Mausam, (1982), **33**, 4, 465-476

551.586.551.571 : 631.586 (547)

Agroclimatic classification on the basis of moisture availability index and its application to the dry farming tract of Gujarat

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(*Received 5 August 1981*)

सार – गुजरात के शुष्क खेती वाले क्षेत्र में 81 स्टेशनों के विभिन्न प्रायिकता स्तरों पर साप्ताहिक नमी उपलब्धतांक की गणना की गई है । इस क्षेत्र को चार कृषि जलवायु क्षेत्रों में विभक्त किया गया है । वे हैं 50% स्तर पर नमी उपलब्धतांक के आधार पर D, E, F एवं G क्षेत्र ।

D क्षेत्र फसल का निम्न विभव क्षेत्र है जहां कि 30-40% वर्षों में कम वर्षा वाली फसल की संभावना होती है । 40-50% अवसरों पर E क्षेत्र में अल्पावधि फसल उगाई जा सकती है । 50-55% वर्षों में क्षेत्र F में फसल की पैदावार की शक्ति होती है । G क्षेत्र में कम वर्षा वाली फसल को 60% वर्षों तक उगाया जा सकता है । जोखिम वाले विभिन्न स्तरों पर कृषि विभव को ज्ञात करने के लिए 40, 60 और 70 प्रतिशत पर नमी उपलब्धतांक की गणना की गई है। इस विश्लेषण से फसल के निम्न विभव क्षेत्र के क्रोड़ और फसल के जीवन की सुरक्षा की सिंचाई के समय की जानकारी संभव है । जोखिम वाले विभिन्न स्तरों पर प्रत्येक क्षेत्र में एक स्टेशन पर मृदा की जल प्रतिबल अवधि, प्रकार एवं गहराई के संदर्भ में फसल की संभावना का विवेचन किया गया है ।

ABSTRACT. Weekly Moisture Availability Index (MAI) at different probability levels has been calculated at 81 stations in the dry farming tract of Gujarat. This tract has been divided into four agroclimatic zones, *i.e.*, D, E, F and G on the basis of MAI at 50 per cent level.

The zone D is the low crop potential area where rainfed crops are possible in 30-40 per cent of the years. A short duration crop may be grown from area E at 40-50 per cent of occasions. Area F has the potential to grow crops 50-55 per cent of years. Rainfed crops may be raised in 60 per cent of the years from area G. Moisture availability index at 40, 60 and 70 per cent levels have also been computed to find out agricultural potential at different risk levels. From this analysis, it is possible to identify the core of low crop potential area and time of life saving irrigation. Crop prospect of one station at each zone at various risk levels has been discussed, taking into account the water stress period, type and depth of soil.

1. Introduction

The basic requirement for a study of dryland farming is the rainfall pattern and water availability period. A certain amount of rainfall does not indicate that all that amount will be used up by the crop, because the same amount of water behaves differently depending on the atmospheric demand of the place, depth and slope of the land. So, it is required to account for not only assured rainfall but also atmospheric demand of a place and type and depth of the soil for any agroclimatic classification and to know crop potential of a place.

More than 80 per cent of the area of Gujarat comes under dry farming tract which is defined as an area where annual rainfall varies from 400 to 1000 mm and arid zone. Only eleven per cent of cultivatable land enjoys the benefit of irrigation. There is scope of increasing irrigation, but estimates show that area under irrigation is not expected to be more than 40 per cent of total cropped area even in 2000 A.D. (Commission on Agriculture 1976). Therefore, it is necessary that a close study of the climatic resources of the State is made so that the information evolved may be made use of for increasing agricultural production.

Isolated attempts were made to study rainfall and in a few cases it was tried to correlate with yield. National commission on Agriculture (1976) tried to divide the State into different parts on the basis of monthly rainfall and average temperature. Gujarat State Government (1976) demarcated the State into different agroclimatic zones on the basis of monthly rainfall, average maximum and minimum temperatures. Khambete and Biswas

(1978) studied runs of wet and dry spells and computed weekly probabilistic rainfall of 15 stations taking one station in each district.

An attempt has been made in this paper to classify the dry-farming tract of Gujarat into various agroclimatic zones by using moisture availability index so that the agricultural scientists and progressive farmers may get reliable guidance of crop potential of a place at different risk levels.

Review of literature

The earlier attempts to classify climate mainly centred round the identification of average annual, seasonal or monthly rainfall and/or temperature regimes that naturally produced some typical types of vegetation or crops in abundance [Koppen (1936), Prescott (1938), Trewartha (1954), Burgos (1958) and others]. Thornthwaite (1948) developed the concept of potential evapotranspiration (PE). He adopted the water balance technique by using monthly PE and average monthly rainfall for the calculation of the various degrees of water surplus and water deficit and the classified climates with the help of these parameters. He & Mather (1955) further improved the work by incorporating realistic assumptions. Subrahmanyam (1956) made a classification of India's climates following this method. For assessing agricultural potential of various countries Papadakis (1961, 1975) used a very simple water balance technique along with average maximum and minimum temperatures. Although Thornthwaite & Mather and Papadakis used some kind of comparison between the potential evapotranspiration and the water 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. Because wind speed and radiation which play a vital part for the loss of water, especially in the trpoics, are not taken into account. Moreover, the period used by them is too long in comparison with the entire life cycle for a present agricultural crop. And as they used only monthly average rainfall, their methods do not help the users to assess the element of risk involved, if agriculture of a country is planned using their classifications.

Wallen *et al.* (1962) improved upon their methods by using Penman's formula for calculating potential evapotranspiration for purpose of water balance and by providing a very rough and short range answer to a risk factor by coupling the water balance with inter-annual variability of annual rainfall. Cocheme and Franquin (1967) used monthly precipitation and potential evaporation to find out the crop growing period and suggested tackling of the risk factor from probability of rainfall determined by semi-logarithmic distribution. Hargreaves (1971) used the ratio of monthly assured rainfall at 75 per cent probability level and average monthly potential evapotranspiration calculated by Penman's method to classify agroclimate of northeast Brazil.

Short period rainfall distribution is skew, the skewness being more when the period is short (monthly, bi-weekly, weekly). Under this condition the use of incomplete gamma distribution gives a better fit (Mooley 1970, 1973 and Sarker *et al.* 1981). Hence use of the probability of rainfall obtained from such a distribution should be more appropriate in handling the risk factor.

2. Method

Several factors have to be considered to assess the agricultural potential of a place. Among these, an accurate evaluation of the moisture available to plants during their various phases of growth at different probability levels of rainfall is the most important.

2.1. *Choice of interval*

As already mentioned, a month is too long a period compared to the entire crop-life. This is particularly so now a days because the plant breeders are constantly evolving new varieties of short duration to raise more number of crops per year for increasing production. Use of monthly rainfall suffers from another defect too. There are areas where even during the height of the wet season the daily rainfall varies immensely in amount, 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 generally of a showery type and highly erratic in intensity, amount and distribution (both in time and source), it is necessary to use the week as the unit of time at least for the early part of the crop-life and later not more than two weeks and a taluka or its equivalent as the unit of area.

2.2. *Moisture availability index*

An index called the Moisture Availability Index (MAI) has been defined as the ratio of assured rainfall (weekly, bi-weekly or monthly) to potential evapotranspiration of the corresponding period. This MAI has, however, been calculated for 30, 40, 50, 60 and 70 per cent probability levels, although the climatic classification has been done on the basis of the index at 50 per cent level. Considering the MIAs at all the probability levels, a suitable label can be selected for each zone depending upon the duration of adequacy of moisture.

2.2.1. *Range of MAI*

Water requirement of 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 are known as evapotranspiration. The last one is 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 the plant and also perhaps, to some extent, from crop to crop. However, it is assumed in the all agrometeorological studies that potential evapotranspiration covers the maximum requirement of fully grown 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 a 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 crop field (Replay 1966). But experiments have shown that due to its stomatal openings to restrict transpiration when there is moisture stress plants grow almost normally as long as the moisture supply does not fall below about three quarters of the potential rate (Arnon 1972). After completion of grain formation the water demand falls off rapidly becoming small at the ripening stage (Holmes 1963).

In view of 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. The varying degree to which this condition is satisfied using precipitation expected at different probability levels obtained from incomplete gamma distribution forms the basis of the present study.

2.2.2. *Criteria for classification*

Classification has been made using MAI mentioned above. Increasing MAI both in duration and magnitude has been denoted in alphabetical order of the English capital letters starting from D. Some letters at the beginning, *i.e.*, A to C have been kept reserved for classification, by the author, of arid zone where annual rainfall is less than 400 mm.

Following is the classification in the present study :

Classification	*No of weeks at 50% MAI at least*	
	0.3	*0.7*
D	<10	<1
E	10	1
F	11	4
G	14	7

2.2.3. *Sub-division to water stress period*

The mid-monsoon season water stress, *i.e.* when MAI is less than 0.3 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 water stress period, while suffixes '2', '3' and '4' indicate 2-3 weeks, 4-5 weeks and more than 5 weeks water stress respectively.

2.3. *End of growing season*

Cessation of rainy season does not mean the end of crop season. Crop 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 the 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 per cent of PE (Jenson 1968). Riplay (1966) observed that in many farm crops seasonal water use may range from 55 to 75 per cent of PE.

India Meteorological Department installed about 35 lysimeters in various soils and climatic zones of the country to find out the water requirement of different crops. Venkataraman *et al.* (1976) found that cumulative seasonal ET is about 70 per cent of the PE. It has, therefore, been taken for this study that difference between seasonal total assured rainfall and two-third of PE of the corresponding period will go into stored soil moisture and the plant can use it even after the end of rainy season.

It may be noted that the use of potential evapotranspiration in this classification takes account of an integrated picture of air temperature, radiation (sunshine duration), relative humidity and aeration (wind speed), the meteorological factors known to influence the health and growth of a plant. Temperature has, therefore, not been considered separately in classifying agroclimatic zones specially in the area under consideration, where variation of maximum and minimum temperatures is not much during the monsoon season.

TABLE 1

Moisture Availablity Index (MAI) and Accumulated Assured Rainfall (AAR) in weekly and bi-weekly periods

Probability levels	Weekly					Bi-weekly				
	No. of weeks MAI				AAR (mm)	No. of weeks MAI				AAR (mm)
	.3	.5	.7	.9		.3	.5	.7	.9	
					Deesa					
40	11	10	9	6	329	14	10	10	18	428
50	9	8	3	2	180	10	10	6	4	260
60	6	3	0	0	80	10	6	4	0	168
70	1	0	0	0	08	6	2	0	0	68
					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
					Veraval					
40	14	11	7	5	411	14	12	12	6	521
50	11	6	5	3	216	14	12	6	4	431
60	7	5	1	0	102	12	6	6	4	203
70	3	0	0	0	47	6	6	0	0	111
					Baroda					
40	15	14	12	12	634	16	14	14	12	764
50	13	12	11	8	427	14	14	12	10	549
60	12	9	6	5	263	14	12	10	6	397
70	8	5	3	0	125	12	10	6	4	259

2.4. *Rational approach to dependability*

Table 1 gives the MAIs of weekly and bi-weekly assured rainfall at different probability levels for selected stations. It is seen that classification based on weekly MAIs at 50 per cent probability level remains practically same as that of bi-weekly at 60 per cent level. In other words for the purpose of classification, use of weekly MAIs at 50 per cent probability level is equivalent to using the bi-weekly MAI at 60 per cent level during the period when MAI is more than 0.3. An examination of MAIs and assured accumulated rainfall at various levels leads to a conclusion that, in general dependability increases by 10 per cent if one switches over from weekly to bi-weekly analysis. But as mentioned earlier, it should be kept in mind 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. Secondly, each week is not carried over to the successive weeks. But in reality the crops do not suffer such water stress for two or three weeks after a heavy rainy week. This situation occurs on many occasions during the monsoon period in the tropics where most of the rainfall occurs in association with synoptic disturbances. Thirdly, due to the adoption of drought resistant crops, the yield may be more or less good even under partial drought condition. In view of the above, the dependability may be 10-15 % more than what has been brought out by this classification.

3. Data

Application of the classification — The classification developed has been applied to the dry farming tract of Gujarat (Fig. 1). The following data have been used for this purpose. Weekly assured rainfall at different risk levels of 76 stations computed by Biswas and Basarkar (1981) has been used in this study. Weekly potential evapotranspiration has been obtained by interpolation both in time and space from monthly PE calculated by Rao *et al.* (1971). Soil characteristics have been extracted from Technical Bulletin No. 36 published by Government of Gujarat. There are 184 talukas in the Gujarat State. Of these about 120 talukas come under dry farming tract. It would have been ideal to have had one station in each taluka, but it was not possible due to paucity of data. Five stations in arid zone have been used for the sake of comparison.

TABLE 2

MAI, PE and Accumulated Assured Rainfall (AAR)

District	Station	At 40% probability level						At 50% probability level						Agro-climatic classification
		No. of weeks MAI				AAR (mm)	PE (mm)	No. of weeks MAI				AAR (mm)	PE (mm)	
		.3	.5	.7	.9			.3	.5	.7	.9			
Broach	Amod	15	14	12	11	585	422	13	11	9	8	362	391	F1
	Ankleshwar	16	15	14	12	593	448	15	13	11	9	466	418	G1
	Bharuch	16	15	13	11	621	462	14	11	11	7	417	430	G1
	Dahej	15	14	11	7	487	480	11	10	7	6	281	336	F1
	Hansot	16	15	14	11	612	483	14	11	11	6	387	413	G1
	Jambusar	15	13	12	11	551	475	12	10	7	5	334	362	F1
	Rajpipla	16	16	14	13	752	421	15	13	11	10	517	392	G1
	Vagra	16	14	13	11	592	502	13	11	8	5	380	429	F1
Baroda	Vadodara	15	13	12	12	654	454	13	12	11	8	427	381	G1
	Chota-Udepur	16	16	15	14	925	468	14	12	12	12	653	389	G1
Panchmahal	Deogad-Baria	16	14	14	12	783	471	14	13	11	9	516	398	G1
	Dahod	16	14	13	12	592	467	14	13	11	11	398	394	G1
	Godhra	15	15	14	12	737	449	14	12	11	10	480	405	G1
	Halol	15	14	13	12	765	449	14	11	11	10	511	405	G1
	Jambughoda	16	14	14	12	961	465	14	12	12	11	667	394	G1
	Jhalod	15	14	14	13	610	443	14	12	11	9	400	400	G1
	Kalol	15	14	12	12	735	451	13	12	11	9	476	378	F1
	Lunawada	15	12	11	11	558	453	12	11	10	9	363	340	F1
Kaira	Anand	14	13	12	11	636	408	11	11	9	7	408	338	F1
	Balasinor	14	14	12	11	630	413	13	11	11	10	399	373	F1
	Borsad	15	13	12	11	626	470	12	11	9	8	389	356	F1
	Cambay	14	12	10	9	441	450	11	9	6	3	259	344	F1
	Dakor	14	13	12	11	569	419	11	10	10	9	359	349	F1
	Kapadvanj	14	13	11	11	580	420	12	11	10	8	268	349	F1
	Kaira	14	12	10	10	488	440	12	5	8	5	298	366	F1
	Matar	14	12	11	10	526	438	11	11	9	7	329	334	F1
	Mehmedabad	15	13	12	11	516	475	12	11	9	7	375	360	F1
	Nadiad	14	12	11	11	591	428	11	11	9	7	371	326	F1
	Thasra	14	13	11	11	446	485	12	11	9	7	338	414	F1
Ahmedabad	Ahmedabad	14	12	11	11	531	436	12	11	10	5	330	363	F1
	Dhandhuka	13	6	4	1	241	453	7	2	1	—	105	248	D1
	Dholka	14	13	11	8	408	421	12	9	4	3	242	347	F1
	Dholera	12	7	5	4	241	395	6	4	—	—	101	201	D1
	Mandal	10	10	8	5	284	336	10	7	3	—	177	336	E1
	Ranpur	6	5	1	0	187	454	5	1	—	—	66	183	D1
	Sanand	11	9	4	4	251	346	9	4	2	—	136	287	D1
	Viramgam	14	11	9	6	374	473	11	8	4	2	217	363	F1
Sabarkantha	Bayad	15	12	11	11	587	461	11	11	9	9	364	317	F1
	Himatnagar	14	11	11	10	582	428	11	10	9	9	370	325	F1
	Idar	15	13	11	11	736	475	11	11	9	9	460	325	F1
	Modasa	14	12	11	11	576	417	12	11	9	8	378	358	F1
	Mohanpur	13	13	11	11	562	391	12	11	10	8	362	361	F1
	Prantij	13	12	11	9	488	396	11	10	9	6	308	325	F1

TABLE 2 (*contd*)

District	Station	At 40% probability level						At 50% probability level						Agro-climatic classification
		No. of weeks MAI				AAR	PE	No. of weeks MAI				AAR	PE	
		.3	.5	.7	.9	(mm)	(mm)	.3	.5	.7	.9	(mm)	(mm)	
Banaskantha	Deesa	11	10	10	7	329	352	10	8	3	2	181	277	E1
	Palanpur	12	10	9	9	456	374	11	9	8	3	258	271	F1
	Radhanpur	9	8	3	3	241	298	7	4	2	1	126	239	D1
	Tharad	10	8	6	2	220	295	6	2	1	—	85	206	D1
Mehasana	Mehasana	11	11	10	7	407	372	11	7	6	4	259	341	F1
	Patan	12	11	9	6	386	399	10	6	6	5	221	311	E1
Surendranagar	Bajana	11	10	5	2	258	376	10	3	1	1	138	313	E1
	Chuda	14	9	6	4	318	499	7	5	1	—	122	255	D1
	Dharngadhra	11	8	4	3	268	392	6	4	1	—	120	219	D1
	Kharaghoda	11	5	4	1	276	373	7	5	3	—	160	297	D1
	Wadhwan	12	8	5	2	263	419	8	4	1	—	129	290	D1
Bhavnagar	Bhavnagar	15	13	8	5	399	508	12	5	5	2	229	391	F1
	Ghogha	15	13	9	5	408	511	12	8	5	2	242	397	F1
	Mahuwa	15	13	9	6	407	443	12	7	6	3	250	347	F1
	Palitana	15	14	9	6	417	485	13	8	4	3	261	447	F1
	Songadh	16	12	9	5	411	547	11	7	4	2	217	367	F1
Amreli	Amreli	14	10	8	4	331	446	9	7	3	1	173	286	D2
	Jafrabad	14	12	8	6	381	406	12	11	11	6	240	343	F1
Junagadh	Junagadh	15	12	11	10	689	471	12	11	8	5	361	371	F1
	Porbandar	10	6	4	3	220	301	3	3	2	1	100	153	D1
	Veraval	14	11	7	5	363	411	11	6	5	3	216	347	F1
Rajkot	Dhoraji	15	12	5	5	375	485	12	5	4	4	214	377	F1
	Gondal	16	11	7	5	414	555	11	6	5	2	226	370	F1
	Jasdan	14	11	6	5	380	402	11	6	4	3	223	353	E1
	Morvi	10	8	4	2	262	381	6	3	1	—	117	231	D1
	Rajkot	15	9	5	5	394	599	10	5	2	1	205	383	E1
	Wankaner	10	7	5	4	302	418	6	5	2	1	142	231	D1
Jamnagar	Dwarka	8	4	3	2	141	257	3	1	0	0	54	130	D1
	Jamanagar	10	6	4	2	205	331	5	2	0	0	81	168	D1
	Navanagar	9	5	5	2	213	291	5	3	2	2	102	168	D1
Kutch	Anjar	5	2	2	0	104	197	2	—	—	—	33	77	D1
	Bhuj	6	2	0	0	92	232	—	—	—	—	—	—	D1
	Mandvi	8	4	2	2	160	267	3	2	1	—	53	100	D1
	Naliya	3	2	1	0	55	141	2	—	—	—	22	73	D1
	Rahpur	7	2	1	1	117	262	2	—	—	—	26	77	D1

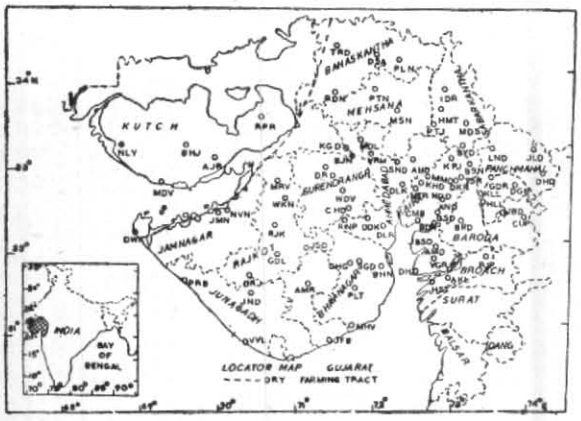

Fig. 1. Locator map of Gujarat

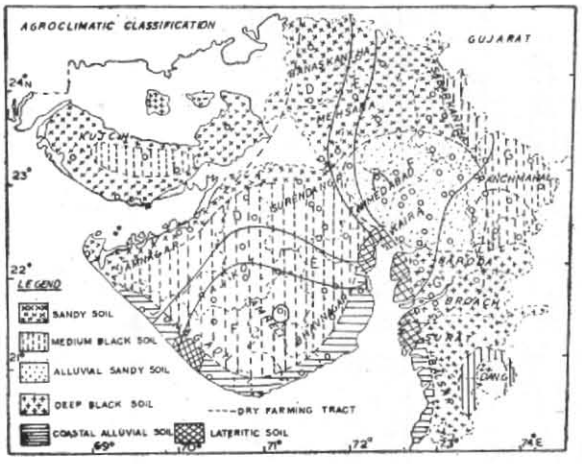

Fig. 2. Agroclimatic classification of Gujarat

4. Discussion

Dry farming tract of Gujarat has been divided into four broad climatic zones following the present classification based on MAI. It is already mentioned that type, depth and quality of soil play a vital role for crop production. Even the same climate of two different places will give different yields due to variation of soil. When the climatic information is superimposed over that of soil, it will give various agroclimatic zones. Fig. 2 gives such an agroclimatic classification of Gujarat. Figs. 3 and 4 give the accumulated assured rainfall (AAR) during the period when MAI is more than 0.3 at 30 and 50 per cent levels respectively. Table 2 gives the MAI at 40 and 50 per cent levels along with the agroclimatic classification whereas Table 3 depicts the MAI of 60 and 70 per cent levels. These tables reveal the gradual reduction of moisture adequency period with increasing probability level. Appendix I gives the dates of standard weeks.

In the same climatic zone variation of depth-texture, field capacity and wilting point of the soil are so much that cropping pattern of each zone has not been suggested as all this information is not available. Moisture adequacy at various levels has been discussed. Cropping pattern has been left to the agricultural scientists or progressive farmers of the region. These zones are discussed below :

4.1. *Area D*

This area comprises of Jamnagar and Surendranagar districts, parts of Junagad, Rajkot and Banaskantha districts. Three types of soils are found over this area namely, coastal alluvial, medium black and sandy soil.

Coastal alluvial soils are found in Porbandar and adjacent coastal area. As this soil is formed from a mixture of black clay material and old marine salt deposit, it has good water holding capacity. Soil of this area is about 60 cm deep.

Medium black soil is observed in the whole area of Saurashtra except in the coastal region. Depth of the soil varies from a few centimetres to 60 cm. At many places colour of the soil in the surface layer is dark grey to light grey and the texture is clayey. A layer of murum is generally found at 40-60 cm depth. Field capacity of this soil varies from 21 to 27 per cent by weight.

Sandy soil is found in Surendranagar district. This soil contains very low percentage of clay and has good drainage capacity. But irrigation facilities are low due to paucity of water resources. Moreover, the underground water being brackish is unsuitable for irrigation.

Prospect of dryland crop once in two years is speculative as MAI more than 0.7 varies from zero to 4 weeks. Even at 40 per cent probability level it is difficult to raise short duration crop from many stations. At 30% level most of the stations have the potential to raise a crop of 14-16 weeks duration as MAI is more than 0.3 for these weeks and accumulated assured rainfall varies from 559 to 353 mm.

4.2. *Area E*

This may be considered as a transitional zone. Parts of the districts of Junagad, Rajkot, Bhavnagar, Ahmedabad, Mehsana and Banaskantha come under this zone. In this area three types of soils can be identified. In the coastal zone, soils are alkaline in some places. Depth of soil varies from 40 to 70 cm. The major portion of the soil is medium black. Porosity of soil is good and the soil is rich in chemical nutrients. Sandy soils are found over Chanasma and Patan talukas of Mehsana district and Dhanera, Deesa and Barij talukas of Banaskantha district.

In this area MAI at 50 per cent level is more than 0.3 and 0.7 at least for ten and one weeks respectively. Most of the stations are not suitable for rainfed agriculture although in a few stations short duration crop may be raised. Table 2 (40

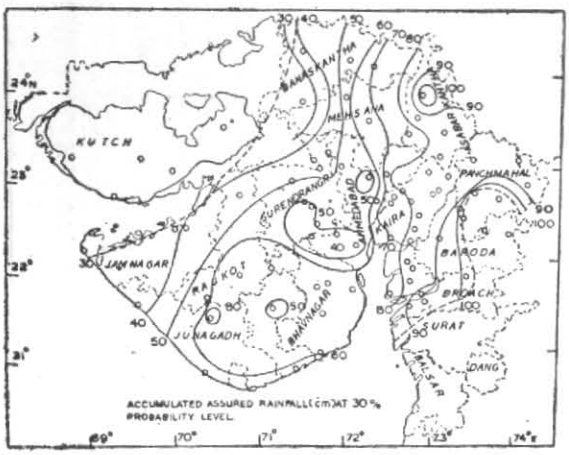

Fig. 3. Accumulated assured rainfall (cm) at 30 per cent probability level

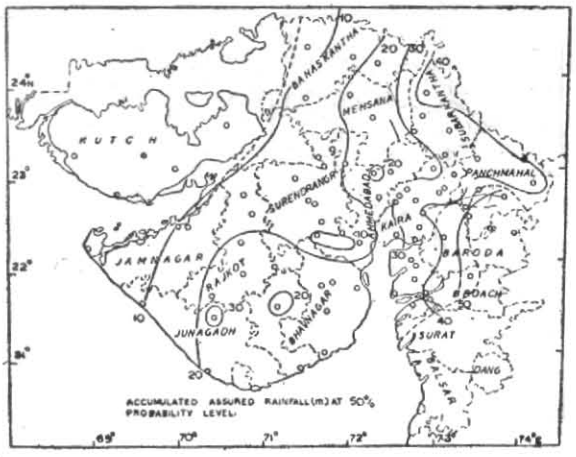

Fig. 4. Accumulated assured rainfall (cm) at 50 per cent probability level

per cent probability level) shows that MAI more than 0.7 varies from 4 to 9 weeks. A medium duration (12-16 weeks) crop may be raised from this area. A mixed crop or a long duration crop may be grown at 30 per cent probability level as accumulated assured rainfall is about 600 mm in many stations.

4.3. *Area F*

Almost 50 per cent of area of dry farming tract of Gujarat is under this zone (Fig. 2). Proportion of sand is more and soil is fairly deep in most of the area. Clay loam or loamy clay soil is dominant in a major part of Ahmedabad, Mehsana, Sabarkantha and most of Kaira district. Medium black soil is found over Junagadh, Amroli and Bhavnagar except in the coastal area. This soil is fairly deep and of good water holding capacity. Sandy soil is noticed in the northern part of the region and depth of this soil is about 70 cm. In the coastal area clay soils are dominant and in many places in this region soils are alkaline.

Duration of MAI at 50 per cent level more than 0.3 and 0.7 is atleast 11 and 3 weeks respectively. Table 2 and Fig. 4 show that accumulated assured rainfall is more than 400 mm in many stations. From most of the area a short duration rainfed crop may be raised. Table 2 gives the total assured rainfall at 40 per cent level which is as high as 650 mm in many stations. Duration of MAI more than 0.3 is about 13 weeks of which for 7-8 weeks it exceeds 1.0 and the porosity of soil is more or less good. Hence a good amount of stored moisture may be available at the end of the rainy season. A medium duration (14-16 weeks) crop or a mixed crop can be raised from this region. Two short duration crops can be had from some of the stations, with proper adjustment of sowing time.

4.4. *Area G*

This region occupies a comparatively small area of Gujarat, but at the same time three types of soils are found in it, *i.e.*, alluvial, sandy loam and loamy sand. Depth of the soils is about 60-70 cm and it is well drained. This area mostly comprises of parts of Broach, Baroda and Panchmahal districts. Medium black soil is observed in the northern parts of Baroda and deep black soil is predominant in the southern parts of Baroda and Broach districts.

In this zone, MAI will be more than 0.3 and 0.7 atleast for 14 and 7 weeks respectively. Table 2 shows that accumulated assured rainfall varies from 667 to 386 mm and stored soil moisture available in many stations at the end of the rainy season could be used by the plants. Therefore, crop growing period may be extended even after cessation of the rainy season. A crop of 14-18 weeks duration could be raised from this area once in two years. Even at 60 per cent probability level (Table 3) a medium to short duration crop may be raised from some parts. Table 2 shows that crop prospect is very high at 40 per cent probability level as seasonal assured rainfall ranges from 960 to 590 mm. Most of the stations are having potential of two short duration crops or a mixed crop.

4.5. *Crop prospect at a few representative stations*

Crop potential at various probability levels of one station of each agroclimatic zone has been discussed taking into consideration the depth and type of soil. In this discussion socio-economic problems of this station have not been taken into account.

4.5.1. *Jamnagar*

This station is having medium black soil about 90 cm depth of good porosity. There is hardly any problem of drainage. Soil is fertile and there is much difference in chemical and physical properties of the soil at different layers.

The station comes under D zone. MAI is more than 0.3 for 5 weeks only at 50 per cent level but all these weeks it is less than 0.7 (Fig. 5). No rainfed crop is possible once in two years. MAIs are

TABLE 3

MAI, PE and Accumulated Assured Rainfall (AAR)

District	Station	At 60% probability level						At 70% probability level					
		No. of weeks MAI				AAR (mm)	PE (mm)	No. of weeks MAI				AAR (mm)	PE (mm)
		.3	.5	.7	.9			.3	.5	.7	.9		
Broach	Amod	10	6	5	3	209	299	5	5	2	0	91	152
	Ankleshwar	12	11	6	5	285	339	10	5	5	3	160	281
	Bharuch	11	10	7	4	253	328	10	5	2	0	147	298
	Dahej	8	6	2	2	157	278	5	2	0	0	63	156
	Hansot	11	6	5	5	225	315	6	5	3	0	103	171
	Jambusar	10	6	5	3	196	301	5	3	0	0	85	153
	Rajpipla	13	11	9	7	333	335	10	9	5	4	195	271
	Vagra	11	8	5	5	219	328	5	4	1	0	105	207
Baroda	Vadodara	12	9	6	5	263	343	7	5	3	0	125	223
	Chota-Udepur	12	12	11	9	441	320	11.	9	9	7	284	293
Panchmahal	Deogad-Baria	11	11	9	7	311	303	10	6	5	4	187	275
	Dahod	12	11	6	6	252	327	10.	6	4	0	147	272
	Godhra	11	10	8	6	288	309	8	6	4	3	151	217
	Halol	11	10	8	6	314	309	9	7	5	3	173	245
	Jambughoda	13	11	11	9	450	366	11	9	8	5	279	300
	Jhalod	11	10	8	4	243	303	9	7	3	0	130	237
	Kalol	11	10	8	6	293	310	9	6	5	2	157	246
	Lunawada	11	9	6	4	227	311	8	5	4	0	117	128
Kaira	Anand	11	9	6	5	255	310	6	5	3	1	124	194
	Balasinor	11	9	5	5	240	314	7	5	2	0	160	195
	Borsad	11	9	6	4	240	326	7	5	3	0	116	206
	Cambay	9	5	2	1	147	285	4	1	0	0	49	125
	Dakor	10	8	5	4	215	291	8	4	2	0	112	229
	Kapadvanj	11	8	6	3	229	319	8	4	2	0	114	225
	Kaira	9	5	3	1	164	265	5	2	1	0	69	155
	Matar	10	7	5	2	198	304	6	3	2	0	91	183
	Mohmedabad	11	9	6	3	227	329	8	4	1	0	109	233
	Nadiad	11	8	5	4	234	326	7	4	3	0	112	204
	Thasra	11	9	5	3	203	385	7	4	0	0	89	266
Ahmedabad	Ahmedabad	10	8	5	2	195	303	9	2	0	0	106	274
	Dhandhuka	3	0	0	0	33	105	0	0	0	0	0	0
	Dholka	9	4	0	0	121	275	4	0	0	0	40	126
	Dholera	4	0	0	0	41	133	0	0	0	0	0	0
	Mandal	6	1	0	0	75	205	1	0	0	0	10	37
	Ranpur	0	0	0	0	0	0	0	0	0	0	0	0
	Sanand	4	0	0	0	48	126	0	0	0	0	0	0
	Viramgam	8	4	0	0	110	259	2	0	0	0	24	75
Sabarkantha	Bayad	10	9	6	5	224	288	8	5	1	0	113	223
	Himatnagar	9	9	7	4	221	257	8	4	2	0	120	228
	Idar	10	9	9	6	285	286	9	6	4	2	162	256

TABLE 3 (*contd*)

District	Station	At 60% probability level						At 70% probability level					
		No. of weeks MAI				AAR (mm)	PE (mm)	No. of weeks MAI				AAR (mm)	PE (mm)
		.3	.5	.7	.9			.3	.5	.7	.9		
Sabarkantha (*contd*)	Modasa	10	9	6	5	229	289	8	5	2	0	121	222
	Mohanpur	10	8	6	4	211	291	7	4	1	0	99	199
	Prantij	10	7	5	3	187	295	7	2	0	0	89	202
Banaskantha	Deesa	6	3	0	0	80	192	1	0	0	0	9	29
	Palanpur	8	5	3	1	131	215	3	1	0	0	38	87
	Radhanpur	4	1	0	0	51	138	0	0	0	0	0	0
	Tharad	1	0	0	0	11	33	0	0	0	0	0	0
Mehasana	Mehasana	6	6	2	1	134	214	5	1	0	0	65	157
	Patan	6	6	1	0	110	195	3	1	0	0	34	102
Surendranagar	Bajana	3	1	0	0	40	160	1	0	0	0	9	34
	Chuda	3	0	0	0	37	114	0	0	0	0	0	0
	Dhrangadhra	3	0	0	0	45	118	0	0	0	0	0	0
	Kharaghoda	4	1	0	0	57	139	0	0	0	0	0	0
	Wadhwan	4	0	0	0	50	151	0	0	0	0	0	0
Bhavnagar	Bhavnagar	6	5	0	0	99	197	5	0	0	0	51	167
	Ghogha	8	3	2	0	120	270	2	1	0	0	31	67
	Mahuwa	9	5	3	2	145	258	5	3	0	0	66	141
	Palitana	7	4	1	0	110	226	4	0	0	0	42	128
	Songadh	7	2	0	0	103	241	1	0	0	0	11	36
Amreli	Amerli	7	1	1	0	83	220	1	0	0	0	13	34
	Jafrabad	8	5	4	1	129	227	5	2	0	0	61	140
Junagadh	Junagadh	10	6	4	3	219	334	6	3	1	0	102	210
	Porbandar	3	2	0	0	43	90	2	0	0	0	17	60
	Veraval	7	5	1	0	102	195	3	0	0	0	47	143
Rajkot	Dhoraji	5	4	0	0	84	160	3	0	0	0	30	95
	Gondal	6	5	2	0	103	199	4	0	0	0	43	131
	Jasdan	5	3	1	0	102	218	3	1	0	0	45	110
	Morvi	2	1	0	0	28	77	0	0	0	0	0	0
	Rajkot	5	1	0	0	85	196	1	0	0	0	14	37
	Wankaner	5	1	0	0	73	198	1	0	0	0	9	36
Jamnagar	Dwarka	0	0	0	0	0	0	0	0	0	0	0	0
	Jamnagar	2	0	0	0	21	67	0	0	0	0	0	0
	Navanagar	2	1	0	0	31	67	0	0	0	0	0	0
Kutch	Anjar	0	0	0	0	0	0	0	0	0	0	0	0
	Bhuj	0	0	0	0	0	0	0	0	0	0	0	0
	Mandvi	2	0	0	0	22	67	0	0	0	0	0	0
	Naliya	0	0	0	0	0	0	0	0	0	0	0	0
	Rahpur	0	0	0	0	0	0	0	0	0	0	0	0

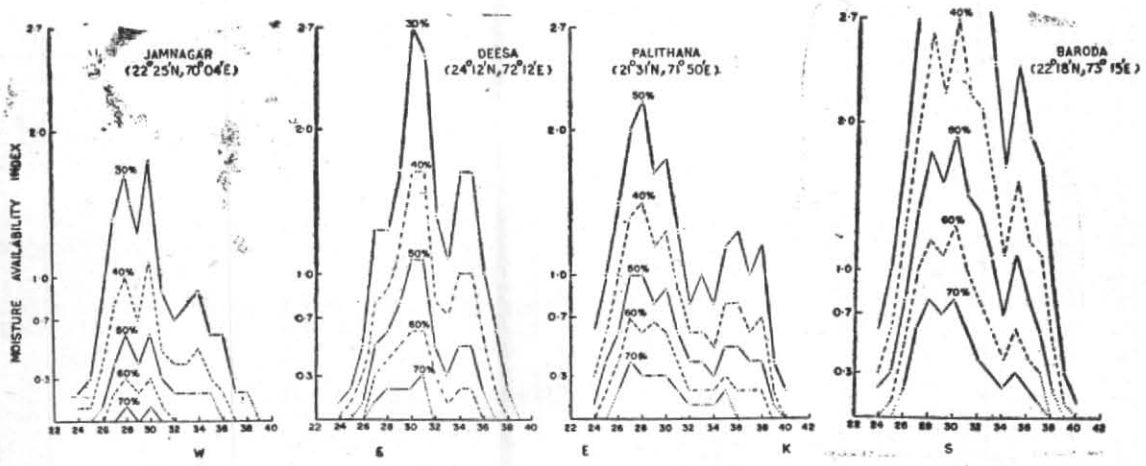

Fig. 5 Fig. 6 Fig. 7 Fig. 8

Figs. 5-8. Moisture availability index at different probability levels

more than 0.3 and 0.7 for 10 and 4 weeks respectively at 40 per cent level. A short duration crop (ground-nut, pulses) may be raised. A crop of 13-16 weeks duration (jowar, millet) may be possible to be raised as total assured rain at 30 per cent probability is about 400 mm.

4.5.2. *Deesa*

It represents the sandy loam soil of zone E. Depth of the soil is about 60 cm with good porosity. Field capacity of the soil is 12-14 per cent by weight. Salinity is one of the major problems which is further increased due to deposition of desert sand containing salt.

Fig. 6 depicts MAIs at different probability levels. The number of weeks with MAI more than 0.3 and 0.7 is 10 and 3 weeks respectively once in two years. A short duration cereal like ground-nut and pulses may be raised with one/two irrigations. Crop prospect at 40 per cent level is good as MAI is more than 0.7 for 10 weeks. Plants can thrive on stored moisture after cessation of rainy season as total assured rainfall there will be more than PE by 150 mm at 30 per cent level. A crop (jowar, millet) of 14-16 weeks duration may be raised in rainfed condition.

4.5.3. *Palithana*

It represents medium black soil of climatic zone F. Depth of the soil is about 60 cm. Colour of the soil is dark grey to light grey. It has medium porosity and hardly any problem of drainage.

MAI at 50 per cent probability level is more than 0.3 for 13 weeks from 25th to 38th except 34th week (Fig. 7). A crop of 12-14 weeks duration (jowar, millet, pulses) may be possible to be raised. Rainfed crop at 60 per cent probability level is not possible to be grown. Crop prospect at 40 per cent level is very good as MAI is more than 0.7 for 9 weeks and total assured rainfall is about 420 mm. Short duration cotton, jowar and ground-nut may be suitable in this land. Two short duration (khariff followed by rabi crop) crops or a mixed crop may be raised once in three years because crop may use stored moisture at the end of rainy season as total assured rainfall is more than PE by 115 mm.

4.5.4. *Baroda*

Baroda comes under zone G having alluvial sandy loam soil. Depth of soil varies from a few centimetre to more than a metre. There is hardly any difference observed in respect of soil properties at different layers. Drainage problem is not much as the soil is having good porosity.

As MAI is more than 0.7 for 11 weeks and total assured rainfall is more than PE (Table 2), a crop of 14-16 weeks duration (short duration cotton, paddy and millet) may be planned for this station at 50% level. Fig. 8 and Table 3 show that 11-13 week duration crop is possible to be raised in rainfed condition at 60 per cent probability level. A short duration crop (ground-nut, pulses) may be grown with one or two irrigation even in 70 per cent level. A mixed crop or two short duration crops may be raised at 40 per cent probability level. Crop prospect at 30 per cent level is very high as crop can thrive about 4 weeks after cessation of rainfall.

5. Conclusions

The present analysis enables one to demarcate the dry farming tract of Gujarat into four zones. The zone D is the low crop potential area; rainfed crops are possible to be raised in about 30-40 per cent of the years. A short duration crop may be grown from area E at 40-45 per cent probability level. Area F has the potential to raise a crop in 50-55 per cent of the years. Rainfed crops may be raised more than 60 pe cent of the years from area G.

Duration of stress period at different probability levels and time of life saving irrigation at various levels could be identified from this study.

Soil moisture storage at the end of rainy season at different risk levels could be roughly identified so as to find out where the crop could thrive on stored moisture after cessation of rain.

The core of low crop potential area is located around western part of dry farming tract and an area comprising of Ranpur, Danduka and Dholera, where accumulated assured rainfall is only about 100 mm at 50 per cent probability level but at 40 per cent level it exceeds 400 mm.

Acknowledgements

The author wishes to express his sincere thanks to Dr. R.P. Sarker, Deputy Director General of Meteorology (C & G), for his guidance and encouragement. The author also thanks Dr. A.K. Mukherjee, Deputy Director General of Meteorology (WF), Shri S. Venkataraman, Retired Director, Shri P.E. Morey, Smt. N.N. Khambete and Shri P.S. Nayar for their constructive criticism. Thanks are also due to the staff of DFR unit and drawing branch and Shri S.R. Das for typing the paper.

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Appendix I

Week No.	Dates	Week No.	Dates	Week No	Dates	Week No.	Dates
1	1- 7 Jan	14	2- 8 Apr	27	2- 8 July	40	1- 7 Oct
2	8-14	15	9-15	28	9-15	41	8-14
3	15-21	16	16-22	29	16-22	42	15-21
4	22-28	17	23-29	30	23-29	43	22-28
5	29- 4 Feb	18	30- 6 May	31	30- 5 Aug	44	29- 4 Nov
6	5-11 Feb	19	7-13 May	32	6-12 Aug	45	5-11 Nov
7	12-18	20	14-20	33	13-19	46	12-18
8	19-25	21	21-27	34	20-26	47	19-25
9	26- 4* Mar	22	28- 3 Jun	35	27- 2 Sep	48	26- 2 Dec
10	5-11 Mar	23	4-10 Jun	36	3- 9 Sep	49	3- 9 Dec
11	12-18	24	11-17	37	10-16	50	10-16
12	19-25	25	18-24	38	17-23	51	17-23
13	26- 1	26	25-1 Jul	39	24-30	52	24-31**

*In leap year the week No. 9 will be 26 February to 4 March, *i.e.*, 8 days instead of 7.

**Last week will have 8 days, 24 to 31 December.