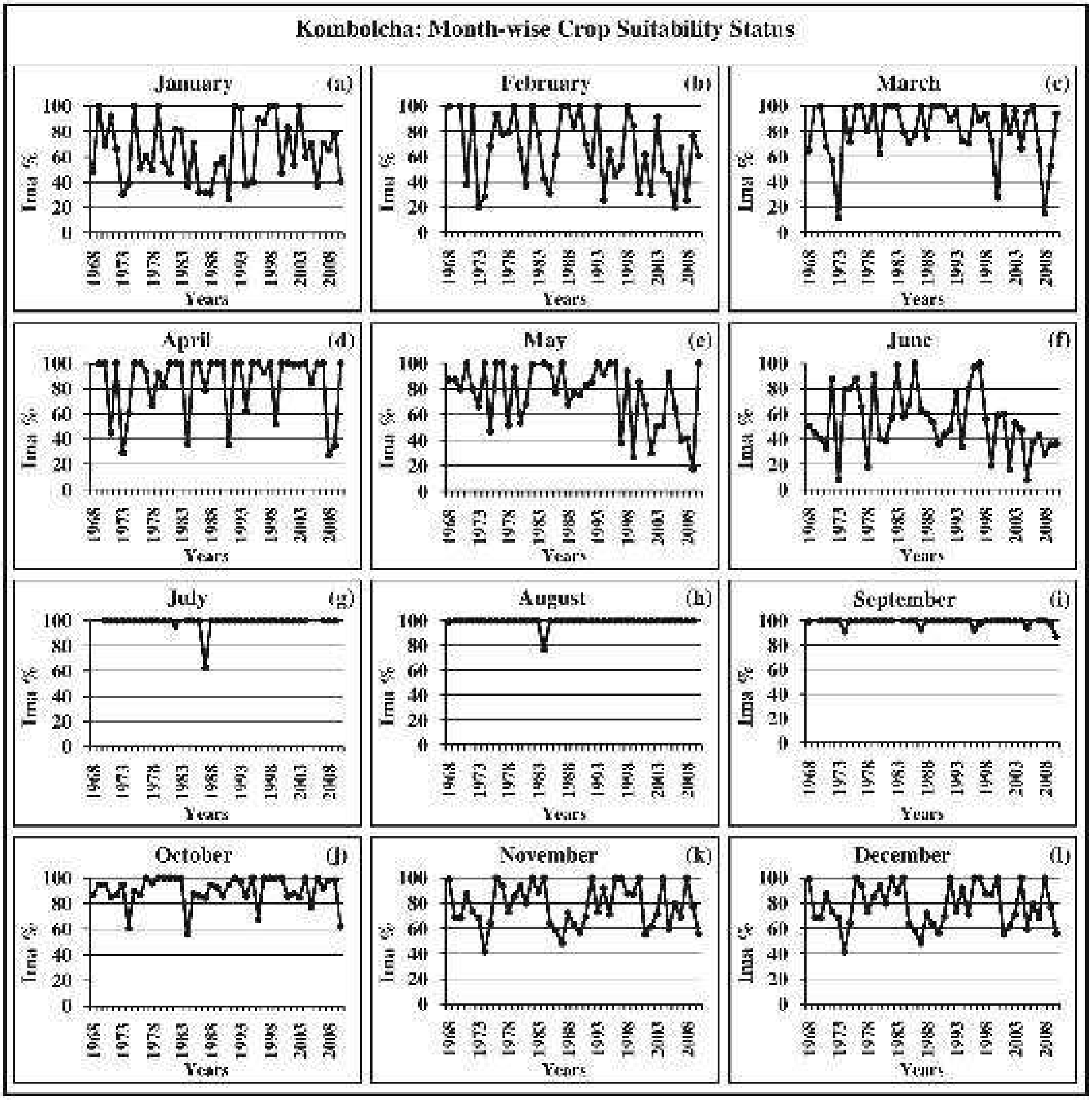
Kombolcha: Month-wise Crop Suitability Status
January (a)
February (b)
March (c)
April (d)
May (e)
June (f)
July (g)
August (h)
September (i)
October (j)
November (k)
December (l)
Ima %
Years
0
20
40
60
80
100
1968
1973
1978
1983
1988
1993
1998
2003
2008

Fig. 3

Table 2
Kombolcha: Showing Growth Period Based on Their Crop Suitability

Crop Suitability Class	Growth Period
Highly Suitable	120 days (July-Oct.)
Moderately Suitable	-
Marginally Suitable	60 days (Nov.-Dec.)
Total LGP	180 days

which 120 days are highly and 60 days are marginally suitable. The 60 days of the marginally suitable months are below the 90 days threshold. But as these two months (November and December) are preceded by a highly suitable month (October), they are considered in this analysis as growing period. This analysis has clearly revealed that January, February, March, April, May, and June are not suitable for crop culture.

The finding of this study showed two situations in the study area, as far as LGP is concerned. Firstly, the average Ima showed a year round growing period for the study area. It showed that AE and PE are almost equal during March, April, and from July to October, while AE became lower than PE with average Ima values of 40% to 100% during months of November to February, May and June. This implies that the station is experiencing adequate moisture conditions in all months to support growth of crops without moisture stress. However, from November to February and during May and June, some water shortage prevailed to meet the demands of the atmosphere as AE became lower than PE. This year round growing period, however, seem unrealistic as the mean values ignore monthly moisture variability, hence less dependable.

Secondly, LGP analysis limited the growing period to 180 days only. This monthly Ima analysis on the other hand pointed out that crops can grow at the station during these 180 days (July – December). This analysis further showed that the first four months (July – October) are highly suitable for different types of crops including wet land crops like rice, while the moisture statuses of the remaining two months (November-December) are progressively declining and are marginally suitable for crops. The lower moisture availability of the last two months could potentially enhance the late sowing of crops, which require low moisture during their maturity. However, to make use of the moisture of the marginally suitable months caution must be made due to the greater probability of drought to occur. To safely utilize the declining moisture of November and December, moisture stability analysis is made. The stability analysis hence revealed that months from July to November are stable and moderately stable in their moisture fluctuation while December is highly fluctuating. December in this study is therefore excluded from the growing season for the greater risk of drought occurrences. It can therefore be concluded from this study that, the study area is having a single growing period of

150 days, since the last month's (December) moisture dependability is not justified by the stability analysis.

Conclusions

The moisture availability assessment of the study area, based on monthly Ima, suggests varying patterns of crop suitability of the area under study. The analysis of the average Index of Moisture Adequacy revealed that all months in the study area are suitable for crop culture as far as their average moisture content is concerned. On the other hand, only six months of the year are justified to be suitable when LGPs are analyzed on monthly basis. The discrepancy is apparent. The analysis in the former is made on average values in which single representative monthly mean values are concerned, while in the case of the latter all monthly occurrences of the study period against the predetermined parameter are analyzed. So, the latter analysis result is preferred to the former since a yearly moisture variability of each month is considered. The result of this analysis showed 180 days of LGP, of which 120 are highly and the remaining 60 days marginally suitable. Soil moisture is progressively declining during the last two months (November and December). Due to the greater reduction and unreliability of moisture in December, the stability analysis excludes December from growing period. So it is inferred from this study that the study area is having a single growing period of 150 days from July to November. Months which are not suitable for crop production, because of the insufficient moisture, are between December and June.

This type of study is beneficial for a proper crop scheduling of a particular area. It is also possible to properly manage the growth of drought resistant crops and produce other crops with supplemental irrigation by identifying water deficit months. Knowledge on the water surplus months are also of immense contribution for rain water harvesting and supplemental irrigation schemes.

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