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A new approach to agroclimatic classification to find out crop potential

R. P. SARKER and B. C. BISWAS*

India Meteorological Department, New Delhi

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सार -- किसी प्रदेश की फसल क्षमता व संभावना का पता लगाने के लिए समुचित जलवायु सम्बंधी प्राचलों का उपयोग करके कृषि-जलवायु वर्गीकरण एक अत्यंत उपयोगी साधन हो सकता हैं। वहां वर्गीकरण की विभिन्न उपागम हो सकते ह और उपागम की उपयुक्तता चरम उद्देश्यों पर निर्भर होती है। इस शोध-पत्र में आर्द्रता उपलब्धता सूचक नामक एक सूचक के आधार पर, जो विभव वाष्पोत्सर्जन और साप्ताहिक सुनिश्चित वर्षा के अनुपात के रूप में परिभाषित किया जाता है; कृषि जलवायु वर्गीकरण के लिए एक सिद्धान्त विकसित किया गया है। इस वर्गीकरण में साप्ताहिक आधार पर आर्द्रता उपलब्धता सूचक विभिन्न ॠतुजैविकी प्रावस्था के लिए उपयुक्त आर्द्रता उपलब्धता सूचकों के विभिन्न मानों का ध्यान रखा गया है। वर्गीकरण 50% स्तर पर आर्द्रता उपलब्धता सूचक के आधार पर किया गया है। तथापि फसल वृद्धि की समयावधि का भी अन्य स्तरों पर विश्लेषण किया गया है।

इस वर्गीकरण का अनुसरण करते हुए भारत के उस भाग को जहां वार्षिक वर्षा 400 मि. मी. से अधिक होती है 7 विस्तृत कृषि जलवायु-अंचलों में विभाजित किया गया है। शुष्क प्रदेश को 30% स्तर पर आर्द्रता उपलब्धता सूचक के आधार पर 3 अंचलों में विभाजित किया गया है। सूक्ष्मस्तर आंकड़ों को लेकर इस सिद्धान्त को महाराष्ट्र के सूखे कृषि भू-भाग पर लागू किया गया है। इससे इस बात का संकेत मिलता है कि जब दीर्घस्तर अध्ययन से फसल की क्षमता व संभावना के विस्तृत पहलुओं का पता चल सकता है तो सूक्ष्म विश्लेषण करना आवश्यक है ताकि फसल की घटती-बढ़ती क्षमता व संभावना के विशिष्ट क्षेत्रों का ठीक-ठीक पता लगाया जा सके और उनके लिए समुचित सिफारिश की जा सके।

ABSTRACT. Agroclimatic classification using appropriate climatic parameters can be a very useful tool to identify crop potential of a region. There may be different approaches of classification and the adequacy of an approach depends on ultimate objectives. In this paper, a theory has been developed for agroclimatic classification on the basis of an index called Moisture Availability Index (MAI) which is defined as the ratio of weekly assured rainfall and potential evapotranspiration. In this classification, MAI on weekly basis and different values of MAI appropriate to various pheno-phases have been taken into account. The classification has been made on the basis of moisture availability index at 50% level. However, duration of the crop growing period has also been discussed at other levels.

Following this methodology, the part of the India, where annual rainfall is more than 400 mm, has been divided into 7 broad agroclimatic zones. The arid region has been divided into three zones on the basis of moisture availability index at 30% level. The theory has been applied to the dry farming tract of Maharashtra taking micro-level data. This indicates that while a macro-scale study can give some broad aspects of crop potential, it is necessary to do micro-level analysis so that specific areas of varying crop potential can be pin-pointed and appropriate recommendation can be drawn up.

1. Introduction

Agroclimatic classification is the delineation of an area into different zones in order to enable the best use to be made of climatic information for increasing agricultural production or to define climatic types in terms of basic climatic parameters so that it may evolve homogeneous and rational climatic regions. The approach of classification may be either thermal or moisture or a combined one. The choice of approach depends on ultimate objectives. In this paper, the objective of concern is provision of required information to enable the best use to be made of climatic resources and soil information for planning and management of agriculture.

The classifications that are developed primarily for world overview cover wide range of climates and provide hardly any mechanism for refined sub-divisions that are necessary for agricultural purposes. Such a system may be useful to understand the general climate of the world, but not for planning and management of agriculture. For this, a classification that takes into account agroclimatic resources including local peculiarities is a suitable one.

Water is the limiting factor of agricultural production, especially in the low rainfall areas of the tropics and temperature in the sub-tropics. Usually, month is taken as unit of time of climatic data analysis. As crop growing period has been reduced to about 100

*Agricultural Meteorology Division, Meteorological Office, Pune-411005.

days, time unit needs to be shortened to get the effect of distribution within a month. Most of the studies utilize average rainfall. The average rainfall occurs only in a few years. It does not give any idea of its distribution in time. Hence, use of probabilistic rainfall is essential to bring out crop potential. In the semi-arid tropics, moisture is not adequate for agricultural production every year. Risk involved in agriculture needs to be brought out to know the chances of success and failure of crop at a place under prevailing climatic condition.

In this paper, an attempt has been made to delineate India into different agroclimatic zones in order to find out level of crop success and duration of crop growing period at each zone using weekly probabilistic rainfall, potential evapotranspiration and soil information.

2. Review of literature

The earlier attempts to classify climate mainly centred round the identification of average annual—seasonal or monthly and/or temperature regimes that naturally produce some typical types of vegetation or crops in abundance (Koppen 1936; Prescott 1938; Trewartha 1954; Burgos 1958 etc). Thornthwaite (1948) used the concept of water balance with the help of average monthly potential evapotranspiration as developed by him, along with the corresponding rainfall to classify climate. He and Mather (1955) improved upon this classification by introducing the various degrees of water deficit and water surplus and called it "Rational Classification". Subrahmanyam (1956) made a "Rational Classification" of India's climate following this method. For assessing agricultural potential of various countries, Papadakis (1966, 1975) used a very simple water balance technique along with average maximum and minimum temperatures. Although Thornthwaite and Mather, and Papadakis used some kind of comparison between the moisture required by plants and that available from precipitation, the results obtained by them are not quite satisfactory as the respective empirical formulae, used by them to compute evapotranspiration are not found suitable for universal application. Moreover, the period used by them is too long in comparison with the entire life cycle of an agricultural crop. Also their methods do not help the users to assess the element of risk involved, if agriculture of a country is planned using their classifications.

Troll (1965) proposed a classification called the seasonal climate of the earth using monthly rainfall and potential evapotranspiration calculated by Penman's method. His classification was based on the duration of arid and humid months. The month having mean rainfall more than mean potential evapotranspiration is defined as a humid month, otherwise it is an arid month. He divided the climate of the world into six groups and each was associated with some type of vegetation. For example, the semi-arid area is defined as one where the humid months are from 2 to 7. It appears that the method is quite satisfactory in delineating areas in very broad terms, but cannot provide the kind of detailed and small scale information needed for agriculture.

Troll's classification done for India is found to suffer from a number of defects. For example, the Kutch area and part of west Rajasthan have been brought under semi-arid which is actually arid. A number of stations, like Jodhpur, Hyderabad and Jalgaon have been brought under the same group which is difficult to accept from the point of vegetation. The same method has been applied by ICRISAT (1978) by utilising data for about 300 locations. The map produced by ICRISAT does not also appear to be satisfactory. In this map, areas around Saurashtra and central parts of east Rajasthan have been brought under arid zone. But it is well known that groundnut and other oilseeds sorghum and pearlmillet are grown in these areas. Similarly, areas in part of Karnataka and Rayalaseema and parts of Madhya Maharashtra have been brought under arid zone, where seasonal crops are produced in these areas in most of the years. Another large area in Orissa, West Bengal, Bihar and Andhra Pradesh has been categorised as semi-arid where the rainfall is more than 150 cm and rice is grown in plenty. Some of these points have been mentioned in Agroclimatology Progress Report-2 of ICRISAT (1978).

Cocheme' and Franquin (1967) computed water balance following the simple book-keeping procedure of Thornthwaite and Mather (1955) and tried a classification based on different degrees of monthly ratio of P'/PE, where P' is the sum of rainfall and ground storage (available water in the root zone) and PE is the potential evapotranspiration. The ratios of P'/PE equal to 1/8, 1/4, 1/2 and 1 were successively computed and the intervals between the successive limits were defined as Dry (D), Moderately Dry (MD) and Moist (M) respectively. The condition $P'/PE \geqslant 1$ was called Humid (H). This approach has some definite merits in which the length of the growing season could be determined for crop planning at a particular location. They used this method in interpreting the semi-arid areas in south of Sahara and in West Africa. However, the method appears rather difficult for global classification of climates. They also suggested to include risk factor from probability of rainfall determined by semi-logarithmic distribution.

Another important classification is due to Hargreaves (1974). He gave a classification based on monthly moisture availability index (MAI) which he defined as the ratio of monthly precipitation at 75% probability level to monthly potential evapotranspiration. He introduced the risk factor by taking probabilistic rainfall value instead of the monthly average. He also assumed that rainfall at the 75% probability of occurrence is very much deficit if it does not meet more than a third of potential evapotranspiration requirements. He emphasized the importance of continuity of the period when MAI $\geqslant 0.34$. Although Hargreaves has taken account of risk factor which is very necessary for crop planning still according to us, his classification has three shortcomings, *i.e.*,

(*i*) Only one risk factor has been taken into account,

(ii) Month is too long a period for modern cereal crops, and

(*iii*) MAI value $\geqslant 0.34$ has been considered adequate for all the growth stages of the crops.

3. Present study

In this paper, we wish to develop the methodology for agroclimatic classification using moisture availability index (MAI). We, however, introduce the following three modifications in the methodology developed by Hargreaves (1974) :

(*i*) Weekly MAI rather than monthly,

(*ii*) Different risk factors, instead of one, so that the planner could choose his own risk level, and

(*iii*) MAI $\geqslant 0.3$ and $\geqslant 0.7$ depending upon crop growth phase.

On the basis of the MAI, we made broad classification which we further sub-divided depending upon the length of the water stress period. On this we superimposed soil types to get real agroclimatic classification.

3.1. *Moisture Availability Index (MAI)*

For our specific classification, we first obtained the moisture availability index (MAI) which is defined as follows :

$$\text{MAI} = \frac{\text{Assured rainfall}}{\text{Potential evapotranspiration}}$$

3.2. *Assured rainfall at different probability levels*

It goes without saying that the planner, be he a farmer or a hydrologist, must know the risk he is going to take in his endeavour. The study by using average or normal rainfall cannot include this risk factor. In the dry farming tract or low rainfall areas, there is considerable year to year deviation from the normal. In such low rainfall areas, the normal rainfall (monthly, seasonal or annual) quite often is too short of the water requirements of the crops. But experience shows that on a number of occasions crops are successfully raised. Apparently, in such years the rainfall is more than the normal values and meets the water demand of the crops. So, for any crop planning purpose, one should know from long records what is the chance of meeting the water requirement of the crops. Accordingly, the planning has to be done on a probabilistic basis, which eventually takes into account the chance of success or failure. The minimum assured rainfall (AR) at different probability levels has been computed by Sarker *et al.* (1982) by fitting incomplete Gamma distribution for the dry farming tract of India which forms the basis of our study.

The equations used for computation of minimum assured rainfall (Sarker *et al.* 1982) are the mixed Gamma distribution :

$$G(X) = q + p\,F(X) \qquad (1)$$

where $F(X)$ is the Gamma distribution and q is the probability of zero precipitation and $p = 1-q$. $F(X)$ is given by :

$$F(X) = \int_0^x \frac{x^{\gamma-1}\, e^{-x/\beta}}{\beta^{\gamma}\,\Gamma(\gamma)}\,dx \qquad (2)$$

where, $F(X) = 0$ when $x \leqslant 0$.

In the above γ and β are shape and scale parameters respectively of the distribution and $\Gamma(\gamma)$ is the Gamma function of γ. The distribution is bounded at the left side by zero. $G(X)$ is the probability of rain $< X$.

The parameters γ and β have been estimated from observed data by maximum likelihood method.

$P(X)$, the probability of rain $\geqslant X$ is given by :

$$P(X) = 1 - G(X) = 1 - q - (1-q)\,F(X)$$

$$= (1-q)\left[1 - \int_0^x \frac{x^{\gamma-1}\, e^{-x/\beta}}{\beta^{\gamma}\,\Gamma(\gamma)}\,dx\right] \qquad (3)$$

The above equation was solved on electronic computer for probabilities of rainfall exceeding specified amounts X_1, X_2, etc. Alternatively the minimum assured rainfall (AR) was obtained by solving the above equation by iteration process for X and for $P(X) = 0.10, 0.20, 0.30, \ldots, 0.90$ respectively.

3.3. *Range of MAI used*

Water required by a plant growing under natural conditions mainly consists of three parts, namely (*i*) transpiration for maintenance of its life process, (*ii*) evaporation from soil and (*iii*) the part that enters into its body building. The first two together is known as evapotranspiration. The last one is so small compared to the sum of the first two that it is neglected in agrometeorological studies and actual evapotranspiration is taken as a good measure of the water requirement of crop plants.

It is very difficult to have data on actual evapotranspiration which varies with the growth of plant and also perhaps, to some extent, from crop to crop. However, it is assumed in all the agrometeorological studies that potential evapotranspiration covers the maximum requirement of fully growth crop plants (the peak period of their moisture demand) covering the soil surface completely. It has been found that during its early stage of growth (first 3 to 4 weeks) actual evapotranspiration is about one-quarter of the potential rate due to small and sparse foliage and that the maximum demand may even slightly exceed the potential rate if the size of the field is not too large and there is considerable advection of sensible heat into the crop field (Replay 1966). But experiments have shown that due to its built-in natural protective capacity, a plant can narrow down its stomatal openings to restrict transpiration when there is moisture stress and grow almost normally as long as the moisture supply does not fall below about three-quarter of the potential rate (Arnon 1972). After completion of grain formation, the water demand falls off rapidly becoming small at the ripening stage (Holmes and Robertson 1963).

In view of the above, the classification in the present study has been made on the basis that a crop will be nearly normal if it gets moisture varying from 0.3 to 0.7 of potential evapotranspiration commencing from germination to completion of grain formation stage.

3.4. *Choice of interval*

As mentioned earlier, a month is too long a period compared to the entire crop life. This is particularly so as the plant breeders are constantly evolving short duration varieties with a view to producing more number of crops per year. Use of monthly rainfall suffers from another defect also. There are areas where even during

TABLE 1

Moisture Availability Index (MAI) and accumulated assured rainfall in weekly and bi-weekly period

Probability level	Weekly: No. of weeks at MAI ⩾.3	⩾.5	⩾.7	⩾.9	Accumulated assured rainfall (mm) for the period when MAI ⩾0.3	Bi-weekly: No. of weeks at MAI ⩾.3	⩾.5	⩾.7	⩾.9	Accumulated assured rainfall (mm) for the period when MAI ⩾0.3
New Delhi										
40	12	11	9	7	396	18	12	12	8	503
50	11	8	7	3	255	12	10	8	4	338
60	8	5	3	0	141	10	8	4	2	226
70	5	0	0	0	61	8	4	2	0	142
Rajkot										
40	15	9	5	5	380	16	14	10	6	489
50	10	5	3	1	203	14	10	6	4	322
60	5	1	0	0	82	10	4	2	0	182
70	1	0	0	0	12	6	0	0	0	86
Rahuri										
40	16	10	5	2	293	20	14	6	4	392
50	9	4	2	0	134	16	6	4	0	256
60	3	1	0	0	38	12	4	0	0	153
70	0	0	0	0	0	4	0	0	0	43
Nandurbar										
40	16	14	12	9	497	18	16	14	10	568
50	14	12	6	5	338	16	14	12	6	422
60	12	6	4	0	225	14	12	6	4	311
70	9	5	0	0	126	14	6	4	0	233

the height of the wet season, the daily rainfall varies immensely in amount, so much so that a month's average rainfall may be realised only in a few days (say a week or even less), while the rest of the month may go dry. If this happens during the early part of the life of a crop, it may cause irreparable damage to it. In the tropics where the rainfall is showery and highly variable in intensity, amount and distribution (both in time and space), it is necessary to use the week as the unit of time, at least for the early part of the crop life, and not more than two weeks at a later stage.

3.5. *Moisture Availability Index (MAI)*

An index called the Moisture Availability Index (MAI) has been calculated and it is defined as the ratio of assured rainfall (weekly, bi-weekly or monthly) to potential evapotranspiration of the corresponding period. The MAI has, however, been calculated for 30, 40, 50, 60, 70 and 80 per cent probability levels, although the climatic classification has been done on the basis of the index at 50% level. Crop potentials at other levels such as 30, 40, 60, 70 have also been discussed.

Table 1 gives the MAI of weekly and bi-weekly assured rainfall at different probability levels for a few selected stations. It is seen that classification based on weekly MAI at 50% probability level remains practically same as that of bi-weekly at 60% level. In other words, for the purpose of classification, use of weekly MAI at 50% probability is equivalent to using bi-weekly MAI at 60% probability, both in duration and accumulated rainfall during the period when MAI is more than 0.3. An examination of MAI and Assured Accumulated Rainfall (AAR) at various levels leads to the conclusion that, in general, dependability increases by 10% if one switches over from weekly to bi-weekly analysis. But as mentioned earlier, it should be kept in mind that though the minimum water requirement for the crop in its early stage is low, it is very susceptible to moderately prolonged moisture deficiency. Hence, choice of a bi-weekly assured rainfall is not desirable for the early growth stage, particularly in areas where time variability of rainfall is high. Therefore, choice of weekly assured rainfall at 50% probability level seems to be the reasonable criterion for classification of areas on the basis of moisture availability index, as it also covers 60% probability with bi-weekly rainfall for that growth stage when the crop has already developed the capacity to stand moisture stress for a week or so. The MAI obtained by using assured weekly rainfall at 50% has, therefore, been used in the method applied here.

Using the MAI mentioned above, the area has been classified into following broad agroclimatic zones. Increasing MAI both in duration and magnitude has been denoted in alphabetical order of the English capital letters starting from 'D' :

Classification	No. of weeks when MAI at 50% level at least	
	⩾0.3	⩾0.7
D	< 10	<1
E	⩾ 10	⩾1
F	⩾ 11	⩾4
G	⩾ 14	⩾7
H	⩾ 18	⩾9
I	⩾ 20	⩾10
J	⩾ 24	⩾12

Letters A to C at the beginning have been used for classification for the zone where annual rainfall is less than 40 cm.

3.5.1. *Sub-divisions due to water stress period*

The mid-monsoon season water stress, *i.e.*, when MAI is less than 0.3 which is called water stress period has been designated by the use of numerical suffixes in the ascending order of duration to the above broad classification. Suffix 1 indicates that there is hardly one week's water stress period, while suffixes 2, 3 and 4 indicate 2-3 weeks; 4-5 weeks and more than 5 weeks water stress respectively.

4. End of the growing season

On the basis of computation of MAI discussed above, one will be tempted to think that the growing season is over when MAI comes below 0.3. But cessation of rainy reason does not mean the end of crop season. Crops can thrive on stored moisture. It is, therefore, necessary to examine and find out the amount of moisture stored in the soil at the end of the season when MAI is just 0.3. This could be done by water balance technique which is not within the scope of present study. However, the cumulative seasonal evapotranspiration for dry land crops like sorghum, etc even under relatively favourable moisture conditions may be only 65% of potential evapotranspiration (Jenson 1968). Replay (1966) observed that in many farm crops, seasonal water use may range from 55 to 75% of potential evapotranspiration (PET).

India Meteorological Department installed about 35 lysimeters in various soil and climatic zones of the country to find out water requirement of different crops. Venkataraman *et al.* (1976) found that cumulative seasonal evapotranspiration is about 70% of PET. Biswas and Khambete (1988) concluded from the analysis of lysimeter data for sorghum and millet that these crops used 61 and 66% of pan evaporation during their life span. It has, therefore, been taken for this study that difference between seasonal total assured rainfall and two-third of PET of corresponding period will go into stored soil moisture and plant can use it even after the end of the rainy season.

5. Classification for low rainfall areas

The above mentioned classification can be used only at a place where crop can be raised at 50% or more years. Farmers of Afro-Asian countries go for cultivation in the marginal land where crop can be raised only 30–40% of years. Criteria have been also evolved in assessing crop potential, especially of low rainfall areas where annual rainfall is less than 400 mm. Moisture Availability Index (MAI) computed at 30% level has been used for classifying the area into broad agroclimatic zones.

Classification	No. of weeks when MAI at 30% level at least	
	0.3	0.7
A	<9	<3
B	⩾9	⩾3
C	⩾12	⩾7

6. Data used

We have used rainfall data of 350 stations for agroclimatic classification of India. For all these stations assured weekly rainfall at different probability levels have been computed by incomplete Gamma distribution model described earlier. For Maharashtra assured weekly rainfall for 84 stations computed by Biswas and Khambete (1979) has been used so that each district has been represented by a few stations. Further sub-classification of Maharashtra has been made by superimposing the types of soils. Classification of arid zone has been made by using rainfall data of 26 stations and computing assured weekly rainfall at different probability levels.

7. Application of the methodology to India

The methodology of agroclimatic classification developed has been first applied to areas where annual rainfall is more than 400 mm. This has divided the area into seven agroclimatic zones of varying crop potential. As was mentioned earlier that area where annual rainfall is less than 400 mm cannot be classified with the help of MAI at 50% level. MAI at 30% level has been used for this purpose and the area has been delineated into three zones, *viz.*, A, B and C. Further, micro-level analysis has been carried out for dry farming tracts of Maharashtra which was divided into four zones. This classification has been superimposed on the soil map which has further sub-divided each zone. This sub-zone gives the crop potential in terms of duration of MAI.

Figs. 1-3 give the duration in weeks of MAI ⩾.3 and ⩾ 0.7 at 30, 50 and 70% probability levels respectively. The values of MAI have been computed for the different decile levels (10 to 90%), but all could not be included here for the sake of brevity. Accumulated Assured Rainfall (AAR) and PET for different probability levels are given in Tables 2 and 3. They indicate the duration for which crop can thrive on stored moisture at the end of rainy season. The classification of India is shown in Fig. 4.

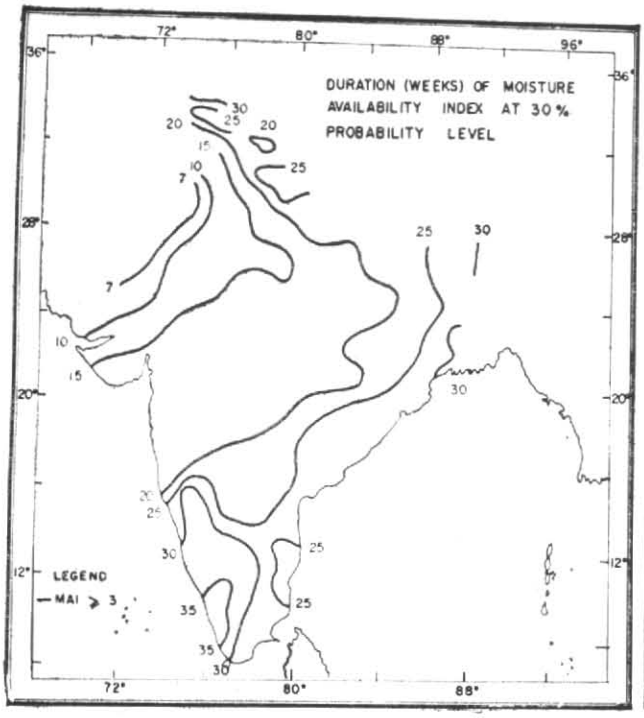


Fig. 1(a). Duration of moisture availability index at 30 per cent probability level (MAI ≥.3)

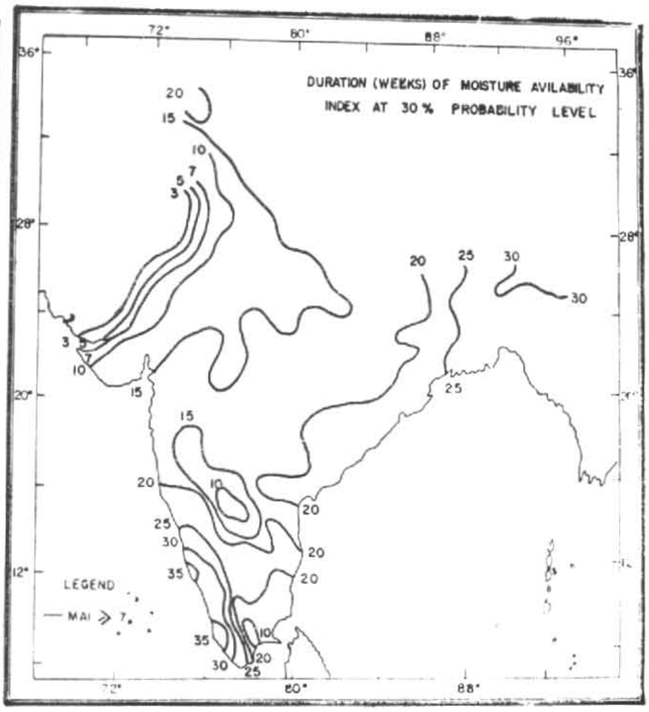


Fig. 1(b). Duration of moisture availability index at 30 per cent probability level (MAI ≥.7)

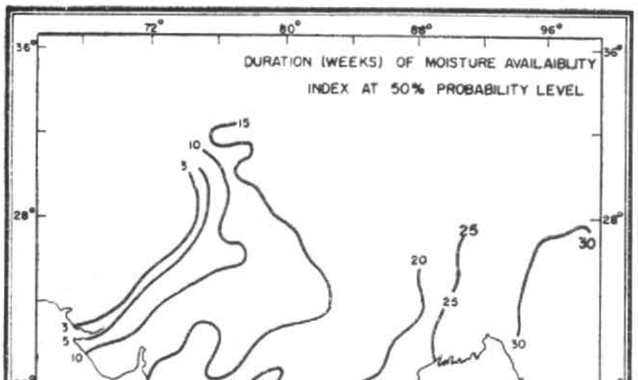


Fig. 2 (a). Duration of moisture availability index at 50 per cent probability level (MAI ≥0.3)

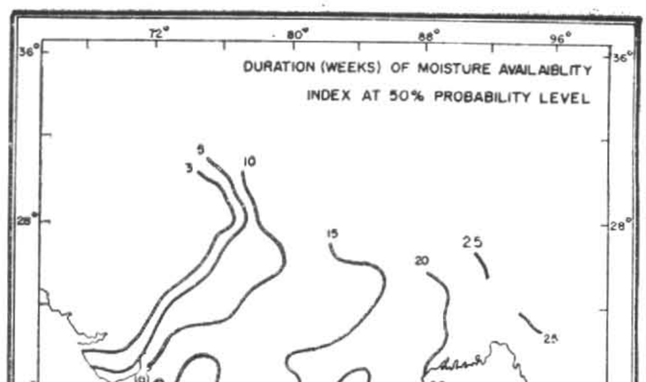


Fig. 2 (b). Duration of moisture availability index at 50 per cent probability level (MAI ≥0.7)

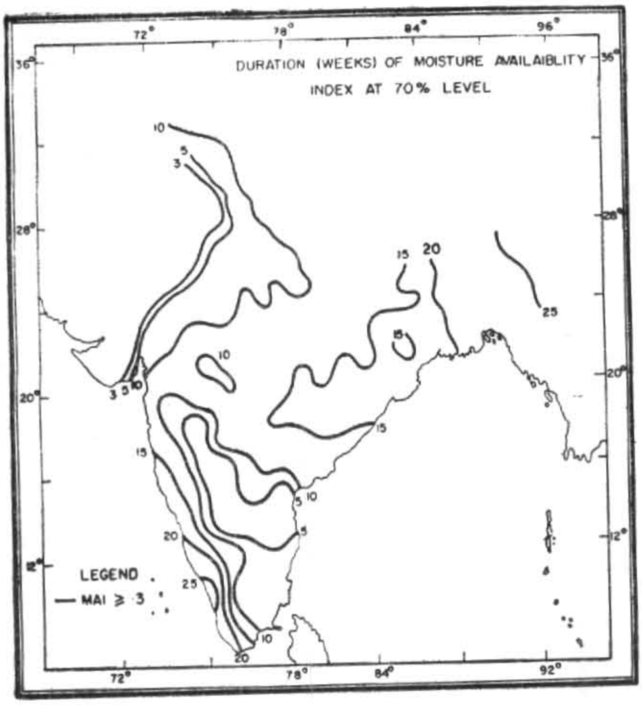


Fig. 3 (a). Duration of moisture availabilty index at 70 per cent probability level (MAI ≥ 0.3)

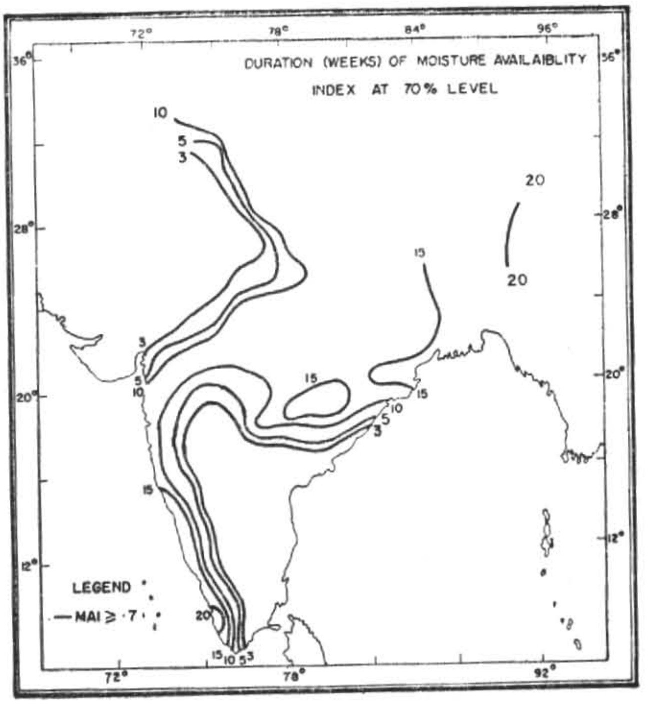


Fig. 3 (b). Duration of moisture availability index at 70 per cent probability level (MAI ≥ 0.7)

TABLE 2

Moisture Availability Index (MAI), Potential Evapotranspiration (PET) and Accumulated Assured Rainfall (AAR)

Station	ABR	No. of weeks with MAI at 40% probability level						No. of weeks with MAI at 50% probability level						Classification
		$\geq$.3	$\geq$.5	$\geq$.7	$\geq$.9	AAR (mm)	PET (mm)	$\geq$.3	$\geq$.5	$\geq$.7	$\geq$.9	AAR (mm)	PET (mm)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Uttar Pradesh														
Dehradun	DDN	18	18	16	15	1929	480	16	15	15	15	1484	410	G_1
Hamirpur	HAM	15	13	13	11	674	447	13	12	11	10	498	375	F_1
Banaras	BNS	17	15	15	13	813	504	16	14	13	12	616	461	G_1
Agra	AGR	13	12	11	9	496	422	11	10	8	7	344	353	G_1
Nainital	NTL	21	19	18	17	2219	710	18	17	16	16	1715	599	H_1
Madhya Pradesh														
Raipur	RPR	17	17	16	15	1067	472	17	16	15	14	832	472	G_1
Jagdalpur	JGD	24	21	19	18	1364	652	21	18	18	18	1087	534	I_1
Nimar (Khargaon)	NMR	16	15	13	11	435	464	15	12	10	3	333	456	E_1
Shivpuri	SVP	14	13	12	11	685	450	18	11	10	9	495	403	F_1
Orissa														
Cuttack	CTK	25	22	20	20	1252	698	22	20	19	18	932	598	I_1
Sambalpur	SBP	19	17	17	16	1402	489	17	16	15	15	1102	428	G_1
Punjab & Haryana														
Hissar	HSR	10	8	3	1	241	403	3	3	0	0	132	320	D_1
Jind	JND	11	9	7	1	303	412	8	7	0	0	167	288	E_1
Hoshiarpur	HSP	12	12	11	10	553	404	12	10	9	7	406	404	F_1
Kerala														
Arukutty	AKT	35	35	34	30	2936	1161	35	32	30	27	2327	1101	J_1
Kozhikode	KZK	34	31	28	28	2969	980	30	29	27	26	2337	863	J_1

TABLE 2 (*contd*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Rajasthan														
Jalore	JLR	9	4	3	0	167	299	3	2	0	0	43	93	D_1
Sawai Madhopur	SMP	12	11	11	11	672	375	11	11	9	9	458	332	F_1
Bhilwara	BWR	12	10	10	9	452	388	10	9	8	7	289	296	E_2
Ajmer	AJM	12	9	9	6	328	403	9	8	3	0	188	293	D_1
West Bengal														
Alipore	ALP	27	25	23	21	1383	723	23	23	19	19	1027	588	I_1
Krishnanagar	KRG	26	25	23	21	1190	711	26	22	19	18	924	711	J_1
Midnapur	MDP	25	22	19	19	1264	753	22	20	18	18	945	636	I_1
Bihar														
Purnea	PRN	25	21	19	19	1242	684	21	19	19	17	980	562	I_1
Patna	PTN	18	17	17	16	852	460	17	17	14	14	627	427	G_1
Muzaffarpur	MFP	19	19	17	16	970	487	19	18	15	15	720	487	H_1
Karnataka														
Bangalore	BNG	30	23	20	10	707	807	24	20	10	6	470	845	I_1
Bidar	BDR	19	17	15	14	680	560	18	15	14	11	501	580	H_1
Bijapur	BJP	20	9	5	2	365	631	8	3	2	2	149	241	D_3
Coorg (Marcara)	MRC	33	31	27	24	3073	883	31	26	23	22	2506	827	I_1
Andhra Pradesh														
Anantapur	ANT	18	6	5	4	329	617	5	4	2	1	99	156	D_2
Hyderabad	HYD	19	15	14	4	538	603	15	14	9	5	371	474	G_1
Visakhapatnam	VSK	23	22	19	12	647	607	22	18	12	8	450	583	I_1
Maharashtra														
Chandrapur	CHN	16	16	15	15	968	418	16	15	15	14	748	418	G_1
Solapur	SLP	20	17	12	5	518	666	18	9	3	2	339	604	E_3
Tasgaon	TGN	21	13	8	4	404	629	15	8	2	0	234	434	E_3
Malsiras	MLS	12	6	3	2	249	397	7	2	2	2	129	232	D_4
Barsi	BRS	19	16	10	5	468	652	15	8	4	1	288	515	F_2
Gujarat														
Deesa	DSA	12	10	9	8	399	383	10	9	3	2	217	307	E_1
Mehsana	MSN	9	9	7	3	262	270	8	4	2	2	143	245	D_1
Godhra	GDH	1	0	0	0	9	28	0	0	0	0	0	0	D_1
Amreli	AMR	6	5	4	3	149	196	4	3	0	0	64	128	D_1
Tamil Nadu														
Coimbatore	CMB	16	8	7	5	341	469	9	6	5	3	180	244	D_5
Madras	MDS	24	21	17	12	905	704	23	18	9	7	590	670	I_1
Ootacamund	OTC	34	32	29	19	1014	1051	33	30	18	9	760	1015	I_1
Tiruchirapalli	TRP	18	13	11	6	494	686	13	9	6	3	291	448	F_2
Assam														
Nowgong	NWG	30	29	28	25	1889	716	29	28	24	24	1485	697	J_1
Agartala	AGT	30	29	28	27	1764	800	28	28	26	26	1347	746	J_1
Jammu & Kashmir														
Anantnag S.	ATG	13	9	5	2	191	312	10	4	3	2	104	198	E_1
Jammu	JMU	14	13	11	11	695	378	13	11	10	10	539	348	F_1
Muzzafarabad	MFB	25	22	19	15	798	514	22	18	15	12	578	459	I_1
Himachal Pradesh														
Kotkhai	KTH	24	19	13	11	637	621	19	14	11	8	451	500	H_1
Kilba	KLB	20	12	2	2	280	458	15	5	1	0	156	344	E_1
Keylong	KLG	13	7	4	2	179	299	7	4	2	1	85	158	D_1
Shimla	SML	24	20	16	14	1201	614	20	15	14	14	938	524	I_1

TABLE 3

Moisture Availability Index (MAI), Potential Evapotranspiration (PET) and Accumulated Assured Rainfall (AAR)

Station	ABR	No. of weeks with MAI at 60% probability level						No. of weeks with MAI at 70% probability level					
		⩾.3	⩾.5	⩾.7	⩾.9	AAR (mm)	PET (mm)	⩾.3	⩾.5	⩾.7	⩾.9	AAR (mm)	PET (mm)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Uttar Pradesh													
Dehradun	DDN	15	14	13	12	1132	377	13	12	12	11	860	331
Hamirpur	HAM	11	11	9	8	356	307	11	8	6	6	254	307
Banaras	BNS	14	14	11	11	446	394	13	11	9	7	311	366
Agra	AGR	11	8	7	4	242	321	8	5	2	0	139	248
Nainital	NTL	17	15	14	13	1288	555	15	13	13	13	973	481
Madhya Pradesh													
Raipur	RPR	16	14	13	12	634	445	14	13	13	11	480	378
Jagdalpur	JGD	19	18	17	16	835	471	17	16	15	14	624	409
Nimar (Khargaon)	NMR	12	10	3	0	209	338	9	4	0	0	119	255
Shivpuri	SVP	11	10	9	8	357	329	10	8	6	5	238	299
Orissa													
Cuttack	CTK	19	18	17	15	705	500	17	16	15	14	533	449
Sambalpur	SBP	16	15	15	14	846	493	15	15	13	12	641	378
Punjab & Haryana													
Hissar	HSR	3	0	0	0	44	118	0	0	0	0	0	0
Jind	JND	5	0	0	0	70	186	0	0	0	0	0	0
Hoshiarpur	HSP	10	8	6	5	271	330	8	5	4	1	176	269
Kerala													
Arukutty	AKT	32	29	26	23	1809	1050	27	25	21	19	1315	801
Kozhikode	KZK	29	26	23	20	1804	832	25	21	16	13	1303	712
Rajasthan													
Jalore	JLR	0	0	0	0	0	0	0	0	0	0	0	0
Sawai Madhopur	SMP	10	9	8	6	291	302	8	6	2	0	150	245
Bhilwara	BWR	9	7	3	1	175	268	4	2	0	0	56	121
Ajmer	AJM	6	2	0	0	106	262	1	0	0	0	12	33
West Bengal													
Alipore	ALP	23	19	18	16	798	588	19	16	16	15	579	466
Krishnanagar	KRG	23	20	18	17	679	611	20	18	16	14	502	509
Midnapur	MDP	20	18	18	16	732	547	19	17	14	14	557	522
Bihar													
Purnea	PRN	19	18	16	13	670	482	17	15	14	11	473	430
Patna	PTN	16	14	13	11	485	406	13	11	11	10	322	328
Muzaffarpur	MZF	16	15	14	13	508	397	14	13	12	9	330	341
Karnataka													
Bangalore	BNG	21	9	5	2	309	559	12	5	0	0	146	332
Bidar	BDR	15	14	8	2	339	450	15	4	0	0	216	450
Bijapur	BJP	3	2	2	0	56	84	2	1	0	0	32	56
Coorg (Marcara)	MRC	26	23	21	20	1915	680	22	20	20	19	1454	557
Andhra Pradesh													
Anantapur	ANT	3	2	0	0	44	92	0	0	0	0	0	0
Hyderabad	HYD	15	12	3	0	270	474	11	4	0	0	149	342
Khammam	KMM	17	15	13	10	493	519	14	14	10	5	351	423
Visakhapatnam	VSK	18	13	5	2	291	471	12	5	0	0	138	310

TABLE 3 (*contd*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Maharashtra													
Chandrapur	CHN	15	14	13	12	573	395	14	13	11	10	428	370
Solapur	SLP	11	2	2	0	161	355	2	0	0	0	27	59
Tasgaon	TGN	9	3	0	0	130	257	2	0	0	0	63	56
Malsiras	MLS	2	2	1	0	29	60	2	0	0	0	24	60
Barsi	BRS	10	2	1	0	142	335	3	0	0	0	34	94
Gujarat													
Deesa	DSA	8	3	0	0	108	249	1	0	0	0	11	28
Mehsana	MSN	4	2	0	0	53	121	0	0	0	0	0	0
Godhra	GDH	0	0	0	0	0	0	0	0	0	0	0	0
Amreli	AMR	0	0	0	0	0	0	0	0	0	0	0	0
Tamil Nadu													
Coimbatore	CMB	7	4	2	0	103	184	3	1	0	0	40	78
Madras	MDS	21	9	6	3	385	605	10	3	3	1	159	271
Ootacamund	OTC	31	21	9	1	566	954	27	10	1	1	693	848
Tiruchirapalli	TRP	9	5	1	0	153	387	5	1	0	0	66	159
Assam													
Nowgong	NWG	28	26	24	23	1168	677	27	23	21	18	901	657
Agartala	AGT	27	26	23	22	1021	725	26	22	21	19	773	689
Jammu & Kashmir													
Anantnag S.	ATG	5	3	2	0	44	85	3	1	0	0	20	45
Jammu	JMU	10	9	8	7	380	289	9	8	7	6	278	237
Muzzafarabad	MFB	19	14	11	10	431	402	13	11	8	7	286	277
Himachal Pradesh													
Kotkhai	KTH	15	13	9	6	323	389	11	9	6	4	216	293
Kilba	KLB	1	0	0	0	59	158	0	0	0	0	0	0
Keylong	KLG	4	2	0	0	41	84	3	0	0	0	18	58
Shimla	SML	16	14	13	12	704	423	13	13	11	10	578	341

7.1. *Different crop potential zones*

Area D — This is the low crop potential area. Fig. 4 shows that there are two parts of area D in the tract. The first part comprises western part of the dry farming tract extending from Jamnagar district of Gujarat to Ferozepur in Punjab. The second area includes the parts of Ahmednagar, Pune, Satara, Solapur and Sangli districts of Maharashtra and having the portions of the districts of Bijapur, Raichur, Bellary in Karnataka and Kurnool and Anantapur in Andhra Pradesh.

In the area D, there may be a break of MAI of one week duration and in many cases it may be of 4–5 weeks. Assured rainfall is of the order of 80–100 mm in the western part of the tract in Gujarat and 200–225 mm in Punjab at 50% probability levels. Crop production without irrigation is almost a speculation. However, in some stations where AAR is of the order of 200–250 mm and there is hardly any break in MAI, a short duration crop may be raised.

At 40% probability level accumulated rainfall is low and it is of the order of 220–250 mm over Pali area of Rajasthan, Dhond in Pune district of Maharashtra and Bellary district of Karnataka. A short duration crop may be raised from most parts of the area D.

Crop prospect is high at 30% probability level as MAI $\geqslant 0.3$ and $\geqslant 0.7$ are of the order of 12–18 and 5–10 weeks respectively [Figs. 1 (a & b)].

As rainfall is the limiting factor of crop production, all sorts of commercial crops may be discouraged in this region. The areas where break is more than two weeks are suitable for pasture development and cattle rearing.

Area E — Fig. 4 shows that the area E is extending from Rajkot in Gujarat along the east side of the area D up to Punjab through Rajasthan and Haryana. The second part is spread from Ahmednagar district in Maharashtra up to coastal area of Gudappa district in Andhra Pradesh through Satara, Pune, Solapur and Sangli district in Maharashtra and Bijapur, Bellary and Tumkur districts of Karnataka. Crop potential of this area is not very high because the duration of MAI more than $\geqslant 0.3$ and $\geqslant 0.7$ ranges from 10–13 and 1-5 weeks respectively (Figs. 2a & b) and assured rainfall is of the order of 350–375 mm in Karnataka and Andhra Pradesh at 50% probability level (Tables 2 and 3). A short to medium duration crop may be raised from most of the stations.

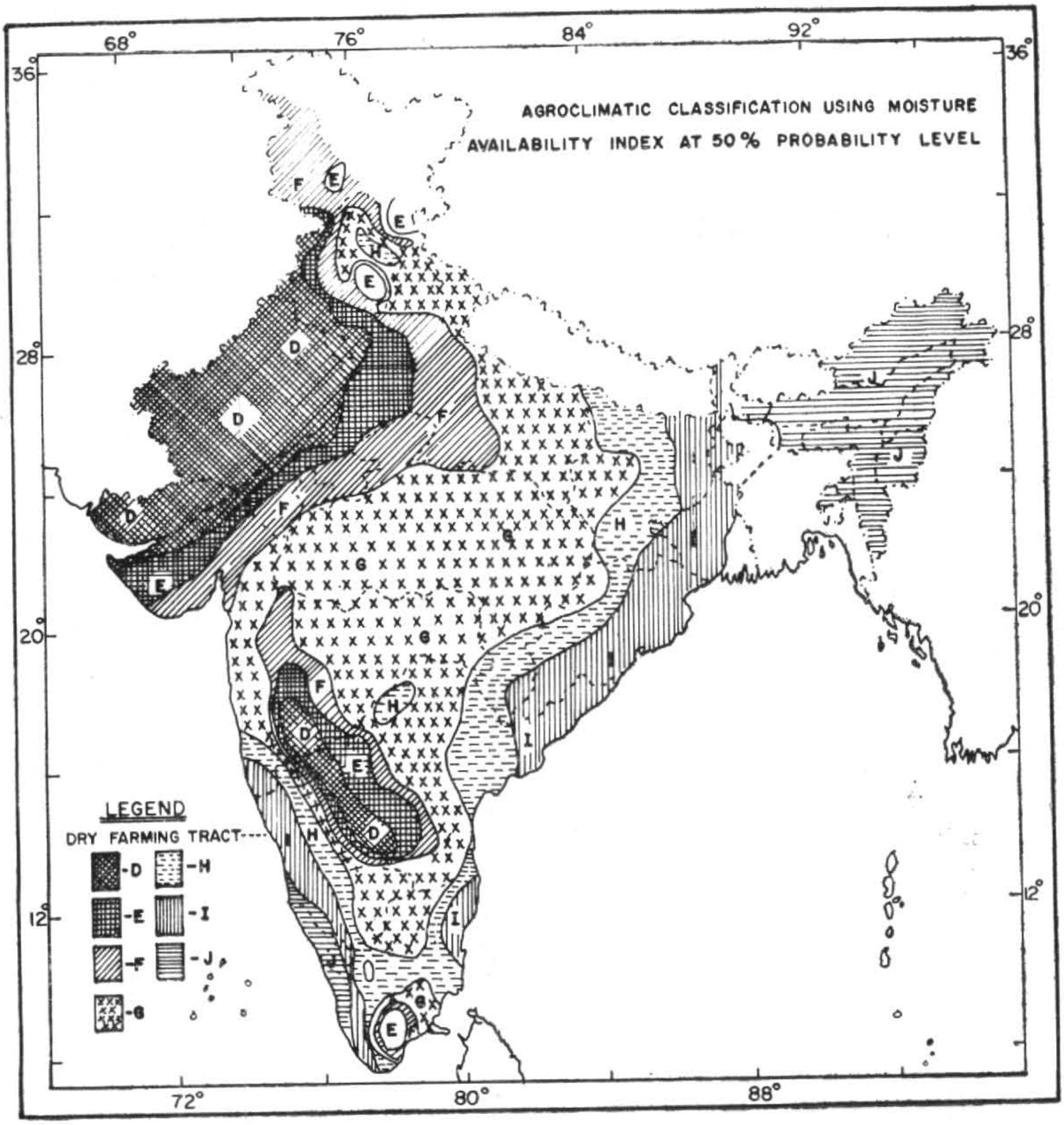


Fig. 4. Agroclimatic classification using moisture availability index at 50 per cent probability level

Many stations get accumulated assured rainfall as high as 460 mm at 40% probability level (Table 2). So, some soil moisture may be available at the end of rainy season. A medium to long duration crop may be raised from this area as crop can thrive on stored moisture for a few weeks even after cessation of rainy season.

A long duration crop may be raised from most of the stations of this area once in three years as MAI ≥ 0.3 and ≥ 0.7 are of the order of 14–20 and 8–12 weeks respectively [Figs. 1 (a & b)]. Accumulated assured rainfall (AAR) ranges from 530 mm at Ahmednagar in Maharashtra to 940 mm at Tumkur in Karnataka (Table 2) and crop can use stored moisture at the end of the rainy season.

Area F — Like the region E, the area F has also two parts. The northern part comprises vast areas of Gujarat, Rajasthan, Uttar Pradesh and a small portion of Haryana and Punjab (Fig. 4). The southern part stretches from Nasik district of Maharashtra to Kanya Kumari in Tamil Nadu. A large portion of Karnataka and Andhra Pradesh also comes under this agroclimatic zone.

Figs. 2 (a & b) give the duration of MAI ≥ 0.3 and ≥ 0.7 at 50% probability level. As there is hardly any break of MAI and assured rainfall is of the order of 230 to 450 mm around Sangli area of Maharashtra and Sawai Madhopur of Rajasthan, a medium duration crop may be raised from most of the stations once in two years.

At 40% probability level crop prospect is high as AAR ranges 330 mm at Sangli (Maharashtra) to 730 mm at Idar (Gujarat). Two short duration crops or a mixed crop may be raised from this region at this level.

A short duration crop may be raised at 60% probability level from some of the stations where AAR is of the order of 225–250 mm (Table 3).

Area G — This area consists of portions of Uttar Pradesh, Madhya Pradesh, Gujarat, Tamil Nadu and considerable parts of Maharashtra, Andhra Pradesh, Karnataka, Gujarat and small portion of Himachal Pradesh (Fig. 4). This portion in Tamil Nadu enjoys the northeast monsoon. Growing season, therefore, differs significantly from rest of the areas of this region.

MAI $\geqslant$ 0.3 and $\geqslant$ 0.7 ranges from 14–19 and 7–13 weeks respectively and AAR from 330 to 480 mm. Some stored moisture will be available at some of the stations. A crop of 13–18 week duration may be raised from this region in rainfed condition once in two years.

At 60% probability level, most of the stations have the potential to grow a medium/short duration crop as assured rainfall ranges from 180 mm at Dharampuri district of Tamil Nadu to 380 mm at Nanded district of Maharashtra (Table 3).

At 30% level, duration of MAI $\geqslant$0.3 and $\geqslant$0.7 is of the order of 18–20 and 12–15 weeks respectively (Figs. 1a & b). A long duration crop or a mixed crop may, therefore, be raised at this level.

Crop prospect is very high at 40% probability level as the AAR ranges from 460 mm to 850 mm (Table 2). Two short duration crops or a mixed crop may be raised from this region at this level.

Area H — This is comparatively smaller area, comprising parts of Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Bihar and West Bengal. Duration of MAI more than 0.3 and 0.7 varies from 18–21 and 9–11 weeks at 50% level (Figs. 2a & b). Accumulated assured rainfall in many stations is of the order of 600–700 mm and crop can thrive for 4–6 weeks on stored moisture after cessation or rainy season (Table 2).

At 70% level duration of crop growing period (MAI $\geqslant$ 0.3) may be about 12–14 weeks (Figs. 3a & b). AAR is also found about 350–450 mm and in many stations stored moisture may be available at the end of rainy season. A medium duration crop can be raised under rainfed condition.

At 40% level MAI $\geqslant$ 0.3 is of the order of 18–22 weeks, and in most of the stations crop can thrive on stored moisture at the end of rainy season. Two crops or multiple crop can be raised from most of the stations. Mid-season water stress period is very rare in this level. Hence crop can be raised without irrigation. A suitable crop variety and efficient management can increase the production to a high level.

Area I — The area includes part of Karnataka, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal (Fig. 4). In many stations MAI $\geqslant$0.3 and $\geqslant$0.7 ranges from 24-20 and 13–10 weeks respectively at 50% level (Figs. 2a & b). Hence, crop potential is very high at this level. Stored moisture is also available at all the stations at the end of rainy season (Table 2).

At 70% probability level, crop potential is high as MAI $\geqslant$ 0.3 is found varying from 18–12 weeks (Figs. 3a & b). Even at 80% level most of the stations have potential to raise crop of 12–14 weeks duration.

Crop growing period may be extended up to 8–6 weeks in this area at 40% level as adequate soil moisture may be available after cessation of rainy season (Table 2). Hence, two crops can be grown from this area by properly choosing sowing time and efficient management of climatic resources.

Area J — This is the highest crop potential area which comprises of parts of Kerala, West Bengal and whole of eastern India. At 50% level crop growing period varies from 24 to 30 weeks of which MAI $\geqslant$ 1 ranges from 10 to 18 weeks. Stored moisture is available at the end of rainy season at all the stations (Table 2).

Figs. 3(a) & (b) indicate that moisture is adequate to raise a rainfed crop from all stations at 70% level. A crop of 10–14 weeks duration can be grown even at 90% level from most of the stations in the eastern India.

At 40% level AAR range is more than 1000 mm. Two long duration crops can be raised at this level. A close scrutiny of the tables reveals that flood may occur at most of the area at 10–15% of years.

8. Crop potential in low rainfall areas

Following the MAI at 30% level the area where annual rainfall is less than 400 mm has been divided into three agroclimatic zones (Fig. 5). This area comprises parts of Gujarat, Rajasthan and Haryana. Crop growing period of each zone has been discussed briefly.

Area A — This is the most dry area of arid zone of India. Duration of MAI at 30% probability level (more than 0.3) is less than 9 weeks. Crop production without irrigation is speculative. However, a short duration crop may be raised with two or three irrigations from this area. This area is mainly suitable for pasture production and cattle rearing.

Area B — In this area duration of MAI, more than 0.3 and 0.7, will be at least 9 and 3 weeks respectively. It shows that crops get three quarters of its requirement of moisture from 3 to 7 weeks in various stations. In many of these weeks MAI is more than 1.0. A short duration (11–13 weeks) crop may be raised even in rainfed condition. With one or two irrigations crop may be grown even at 40% probability level.

Area C — Duration of MAI more than 0.7 is as long as 11 weeks. Total assured rainfall during the period when MAI exceeds 0.3 is more than PET in many stations at 30% probability level. Crop can thrive on stored moisture after rainy season. A crop of 14–16 weeks duration may be raised in rainfed condition. Many stations have the potential to raise crop even in 40% probability level.

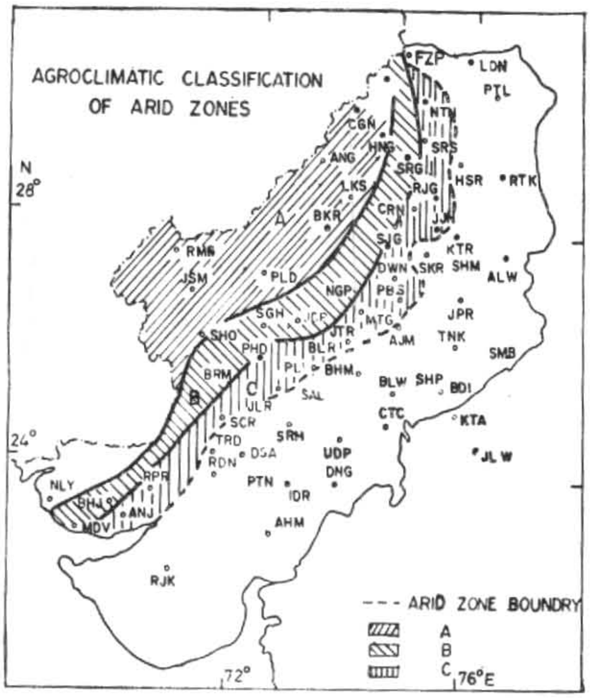


Fig. 5. Agroclimatic classification of arid zones

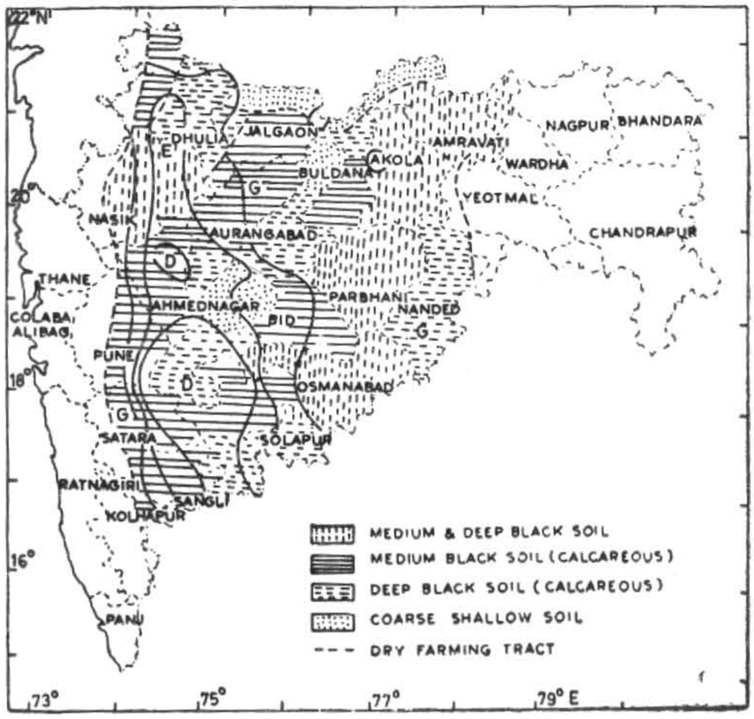


Fig. 6. Agroclimatic classification of dry farming tract of Maharashtra

9. Application to Maharashtra

We have also divided the dry farming tract of Maharashtra into 4 agroclimatic zones. D, E, F and G by using data of 84 stations. Assured rainfall has been taken from the publication of Biswas and Khambete (1979).

This micro-analysis divides the dry farming tract of Maharashtra (Fig. 6) into different agroclimatic zones and brings out many local features that could not be located in the macro-analysis of the entire country. The analysis has brought out the core of the drought prone areas comprising 6 talukas, *viz.*, Dhond, Baramati, Indapur, Malsiras and parts of Karmala and Dahiwadi. We have superimposed soil types on this classification (Fig. 6) which has further sub-divided the area into various sub-zones. This analysis has brought out crop potential of each sub-zone in terms of soil, precipitation and atmospheric evaporative demand and also the risk involved in the agriculture. This indicates clearly the necessity of micro-analysis to assess the crop potential of small areas.

10. Crop potential at individual stations

In order to examine the crop potential at few stations, the moisture availability indices (MAI) at different probability levels for one station on each agroclimatic zone are discussed in the following paragraphs :

Anantapur (*Lat.* 14°41′ *N*; *Long.* 77°37′ *E*)

The station (Fig. 7a) falls in the climatic category D. No rainfed crop can be raised from this station at 50% level, as MAI $\geqslant$ 0.3 is only 5 weeks. At 40% level, although MAI $\geqslant$ 0.3 begins from 21st week, but water stress period is encountered for five weeks (24th to 29th). Practically, growing period may be taken from 33rd to 45th weeks of which MAI $\geqslant$0.7 is 6 weeks. A dryland crop (millet, pulses) of 12–14 weeks duration may be raised under rainfed condition from this station.

At 30% level, duration of MAI $\geqslant$0.3 is 24 weeks but MAI exceeds 0.7 in 8 weeks only. A crop of long duration or a mixed crop can be raised from Anantapur.

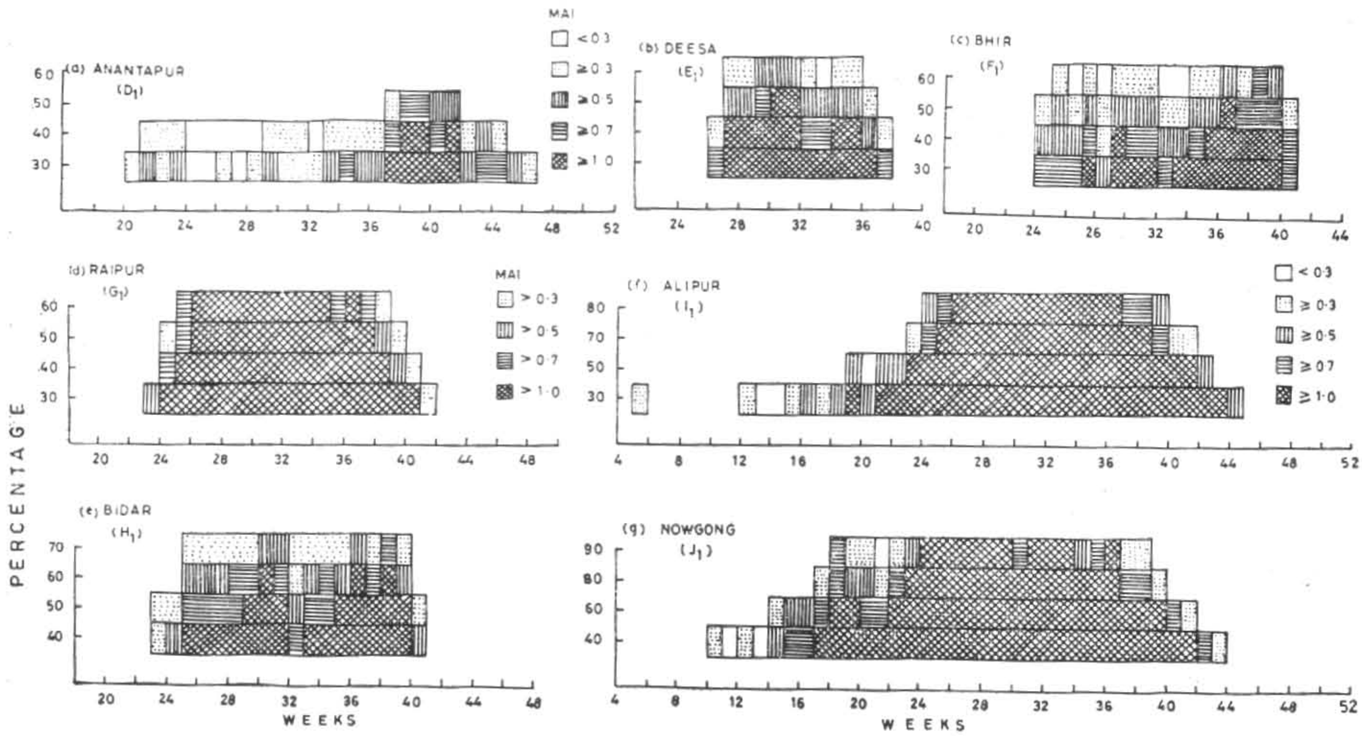
Deesa (*Lat.* 24°12′ *N*; *Long.* 72°12′ *E*)

This station comes under E zone. Fig. 7(b) depicts MAI at different probability levels. The number of weeks with MAI more than 0.3 and 0.7 is 10 and 3 respectively once in two years. A short duration crop like groundnut and pulses may be grown from this station. Crop prospect at 40% level is good as MAI $\geqslant$0.7 is 9 weeks. A dryland crop of medium duration crop (13–15 weeks) may be raised from here under rainfed condition.

At 30% level MAI $\geqslant$0.7 is 12 weeks. Plants can thrive on stored moisture after cessation of rainy season as total assured rainfall there will be more than PET by 150 mm. A long duration or a mixed crop can be raised from this station under rainfed condition.

Bhir (*Lat.* 19°00′ *N*; *Long.* 75°46′ *E*)

It represents agroclimatic zone F. Fig. 7(c) gives the MAI at different probability levels. One of the important features of this station is that there is no water stress period at 50% level. MAI $\geqslant$0.3 and $\geqslant$0.7 are 16 and 4 weeks respectively. Usually a short duration crop can be raised under rainfed condition once in two years. A crop of 16–18 weeks duration can be grown from this station applying one irrigation at 32nd/33rd week.



Figs. 7 (a)-(g). MAI at different probability levels

At 60% level, although MAI $\geqslant 0.3$ is 11 weeks, no crop can be raised without irrigation because MAI $\geqslant 0.7$ is only one week.

Crop prospect at 40% level is high as MAI $\geqslant 0.7$ is 10 weeks, and stored moisture is available at the end of rainy season. Crops can thrive on stored moisture for 5/6 weeks once in three years as AAR is more than PET by 160 mm at this level. A mixed crop can be raised from this station at 30% level.

Raipur (*Lat.* 21°14′ N; *Long.* 81°39′ *E*)

This station (Fig. 7d) comes under G group. MAI $\geqslant 0.3$ and $\geqslant 0.7$ are 16 and 13 weeks respectively. Stored moisture adequate for survival of crops for 5/7 weeks at the end of rainy season is available at 50% level. Mixed crop or two short duration crops can be raised from this station. At 60% level, crop of 16-28 weeks duration can be grown as MAI $\geqslant 0.7$ is 12 weeks.

Even at 70% level a medium duration crop can be raised under rainfed condition.

The main crops grown are paddy, sorghum and maize. Double crop may be introduced in place of paddy.

Bidar (*Lat.* 17°55′ *N*; *Long.* 77°32′ *E*)

Fig. 7(e) depicts the MAI at various probability levels of this station (Bidar) which comes under climatic zone H. There is no mid-season water stress period. At 50% probability level, MAI $\geqslant 0.3$ and $\geqslant 0.7$ are for 19 and 14 weeks respectively. AAR is more than PET by 160 mm during the period 23rd to 41st week. A mixed crop or two short duration crops can be raised from this station. At 60% level crop prospect is high as MAI is more than 0.3 in 16 weeks of which MAI exceeds 0.7 in 8 weeks. A long duration (16-19 weeks) crop can be planned at this level. Even at 70% level a crop of 15-16 weeks duration can be raised by applying one or two irrigations, otherwise a short duration crop under rainfed condition may be raised at this level.

Two crops or a mixed crop can be raised at 40% level as MAI $\geqslant 0.7$ is from 24th to 40th weeks. Moreover, sufficient amount of stored moisture will be available at the end of rainy season.

Alipore (*Lat.* 22°32′ *N*; *Long.* 88°20′ *E*)

Alipore comes under I zone (Fig. 7f). In this station MAI more than 0.3 and 0.7 are for 23 and 19 weeks respectively once in two years. Crops can sustain on stored moisture for 6-7 weeks after cessation of rainfall. Two crops can be raised from this station under proper management of water resources. At 70% level MAI $\geqslant 0.7$ are for 16 weeks. Since stored soil moisture will be available at the end of rainy season a long duration crop or a mixed crop can be grown at this level. Even at 80% level a rice crop can be raised as MAI $\geqslant 0.7$ are for 14 weeks.

Nowgong (*Lat.* 26°22′ *N*; *Long.* 92°42′ *E*)

This station belongs to category J (Fig. 7g). This is the highest rainfall zone and crop prospect is very high. Crops are damaged or lost due to flood in many years. At Nowgong MAI $\geqslant 0.3$ and $\geqslant 0.7$ are for 28 and 24 weeks at 60% level. Two rice crops can be grown from this station. Even at 80% level MAI more than 0.7 are for 17 weeks. At this level too a mixed crop can be raised under rainfed condition.

At 90% probability level crop growing period may be from 22nd to 40th week and even stored moisture is available at this level. A long duration crop can be raised from this station at 90% level.

11. Conclusion

Agroclimatic classification can be used for bringing out crop potential provided the units of time are adequate and data are sufficient for the purpose. The adequacy of an approach depends on the ultimate objectives. Hence, proper emphasis needs to be placed on the approach.

The agroclimatic classification of entire India has brought out many interesting features. The area where annual normal rainfall is more than 400 mm could be divided into seven agroclimatic zones of different crop potentials. The lowest crop potential area D comprises two parts. Rainfed agriculture does not suit this area. However, a short duration crop may be raised from this area once in 3 years. Area E has the potential to raise crops in about 40% of years. Rainfed crop can be successfully raised from area F, once in 2 years. From area G rainfed crop may be grown about 60% of years. Crop can be raised from area H in about 70% of years. Area I has high crop potential from where crop can be raised about 80% of years. Two crops can be harvested from area H at 70% probability level and even a crop of 10–14 weeks duration can be harvested in 9 out of 10 years.

The core of low crop potential area or scarcity zone could clearly be identified from the accumulated assured rainfall at 50% level. This comprises two parts. The total seasonal assured rainfall in this area is less than 100 mm at 50% probability level and the assured rainfall exceeds 400 mm at 30% level.

Areas and duration could also be identified where crop can thrive on stored moisture at the end of the rainy season.

Mid-season water stress period, stored soil moisture at the end of rainy season and additional water from run off are of enormous importance in assessing crop potential, especially of low rainfall areas of the tropics. Micro-level study is required to handle these problems.

Soil plays a vital role in shaping cropping pattern and yield of crops. Climatic classification coupled with the various information of soil evolves homogenous cropping zones. These zonings help in transferring knowledge and experience from one place to another. Hence, growing season may be adjusted or new crop may be adopted to get higher yield.

The entire country being very big and the number of stations chosen being limited, the classification is expected to be quite general and one cannot expect one to one correspondence between macro and micro analysis. For example, the scarcity zone areas identified in Maharashtra could hardly be located and identified with the large scarcity areas obtained from macro scale analysis. While a macro scale analysis can give some broad aspects of crop potential, it is essential to do the analysis on a micro scale so that the specific areas of scarcity zone comprising small areas can be identified and specific recommendations are drawn up.

It is hoped that the classification given here will enable the agricultural scientists to evolve a suitable cropping pattern for each zone, thereby boosting up crop productivity. However, before doing that superimposition of soil type will be necessary, which we have not done.

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