CS–52

DROUGHT IMPACTS ON AGRICULTURE—A CASE STUDY

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE—247 667 (U.P.)

1990—91

PREFACE

Drought, the precursor of famine, is undoubtedly one of man's worst natural enemies. Not only does it affect the social and economic life of millions of people every year, but from time to time the existence of whole nation is endangered. There have been a number of drought years in our country in the current century. The economy of the country which is largely based on agricultural production, gets affected due to frequent occurrences of droughts.

In order to asses the impact of droughts on Agriculture, this study has been carried out for the district of Khargone of Madhya Pradesh. Since the IMD has given classification of droughts based on variations in rainfall amount, an effort has been made to classify droughts based on variations in agricultural areas. The agricultural drought indices have been mainly based on rainfall deficiency (both amount and distribution) and occurrence of dry spells, evapotranspiration, soil moisture deficit and water balance. Effect of these factors on crop yield is generally considered as a measure of drought. The agricultural drought indices based on various factors have been discussed in this report.

This report entitled 'Drought Impacts on Agriculture - A Case Study' is a part of research work of 'Drought Studies Division' of the Institute. The study has been carried out by Shri V K Lohani, Scientist 'C',

Shri Sudhir Kumar Goyal, Scientist 'B' and Shri Anupam Srivastava, Ex-S.R.A. under the guidance of Dr. G C Mishra, Scientist 'F'. The manuscript has been typed by Shri Rajneesh Goyal, L.D.C. and Shri S S Kanwar, Documentation Officer.

ROORKEE

SATISH CHANDRA

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Drought is a global problem affecting various countries in the world. There have been a number of drought years in our country in the current century. The economy of the country which is largely agriculture based, gets affected due to frequent occurrences of droughts. In view of frequent occurrences of droughts in the country, the Institute initiated studies on hydrological aspects of droughts. The effects of droughts on groundwater and streamflow regimes were evaluated in these studies.

In order to assess the drought impacts on agriculture, a study was carried out for the district of Khargone in M.P. It was found that the water year of 1985-86 showed a seasonal rainfall deficiency of 44.41%. Analysis of groundwater regime indicated a falling trend in groundwater levels over the years as a result of rainfall deficiency. The crop yield and cropped area as reported during the year were compared with the average values of these during 1976-80. It was found that during the year the average yield of most of the crops, namely; Jowar, Groundnut, Bajra, Wheat, Maize etc. got dreduced by 50% as compared with average values during 1976-80. The cropped area as reported during 1985-86 was compared with the average figures of cropped area during 1976-80. It was found that during 1985-86, there has been 37.3% reduction in cropped area in wheat crop. It was further evaluated that the crops of groundnut, bajra, and wheat were worst affected from both yield and cropped area points of view.

1.0 INTRODUCTION

Drought is a dreadfully familiar word whose reference can easily be found in our scriptures and other records of antiquity all over the world. Hardly does the country appear to be overcoming the blows of a serious drought when another, probably the more vicious, strikes it tending to throw out of gear the careful economic planning and strategies. It is generally viewed as a sustained and regionally extensive occurrence of lower precipitation, soil moisture, river runoff or ground water as compared to their normal values. The variation of rainfall in the country over space and time has created conditions that about one third of the geographical area and 29% of the population of the country are affected by drought.

The occurrence of drought leads to depletion of soil moisture, reduction in stream flow and consequent reservoir and tank levels and depletion of ground water. Their occurrence on a continued basis leads to reduced domestic and industrial water supply, reduction in availability of fodder and decline in agricultural production.

During recent years, the occurrence of drought has led to use of latest techniques for studying various aspects of it. In view of the repleated occurrences of droughts, the Institute initiated studies on hydrological aspects of drought in six drought prone states. Upto year 1987-88, six districts in each state have been taken up for such study. In the state of Madhya Pradesh, the districts of Khargone, Jhabua, Shahdol, Dhar, Sidhi and Betul have been taken for studies. While these study reports have highlighted hydrological aspects of droughts, it was decided to carry out studies to find impacts of drought on agriculture. Accordingly the district of Khargone, where the position of data availability was relatively better, was chosen for such a study. Since the IMD has given classification of droughts based on variations in rainfall amount, a suggestion was made to classify droughts based on variations in agricultural areas. The present report, thus, presents analysis of data for assessment of drought impacts on agriculture.

2.0 AGRICULTURAL DROUGHT INDICES

2.1 General

Agricultural drought indices have been developed and used by many workers. A meaningful définition of agricultural drought is the situation when soil moisture in the crop root zone and rainfall are inadequate to support healthy crop growth during any part of the growing season leading to water stress, crop wilt and damage of the crops. Availability of useful moisture to crop could be a better index of agricultural drought.

The agricultural drought indices have been mainly based on rainfall deficiency (both amount and distribution) and occurrence of dry spells, evapotranspiration, soil moisture deficit, and water balance. Effect of these factors on crop yield is generally considered as a measure of drought. The indices other than rainfall deficiency, take into according soil moisture budgeting approach in some way or the other. The general form of basic water balance equation is:

$$(P + I) - (Q \pm D + AE) = W$$

where P = precipitation, mm

I = irrigation water, mm

Q = surface runoff, mm

D = deep drainage below the root zone, mm (opposite sign when there is groundwater table contribution)

AE = actual evapotranspiration, mm

W = chance in soil water storage, mm

During condition of drought, associated with extended rainless period and in the absence of irrigation, the terms P, I, Q and D are zero or negligible, thus study of evapotranspiration and soil water content changes become very important for drought analysis. The agricultural drought indices based on various factors are dicussed below:

2.2 Indices Based on Rainfall Deficiency and Dry Spells

Different limits of rainfall deficiency have been proposed by various workers and organisations to study their impacts on agricultural drought (Malik, 1963, Malik & Govindaswsamy, 1962-63, NCA, 1976). It has been defined as an occasion when weekly rainfall in four consecutive weeks is half of the normal or less (normal weekly rainfall being 5 mm or more) in the period from middle of May to middle of October or six such consecutive weeks during the rest of the year (NCA, 1976). Khambete and Biswas (1964) inferred from their drought study over the dry farming tract of Maharashtra that agricultural drought occurs when there is a rainfall deficiency of less than 18 mm per week during the month June to October. Sastry and Chakravarty (1984) defined drought in consideration of crop growth stages and considered a day having less than 6 mm of rainfall as a dry day. If a dry week of seven such sequential dry days occurs 4 times during vegetative, 2 times in tasselling, 4 times in grain filling and maturity phases of maize crop or 10 times during sowing to harvest of this crop, it is called an agricultural drought. Chowdhary et al. (1979), Victor and Sastry (1979), Ramana Rao et al. (1979) and many others have tried probability analysis of occurrence of 'dry spells' of short and long duration (raining from few days to 2 to 3 weeks) for determining droughtproneness and crop planning generally using Markov-Chain model. The probability of rainfall occurrence at various probability levels on weeklly basis has been also attempted by many to study agricultural drought using Weibull plotting position formula (Rao & Phulari, 1984; Sikka & Soni, 1987 and others). Studies have been carried out at the National Institute of Hydrology on dry spell analysis for 24 drought prone district of six states (NIH, CS-24).

2.3 Indices on Rainfall and Evapotranspiration

Since rainfall governs the water supply and evapotranspiration represents the crop water demand, both of these hydrologic variables have been used to define index of agricultural drought.

2.3.1 Climatic crop growth indices (CCGI)

In order to replace crude rainfall indices, Presscott (1958) advanced this index in Australia considering the fact that water need of growing plants is dependent on climatic conditions vis-a-vis complex association between soil and vegetation. This index utilises plant soil rainfall interaction concept in any indirect way and uses different ratios of pan evaporation to classify intensity of droughts. The CCGI is given as:

$$CCGI = P/E^{0.75})$$

where P = rainfall , and

E = measured or calculated evaporation rate

Das et al. (1971) modified this equation using potential evapotranspiration (PE) estimates instead of E and gave the following equation :

$$CCGI = P/(0.769\ PE)$$

Das (1980) classified the country into various drought intensity classes using this concept for advocating necessary soil conservation measures.

2.3.2 Ratio of rainfall to PE

This ratio has been used for obtaining various moisture condition classes in India (IMD) and abroad (FAO). Hargreaves (1974) estimated monthly rainfall at 75% probability level and used ratio of this to the average monthly PE for classification of agro-climate of Brazil and designated this ratio as 'Moisture Availability Index (MAI). Biswas and Nayar (1984) applied MAI (defined as ratio of probabilistic rainfall of a week to PE) for agricultural drought studies. The percentage disparities of actual rainfall from the normal requirement of paddy crop for each month and for the season were calculated and classified in five categories of drought of different intensities with respect to this crop in West Bengal by Misra (1983) as given below:

Categories of droughts	Percentage departure of rainfall from the normal requirement of crop
Very slight drought	Less than 10
Slight drought	10-20
Moderate drought	21-40
Severe drought	41-60
Disastrous drought	More than 60

2.4 Based on Water Balance Method

Water balance computations have been extensively used in drought studies by providing an estimate of the moisture availability to the crop over time and space. The knowledge of probable moisture deficiency (i.e. the extent to which AE fall short of the PE) helps in identifying the onset of drought, its severity and planning water management schemes to lessen the effect of drought. In this direction, aridity index of Thornthwaite and index of moisture adequacy (IMA) have been used with different threshold values for different crops and regions and also on seasonal and weekly basis.

2.4.1 Aridity index for agricultural drought

Aridity index (Ia) may be defined as:

$$Ia = \frac{PE - AE}{PE} \times 100 = \frac{\text{Water deficit}}{\text{Water need}}$$

Where: PE = Potential evapotranspiration

AE = Actual evapotranspiration

Chowdhary et al. (1977), Appa Rao (1983) and few others used weekly aridity anomalies using Thornthwaite and Mather (1955) water balance model to study the incidence, spread, intensity and cessation of agricultural droughts on the basis of following drought intensity classification criteria.

Drought Intensity	Aridity anomaly(%)
Mild	25
Moderate	26-50
Severe	More than 50

The aridity anomalies maps are prepared by IMD on weekly basis for the country to identify and monitor drought on a regional scale as a useful tool to faramers and planners.

2.4.2 Index of moisture adequacy (IMA)

The ratio of actual to potential evapotranspiration (AE/PE) also known as the index of moisture adequacy (IMA), indicates the rate at which moisture is available to the crop compared to its water demand. Subrahmanyam et al.(1963), Subramaniam and Sastri (1979), Sastri et al. (1984),Patel et al.(1986) and others have employed this criteria using Thornthwaite and Mather (1955) water balance approach to study agricultural droughts in India. Subrahmanyam et al.(1963) concluded that most of the agricultural crops in India do not seem to have favourable conditions for development below 40% value of IMA (i.e. AE/PE =0.4 which corresponds to aridity index of 60%). A value in the range of 60-100% of IMA is required for efficient growth and development of rice. Similarly for millets a lower range of 40-60% was suggested. Subramaniam and Sastri (1979) obtained the minimal value of IMA (i.e. above which yield is always higher than the average yield and below which it would be lower than the average) for pearl millet, sorghum and finger millets for Andhra Pradesh in the range of 52 to 58%. Studies have been done in Rajasthan and Rayalseema region of A.P. to find out minimum values of IMA required for different crops and the results are given in following table:

Table 1: Values of Index of Moisture Adequacy (IMA) for Different Crops

Station	Kharif pulses%	Bajra (Pearl millet)%	Jowar (Sorghum) %	Groundnut %
Rajasthan				
Jaisalmer	20	20	20	-
Jodhpur	38	40	43	-
Bikaner	27	30	35	-
Ganganagar	29	30	35	-
Rayalaseema				
Anantapur	-	50	48	60
Cuddapah	-	62	58	68
Chittoor	-	58	60	76
Kurnool	-	56	54	60

The departure of IMA from the minimal value can be considered as a yardstick of measurement of drought intensity. The following classification has been suggested for various regions:

Departure of IMA below the minimal value		Agricultural drought intensity
Andhra Pradesh	**Western Rajasthan**	
Less than 10%	5%	Moderate
10 to 20%	5-10%	Large
20 to 30%	10-15%	Severe
Greater than 30%	15%	Disastrous

The seasonal values of IMA may not be as accurate in analysing agricultural drought (e.g. Kharif) as the IMA values at different crop growth stages are different because different growth stages have varying vulnerability to moisture stress. Efforts have been made by Ramana Rao et al. (1982), Sastri et al.(1982), Ramakrishna (1986) & Patel et al.(1986) to suggest optimum values of IMA (i.e. AE/PE) during different growth stages of different crops in Rajasthan & Madhya Pradesh for crops like pearl millet, soyabean , rice, black gram etc. The optimal required values of AE/PE during seedling, vegetation, reproduction and maturity stages of dry land crop in general were given as 0.25, 0.50 , 0.75 and 0.25 respectively by Ramna Rao et al. (1979), based on the knowledge of crop water requirements. In general. the maturity stage may not be that important as water stress during this stage is not that detrimental to crop yield. A generalised classification of growth stages with no specification of any crop suggested by Ramana Rao et al. (1981) is as below:

AE/PE (%) during different growth stages	Drought Intensity
76 to 100	No drought
51 to 75	Mild drought
26 to 50	Moderate drought
25 or less	Severe drought

Sastri et al.(1982) have presented a scheme of drought coding for pearl millet which is the major rainfed crop in Indian arid zone considering AE/PE ratio at seedling, vegetative and reproductive stages of crop growth.

2.5 Crop Moisture Index

Palmer (1968) modified PDSI to better reflect agricultural drought conditions and developed crop moisture index to prepare weekly crop moisture index map of USA for the growing season as a measure of agricultural drought. The Crop Moisture Index (CMI) considers agricultural drought as an evapotranspiration deficit.

The final crop moisture index is the algebric sum of the two numbers, namely the evapotranspiration anomaly index and the wetness index. The CMI stands at or near zero at the start of growing season, remains near zero so long as the crop moisture supply and the weather are near normal, and returns to near zero at the end of growing season. Negative values of CMI always mean that evapotranspiration has been abnormally deficient. CMI provides short term (Upto about 4 weeks) abnormal dryness or wetness affecting agriculture, responds rapidly, changes considerably from week to week and indicates normal conditions at the beginning and ending of the growing season. The studies conducted by Biswas (1984) at Hisar, indicate that the Palmer crop moisture index failed to explain the behaviour of crop conditions and analysis of agricultural droughts under rainfed crops. A new crop moisture index developed by him is reported to have explained the crop conditions in accordance with results obtained from experimental plots under dry land agriculture. The agricultural drought has been classified as under based on the crop moisture index values during the growing season of the crop:

CMI	Category of agricultural drought
0 - 0.33	Extremely dry
0.34 - 0.75	Dry
0.76 - 1.00	Semi-dry
1.01 - 2.00	Normal
2.01 - 3.00	Moist
3.01 - 4.00	Wet
4.01	Extremely wet

2.6 Based on Soil Moisture

Soil moisture is one of the important components of land phase of hydrologic cycle from where plants extract moisture for their evapotranspirational needs. Soil moisture deficit (i.e. the difference between field capacity and actual or current soil moisture) beyond a certain limit adversely affects plant growth and causes wilting. This results in declined agricultural production which is normally taken as a measure of drought. It is observed that the crop would normally sustain permanent injury when soil moisture falls below permanent wilting point and this may lead to situation of severe or disastrous drought. Therefore, availability of useful soil moisture to the vegetation appears to be a better index of agricultural drought. Van Bavel (1953) suggested the definition of drought on the basis of soil moisture conditions and resultant plant behaviour, rather than on some direct interpretation of the rainfall record. A drought day was defined as a 24 hour period (starting at the time of the day at which the precipitation of the previous day was recorded) in which the soil moisture stress exceeds a limit which, on the basis of experimental evidence, may be taken as a point at which the productive processes of the crop are appreciably decrased. On this basis, number of drought days for each season can be computed. Wilhite and Glantz (1985) quoted the studies done by Kulik in 1960 which represented drought intensity as the difference between plant water demand and available soil water. It was reported that the upper 0.2 m of soil was critical to plant growth because of nutrient supplies, root activity and activities of micro organisms.

2.6.1 Soil Water Models for Drought

A multitude of soil moisture accounting models have been developed by several investigators (Holmes and Robertson, 1959; Baier and Robertson, 1966; Saxton et al. 1974; Thornthwaite and Mather, 1955; Smart, 1983 and Jain and Murty, 1986) but less attention has been paid to application of these models for drought analysis and management.

Some of the investigators have tried to use soil moisture models in drought related studies (Cordery, 1981; Owtadolajam, 1982; Smart, 1983; Khaliki, 1984; Sikka & Mishra; 1986 and others).Owtadolajam (1982) and Khalili (1984) employed a soil water budgeting model to simulate soil moisture stress (i.e. the difference between potential and actual evapotranspiration) of forage and rangeland production in semi-arid and arid areas of USA. Single layer soil model applying the concept of Bukyko-Selleers water balance approach was used. The general form of regression model of soil moisture stress to yield was:

$$Yield = a_o + Sum (a_i \times Stress_i)$$

The above relationship represents annual production as a linear function of the individual stresses from various months or seasons. The coefficients a_o and a_i indicate the relative influence of various monthly or seasonal stresses on herbage production. Sikka and Lohani (1987) have used the ratio of soil water deficit (SWD) and Available Water Holding Capacity (AWC) to characterise drought conditions using following classification:

If, SWD/AWC	=	0.7 to 0.8	Moderate drought
SWD/AWC	=	0.8 to 0.9	Severe drought
SED/AWC	>	0.9	Disastrous drought

The authors have analysed drought conditions for pearl millet crop in Jodhpur, Rajasthan.

3.0 DESCRIPTION OF STUDY AREA

As has been described in earlier section, the distict of Khargone has been chosen for the present study. The selection of district was governed by data availability status. The district has an areal extent of 13490 sq. km., and is located between 21° 22' and 22° 35' North latitude, and 74° 25' and 76° 14' East longitude. The distict shares its northern and eastern boundaries with Dhar and Indore districts of state of Madhya Pradesh and southern and western boundaries with Dhulia and Jalgaon districts of state of Maharashtra (Figure 1.0). The district map with taluks is shown in Figure 2. For most of its length, the district boundary is delineated by natural features. The northern boundary runs along the watershed line of the Vindhyan Scrap, the Narmada river and some of its tributaries. In most of the portions, the southern boundary is formed by the Aner river and Manial Nala, which drain into the Tapti river. A part of the western boundary is formed by the Jharkal river, a southern tributary of the Narmada river. Only the eastern boundary by and large can be called to be an artificial demarcation.

The Narmada is the main river that flows through the district except some tributaries of the Tapti river. The Narmada, an inter-state river of the country, rises near Amarkantak in state of Madhya Pradesh at an elevatioin of 400 m. The major tributaries of the river are Kundi, Board, Dab, Goi, Karam and Choral. The Tapti river has no important tributary flowing through the district. The length and catchment area of some of important rivrs and streams lying within the Khargone district are given below in Table 2.

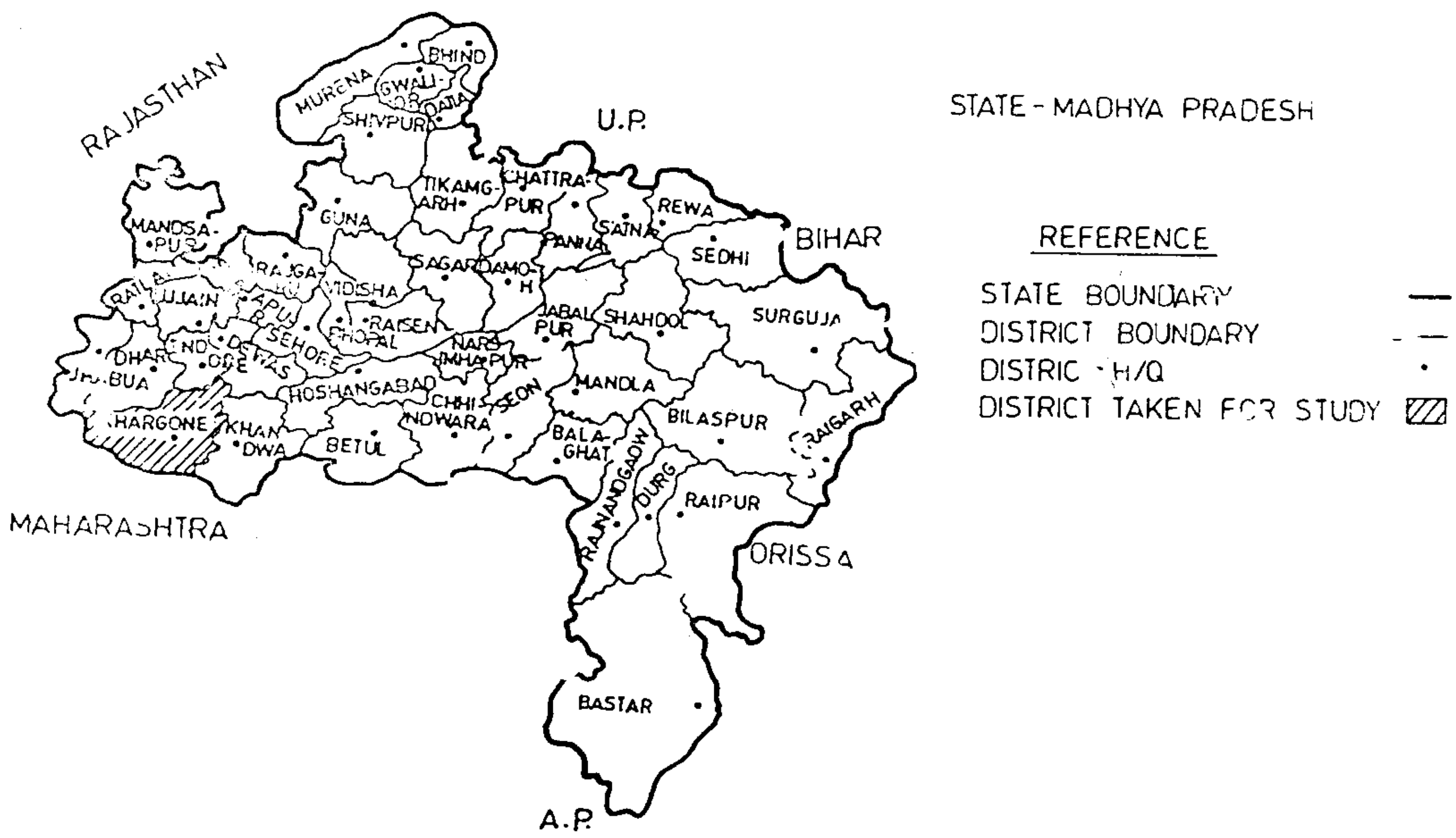

Fig.1 : Map of M.P. state showing location of Khargone district.

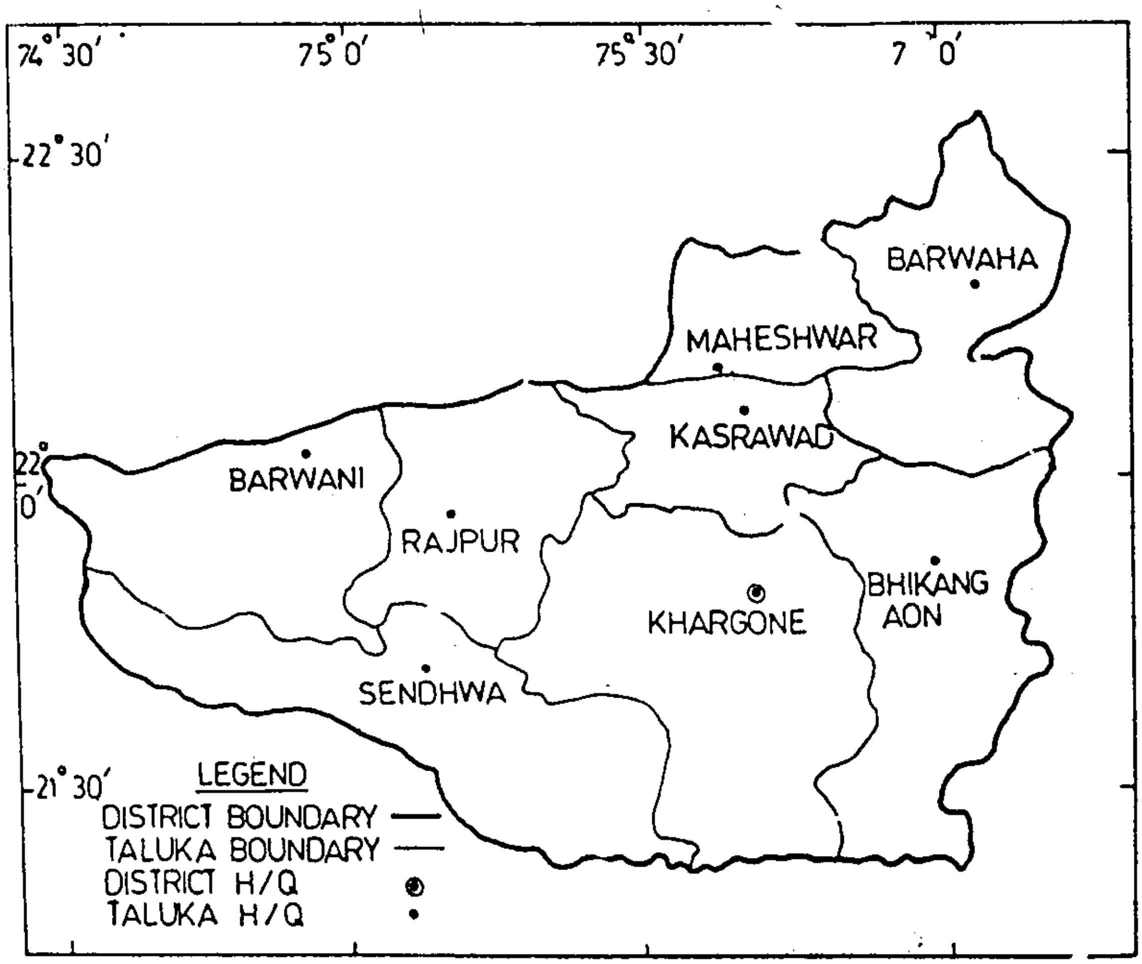

Fig.2 : Map of Khargone district showing various taluks.

Table 2: Length and catchm ... eas of rivrs in Khargone District

Name of the rivers	Length in district in km.	catchment area in sq. km.
A.- **Narmada Basin**		
i) Choral	277	167.6
ii) Kharkia	552	823.0
iii) Kundi	121	3823.0
iv) Karam	21	150.4
v) Board	64	866.0
vi) Dab	84	969.0
vii) Goi	129	1892.0
viii Direct catchment of Narmada		3123.0
B. **Tapti Basin**		
Direct catchment of of Tapti	6	1680.0
	Total	13490.0

The Khargone district has 1764 inhabited and 324 unhabited villages. 134 of the inhabited villages are forest villages. In addition, there are 13 towns. The population of the district according to the 1981 census is 16,36,682. Out of the total population, 85% people live in rural areas. The percentage of people engaged in agriculture profession is 40% of rural population and 34% of the total population of the district (CWC, 1982).

CROPPING PATTERN

Agriculture is the main occupation of about 40% of the people living in rural areas. There are two main cropping seasons viz., Kharif from last week of June to September and Rabi from October to March. More than 80% of the main source of water is used for more than 80% of Kharif crop and only about 20% of

Rabi crop. The rest of the areas in both the seasons is largely dependent on well and tank irrigation. The main crops of the district are Jowar, Rice, Wheat, Maize, Bajra, Groundnut and cotton. Table 3 presents the average area (in the period 1976-80) under 10 major crops in the district covering about 74% of the total cropped area.

Table 3: Average Area Under Different Crops

Sl.No.	Name of crop	Average area in hectares
1.	Jowar	146230
2	Rice	18916
3.	Pulses	137416
4.	Groundnut	62983
5.	Bajra	33339
6.	Castor	26
7.	Wheat	39870
8.	Maize	38642
9	Sugarcane	3415
10.	Cotton	162947
	G.Total	498554

RAINFALL AND SOIL

The normal seasonal rainfall of the district is 792.74 mm, which is below the average annual rainfall of the state. The district gets 91.23% of annual rainfall from the south west monsoon. The soils of the district fall under different categories of black cotton soils. The soil colour range varies from red to deep brown and black.

4.0 METHODOLOGY AND ANALYSIS OF DATA

As per the objectives of the study, data concerning annual rainfall, longterm normal value of rainfall, yields of crops during different years representing drought and normal years and total cropped area during various years of analysis were collected. The results as reported in the study report on hydrological aspects of droughts for year 1986-87 were used for making inferences regarding classification of drought and its impacts. Accordingly, the drought classification was done based on following criteria as adopted by the IMD:

% departure from normal rainfall	Drought classification
0.00 or above	No drought
0.00 to -25.00	Mild drought
-25.1 to -50.0	Moderate drought
-50.1 or less	Severe drought

The seasonal normal rainfall (May-November) computed for the district was reported as 792.74 mm. The seasonal rainfall for year 1985-86 was computed as 440.7 mm. This represents a negative departure of 44.41 percent and thereby as per IMD criteria, the district faced moderate drought conditions during the year. In order to compare the annual rainfall during year 1985-86 with the rainfall of previous years, data was collected since year 1976. Table 4 gives percentage departure of rainfall from normal for various years under study.

Table 4: Seasonal Rainfall Departure

Year rainfall	Seasonal rainfall (mm)	Seasonal normal rainfall (mm)	% Departure
1976	907.96	792.74	+14.53
1977	697.77		-14.25
1978	790.69		- 0.26
1979	726.31		- 8.38
1980	609.99		-23.05
1981	976.6		+23.19
1982	530.9		-33.03
1983	819.1		+ 3.33
1984	561.8		-29.13
1985	440.7		-44.41

It canbe observed from Table 4 that 1984 and 1985 have experienced deficiency in seasonal rainfall. It may further be noted that the rainfall in year 1978 was close to seasonal normal rainfall.

Impacts on Ground Water Regime

Ground waster is a valuable resource which plays an important role in water supply for arid and semi-arid regions. Because of improper management of groundwater aquifers after development, numerous undesirable consequences such as the depletion of aquifers and ground water mining emerge, especially during drought years. Statistics recently compiled on the use of ground water and surface water show that in a number of areas, ground water is being over exploited in certain pockets resulting in fall in the water table. Besides entailing high costs year after year, for the deepening of wells, this results in an increased use of energy for pumping water from greater depths. Therefore withdrawal of groundwater should be restricted to average annual recharge. This will conserve water for over exploitation during drought periods. In areas where excessive lowering has taken place, possibilities of aquifer recharge augmentation should be explored and implemented. Conjunctive use planning of surface and ground water should be practised for optimal use of ground water to combat drought years.

In earlier studies, impacts of failure of monsoon on ground water regime have been assessed. About 15 wells uniformly spread over the district have been selected for working out average groundwater levels during the period of data analysis.

The water levels in the wells have been calculated with respect to mean sea level. The average values (monthly/seasonal) computed for Khargone district were plotted against time unit. The trend is ground water level fluctuations was worked out by carrying out simple regression analysis. Similarly the total rainfall each year was plotted and again a simple regression line was fitted showing trend of rainfall over the period of ground water table data analysis. These graphs showing trends of rainfall and ground water levels over the period of analysis have been shown in the Fig.3.

As can be seen from figure 3, the ground water level shows continuous decreasing trend during the period of analysis. Rate of decline in ground water level is high which shows that rate of abstraction from ground water, used for irrigation or drinking purposes, is high. This also gives the impression of less ground water recharge. Also, the continued deficiency of rainfall as shown in rainfall analysis led to the depletion of ground water. During these drought years the sustainable source for drinking, irrigation and other purposes has been ground water, since ground water is recharged mainly through precipitation, the over exploitation of this resource year after year has led to decreased ground water level.

The analysis of rainfall data and impacts on ground water regime have been presented in the earlier sections. It has been found that during year 1985-86, a seasonal deficit of 44.41% was recorded in the rainfall which resulted in over-exploitation of ground water and lowering of water tables. As a result the agriculture is bound to have impacts in the forms of reduced crop

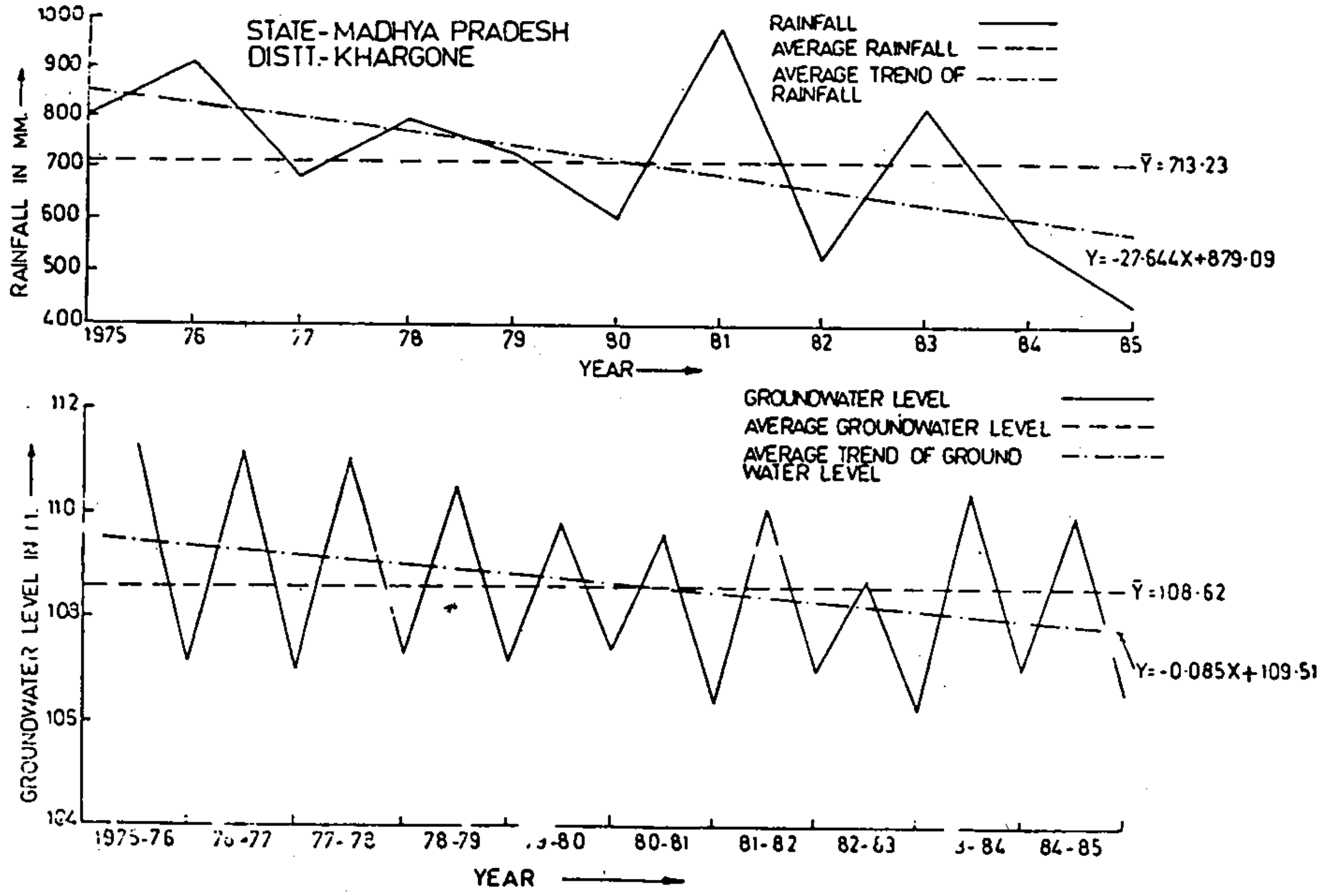

Fig.3 : Ground Water Level Fluctuations and Rainfall and Trend Analysis.

yield and reduction in cropped area. Therefore, the impacts of drought on agriculture were evcaluated from these two view points and the following sections give the analysis of data.

Impacts on crop yields

To find out the impacts of the drought on crop yields of the district, some standard yield values are needed. For this purpose two approaches have been tried. The first one is to take average of yield values of 3-4 years which are less drought affected and the second one to choose yield values of the year which has had least deviation from normal rainfall. In the former category, the yield figures fo years 1976-77, 1977-78, 1978-79 and 1979-80 were averaged as given in CWC (1982). In the latter case the yield values of year 1978 were chosen as it represented the least variation between the seasonal rainfall and seasonal normal rainfall. These yield figures were compared with the yield of year 1985-86, taken from the "Krishi Vikas Karyakram" booklet published by Department of Agriculture, Madhya Pradesh. The comparison of yield figures of 1985-86 with the average values of 1976-80 is given in Table 5. It can be observed from this table that the yield of all crops got affected during 1985-86 as a result of reduced rainfall. In more precise terms, relatively the bajra yield was reported to be affected maximum while the cotton yield was least affected. In most of the cases the deficiency in yield was by more than 50% implying that the yield got reduced to half during drought year 1985-86.

The comparison of 1985-86 yield figures with the year of 1978 is given in Table 6. It canbe seen from the Table that the yield of Jowar showed highest influence as a result of rain failure while cotton continued to have least influence. Again in most of the crops, yields were got reduced by more than 50% during drought year.

Impact on cropped area

In order to see the effects on cultivated area, the area cropped under various crops, namely Jowar, Rice, Groundnut, Bajra, Wheat, Maize and Cotton was averaged during the period 1976-80. These figures were compared with the cropped area figures as reported during year 1985-86. These values are given in Table 7. It can be observed from the table that there has been reduction in cropped areas for four out of seven different crops. Some crops have even shown increase in the cropped areas. This may be due to slight change in cropping practices over the years.

The classification of drought based on area under agriculture can be done with following assumptions:

i) Occurrence of rainfall has direct bearing on agricultural area.

ii. The effect of other factors which contribute to growth in agricultural area have been assumed to be the same throughout all the years of analysis.

iii. The normal area under agriculture is taken for the year expecting normal rainfall.

iv. The percentage departure of rainfall from normal can be correlated with the percentage departure in agricultural area from its normal value.

In order to develop such an index, data regarding percentage departure of rainfall and departure in agricultural area on annual basis are required. Percentage departure of rainfall from the normal and percentage departure of reduction in agricultural area for each year can be plotted on a simple graph paper to fit a straight line. On the basis of IMD classifications of the plot obtained as above can be divided into three categories i.e. Mild Drought, Moderate Drought and Severe Drought. The percentage departure corresponding to these deficiencies in rainfall along y axis will give range percentage departure in agricultural area for classification of drought. The Drought Index can give a rough idea about drought severity based on area under agriculture. However, it is quite a crude index and is subject to thorough testing and improvement.

Table 5 : Comparison of crop yields during 1976-80 (average figures) and 1985-86 in Khargone district

Sl.No.	Name of crop	Average yield (kg/ha.)(on the basis of 1976-80)	Average yield of year 1985-86 (kg/ha.)	%age departure of the yield of 1985-86 with respect to yield of 76-80
1.	Jowar	617.33	268.38	-56.53%
2.	Rice	610.30	263.16	-56.88%
3.	Groundnut	720.00	263.02	-63.47%
4.	Bajra	255.00	85.71	-66.39%
5.	Wheat	1361.00	640.00	-52.98%
6.	Maize	809.50	321.78	-60.25%
7.	Cotton	335.00	208.78	-37.73%

Table 6 : Comparison of crop yields during 1978-79 and year 1985-86 in Khargone district

Sl.No.	Name of crop	Average yield year 1978 (kg/ha.)	Average yield of year 1985-86 (kg/ha.)	%age departure of yield of year 1985-86 with the yield of 1979
1.	Jowar	720.00	268.38	-62.73%
2.	Rice	532.00	263.16	-50.53%
3.	Groundnut	566.00	263.02	-53.53%
4.	Bajra	202.00	85.71	-57.57%
5.	Wheat	1693.00	640.00	-62.20%
6.	Maize	702.00	321.76	-54.16%
7.	Cotton	298.00	208.62	-29.99%

Table 7 : Cropped Area in Khargone district during 1976-80 (Average figures) and year 1985-86

Sl.No.	Name of crop	Average area under the crop for year 1976-80 (thousand ha)	Area under the crop for the year 1985-86 (thousand ha.)	%age departure the area under crop year 86 with that av. year-1976-
1.	Jowar	146.23	186.30	+27.
2.	Rice	18.91	15.20	-19.
3.	Groundnut	62.98	38.20	-39.
4.	Bajra	33.39	24.50	-26.
5.	Wheat	39.87	25.00	-37.
6.	Maize	38.64	40.40	+ 4.
7.	Cotton	162.94	176.40	+ 8.

In order to assess the combined effects of reduction in crop yields and cropped area during 1985-86 as compared with average figures of 1976-80, the percentage figures of yield and cropped area were multiplied and the results are shown in Table 8. It is evident from the Table that crops of groundnut, Bajra and Wheat were worst affected by droughts while the cotton crop was least affected during 1985-86.

Table 8 : Cummulative impacts on crop yield and cropped area

Sl.No.	Name of crop	Yield in 1985-86 as fraction of 1976-80	Cropped area in 85-86 as fraction of 1976-80	Cummulative impact
(1)	(2)	(3)	(4)	(5)=(3)x(4)
1.	Jowar	.43	1.27	.55
2.	Rice	.43	0.80	.34
3.	Groundnut	.37	.60	.22
4.	Bajra	.34	.73	.25
5.	Wheat	.48	.63	.30
6.	Maize	.40	1.05	.42
7.	Cotton	.63	1.08	.68

5.0 CONCLUSIONS AND RECOMMENDATIONS

The impacts of drought on agriculture were assessed in the district of Khargone in M.P. Based on the study the following conclusions and recommendations can be drawn:

i) The district of Khargone experienced deficiency in seasonal rainfall of the order of 44.41 percent during year 1985-86. As a result the groundwater regime and agricultural activities got affected in the district. The ground water levels as recorded during the year showed minimum values as compared with previous 5-6 years.

ii) The average yield of most of the crops got reduced by more than 50% during year 85-86 as compared with the figures of yield obtained during 1976-80. The crop of cotton seems to have been least affected by drought conditions.

iii) The yield values of year 85-86 when compared with the yield of 1978-79, which had minimum deviation in terms of deficiency from seasonal rainfall, showed deficiency of more than 50% in most of the cases. The cotton still remained to be least affected crop.

iv) The comparison of cropped area during 85-86 with the average values during 1978-80 showed that as a result of drought, the wheat crop was seriously affected. The impacts of drought can be further assessed by computing figures as a multiplication of percentages of yield and croped area values. These values indicate that groundnut, bajra and wheat were the worst affected crops as a result of droughts in 85-86. The crop of cotton seems to have been least affected during 1985-86.

v) In order to develop an index based on cropped area basis, it is required to develop values of normal cropped area in a district based on long term records. Then departures of annual cropped areas from the normal values can be correlated with the departures in seasonal rainfall from seasonal normal. Using the IMD criteria of classification of drought, the corresponding criteria based on cropped area can be developed.

vi) For studies as presented in the report and future such works, the quality of data is an important aspect. Therefore, further improvements are needed in collection and storage of data concerning crop yields, cropped area, cropping patterns and climatic variartions.

ACKNOWLEDGEMENT

The authors wish to sincerely acknowledge the help rendered by authorities of M.P. Govt. during the data collection tours. The agencies which have provided the data are also gratefully thanked.

REFERENCE

1. Appa Rao,G. and G.S. Vijayaraghavan, (1983), Study of 1982 Kharif agricultural drought over India', Vayu Mandal IMD, New Delhi, India.

2. Biswas, B.C. & P.S. Nayar (1984), 'Quantification of drought and crop potential', Mausam, 35(3) pp.281-286.

3. Chowdhury, A., K.S.Ramasastri and G.S.Rentala (1977), 'A study of agricultural drought of 1965 and 1966 Kharif season', IMD Pre-published Sc.Rep.77c4.

4. Chowdhury, A. and S.S.Gokhale and G.S. Rentala (1979), 'Spells of dry days related to agricultural drought in India', Mausam 30(4): 501-510.

5. Cordery, I. (1981), 'Probabilistic forecasting of droughts Jr. of the Ind. Assoc. Hydrologists, V (1 & 2), pp.1-7.

6. CWC (1982), Identification of Drought Prone Areas in District Khargone, Report published by CWC, Delhi.

7. Das, D.C., K.Chandrasekhar, K. Hurain and P.K. Thomas (1971), 'Investigations on drought from various climatic parameters at OOotacamund', J. Agr. Engg. ISAE VIII(4), pp.13-23.

8. Das, D.C. (1980), 'Climatic Crop growth indices for drought classification and delineation in India', Personal communication.

9. Droughr Prone Area Programme of District Khargone (1980), Deptt. of Agriculture, Govt. of Madhya Pradesh.

10. Hargreaves, G.H. (1974), 'Precipitation dependability and potential for agricultural production in North East Brazil Publ. No.74-D-159, EMBRAPA and Utah State University (USA), pp.123,

11. Jain A.K. & V.V.N. Murty (1986), 'Simulation of Soil Moisture Profiles of Scheduling of Irrigation', Ag. Water, Mgt., 10, 175-181.

12. Khambete, N.N. and C.C. Biswas (1984), 'Application of Markov chain model in determining drought proneness', Mausam 35:407-410.

13. Khalili Davar (1984), 'Simulative of Range Land Resources Dynamics using Historical Rainfall Data', paper presented at the Arizona/Nevada Academy of Science and IWRD Meeting, March, 1984

14. Krishi Vikas Karyakram, Deptt. of Agriculture, M.P.Govt.

15 Malik, A.K. (1958), 'Is the incidence of drought increasing in Bihar and eastern districts of U.P.', 'Proc. Symp. Met. Hydrol. Aspects of Floods and Droughts in India, pp.65-79.

16 Malik, A.K. and T.S. Govindaswamy 91962-63), 'The drought Problem in India in relation to agriculture', Ann. Arid zone, 1(2). pp.106-113.

17 Misra, S. (1983), 'Agricultural drought over Gangetic West Bengal in relation to aman rice', Geograph review of India. 45(2) pp.72-83.

18 Owtadolajam, Esmail (1982), 'Herbage Production as a Function of Soil Moisture Stress in a Semi-arid; unpublished Ph.D. Thesis, University of Arizona, Tucson.

19 Palmer, W.C. (1968), 'Keeping tract of crop moisture conditions nationwise', The new moisture index'.

20. Patel S.R. et.al. (1986), ' pp.341-342.

21. Ramana Rao, B.V. et.al. (1979), 'A study on the water availability to the crops grown under rainfed condition in different soils of Bijapur', Mausam, 30: 469-472.

22. Raman Rao, B.V., et.al. (1982), 'An integrated scheme of drought classification as applicable to the Indian arid zone', Idojaras, 85(6), 317-322.

23. Rama . Krishna, Y.S. (1986), 'Classification of Meteorology and agricultural Drought', Jal Vigyan Sameeksha, HILTECH, NIH, Roorkee.

24. Rao, G.Rama Krishna & D.G. Phulari (1984), 'Extreme probability analysis of drought periods in monsoon in relation to water need of crop stages', Mausam, 45(3), pp.397-402.

25. Sastri, A.S.R.A.S., et.al. (1984), 'Agricultural drought and crop planning - A case study for western Rajasthan Mausam, 45(3), pp.261-264.

26. Sastry P.S.N. and N.V.K. Chakravarty (1984), 'Assessment of atmospheric drought during monsoon cropping season', Proc. WMO Symp. New Delhi, Mausam 35(3): 267-272.

27. Sikka, A.K. and G.C. Mishra (1986), 'Soil moisture simulation for drought studies', TN-17, NIH, Roorkee.

28. Sikka, A.K. & B. Soni (1987), 'Estimation of Rainfall deficit & surplus probabilities for water management & crop planning paper presented in Second National Convention of Ag. Engrs., Inst. of Engrs. (I), Hisar, Feb.-March.

29. Sikka, A.K. and V.K. Lohani (1987), 'Drought Analysis using soil moisture status', Proc. National Symp. on Hydrology, Dec.16-18, 1987, NIH, Roorkee.

30. Smart, G.M. (1983), 'Drought Analysis and soil moisture predictions', J. Irrig. Drain., ASCE, 109(2), pp.251-261.

31. Subramaniam, V.P., B. Subbarao and A.R. Subramaniam (1963), 'Moisture adequacy in relation to the distribution of a few crops in India', Proc. Berkely (cali) Symp. Int. Agri. Sci. Hydro., pp.462-467.

32. Subdramaniam, A.R. and A.S.R.A.S. Sastri, (1979), 'A rational approach to agricultural drought studies', Proc. Inter. Symp. Hydrol., Aspects of drought, New Delhi, pp.267-271.

33. Thornthwaite, C.W. and J.R. Mather (1955), 'The water balancd', Publ. in Climatology, 8(1), Drexel Insyt. of Tech., New Jersey, USA, pp.104.

34 Van Bavel, C.H.M. (1953), 'A drought criterion and its application in evaluating drought incidence and hazard' Agron. J., 45, pp.167-172.

35. Victor, U.S. and P.S.N. Sastri (1979), 'Dry Spell probability by Markov chain model and its application to crop developmental stages', Mausam, 30(4), pp.479-484.

36. Wilhite, D.A. and M.S. Glantz (1985), 'Understanding the Drought Phenomenon : The Role of Definitions', Water International, 10, pp.110-120.

DIRECTOR : DR. SATISH CHANDRA

TECHNICAL COORDINATOR : DR. G C MISHRA

STUDY GROUP : V.K. LOHANI
SUDHIR KUMAR GOYAL
ANUPAM SRIVASTAVA