Rainfall Parameters as Determinants of Area and Yield of some Selected Crops in Drought Prone Area

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Dedicated

To my late Grandfather

Ch. Tirkha Ram

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I certify that the dissertation entitled "Rainfall Parameters as Determinants of Area and Yield of some Selected Crops in Drought Prone Area" submitted by Mahabir Singh Jaglan, in fulfilment of six credits out of the total requirements of twenty-four credits for the Degree of Master of Philosophy (M.Phil) of the University, is a bonafide work to the best of my knowledge and may be placed before the examiners for evaluation.

Dated: 16.7.86

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MAHABIR SINGH JAGLAN

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CHAPTER I

INTRODUCTION

Agriculture is the dominant sector in Indian economy as it contributes about 50 per cent of national income and accounts for about 50 per cent of country's foreign exchange. 70 per cent population of the country derives its livings from this sector. Importance of agriculture in Indian economy lies not only in the fact that it provides employment to masses but also provides raw materials to the agro-based industries and food to the people employed in secondary and tertiary sectors.

Indian agriculture had for a long period of time, experienced colonial exploitation. Besides, it has also suffered from vagaries of nature e.g. floods and droughts. At the time of independence, agricultural sector was almost shattered and it did not have the capacity to feed the large population of the country. Post independence period, however, saw modest growth in agricultural production, which is mainly attributed to physical extension of cultivated land. But production became stagnant in early sixties, as physical extension of cultivated land reached a saturation level and weather continued to dominate production process in agriculture. One of the severest droughts of country in 1965-66 and similar weather conditions in the following year aggrieved the situation. Foodgrains production saw a decline from 89.37 million tonnes in 1964-65 to 74.0 and 74.23 million tonnes in the following two years, 1965-66 and 1966-67. This period exposed the vulnerability of Indian agriculture to adverse weather and need to achieve food self-sufficiency as quickly as possible.[1] With an immediate effect, strategy towards agriculture was reviewed by planners and the period of the annual plans (1966-67 to 1968-69) witnessed the formulation of a new strategy for agricultural development. New strategy included package of new agricultural technology which marked the beginning of the second phase of agricultural growth in independent India. Irrigation was the spearhead of package technology which is popularly known as "Green Revolution". Expansion of irrigation, fertilizers use and insecticides and pesticides led to introduction of H.Y.V. of seeds and hence, foodgrains production increased at modest rate, 3.3 per cent per annum over the period 1964-65 to 1970-71 and 2.8 per cent per annum over the period 1964-65 to 1978-79.[2] Intensive cropping and increase in yield, both played very important role to increase the agricultural production after mid sixties, however, later was major contributor. Hence, green revolution

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1 Research Report 28: "Growth and Equity : Policies and Implementation in Indian Agriculture", November 1981. International Food Policy Research Institute, p. 36.

2 Ibid., p. 20.

enabled to provide a break through to the stagnant agricultural economy during mid sixties. Foodgrains production increased from 89 million tonnes in 1964-65 and 74.23 million tonnes in 1966-67 to 121.03 million tonnes in 1975-76 and 131.37 million tonnes in 1978-79.

But being scale-biased and confined to irrigated tracts only, green revolution accentuated interpersonal and interregional disparities in agricultural development. Punjab, Haryana, western Uttar Pradesh and coastal Andhra Pradesh are most benefitted by green revolution. Assured supply of soil moisture in fact, forms the base of green revolution in these areas and introduction of irrigation sees its past, in some of these areas, even during British period. "The successes have largely come in the 'intermediate' areas which have been generally in the ascendant over the past century. Indeed, many of the most impressive sites of green revolution appear to be places which saw rapid agricultural growth in the period from 1880s to the 1920s and then marked time - Punjab and Doab, Godavari, Narmada and Gujarat. The problem of the drylands and of the old rice lands remain."[3] Foodgrains production, specially wheat production, has been affected by package technology. Hence green revolution has been termed as "Grain Revolution" or 'Wheat Revolution' by some scholars.

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3 Christopher J. Baker, "Frogs and Farmers : The Green Revolution in India and its Murky Past", in T.P. Byless-Smith and Sudhir Wanmali, ed. (1984), Understanding Green Revolutions, Cambridge University Press, p. 50.

Unirrigated and rainfed agricultural lands which cannot assure timely and sufficient supply of soil moisture have not been able to acquire new technology. Hence, agricultural production in these areas has increased at slow pace.

Vast area of the country is rainfed and agricultural productivity in rainfed conditions is comparatively low. More than 70 per cent of the area in the country is still cultivated under rainfed conditions. These areas contribute nearly 42 per cent of total foodgrains production.[4] Rainfed agriculture has also two phases - wetland agriculture and dryland agriculture. Although, there is no objective definition of wet and dry lands, but both concepts are viewed as opposite to each other. Wetland agriculture has rice as a major crop and sufficient soil moisture gained through rainfall during cropping season. Conversely, dryland has millets and coarse grains as major crops and does not receive sufficient rainfall to meet the demand of water. Planning Commission defines dryland as "Those areas which receive an annual rainfall ranging from 375 mm. to 1125 mm. and with very limited irrigation facility. Areas getting rainfall less than 375 mm. are absolutely arid or desert while areas getting rainfall more than 1125 mm. are as good as irrigated areas."[5]

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4 Planning Commission, India, Sixth Five Year Plan (1980-85), p. 103.

5 Planning Commission, India, Fourth Five Year Plan (1969-74), p. 153.

Fourth Five Year Plan lists 128 districts of the country under dryland. Out of them 25 districts of Rajasthan, Saurashtra, and rainshadow regions of Maharashtra and Karnataka are absolute dry, receiving rainfall between 375 mm and 750 mm. and have less than 10 per cent of cultivated land under irrigation. Twelve of the remaining districts have more than 30 per cent of cultivated land under irrigation. While the remaining 91 districts having rainfall between 375 and 750 mm. are spread over Haryana, Tamilnadu, Gujarat, Maharashtra, Andhra Pradesh, Karnataka and Uttar Pradesh.

Planning Commission's definition of dryland, however cannot be considered as objective, because annual rainfall cannot be taken as lonely criteria to delimit dryland. Dryness or wetness of land is determined by soil moisture requirement and received amount of rainfall. Soil moisture requirement or potential evapotranspiration depends on various climatic factors. Hence dryland or wetland can be delimited keeping in view, both soil moisture requirement and its supply. One of the economic characteristics of dryland is that it has very low agricultural productivity which is caused by multifacit factors. Most significant among them is persistance of moisture deficit. Dryland is very vulnerable to drought conditions. In fact, drought is a prominent feature of Indian climate and can occur even in wet areas. But the frequency of drought occurance is high in dryland as compared to wet regions.

The two terms, dryland and drought prone area, are used as synonyms. However, there is difference between the two. Concept of dryland is closely associated with the aridity, and there is difference between aridity and drought. Aridity is a climatic condition which exists permanently, while drought is a function of fluctuations in weather phenomenas. "Aridity is more or less a permanent climatic condition of low to very low rainfall areas, usually associated with higher water demand. Drought on the other hand is a temporary condition occuring in a climatic zone ordinarily adequate rainfall for vegetation or agriculture, river flow and water supply."[6] Drought can occur both in arid and humid climates.

Drought

As mentioned earlier, drought is a temporary climatic phenomenon and caused by shortfall of rainfall. Drought is caused due to long continued dry weather and insufficient rainfall which results in exhaustion of soil moisture, suffering of plants from lack of water, depletion of underground water supply and reduction and eventual cessation of stream flow.[7] It is not possible to evolve an

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6 S.N. Singh, "Climatic Peculiarities of Dryland and Drought Prone Areas : Identification of Important Parameters", Drought Prone Area Programme, Agricultural Management Training, 23 December 1978 to 1 January 1979, Department of Agronomy, Benaras Hindu University, Varanasi.

7 Tapeshwar Singh (1978): Drought Prone Areas in India, New Delhi, p. 26.

universally acceptable definition of drought because insufficiency of soil moisture, depletion of ground water supply and cessation of stream flow depend on various factors, such as climatic phenomenas, slope of the land, cropping pattern and growth stages of crops, which vary in space and time. Climatic phenomenas such as temperature, sunshine, humidity and wind velocity affect the rate of evapotranspiration. Slope of the land has effect on the percolation of rainwater. Texture and structure of soils determine their moisture retention capacity. Moisture requirement vary from crop to crop and stage to stage or plant growth. Hence, water requirement of the crops vary from region to region and time to time. Lower limit of moisture constraint tolerance can be identified for a particular region and fall of soil moisture supply below this level will hamper the crop growth. But this definition of drought cannot be applicable all over the globe because of different environmental settings.

Objective definition of drought has not been evolved till now and various scholars and research organizations have come forward with numerous definitions. They, however, agree on the point that drought is caused due to lack of rainfall. British Rainfall Organisation (1936) defines absolute drought as "A period of atleast 15 consecutive days to none of which is credited a rainfall of 0.01 inch or more." In the USA drought is defined as "a year having less than 85 per cent of the normal precipitation, a period of atleast 21 days when the precipitation is less than 30 per cent of the normal." In European Russia drought is defined as "a period of 10 days with a total rainfall not exceeding 0.2 inch." Indian Meteorological Department has defined drought as a situation occuring in any area when the annual rainfall is less than 75 per cent of the normal. It is a 'moderate drought' if deficit ranges between 25 to 50 per cent of the normal and 'severe drought', if deficit is 50 per cent or above. Some scholars also have put forward objective and quantitative definition of drought. According to Hoyt (1936) "in humid and semiarid climates droughts do not occur until the annual precipitation is as low as 85 per cent of mean". Bates (1935) says that drought occurs when annual precipitation is 75 per cent of the normal value or when the monthly precipitation is 60 per cent of the normal. Ramdas (1950) says, "drought is an occasion when actual rainfall falls short of the normal by more than twice of mean deviation."[8] Conard (1944) defines drought a period of 20 or more consecutive days without 0.25 inch precipitation in 24 hours. Henry (1960) has defined drought as a period of 21 days or more when rainfall is 30 per cent or less of average. It becomes a extreme drought when rainfall is less than 10 per cent of average for 21 days

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8 L.A. Ramdas (1950), "Rainfall and Agriculture", Indian Journal of Meteorology, Hydrology and Geophysics, vol. 1, no. 4, p. 263.

or more.

Some other scholars also have put forward definition of drought, however, most of them are subjective. As Linslay defines drought as 'sustained period of time without significant rainfall'. Blair points out that 'drought is a relative condition'. Tapeshwar Singh considers negative departure of rainfall from normal as basic indication of drought. He says that drought is "dryness due to lack of rain".

In aforementioned definitions drought has been considered as a meteorological phenomena. Other scientists such as Hydrologists, Economists, Biologists and Agricultural Scientists are also concerned with drought conditions and they view and define drought on the basis of their purpose and background. On this basis droughts can be classified as following:

(1) Meteorological Drought: Meteorologists consider drought as a rainless situation for a extended period during which some precipitation should normally have been receiyed, depending on location and season. Thomas says, "drought is a meteorological phenomena and occurs when precipitation is less than the average and when deficiency is great enough and long enough to hurt mankind."

(2) Agricultural Drought: Agricultural scientists consider drought as a shortage of soil moisture which put strains on plant growth, consequently lowers crop and animal production. Deficiency of moisture is caused by failure and decline in rainfall amount, which adversely affects agricultural productivity. According to Rosenberg (1980) "drought is a climatic excursion involving a shortage of precipitation sufficient to adversely affect crop production or grassland or horticultural productivity".[9]

(3) Hydrological Drought: Hydrologists view drought as a depression of surface or underground water levels or diminution of stream flow. According to American Meteorological Society drought is a meteorological phenomena which results in hydrological imbalance. It defines drought as "a period of abnormally dry weather sufficiently prolonged for lack of water to cause serious hydrological imbalance (i.e. crop damage, water supply shortage etc.) in affected areas".

(4) Economic Drought: Economists consider drought a shortage of water which adversely affects the established and existing economy of the region. As Russel has defined drought in Australia as "a period of months or years during which little

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9 Quoted from M.S. Swaminathan (1984), "Climate and Agriculture", in A.K. Biswas, ed., Climate and Development, Dublin, pp. 65-95.

rain falls and country gets burnt up, grass and water disappear, crops become worthless and sheeps and goats die".[10] The cognisance of adverse affect of drought on economy lead James and Gallegner to define "drought as an economic situation recognisible in crop failure".

(5) Biological Drought: Biologists treat drought as a biological, phenomena which ultimately results in adverse affect on biomass of the region, particularly plants. According to Landsberg, "drought is a biological rather than a climatic phenomena and it should be defined separately for each plant species and soil environment", Sastri says, "drought begins when plants can no longer recoup water from the soil as quickly as it is lost by transpiration".

Various scientists view drought from different point of view and have not succeeded in evolving an objective and universally acceptable definition, but they agree on the point that cause of drought occurance lies in negative deviation of rainfall from the normal. Extent of rainfall variation however depend on climatic characteristics of the concerned region. Occurance of drought results in hydrological imbalance, depletion of surface and underground water resources and soil moisture deficiency. It puts strain and stress on the biomass

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10 V.P. Subrahmanyam, *et al.* (1974), *Indian Journal of Meteorology, Hydrology, Geophysics*, vol. 15, no. 3, pp. 394-402.

of the region, i.e. withering and burning of crops, deteriorating animal health and causing their death. Deteriorating agricultural economy sees its influence in overall economic crisis of the region. Therefore, droughts ultimately adversely affect the economy of society as a whole, however, adversity might vary for various sections and classes of society.

Very few scholars have cognizance of drought from spatial point of view. Water resources and requirements vary in space and time. A region might have water requirement different from other regions and might vary during various reasons. Any definition of drought has limited scope in respect of space. It is a relative term and therefore has no precise universally acceptable definition.[11] Heterogeneity in the space, particularly in respect of precipitation, sunshine, windspeed, temperature, soil texture, soil moisture conditions and cropping pattern are responsible for not arriving at any universally acceptable definition of drought. These heterogeneous factors are not only responsible for availability of moisture at the root zones of crops but also for the rate of potential evapotranspiration. Hence a better way to define drought is to estimate potential evapotranspiration and compare it with the availability of water. When potential evapotranspiration exceeds water availability, the condition should be termed as

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11 Tapeshwar Singh, op. cit., p. 31.

drought. Severity of drought can be measured on this scale. Thornethwaite has identified drought conditions adopting water balance approach and has defined drought as 'a period of dryness of weather or climate as affects the earth or prevents the growth of plant'. Irrigation Commission has also followed water balance approach to define the drought conditions. "Drought is a result of imbalance between the soils moisture and evapotranspiration needs of an area, over a fairly long period so as to cause damage to standing crops and a reduction in crop yield".[12] Hence definition of drought conditions differ from region to region depending on water requirement and availability.

Identification of Drought Prone Areas

Drought is one of the climatic calamities in India which does not spare any climatic region, whether it is humid, sub-humid, semi-arid or arid. But its effects are more pronounced in arid and semi-arid climatic zones where rainfall variability is comparatively higher. Frequency of droughts occurance is high in Rajasthan, western Haryana, Gujarat, western Madhya Pradesh, Maharashtra, Karnataka plateau, Andhra Pradesh and Tamilnadu. Droughts also occur in humid areas and cause concern to crop production but their frequency of occurance is low and does not have severe affects on the

12 Ministry of Irrigation and Power, New Delhi, Report of the Irrigation Commission, 1972, vol. 1, pp. 156-76.

economy. "While in humid regions where rainfall is heavy, such uncertainities do not precipitate serious economic crisis consequent upon the failure of crops, but in other areas even marginal variation in the above noted characteristics of monsoon rainfall results in great suffering of people."[13]

After independence, Government of India realized the importance of identification of drought affected areas. Its prime aim was to provide relief measures to the people of the areas who used to suffer from droughts. In 1970 a committee was constituted under Planning Commission. Drought prone areas attracted attention of the Government as 19 per cent of country's area suffers from drought and accounts for 12 per cent population of the country; agricultural productivity in this area is very low and fluctuate with rainfall variability; and drought prone area contribute very little to central financial pool and cause strains on financial resources of centre in terms of relief operation. This committee recommended drought prone areas keeping in view rainfall distribution, irrigational facilities and frequency of occurance of droughts. On the basis of recommendation of this committee and proposals of state governments, Government of India identified 72 drought affected districts of which 54 are fully affected and 18 are partially affected. Drought Prone Area Programme (DPAP) was launched in

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13 Tapeshwar Singh, op. cit., p. 32.

these drought prone districts. These drought affected districts are mainly concentrated in arid and semi-arid areas but some of them are even located in humid areas of West Bengal.

Another exercise, regarding identification of drought affected areas, was done by Irrigation Commission in 1972. Irrigation Commission sought the help of Indian Meteorological Department and state governments to fulfil this task. IMD put forward earlier mentioned definition of drought to identify drought prone areas. It defines drought as 'a situation when rainfall is less than 75 per cent of normal'. It is termed as 'moderate drought' in case rainfall deficit ranges between 25 to 50 per cent and 'severe drought' in case rainfall deficit is above 50 per cent. In the framework of above-mentioned criteria, if drought occurred in 20 per cent of the examined years then that area is considered as drought affected and where it has occurred in more than 40 per cent of the examined years is termed as 'chronic drought area'. Irrigation Commission considered this recommendation to identify drought affected areas.

Governments of various states were asked to identify drought prone areas on the basis of meteorological data, revenue remission, frequency of famines and scarcity and availability of irrigational facilities. States identified drought prone areas on tehsil, taluka or thana levels. But different states adopted different criteria in absence of any concrete guideline.

Different criteria adopted by different states made the drought prone areas identified by them as incomparable. Hence, recommendations of various state governments could not provide any help in identification of drought prone areas in the country. For example, governments of Maharashtra and Gujarat considered report of Fact Finding Committee a base for identification of drought affected areas. Government of Tamilnadu chose the criteria of rainfall less than 900 mm. and irrigation less than 35 per cent to identify it. Whereas Government of Mysore (Karnataka) identified drought affected areas on the basis of the criteria, where kharif season rainfall is less than 400 mm., rabi season rainfall is less than 150 mm and variability of rainfall is more than 30 per cent in each season. Similarly, criteria of revenue remission is also different in different states. As in 'Annawari System' it is purely a subjective exercise.

Irrigation Commission has identified 67 districts as hard core areas affected by drought. Apart from the recommendations of IMD, Irrigation Commission adopted following criteria to identify drought prone areas, as rainfall less than 1000 mm., irrigated area less than 30 per cent of cultivated area and coefficient of variation of rainfall more than 20 to 25 per cent. This identification was done considering taluka or tehsil as a unit. Drought affected districts identified by Irrigation Commission are spread over arid and semi-arid areas of eight states. Complete area or some talukas of 7 districts of Andhra Pradesh, 11 districts of Gujarat, 3 districts of Haryana, 9 districts of Madhya Pradesh, 9 districts of Maharashtra, 12 districts of Karnataka, 9 districts of Tamilnadu are identified as drought prone. Both, Planning Commission and Irrigation Commission have identified almost same area in arid and semi-arid regions as drought affected. But some districts of West Bengal, Bihar, Orissa and Uttar Pradesh which figured in Planning Commission's report as drought affected have been deleted in Irrigation Commission's report.

Irrigation Commission did not consider some of the crucial climatic factors, such as temporal variation of rainfall and frequency of dry spells, in its exercise of drought prone areas identification. However, in sub-humid and humid regions where annual rainfall is sufficient to meet water requirement of crops, drought like conditions sometimes persist because of great deal of variations in weekly and monthly rainfall. Hence drought affected areas in sub-humid and humid regions of India mentioned in Planning Commission report were deleted by Irrigation Commission. Apart from temporal variation in rainfall occurance other physical and cultural factors such as temperature, vegetation cover, wind velocity, soil moisture, antecedent rainfall and topography also play an important role in causing drought like conditions. It is, however, not possible to take into account all these factors while identifying drought affected areas in a vast and diverse country like India.

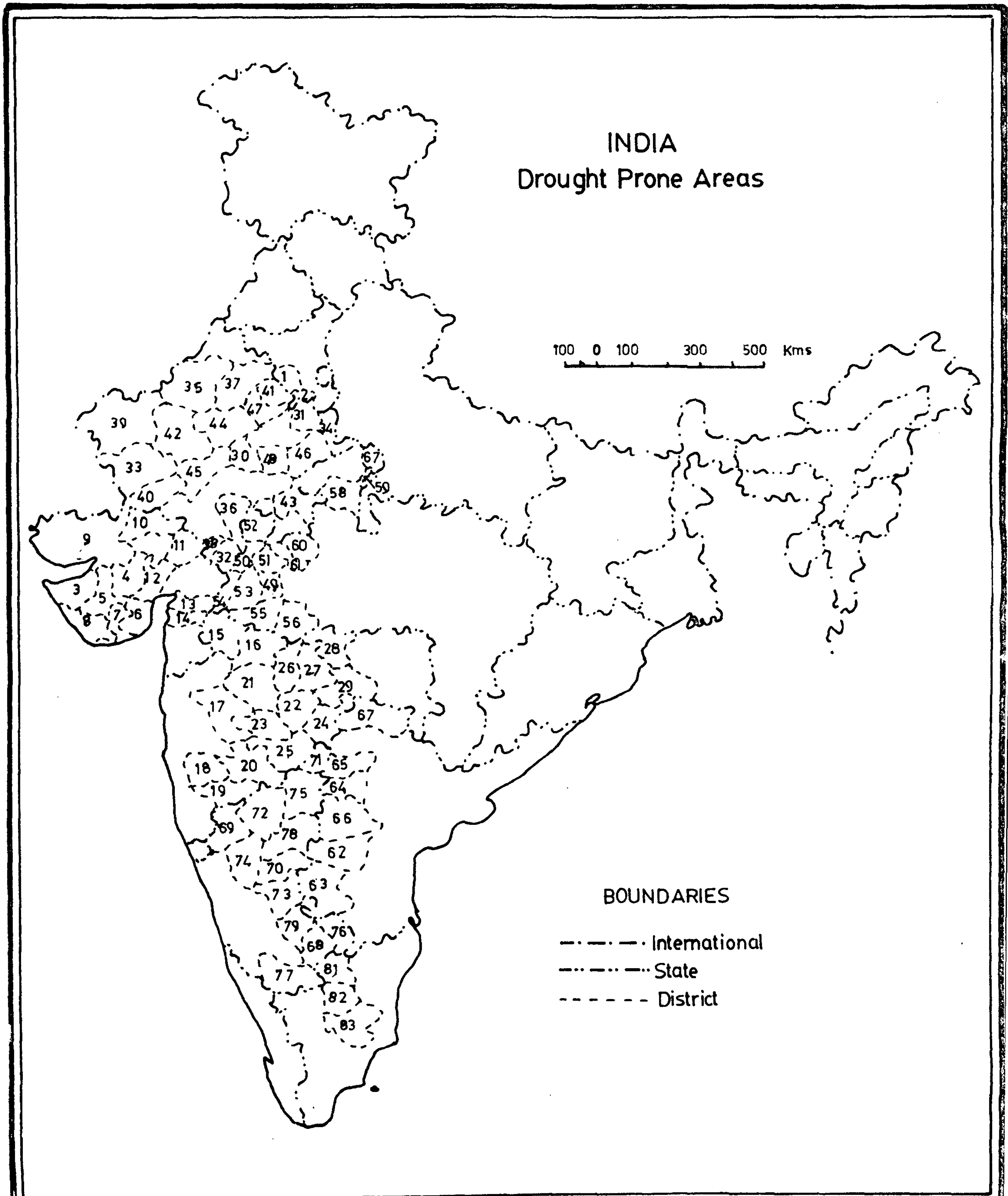

INDIA
Drought Prone Areas
100 0 100 300 500 Kms
BOUNDARIES
International
State
District

Fig.1.1

For the purpose of our study drought prone areas are identified on the basis of three parameters, viz. normal annual rainfall, irrigation and variability of rainfall and district has been chosen as a unit. 1976-77 has been taken as base year to determine proportion of gross area irrigated in gross area sown. Districts having normal annual rainfall less than 100 cm., proportion of irrigated area less than 30 per cent and coefficient of variation of rainfall more than 20 per cent have been identified as drought affected. 82 districts spread over arid and semi-arid regions of Rajasthan, Haryana, Gujarat, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka and Tamilnadu are identified as drought affected. As shown in Fig. 1.1, drought affected districts of India make a contiguous belt from Thar desert, passing through central and western plateau, to the south of Deccan lava trap.

Objective of Study

Drought prone area is a economically backward region of the co untry, having very low agricultural productivity. Yield of crops remain low and drought resistant and hardy crops dominated the cropping pattern, because of high frequency of drought occurance. Parameters of rainfall are major factors to explain variations and fluctuations in yield and acreage of the crops. Objective of this study is -

(i) to examine the influence of various parameters of rainfall viz., annual rainfall, seasonal rainfall and variability of rainfall, on the area of selected crops at two points of time, viz. 1968-69 and 1978-79;

(ii) to examine the influence of various parameters of rainfall viz. annual rainfall, seasonal rainfall and variability of rainfall, on the yield of selected crops at two points of time viz. 1968-69 and 1978-79; and

(iii) to analyse cross-sectional and temporal variations in the yield rates of selected crops in drought affected areas.

Area of Study and its Geographical Personality

The area of study is comprised of 82 districts concentrated in arid and semi-arid regions of the country. These drought affected districts are spread over 8 states viz. Haryana (2), Rajasthan (19), Gujarat (12), Madhya Pradesh (13), Maharashtra (15), Andhra Pradesh (6), Karnataka (12), and Tamilnadu (3). Details about names of drought affected districts is given in Appendix I and Fig. 1.1. Roughly drought affected area cuts across arid and semi-arid land of north western, western and central India and rain shadow areas of peninsular India.

Physiography: Drought prone areas cut across two major physiographic regions of India; Indo-Ganga Plain and Plateaux of central and south India. Drought affected area of Haryana is almost a plain land with patches of sand dunes. The blown sands have covered the western part of Ghaggar Plain. Western Rajasthan is comprised of uneven plain of Thar Desert while stoney outcrops disturb the contiguity of plain of eastern and south eastern Rajasthan. Drought prone districts of Gujarat have sandy desert land in the north, marshy land of Kutch in north west, plateau table land in central parts and coastal plain in south. Drought prone area of Madhya Pradesh cover the dissected Malwa plateau eroded by Chambal, Betwa and their tributaries and parts of Vindhyan and Satpura highlands. Drought affected areas of Maharashtra cover rainshadow and dissected plateau land of Marathwada and Vidarbha. Western districts of Andhra Pradesh, lying over Telangana and Rayalseema plateaus are drought affected. Except western coastal land and western Ghats, rainshadowed and plateau land of Karnataka is affected by droughts. While drought affected area of Tamilnadu is spread over rainshadow parts as well as northern parts of Tamilnadu plateau.

Climate

(i) Rainfall: Annual normal rainfall in drought affected areas is below 100 cm as shown in fig. 1.2. There is great deal of spatial variation in its distribution. It is less than

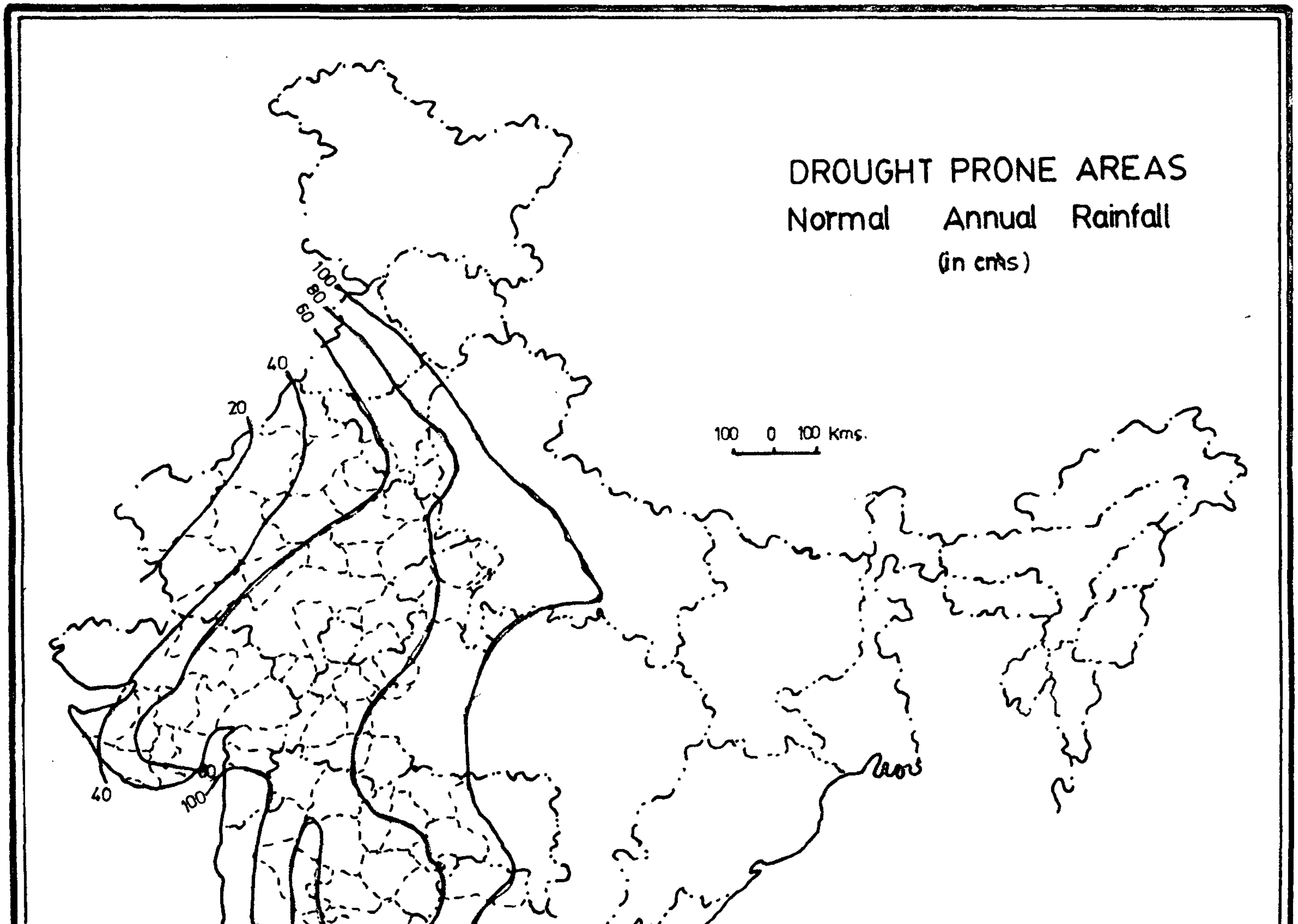
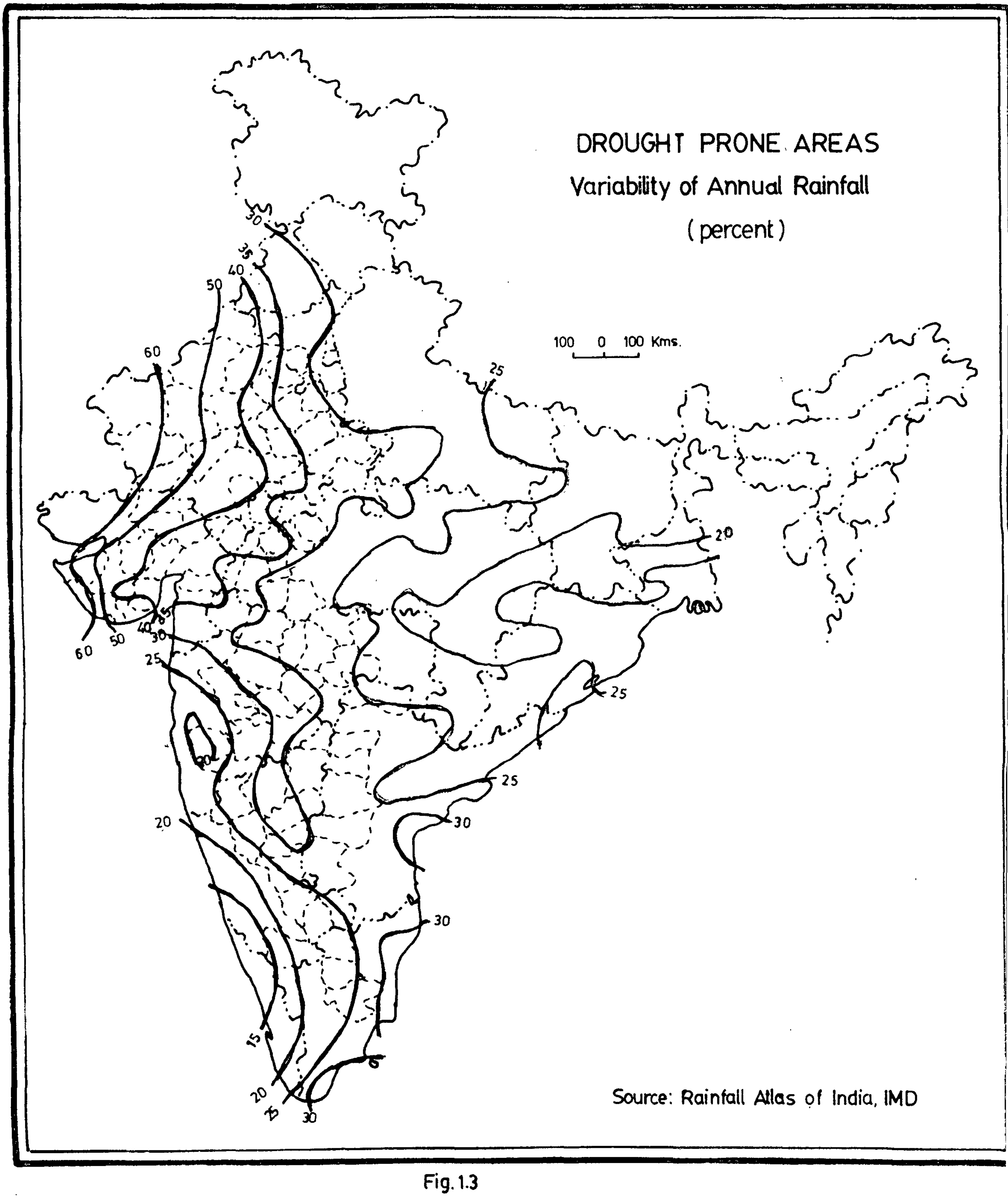

DROUGHT PRONE AREAS
Normal Annual Rainfall
(in cms)
100 0 100 Kms.
100
80
60
40
20
40
100
100
60
100
100
80
Source: RAINFALL ATLAS OF INDIA, IMD.

Fig.1.2

30 cm. in western parts of Rajasthan. For example normal annual rainfall in Barmer, Bikaner, and Jaisalmer is 27.75 cm., 26.37 cm., and 16.40 cm. respectively. It is very low in western Gujarat too, as it is 32.22 cm in Kutch. Annual rainfall is high in eastern parts of drought affected area of Madhya Pradesh. In drought affected areas of Haryana, Rajasthan, Gujarat and Madhya Pradesh annual rainfall decreases as one moves towards west. Drought prone area of Deccan plateau lies in rainshadow area of Western Ghats. While in western coastal plain annual rainfall is as high as more than 300 cm., this quantity is reduced well below 100 cm. in the eastern side of Western Ghats. For example, normal annual rainfall in two coastal districts, Ratnagiri (Maharashtra) and South Kamara (Karnataka) is 330.57 cm and 387.03 cm respectively. But annual rainfall of two adjacent drought affected districts, Sangli and Mysore which incidently are lying east of Western Ghats is 62.48 cm and 75.78 cm respectively. In the drought prone areas lying in the rainshadow in south India, annual rainfall increases as one moves east-ward because of diminishing rainshadow effects and increasing influence of north east monsoon.

Rainfall is comparatively less reliable in drought affected areas. As depicted in fig. 1.3 coefficient of variation of annual rainfall is more than 20 per cent throughout the area. Areas having low rainfall have less reliable rainfall too. It is evident from the fact that drought prone



DROUGHT PRONE AREAS
Variability of Annual Rainfall
(percent)
100 0 100 Kms.
Source: Rainfall Atlas of India, IMD

Fig. 1.3

areas of western Rajasthan and Gujarat having annual rainfall less than 40 cm have high coefficient of variation of rainfall. For example, C.V. of annual rainfall in the districts of Jaisalmer, Barmer, Jodhpur, Junagarh and Kutch is 67.71, 57.88, 57.86, 67.06 and 62.30 per cent respectively. Conversely, rainfall reliability is high in areas having high annual rainfall. Hence rainfall variability is low in drought affected areas of south India.

South western monsoon is major source of rainfall throughout drought affected areas. About 80 per cent of annual rainfall in arid and semi-arid areas of the country occur during south-west monsoon season. In Kutch and Kathiawar regions of Gujarat more than 95 per cent of annual rainfall occurs during this season. But share of south western monsoon in annual rainfall is reduced to 55 to 60 per cent in drought prone areas of Tamilnadu and adjacent parts of Karnataka and Andhra Pradesh. North eastern monsoon accounts for about 40 per cent of annual rainfall in this region. Frequent intrusions of western disturbances in north west India during winter cause rainfall in drought affected areas of Haryana and Rajasthan which is very helpful for 'rabi crops'. Sometimes cyclones also cause rainfall in some parts of Tamilnadu, Andhra Pradesh and Gujarat.

(ii) Temperature: Mean annual temperature remains above 20°C throughout arid and semi-arid climatic zones of the country. It remains above 25°C except parts of Haryana, eastern Rajasthan and some parts of Karnataka plateau. Summer temperature remains relatively higher in northern parts. June temperature in north west India remains above 30°C. While it remains between 25°C and 30°C in southern Maharashtra, Karnataka plateau, Tamilnadu and Andhra Pradesh. During winter, monthly temperature of January ranges between 10°C and 20°C in drought affected areas of north and western India, while in south it remains above 20°C. It is evident that lack of heat is not a obstacle in crop production in drought prone areas. Northern part of drought affected areas has well defined kharif and rabi seasons. In south, however, crop seasons are not well marked as temperature remains high throughout the year.

Soils: Drought prone areas of India cut across various physiographic regions and bed rocks. These areas have various kinds of soils which differ in terms of their physical and chemical properties. Desert sandy soils occupy major part of desert areas of Rajasthan, Gujarat and Haryana. There are two types of desert soils, Regosol which is a deep, coarse textured sandy soil and lithosol which is very shallow and rests on bed rocks of sandstones. Regosolic sand soils are stretched over vast desert land of Rajasthan while lithosolic soils are particularly concentrated in south west Rajasthan. Desert soils lack in humuous and nitrogen contents and their colour vary from yellowish brown to dark reddish brown. Quantity of calcium carbonate increases downwards which results into Kankar bed formation in stabilized sandy areas. Grey brown soils cover eastern Gujarat and south eastern Rajasthan. These are light textured sandy loam soils of alluvial origin. Black soils are spread over drought affected areas, Madhya Pradesh, Maharashtra, and parts of Gujarat, Karnataka and Andhra Pradesh. Derived from weathering of bed rocks of lava trap, black soils have dark colour, varying from dark brown to deep black. On the basis of their depth black soils are divided into three groups -- shallow black soils, medium black soils and deep black soils. Black soils are heavy textured with clay contents ranging from 40 to 60 per cent. They are rich in minerals, sticky and plastic when wet and hard when dry. Black soils show strong swelling and shrinkage under changing moisture conditions resulting in heavy cracking and fissuring. These soils are deficient in nitrogen and phosphoric acid and rich in organic matter, lime and potash. Red soils are spread over drought affected areas of Karnataka plateau, Andhra Pradesh and Tamilnadu. Red sandy soils are extensively spread over this region while red loamy soils cover a considerable area in western parts of Karnataka plateau. They are light textured, porous and comparatively less fertile soils. Red sandy soils are generally derived from grainites, granitiod graisses, quartzites, sand stones etc. and are characterized by being rich in coarse and fine sand fractions. The clay minerals become coated with red haematite or yellow limonite or a mixture of two oxides of iron forming a red, yellow or reddish yellow soil.[14] Red soils are also found mixed with black soils. Coastal alluvial soils cover some parts of drought affected Gujarat.

Natural Vegetation: The drought prone areas of India have very sparse natural vegetation, dominated by thorny bushes and scrubs. Tropical thorn-forests cover dryland of Tamilnadu, Karnataka plateau, Telangana and Rayalaseema, central Maharashtra, Gir forests of Gujarat, western Madhya Pradesh and north west India. 'Acacia' is dominant plant specie. Euphorbias and other thorny trees are also found in some areas. Thorny bushes and scrubs have small leaves in order to conserve soil moisture by reducing evaporation surface. Vegetation is sparsely scattered and grass is almost absent which makes the land vulnerable to erosion hazard. Tropical dry deciduous forests are, however, found in relatively wet areas of eastern Rajasthan, western Madhya Pradesh, Tamilnadu and Andhra Pradesh.[15]

Hypothesis

Attempt has been made to examine the following

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14 S.V. Govinda Rajan and H.G. Gopala Rao (1978), Studies on Soils of India, New Delhi, pp. 14-50.

15 R.L. Singh (1971), ed., India, A Regional Geography, Varanasi, pp. 15-17.

two hypotheses in the present study:

(i) Variation in area under crops in drought prone areas is function of the variations in different rainfall parameters. Area under crops increases with increase in annual and seasonal rainfall, but is inversely correlated with rainfall variability.

(ii) Variation in yield of crops in drought affected areas is function of the variations in various parameters of rainfall. Yield of crops is positively associated with annual and seasonal rainfall and negatively associated with variability of rainfall.

Period of Study

Two periods of time, 1967-68, 1968-69, 1969-70 (late sixties) and 1977-78, 1978-79, 1979-80 (late seventies), having an interval of 10 years have been chosen for the present study. Trennium averages for both periods of time have been computed to show yield levels and avreage of crops during 'late sixties' and 'late seventies'.

Crops Selected for Study

Five crops viz. Bajra, Jawar, Gram, Groundnut and Cotton have been selected for the present study. Except gram all of them are kharif crops. Jawar and groundnut are, however, sown in rabi season in some parts of peninsular India. By and large all of them are dry crops, fulfil their soil moisture requirements from rainfall.

Date Base

Area of study cuts across eight states. Hence data pertaining to districts-wise area and production of crops and rainfall parameters has been collected from various sources published by centre and states. Following are the publications of central Government utilized in the study - Statistical Abstracts of India, Agricultural Situation in India, and Indian Agricultural Statistics of concerned years published by Economic and Statistical Organization, Ministry of Agriculture, New Delhi, India. State level sources of data utilized in this study are following publications of concerned years:

(i) Statistical Abstracts, and Season and Crop Reports of Haryana, Economic and Statistical Organization, Planning Department, Government of Haryana.

(ii) Handbooks of Statistics, and Season and Crop Reports, Bureau of Economic and Statistics, Government of Gujarat.

(iii) Statistical Abstracts, and Season and Crop Reports, Directorate of Economics and Statistics, Rajasthan.

(iv) Statistical Abstracts, and Season and Crop Reports, Directorate of Economics and Statistics, Madhya Pradesh.

(v) Statistical Abstracts, and Season and Crop Reports, Directorate of Economics and Statistics, Government of Maharashtra.

(vi) Statistical Abstracts and Season and Crop Reports, Bureau of Economics and Statistics, Government of Andhra Pradesh, Hyderabad.

(vii) Statistical Abstracts, and Season and Crop Reports, Bureau of Economics and Statistics, Bangalore, Government of Karnataka.

(viii) Statistical Abstracts, and Season and Crop Reports, Directorate of Statistics, Madras, Government of Tamilnadu. Unpublished data pertaining to district-wise gross cropped area and rainfall of Gujarat, Madhya Pradesh and Karnataka for the period 1978-79 and 1979-80 has been collected from processing section of Economic and Statistical Organization, Ministry of Agriculture, Krishi Bhawan, New Delhi.

Coefficient of variation of Annual Rainfall (1901-1950) for drought affected districts has been worked out from isopleth map showing variability of annual rainfall, Agro-Meteorological Atlas of India, Indian Meteorological Department, Poona.

Methodology

In order to examine spatial and temporal variations in yield levels and acreage, triennium averages of area and production have been computed for the periods 1967-70 and 1977-80. Average triennium yields and acreage is also computed for both periods. Annual compound growth rate of yield of five crops has been computed with the help of the formula,

$$R = \left[\left\{ \text{Antilog} \left(\frac{\text{Log } x_2 - \text{Log } x_1}{i} \right) \right\} - 1 \right] \times 100$$

Where R is annual compound growth rate of yield, x_1 is yield during earlier period, x_2 is yield during later period and i is interval between two periods.

Various parameters of rainfall i.e. annual rainfall, seasonal rainfall, variability of rainfall, onset of effective rainfall, number of rainy days, intensity of rainfall and frequency of wet and dry spells, have been identified to analyse variations in yield and acreage of selected crops. However, all these parameters of rainfall could not be included in the exercise because of nonavailability of detailed district-wise data of rainfall. Two sets of dependent variables have been tied with one set of independent variables for the exercises of correlation and step-wise regression. Following are the set of variables:

(A) Independent Variables

x_1 = Annual Rainfall

x_2 = Seasonal Rainfall

x_3 = Variability of Annual Rainfall

(B) Dependent Variables

y_1 = Area under the crop

y_2 = Yield of the crop

Exercises of correlation and step-wise regression have been done for each crop for two periods of time, 1968-69 and 1978-79. Annual rainfall is total quantity of rainfall occurred during respective year and seasonal rainfall is the quantity of rainfall occurred during the season of the respective crop. Correlation matrix explains degree of association between two variables and step-wise regression examines explanatory power of independent variables.

Overview of Literature

Whether it is a humid, sub-humid, semi-arid or arid climatic zone, rainfall is a very important variable to explain variations in agricultural production. Vagaries of monsoon have been countered in some parts of the country by assured irrigation. Yet this facility is not available in vast areas. Both excess and deficit of rainfall are harmful to the crop production. The present study is concerned with drought affected areas of India which do not have sufficient soil moisture available through rainfall or irrigation. Rainfall deficiency in these areas has discernible effect on crop production. Farmers have adjusted the cropping pattern according to availability of rainfall. However, cropping pattern and crop yield are subject to variations with the fluctuations in amount of rainfall and occurance of dry and wet spells. There may be excessive rainfall during a part of the crop season but a single prolonged dry spell will spoil and burn down the crops.

In India, not much study has been done to analyse impact of rainfall parameters on area and yield of the crops. Crop-weather scheme was initiated in 1945 in the country. Agro-Meterorological Division of IMD began collecting farm environment and crop yield data under All India Co-ordinated Crop-Weather Scheme. Crops selected for study were wheat, rice, jowar, cotton and sugarcane. These studies primarily deal with the relationship between crop yield and weather phenomenas including rainfall. One hardly finds any study pertaining to area under crop and rainfall parameters relationship. Moreover, there are very few studies showing relationship between crop yield and rainfall parameters.

Ramdas (1950)[16] studies the behaviour of monsoon in India for the report of Crop outlook. He analysis rainfall data of 30 sub-divisions of country for the period of 75 years. Vagaries of monsoon rainfall have been examined taking weekly and seasonal rainfall. Sreenivasan and Banerjee (1958)[17] have utilized data collected under co-ordinated crop-weather scheme to investigate into the relationship between growth attributes

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16 L.A. Ramdas, "Rainfall and Agriculture : Use of Routine Rainfall Reports for Crop Outlooks", Indian Journal of Meteorology and Geophysics, vol. 1, no. 4, 1950, pp. 262-74.

17 P.S. Sreenivasan and J.R. Banerjee, "A Comparative Study of Rainfall and Cotton Crop under Crop Weather Scheme of Akola and Nagpur", Indian Journal of Meteorology and Geophysics, vol. 9, no. 1, 1958, p. 151.

of plants and yield of cotton, and rainfall at Akola and Nagpur. One part of the paper also deals with comparative growth of plants at various stages at two stations. Malik (1958)[18] has examined relationship between height and yield of kharif jowar and the available rainfall during vegetative growth period in south India. It reveals that height and yield of jowar are positively correlated: Deviation of rainfall from optimal rainfall value has reverse affect on height and yield. Malik etc. (1960)[19] have examined relationship between various meteorological elements, rainfall, rainy days, sunshine, maximum temperature and minimum temperature, and growth of cotton at various stages of growth. Correlation, however, turned out to be weak. Gangopadhyaya and Sarkar (1964)[20] have applied curvilinear correlation technique to examine weather-sugarcane growth relationship at Poona. Study reveals that maximum and minimum temperature cause difference in growth of sugarcane during elongation period. Rainfall turns out to be a weak variable

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18 A.K. Malik, "Height and Yield of Kharif Jowar in Relation to Rainfall during Vegetative Growth", Indian Journal of /Hydrology Meteorology/and Geophysics, vol. 9, no. 4, 1958, pp. 377-82.

19 A.K. Malik, P. Jagannathan, G. Rama Rao and J.R. Banerjee, "Preliminary Studies on Crop-Weather Relationships - Cotton", IJMHG, vol. 11, no. 4, 1960, pp. 377-82.

20 M. Gangopadhaya and R.P. Sarkar, "Curvilinear Study on the Effect of Weather on Growth of Sugarcane", IJMHG, vol. 15, no. 2, 1964, pp. 215-26.

because sugarcane is an irrigated crop. Malik (1964)[21] discusses growth features and yield of rice in relation to existing climatic elements during crop season. It shows that there is remarkable consistency in the average length of the reproductive period, and average date of flowering depends on geographical factors. Sarkar (1965)[22] has investigated into relationship between weather phenomenas during tillering and elongation phases, and yield of sugarcane at Poona. Using successive g raphic approximation method, optimal values of various weather phenomenas, rainfall, maximum temperature, minimum temperature and sunshine hours during two crop growth phases, have been computed. Weather phenomenon explain 50 per cent of variation in yield during tillering phase, and 80 per cent for both phases of growth. Gupta (1966)[23] has studied nature of dry and wet spells in Rajasthan using data of five stations, Bikaner, Ajmer, Jaipur, Jodhpur and Udaipur for the period 1891 to 1919. The study reveals that frequencies of wet spells of less than 5 days are common and for more than 10 days are rare all over the state. Frequencies of dry spell of more than

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21 A.K. Malik, "Climatology of Crop Seasons of India - Rice", IJMHG, vol. 15, no. 4, 1964, pp. 555-64.

22 R.P. Sarkar, "A Curvilinear Study of Yield with reference to Weather - Sugarcane", IJMHG, vol. 14, no. 1, 1965, pp. 103-10.

23 B.R.D. Gupta, "Frequency of wet and dry spells at five stations in Rajasthan", IJMHG, vol. 17, no. 3, 1966, pp. 451-6.

10 days are common except Jaipur and Udaipur stations. Ramamurati and Banerjee (1966)[24] have utilized curvilinear regression techniq ue to examine influence of weather on wheat yield at Dharwar. Optimal values of weather phenomenas, total rainfall, maximum temperature, minimum temperature, mean temperature, sunshine and relative humidity for wheat yield have been computed. Krishna (1968)[25] analyses climatic factors in relation to agricultural set up in Rayalseema Article studies behaviour of rainfall, water deficiency and aridity, and their influence on cropping pattern. Krishna (1969)[26] has analysed relationship between agroclimatic factors and agricultural set up in semi-arid and arid zones of Maharashtra. Influence of soil water deficiency and aridity on cropping pattern has been studied. Shaha and Banerjee (1975)[27] studied the influence of variation in rainfall, humidity, maximum temperature and minimum

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24 K.S. Ramamurati and J.R. Banerjee, "The Influence of Weather on Wheat Yield at Dharwar", IJMHG, vol. 17, no. 4, 1966, pp. 601-6.

25 A. Krishna, "Agro-Climatology of Arid and Semi-Arid Zones of India : Bellary - Bijapur and Rayalseema Tracts", Geographical Review of India, vol. 30, no. 1, 1968, pp. 24-32.

26 A. Krishna, "Agroclimatology of Arid and Semi-Arid Zones of Maharashtra", Geographical Review of India, vol. 31, no. 3, 1969, pp. 13-26.

27 S.K. Shaha and J.R. Banerjee, "Influence of Rainfall, Humidity, Maximum and Minimum Temperature on the Yield of Cotton in Coimbatore", IJMHG, vol. 26, no. 4, 1975, p. 518.

temperature on the per hectare yield of cotton in Coimbatore, using Fisher's technique of multiple correlation and regression. Study reveals that cotton yield has positive response to increase in rainfall and hours of sunshine above normal. Sreenivasan (1977)[28] discusses relationship between yield of two jowar varieties and weather elements (rainfall, minimum temperature and maximum temperature) in Sholapur. He also utilized Fisher's technique of regression which does not bring out satisfactory result for a discontinuous factor, rainfall. Bishoi and Saxena (1978)[29] have studied rainfall pattern, amount, variability and probability in relation to cropping pattern in Haryana. The state has been regionalized on the basis of rainfall parameters and cropping pattern and two maps are superimposed to see relationship between the two. Khambate and Biswas (1978)[30] have analysed distribution of wet and dry weeks during monsoon season in 15 days dry districts of Gujarat (having normal annual rainfall less than 100 cm.) It also discusses spatial variation in duration of

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28 P.S. Sreenivasan, "The Impact of Weather on two Varieties of Winter Jowar at Sholapur", IJMHG, vol. 28, no. 3, 1977, pp. 359-64.

29 O.P. Bishoi and K.K. Saxena, "A Study of Rainfall Pattern in Relation to Crop Planning over the Haryana State", IJMHG, vol. 29, no. 3, 1978, p. 501.

30 M.M. Khambate and Biswas, B.C., "Characteristics of Short Period Rainfall in Gujarat", IJMHG, vol. 29, no. 3, 1978, pp. 521-2.

dry and wet spells. Rangaswamy (1982)[31] has utilized times series station data to investigate into nature and degree of relationship between rainfall parameters and yield of improved variety (K-1) and local variety of bajra at Kovilpatti. Rainfall and rainy days of sowing, growth, flowering and maturity stages of the crop have been tried for correlation with yield, separately and compositively assuming that relationship between the dependent and independent variables in quadratic. As compared to separate parameters, composite index explains variation in yield in a better way and relationship is quadratic for both varieties.

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31 P. Rangaswamy, Dry Farming Technology in India - A of its Profitability in Selected Areas, New Delhi, 1982, pp. 141-56.

CHAPTER II

AGRO-CLIMATIC CONDITIONS AND AREA UNDER SELECTED CROPS

The five crops selected for the present study, are bajra, jowar, gram, groundnut and cotton. These are largely rainfed crops. They are mostly grown in tropical and sub-tropical low rainfall areas and are important crops in drought prone areas of India. In this chapter an attempt has been made to analyse spatial distribution pattern of area under these crops.

Bajra

Agro-Climatic Conditions for Growth

Bajra, a coarse foodgrain, is a staple crop of arid and semi-arid regions of world. It is an important crop of drought prone arid and semi-arid areas of India. It is a rainfed crop except in parts of Gujarat where high yielding varieties are irrigated. Bajra does not require high rainfall and can adjust in low rainfall, up to 25 cm. This crop can bear stresses and strains caused due to soil moisture deficiency which is a common climatic phenomenon during south west monsoon season in drought affected areas. "It is fairly resistant to drought and hence its largest acreage is found in semi-arid regions of the world

TABLE 2.0(a)

Area under some selected crops in the trienniums 1967-70 and 1977-80

((Area in hectares)

S.No.	Crop	Drought prone areas 1967-70	Drought prone areas 1977-80	Drought prone areas Annual compound Growth rate	India 1967-70	India 1977-80	India Annual compound Growth rate	Share of drought prone areas in total area under crop in the country 1967-70	Share 1977-80
1.	Bajra	8589306	7536901	-1.30	12451000	11025000	-1.22	68.98	68.36
2.	Jowar	11651789	11241154	-0.37	18586000	16379000	-1.29	62.69	68.64
3.	Gram	2062442	2362899	1.36	7704000	7556000	-0.19	26.77	31.27
4.	Ground nut	4709059	4784392	0.17	7287000	7409000	0.17	64.62	64.58
5.	Cotton	5966606	5613975	-0.55	7768000	8037000	0.35	76.81	69.85

TABLE 2.0(b)

Percentage share of drought prone areas of states in total area under some selected crops of drought prone areas (1977-80).

S.No.	Crop	Haryana	Gujarat	Maharashtra.	Rajasthan	Madhya Pradesh	Karnataka	Andhra pradesh	Tamilnadu	Total
1.	Bajra	5.17	13.11	14.92	53.02	1.33	8.44	2.07	1.94	100.00
2.	Jowar	0.06	7.11	47.31	5.20	9.85	16.97	11.03	2.47	100.00
3.	Gram	12.86	1.25	13.96	37.70	25.53	7.18	1.46	0.08	100.00
4.	Groun-nut	0.00	40.17	12.81	4.90	6.32	19.06	12.84	4.59	100.00
5.	Cotton	0.02	26.65	38.15	1.53	10.28	17.71	4.79	0.69	100.00

with inferior and lighter types of soils".[1] Bajra requires warm weather, bright sunshine and lighter soil for its better growth and output. Due to its low soil moisture requirement and short duration (which normally does not exceed 70 days) this crop can very well tolerate the adverse affects of droughts. Hence, drought affected sandy and loamy soil lands of western Rajasthan, western Haryana and Gujarat are ecologically suited for bajra cultivation.

Spatial Variation in Area under Bajra

Bajra is a major crop in north western parts of drought prone areas. This crop acquired 13.29 per cent of gross cropped area in drought prone areas during 1977-80. In fact, 68.36 per cent of bajra area of the country was concentrated in drought prone areas. Area under this crop has declined both in drought prone areas and country over the period 1967-70 to 1977-80. However, share of drought prone areas in area under bajra of the country remains the same. More than 50 per cent of bajra acreage of drought prone areas is concentrated in Rajasthan. Drought prone districts of Rajasthan, Gujarat and Haryana account for 71.3 per cent of bajra area of drought prone areas. Out of 82 drought prone districts 15 had more than 25 per cent of their total cropped area under bajra in 1967-70. These

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1 J.R. Kakde, Agriculture Climatology, New Delhi, p. 349.

Table 2.1

Spatial Distribution of Area under Bajra during 1967-70

Number of Districts

Percentage of Bajra area to GCA	Haryana	Gujarat	Maharashtra	Rajasthan	M.P.	A.P.	Karnataka	Tamilnadu	Total
35.0 and above	1	1	-	9	-	-	-	-	11
25.0- 35.00	-	1	1	2	-	-	-	-	4
15.0- 25.0	1	5	5	2	-	-	1	-	14
5.0 - 15.0	-	3	2	2	2	2	4	2	17
Below 5.0	-	2	7	4	11	4	7	1	36
Total	2	12	15	19	13	6	12	3	82

districts are located in Rajasthan (11), Gujarat (2), Haryana (1), and Maharashtra (1). Share of bajra in cultivated area is high in western Rajasthan as 88.19, 77.7, 59.7, 55.2 and 44.3 per cent of total cultivated area was devoted to this crop in Jaisalmer, Barmer, Jalore, Jodhpur and Jhunjhunu districts respectively. 11 districts had more than 35 per cent of total cultivated area under bajra as depicted in figure 2.1. 9 of them spread over western Rajasthan and one each in Haryana and Gujarat. More than 15 per cent of gross cropped area was under bajra in 29 districts which includes 13 districts of Rajasthan, 7 of Gujarat, 6 of Maharashtra and 2 districts of Haryana. Bajra producing districts of Maharashtra which are spread over the north western part of the state are Dhule, Ahmadnagar, Sangli and Aurangabad.

During 1967-70, 36 districts had less than 5 per cent of total cultivated area under bajra. 17 districts had even less than 1.0 per cent of cultivated area under this crop. It is an insignificant crop in most of drought prone districts of Madhya Pradesh, Andhra Pradesh and Karnataka and, some districts of eastern Maharashtra south eastern Gujarat and southern Rajasthan. 17 districts had 5.0 to 15.0 per cent of total cultivated area under bajra, which formed non-contiguous clusters all over drought prone area.

The pattern has not significantly changed after one decade, in 1977-80 as it is evident from table 2.2 and fig 2.1. 12 drought prone districts have more than one-fourth of

Table 2.2

Spatial Distribution of Area Under Bajra during 1977-80
Number of Districts

Percentage of Bajra area to GCA	Haryana	Gujarat	Maharashtra	Rajasthan	M.P.	A.P.	Karnataka	Tamilnadu	Total
35.0 and above	2	-	-	8	-	-	-	-	10
25.0 - 35.0	-	1	-	1	-	-	-	-	2
15.0 - 25.0	-	3	3	3	-	-	1	-	10
5.0 - 15.0	-	6	4	2	1	2	5	2	22
Below 5.0	-	2	8	5	12	4	6	1	38
Total	2	12	15	19	13	6	12	3	82

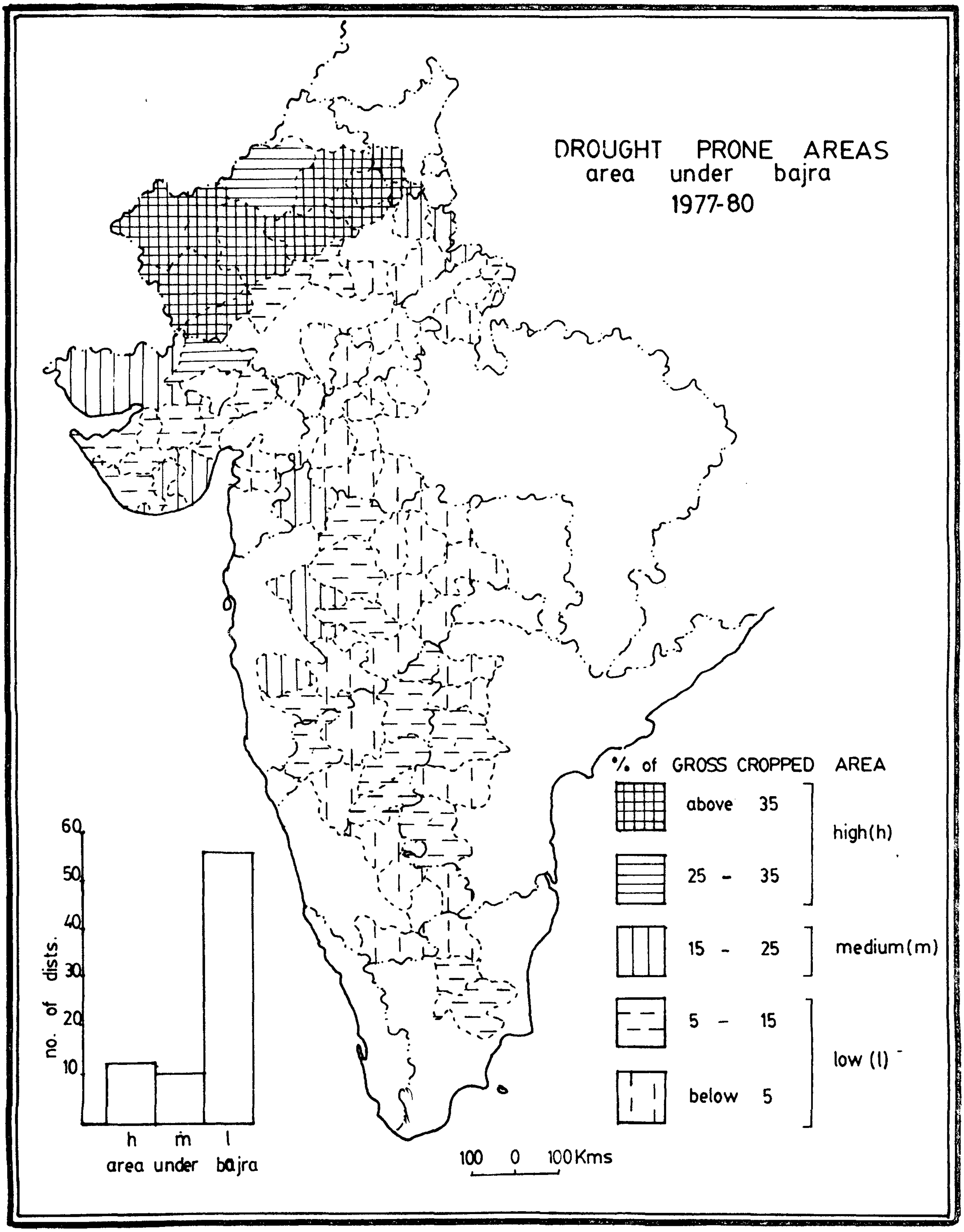
DROUGHT PRONE AREAS
area under bajra
1977-80
% of GROSS CROPPED AREA
above 35
25 - 35
15 - 25
5 - 15
below 5
high(h)
medium(m)
low (l)
60
50
40
30
20
10
no. of dists.
h
m
l
area under bajra
100 0 100 Kms

Fig-2.1

cultivated land devoted to this crop. Barmer, Jaisalmer and Jodhpur have more than 50 per cent of total cultivated land under bajra. Apart from western Rajasthan, Banasbantha in Gujarat and two districts of Haryana have more than one fourth of cultivated land devoted to this crop. In all, 22 districts have more than 15 per cent of total cultivated area under bajra, largely spread over Rajasthan, Haryana and Gujarat. Three districts of north-western Maharashtra and Bijapur district of Karnataka also fall under this category.

38 districts have little area i.e. less than 5 per cent of gross cropped area under bajra. Bajra occupies less than 1.0 per cent share in total cultivated area of 19 districts. These districts are mostly spread over Madhya Pradesh, eastern Maharashtra, Andhra Pradesh, Karnataka and southern Rajasthan. Twenty-two districts with 5 to 15 per cent of GCA under this crop spread all over drought prone areas, particularly in south eastern Gujarat, Karnataka, Tamilnadu and Maharashtra.

Comparison between tables 2.1 and 2.2 show decline in proportion of bajra area over the period, late sixties to late seventies. Share of Bajra in total cropped area has declined in almost all states except Karnataka, where it has marginally increased, and Andhra Pradesh, where it is almost constant. Share of bajra area has even declined in western districts of Rajasthan and major bajra producing districts of Gujarat and Maharashtra. In Haryana, its share has significantly declined in

Mahendergarh, however, it has increased in Bhiwani. But 1967-70 data for Bhiwani pertain to then Hissar district, of which present Bhiwani district was a part. Hissar had high percentage of irrigated area and cotton was main kharif crop, competing with bajra. It has also declined in Madhya Pradesh, where it was a marginal crop except Bhind. Decline in share of area is evident from the fact that during 1967-70 there were 29 districts having above 15 per cent of GCA under this crop. After a decade only 22 districts have more than 15 per cent of their GCA devoted to bajra. Bajra cultivation is concentrated in western Rajasthan, Gujarat, western Haryana and parts of north-western Maharashtra and north Madhya Pradesh.

Jowar

Agro-Climatic Conditions for Growth

Jowar forms staple food in semi-arid drought prone tracts, particularly in rainshadow area of peninsular India. It also occupies significant place in cropping pattern of some parts of drought affected Gujarat, Madhya Pradesh and Rajasthan. It is a kharif crop in north, while is sown in both seasons, kharif and rabi, in south. It is sown on soils with higher moisture retention capacity in south Gujarat, Maharashtra, Andhra Pradesh, Karnataka and Tamilnadu, during rabi season. North eastern monsoon showers and irrigation also add to soil moisture in extreme south of the peninsula.

Jowar is a crop of hot and dry climate, however its heat requirement varies for different varieties. It cannot survive in less than 15° C and more than 41° C temperature. 25° C to 32° C temperature range is optimum for its cultivation. Soil moisture requirement for different varieties also varies. However, it can be sown in low rainfall areas having rainfall up to 30 cm. "The sorghum belt receives an annual rainfall ranging from 400 to 1000 mm per annum, usually distributed between the last week of June and the first week of October in most parts of the country."[2] Jowar is sown on a variety of soils, sandy loam, black and red, however, deep and medium black soils are most suitable. Excess soil moisture and water logging for a long period is undesirable for this crop. Moisture deficit also adversely affects its growth and production, but it can tolerate this strain up to some extent because of its drought resistance nature. "It is known as a 'camel' in plant world due to its high ability to produce fairly well under high temperatures and low soil moisture conditions because of deep root system and effective internal control on transpiration.... In addition to a few deep roots, the high drought resistance ability of jowar is attributed also to lower transpiration rate

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2 Handbook of Agricultures (1984), ICAR, New Delhi, p. 816.

Table 2.3

Spatial Distribution of Area under Jowar (1967-70)

Number of Districts

Percentage of Jowar area to GCA	Haryana	Gujarat	Maharashtra	Rajasthan	M.P.	A.P.	Karnataka	Tamilnadu	Total
35.0 and above	-	-	7	1	2	1	2	-	13
25.0 - 35.0	-	-	4	2	4	4	4	-	18
15.0 - 25.00	-	6	4	1	4	1	3	2	21
5.0 - 15.0	-	5	-	5	3	-	1	1	15
Below 5-0	2	1	-	10	-	-	2	-	15
Total	2	12	15	19	13	6	12	3	82

and waxy coating on leaves and stalk."[3]

Spatial Varieties in Jowar Area

Jowar is an important crop of drought prone areas as it occupied 19.82 per cent of GCA during 1977-80. 68.64 per cent of jowar area in the country is confined to drought prone areas. Area under this crop has declined both in drought prone areas and the country over the period 1967-70 to 1977-80, however, decline is rapid in the latter. Percentage share of drought prone areas in the area under the crop in the country has increased from 62.69 per cent in late sixties to 68.64 per cent in late seventies. Drought affected districts of Maharashtra acquired 47.3 per cent of jowar area of drought prone areas. Drought prone areas of Maharashtra, Karnataka and Andhra Pradesh occupy 75.31 per cent of area under jowar of drought prone areas. Maharashtra, south east Gujarat, south Rajasthan, south west Madhya Pradesh, upland Andhra Pradesh, Karnataka plateau and upland Tamilnadu are jowar growing areas.

Jowar occupied more than 15 per cent of total cropped area in 52 districts, as shown in table 2.3, during 1967-70. All the 15 drought prone districts of Maharashtra, all the six districts of Andhra Pradesh, 10 districts of Madhya Pradesh, 9 districts of Karnataka, two districts of Tamilnadu, 6 districts

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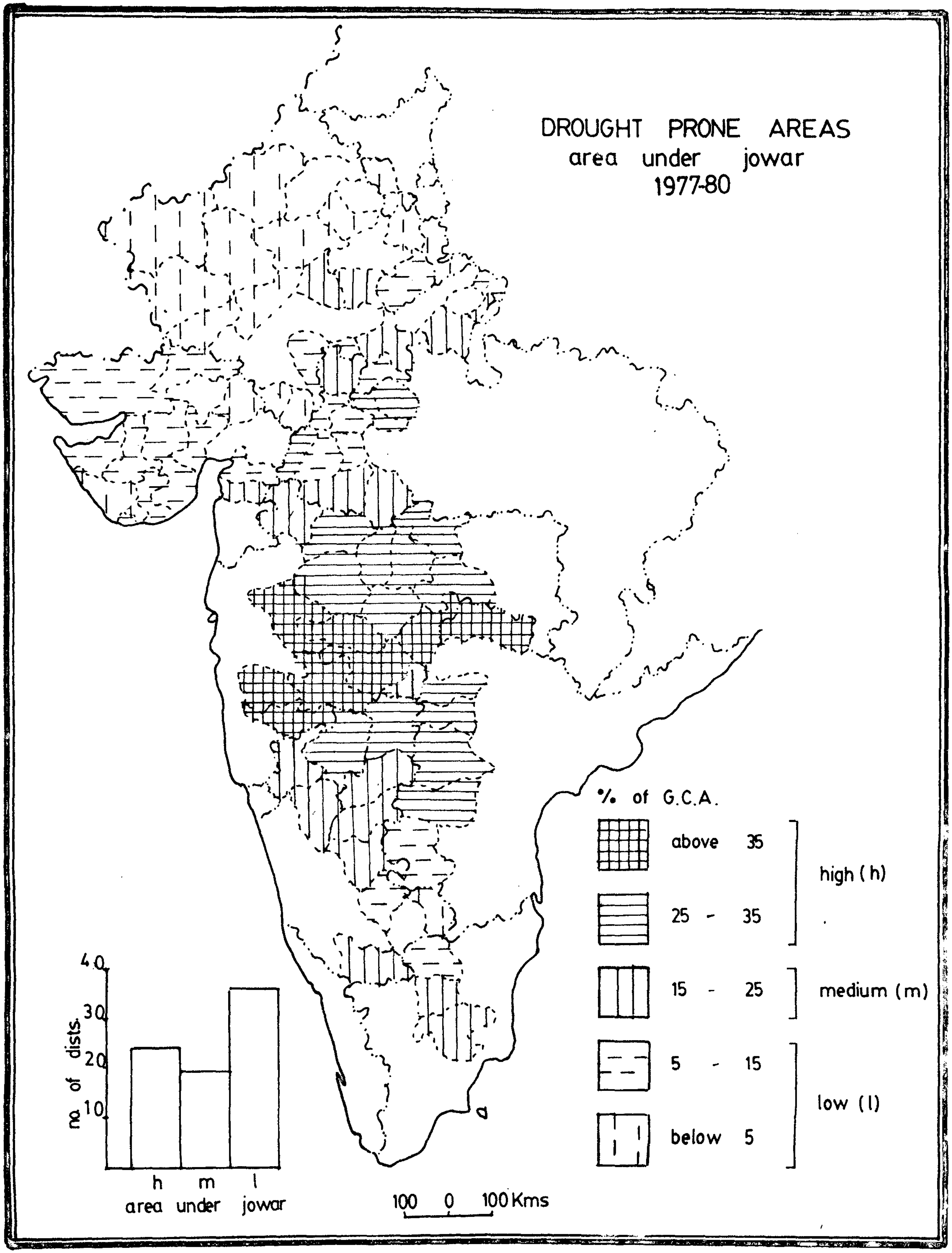
3 Kakde (1985), op. cit., pp. 332-3.

Table 2.4

Spatial Distribution of Area Under Jowar (1977-80)

Number of Districts

Percentage of Jowar Area to GCA	Haryana	Gujarat	Maharashtra	Rajasthan	M.P.	A.P.	Karnataka	Tamilnadu	Total
35.0 and above	-	-	7	-	-	1	-	-	8
25.0 - 35.0	-	-	7	-	3	4	2	-	16
15.0 - 25.0	-	1	1	3	5	-	7	2	19
5.0 - 15.0	-	9	-	2	5	1	1	1	19
Below 5.0	2	2	-	14	-	-	2	-	20
Total	2	12	15	19	13	6	12	3	82



DROUGHT PRONE AREAS
area under jowar
1977-80
% of G.C.A.
above 35
25 - 35
15 - 25
5 - 15
below 5
high (h)
medium (m)
low (l)
no. of dists.
40
30
20
10
h
m
l
area under jowar
100 0 100 Kms

Fig-2·2

of Gujarat and 4 districts of Rajasthan fall under this category. 31 districts had more than one fourth of total cropped area under jowar. Most of them are located in peninsular India. 13 districts, particularly in Maharashtra, had devoted more than 35 per cent of gross cropped area to this crop. It reveals that jowar region of drought prone area is confined to black soil region of Maharashtra and Gujarat and red and laterite soils of Madhya Pradesh, Andhra Pradesh, Karnataka and Tamilnadu. Jowar occupied less than 15 per cent of gross cropped area in 30 drought prone districts, mainly in Rajasthan, Haryana, western Gujarat, north western Madhya Pradesh and southern parts of Karnataka. In 15 districts less than 5 per cent of GCA was under this crop and seven districts of western Rajasthan had negligible area (less than 1 per cent of GCA) under jowar.

Table 2.4 and fig. 2.2 depict spatial variation in jowar acreage during 1977-80. 43 districts have more than 15 per cent of gross cropped area occupied by jowar. These districts are located in peninsular and central drought prone areas including all the 15 districts of Maharashtra, 8 districts of Madhya Pradesh, 9 districts of Karnataka, 5 districts of Andhra Pradesh and 2 districts of Tamilnadu. In eight districts, of which 7 lie in Maharashtra, jowar occupied more than 35 per cent of GCA.

Thirty-nine districts, spread over Rajasthan, Gujarat, Haryana, Madhya Pradesh and Karnataka have less than 15 per cent of cultivated area under this crop. It is not important crop in

20 districts where it occupies less than 5 per cent of total cropped area. Its average is almost negligible (less than 1 per cent of GCA) in 11 districts, most of whom are located in Rajasthan.

It is evident that jowar is a major food crop in drought affected parts of south and central India. It is a fodder crop in north parts of Rajasthan, Haryana and western Gujarat. Its cultivation is almost negligible in western Rajasthan.

Comparison of table 2.3 and 2.4 depicts that share of jowar area in GCA has declined in almost all drought prone districts, except those of Maharashtra and Andhra Pradesh where it has increased and Tamilnadu where it is almost constant. In Gujarat, except Brauch, share of jowar acreage has declined in all districts. During late sixties, six of the drought prone districts in Gujarat had more than 15 per cent of GCA occupied by jowar. The figure reduced to 1 after a decade. Jowar acreage share has increased in all districts of Maharashtra, except Akola where it has declined marginally. In Andhra Pradesh also share of jowar area has increased except in Anantpur.

Gram

Agro-Climatic Conditions for Growth

"Gram is the most important pulse crop accounting for more than a third of the area and about 40 per cent of the production of pulses in this country."[4] It is a rabi crop, sown in the semi-arid areas of western Ganga Plain, eastern Rajasthan, Madhya Pradesh, Punjab and Haryana (in low to medium rainfall areas). This crop utilizes retained soil moisture, however showers due to 'western disturbances' and some irrigation in Punjab and Haryana also add to soil moisture. Retained and conserved soil moisture during south western monsoon season and late monsoon's showers form base of its cultivation.

Being a crop of winter season, gram can tolerate minimum temperature up to 5° C, but frost is harmful. Optimum temperature range for this crop is 15 to 30° C. Excessive rainfall during the early stages of growth and flowering is harmful. Sudden rise in temperature in early summer season harms the crop, as it shortens growing period and quickens maturity which consequently reduces yield. It is sown on a variety of soils as alluvials in north western India and black, clay loam, and red soils of central and south India. Lighter alluvial soils are, however, suitable for gram.

Spatial Variations in Gram Area

Gram is not an important crop in drought prone areas, as it acquired only 4.08 per cent of GCA in 1977-80. Its cultivation is mainly confined to eastern Rajasthan, Madhya Pradesh

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4 Handbook of Agriculture (1984), op. cit., p. 839.

Table 2.5

Spatial Distribution of Area Under Gram (1967-70)

Number of Districts

Percentage of Gram area to GCA	Haryana	Gujarat	Maharashtra	Rajasthan	M.P.	A.P.	Karnataka	Tamilnadu	Total
20.0 and above	2	-	-	2	2	-	-	-	6
15.0 - 20.0	-	-	-	1	-	-	-	-	1
10.0 - 15.0	-	-	-	3	1	-	1	-	5
5.0 - 10.0	-	-	-	2	5	-	-	-	7
Below 5.0	-	12	15	11	5	6	11	3	63
Total	2	12	15	19	13	6	12	3	82

Table 2.6

Spatial Distribution of Area under Gram (1977-80)

Number of Districts

Percentage of Gram area to GCA	Haryana	Gujarat	Maharashtra	Rajasthan	M.P.	A.P.	Karnataka	Tamilnadu	Total
20.0 and above	2	-	-	1	2	-	-	-	5
15.00 - 20.00	-	-	-	1	1	-	-	-	2
10.0 - 15.0	-	-	-	7	4	-	1	-	12
5.0 - 10.0	-	-	1	4	4	-	-	-	9
Below 5.0	-	12	14	6	2	6	11	3	54
Total	2	12	15	19	13	6	12	3	82

and western Haryana. Drought affected districts of these states acquire 76.09 per cent of area under this crop in drought prone areas. Gram occupies about two fifth of gross cropped area in western Haryana. Drought prone areas acquired about one-third (31.27 per cent) gram area of the country. Percentage share of drought prone areas was less in late sixties (26.77 per cent). Area under this crop in the country has declined (by -0.19 per cent per annum) over the period 1967-70 to 1977-80, however, it has increased in drought prone areas by 1.36 per cent per annum.

During 1967-70, as table 2.5 depicts, twelve districts had more than 10 per cent of gross cropped area occupied by gram. Eleven of them are located in drought prone areas of Rajasthan, Haryana and Madhya Pradesh and one in Karnataka. Six districts, two each in Haryana, Rajasthan and Madhya Pradesh, had more than one-fifth of their total cropped area devoted to this crop. Bhind, in Madhya Pradesh, has highest share of gram area in GCA followed by Datia, Bhiwani, Bharatpur, Alwar and Mahendragarh. 70 districts had less than 10 per cent total cropped area under this crop and 63 had even less than 5 p r cent. All districts of Gujarat, Maharashtra, Andhra Pradesh, Tamilnadu and many districts of western Rajasthan, Karnataka and Madhya Pradesh are included in this marginal gram producing area. Thirty-five districts located in south India and Gujarat had negligible area (less than 1.0 per cent of GCA), under this crop.

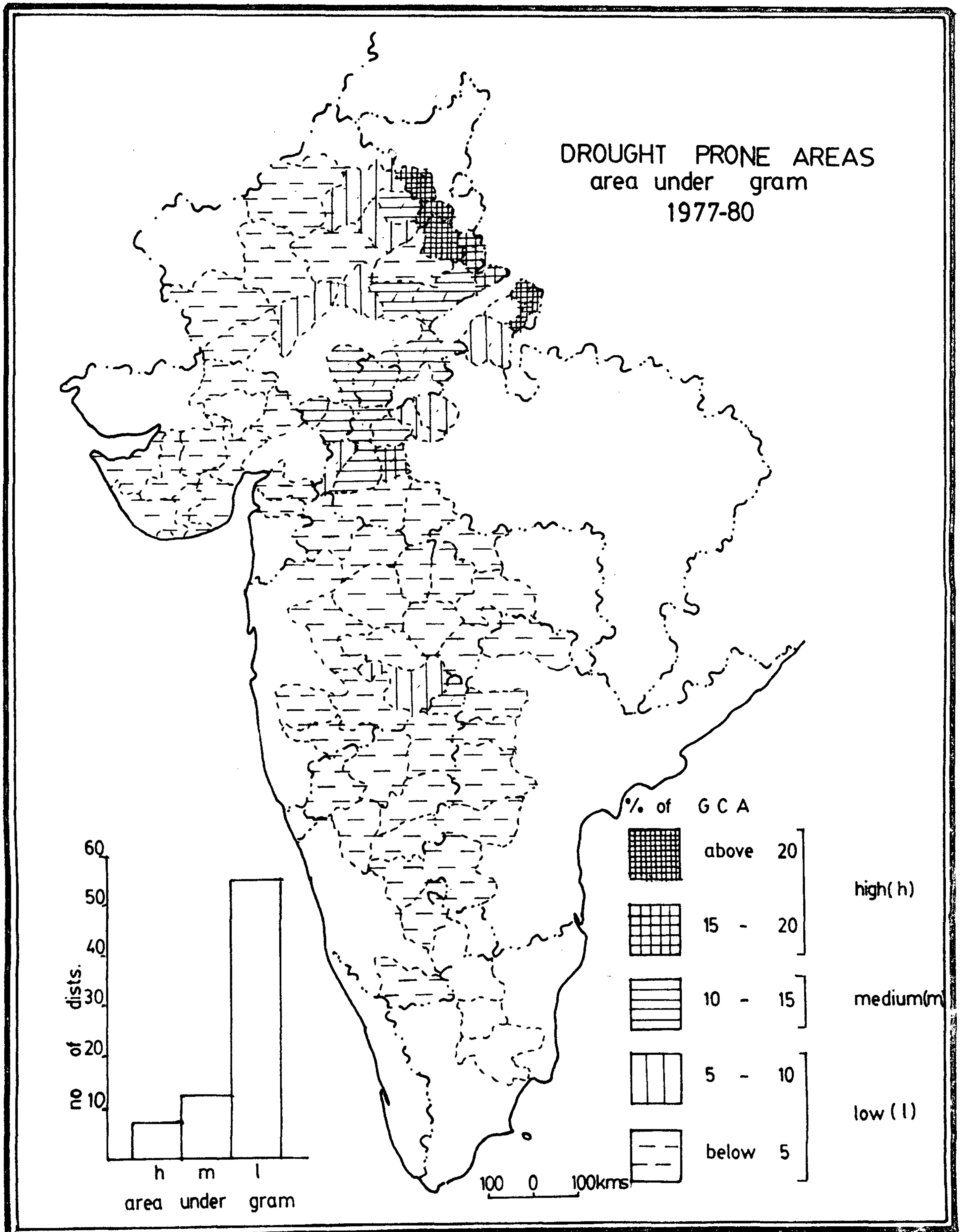
DROUGHT PRONE AREAS
area under gram
1977-80
% of GCA
above 20
15 - 20
high(h)
10 - 15
medium(m)
5 - 10
below 5
low (l)
100 0 100kms
60
50
40
30
20
10
no of dists.
h m l
area under gram

Fig-2·3

After a decade (table 2.6 and fig. 2.3) 19 districts had more than 10 per cent of GCA occupied by gram. Nine of them are located in Rajasthan, 7 in Madhya Pradesh and 2 in Haryana. Seven districts have more than 15 per cent and 5 districts have more than 20 per cent GCA under this crop. These districts are spread over north western Madhya Pradesh, eastern Rajasthan and south western Haryana. Bhiwani district in Haryana has highest share of gram area amongst drought prone districts.

63 districts have less than 10 per cent of GCA occupied by gram. 54 of them have less than 5 per cent area under this crop. 28 of these districts have negligible area (below 1 per cent of total cropped area) under gram. In Gujarat, Maharashtra, Andhra Pradesh, Karnataka, Tamilnadu, western Rajasthan and eastern and southern Madhya Pradesh the area under gram is insignificantly low.

Comparison of tables 2.5 and 2.6 shows that most drought prone districts except some in western Madhya Pradesh, eastern Rajasthan and south-western Haryana have not registered significant growth in proportion of gram area in total cropped area. Drought prone districts of Gujarat, Maharashtra, Andhra Pradesh, Karnataka, Tamilnadu and western Rajasthan devote insignificant area to gram cultivation and the same pattern persists during both periods, 1967-70 to 1977-80. While in western Rajasthan and Gujarat, inadequate south west monsoon rainfall is a handicap in cultivation of this crop, high temperature and competition with jowar and groundnut are major causes for having low area under this crop in south India. Gram growing districts of Rajasthan, Madhya Pradesh and Haryana continue to have increase in proportion of gram area in gross cropped area. Number of districts having more than 10 per cent area under gram have increased over the period 1967-70 to 1977-80, from 6 to 9 in Rajasthan and 3 to 7 in Madhya Pradesh. Proportion of area under this crop has increased in Bhiwani district of Haryana from 25.1 per cent to 35.5 per cent. But the availability of data for Bhiwani for the years 1967-70 is questionable. Proportionate increase of gram area is constant in Mahendergarh district.

Groundnut

Groundnut is an important commercial oilseed crop in India. "India occupies the first position both in regards to the area and the production in the world. About 7.5 million hectares is put under it annually and the production is about 6 million tonnes... Seventy per cent of the area and 75 per cent of the production are concentrated in the four states of Gujarat, Andhra Pradesh, Tamilnadu and Karnataka.... The irrigated area forms about 6 per cent of total groundnut area in India."[5] Semi-arid drought prone areas of India have occupied major place in terms of acreage of groundnut. This crop depends primarily on rainfall for moisture except parts of drought affected areas of Tamilnadu and Karnataka.

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5 Handbook of Agriculture (1984), op. cit., p. 924.

Agro-Climatic Conditions for Growth

Groundnut is a moderately moist and warm climate crop and requires abundant sunshine. Its cultivation is normally concentrated between 30° and 45° N latitudes of the globe. Less than 10°C temperature is not conducive for this crop. 22°C to 32°C temperature range is optimum for its growth and yield. Normal duration of groundnut crop is 130 days. 500-700 mm rainfall, which is fairly distributed is adequate, particularly for quick ripening varieties. "The crop can be grown successfully in places receiving a minimum rainfall of 500 mm. and a maximum rainfall of 1,250 mm. The rainfall should be distributed well during the flowering and pegging of the crop."[6] Very high temperature and low rainfall which lead to soil moisture deficit are harmful for this crop as it is very sensitive to moisture stress during flowering and maturity. "It is worst affected in growth and yield by moisture stress conditions during intensive flowering for pegging and pod development."[7]

Groundnut requires light clay, rich in calcium, and well drained soils. Heavy and stiff clays are not suitable for cultivation of this crop because they hamper pod development and have poor drainage. Well drained sandy loam, loamy and black soils give high yield of groundnut. These soils are

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6 Handbook of Agriculture (1984), op. cit., p. 924.

7 Kakde (1985), op. cit., p. 341.

spread over Gujarat, Maharashtra, Andhra Pradesh, Karnataka and Tamilnadu, which are prominent groundnut growing areas of India.

Spatial Variation in Groundnut Area

Groundnut acquired 8.43 per cent of GCA in drought prone areas in 1977-80. About two third (64.58 per cent) of the area under groundnut in the country is concentrated in drought prone areas. Drought prone districts of Gujarat, Karnataka and Andhra Pradesh are major groundnut sowing areas of the region. These areas occupy 72.07 per cent of groundnut area of the region. Drought prone area of Gujarat alone occupies 40.17 per cent of area under this crop in the region. Area under this crop is constant, both in the country and drought prone areas (increased marginally by 0.17 per cent per annum). As depicted in table 2.7, in late sixties twenty two drought prone districts had more than 10 per cent of their gross cropped area occupied by groundnut. Six of them are located in Gujarat. Five of them had more than 40 per cent of GCA devoted to this crop. In Junagarh, 53.4 per cent and in Rajkot 53.3 per cent of the GCA was devoted to groundnut. The rema ining groundnut growing districts fall mainly in Tamilnadu, Karnataka, Andhra Pradesh and Maharashtra. Nine districts belong to Gujarat, Andhra Pradesh and Tamilnadu had more than 15 per cent area under this crop. Seven districts of these states had more than 20 per cent of GCA under this crop.

Table 2.7

Spatial Distribution of Area Under Groundnut (1967-70)

Number of Districts

Percentage of Groundnut area to GCA	Haryana	Gujarat	Maharashtra	Rajasthan	M.P.	A.P.	Karnataka	Tamilnadu	Total
20.0 and above	-	5	-	-	-	1	-	1	7
15.0 - 20.0	-	1	-	-	-	1	-	-	2
10.0 - 15.0	-	-	3	1	1	1	5	2	13
5.0 - 10.0	-	2	4	1	6	-	6	-	19
Below 5.0	2	4	8	17	6	3	1	-	41
Total	2	12	15	19	13	6	12	3	82

Sixty districts had below 10 per cent of total cultivated land under groundnut. These include most of drought affected districts of Rajasthan, Maharashtra, Madhya Pradesh, Haryana and some districts of Karnataka and Andhra Pradesh. Forty-one districts had less than 5 per cent of their total cropped area under this crop. Seventeen districts spread over Rajasthan and Haryana had negligible area (less than one per cent of total cropped area). Rest of the districts have insignificant area under groundnut.

In 1977-80, as shown in Table 2.8 and fig. 2.4, the pattern remains the same. During this period, 18 districts spread over Gujarat, Andhra Pradesh, Tamilnadu and Karnataka, have more than 10 per cent of total cropped area occupied by groundnut. Eleven districts of these areas have more than 15 per cent of GCA under this crop. This pr oportion even exceeds above 20 per cent in 7 districts, five of which are located in Gujarat and one each in Andhra Pradesh and Tamilnadu. Jamnagar, Rajkot, Amreli and Junagarh districts of Gujarat have more than half of total cropped area occupied by this crop. In Jamnagar proportion of groundnut acreage in total cropped area is 63.7 per cent.

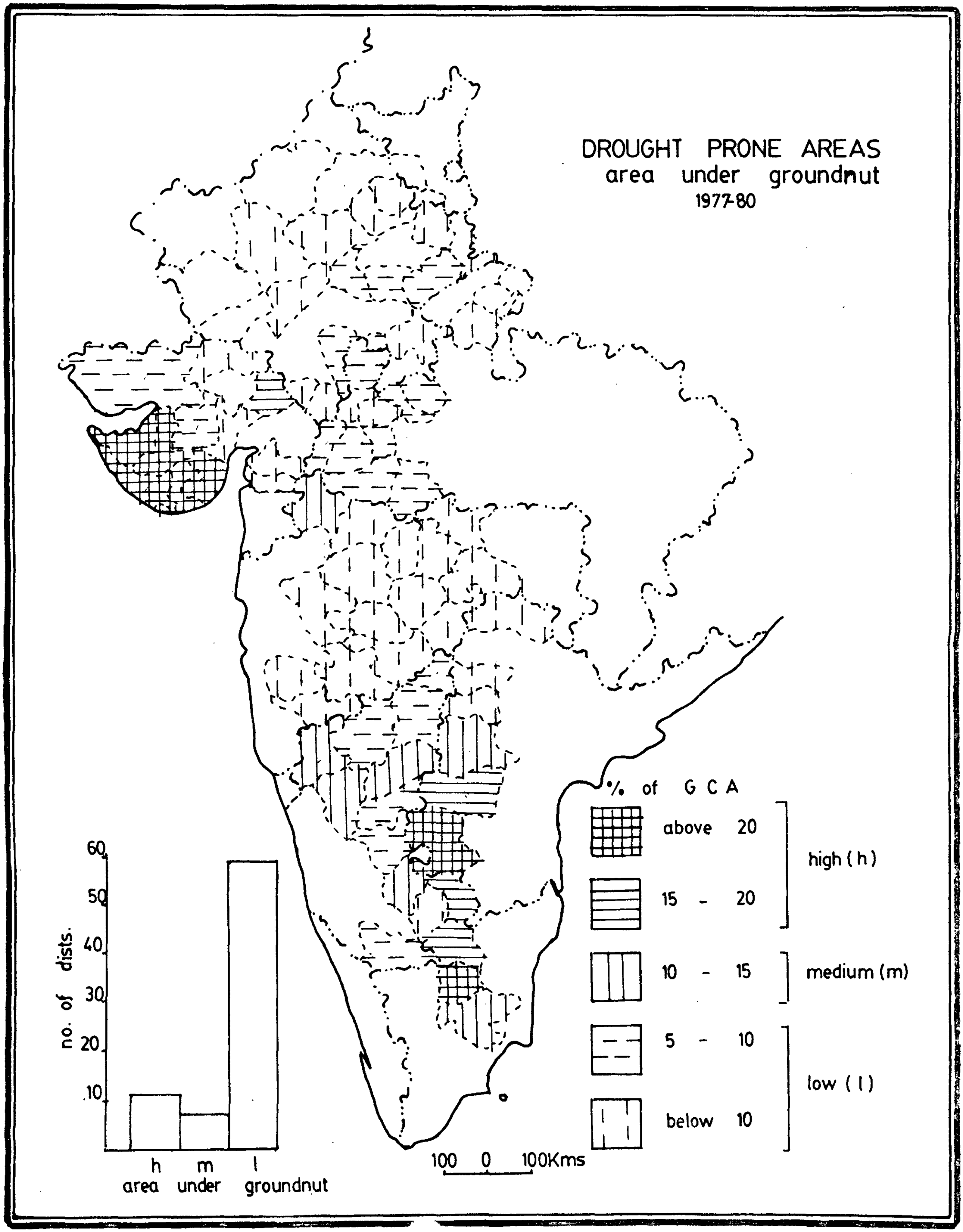
Sixty-four districts have less than 10 per cent of GCA devoted to groundnut. In forty-two districts groundnut acreage accounts for less than 5 per cent of GCA. The districts with low acreage under groundnut are found in Rajasthan, Haryana, Madhya Pradesh and some parts of Gujarat and Andhra

Table 2.8

Spatial Distribution of Area under Groundnut (1977-80)

Number of Districts

Percentage of Groundnut area to GCA	Haryana	Gujarat	Maharashtra	Rajasthan	M.P.	A.P.	Karnataka	Tamilnadu	Total
20.0 and above	-	5	-	-	-	1	-	1	7
15.0 - 20.0	-	1	-	-	-	1	1	1	4
10.0 - 15.0	-	-	1	-	-	1	4	1	7
5.0 - 10.0	-	2	3	4	7	-	6	-	22
Below 5.0	2	4	11	15	6	3	1	-	42
Total	2	12	15	19	13	6	12	3	82



DROUGHT PRONE AREAS
area under groundnut
1977-80
% of G C A
above 20
15 - 20
high (h)
10 - 15
medium (m)
5 - 10
below 10
low (l)
100 0 100Kms
60
50
40
30
20
10
no. of dists.
h
m
l
area under groundnut

Fig. 2.4

Pradesh. Twenty-two districts of Madhya Pradesh, Karnataka, Maharashtra, Rajasthan and Gujarat have 5 to 10 per cent cultivated area under this crop. 18 districts including 11 districts of Rajasthan, 2 districts each of Haryana, Madhya Pradesh and Andhra Pradesh and 1 district of Gujarat, have negligible groundnut acreage (less than 1 per cent of GCA). These districts have either bajra or jowar as dominating crop in kharif season.

Comparison of Tables 2.7 and 2.8 depicts that its proportion in GCA has increased in district of Gujarat and Andhra Pradesh and almost constant in most districts of Tamilnadu and Karnataka. In the remaining states,proportion of its acreage has rather declined in most of the drought prone districts.

Cotton

Cotton is an important fibre crop of semi-arid and sub-humid climatic regions of India. It is primarily a rain-fed crop in Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh and Karnataka but in north west India and Tamilnadu it is grown on irrigated tracts. "In nearly 75 per cent of the area the cotton crop is entirely dependent on rainfall whereas supplementary irrigation facilities exist in about 25 per cent of the area."[8]

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8 Handbook of Agriculture (1984), op. cit., p. 1021.

Agro-Climatic Conditions for Growth

Cotton is a tropical and subtropical plant, which successfully grows under low rainfall and medium to high temperature. "Cotton is said to have been evolved as a desert shrub, adapting to harsh and unpredictable environment, but it is sensitive to temperature and soil water conditions."[9]

Cotton requires abundant sunshine, adequate moisture, and fairly high temperature. Temperature below 16°C is not conducive for this crop, however, it can tolerate as low as 10°C temperature. Cotton cultivation requires a growing season of 180 to 200 frost free days. Temperature range 27°C - 32°C is optimum for its balanced growth and good yield. Sunny and warm days, cool nights and least cloudiness are favourable at the time of flowering and fruition. Cotton can be grown in area receiving rainfall between 50 cm to 150 cm. But 50 cm. to 65 cm. fairly distributed rainfall is suitable for this crop. Soil moisture strains, high temperature and excessive soil moisture cause ball shedding.

Cotton requires deep, well drained fertile soil. In north India it is grown on alluvial soils while in south and central India it is cultivated on black cotton soil and red sandy loams. Excessive soil moisture and water lagging is harmful for it.

Spatial Variations in Cotton Area

Drought prone areas acquired more than two third (69.85 per cent) of the areas under cotton in the country in 1977-80. This crop occupies 9.90 per cent of GCA in drought prone areas. Cotton growing areas are, however, concentrated in Maharashtra, Gujarat and Karnataka. 82.51 per cent of area under cotton in drought prone areas is confined to these areas. Area under cotton has declined in drought prone areas, however, it has increased at a very low rate (0.35 per cent per annum) in the country. Percentage share of drought prone areas, in area under this crop has also declined from 76.81 per cent in 1967-70 to 69.85 per cent in 1977-80. It is a rainfed crop in drought prone areas. Table 2.9 depicts that during 1967-70 cotton had occupied above 10 per cent of total cultivated area in 28 districts. These districts are located in Maharashtra, Gujarat, Madhya Pradesh, Karnataka and Andhra Pradesh. Seventeen districts had high cotton acreage, accounting for more than 20 per cent of GCA, seven are located in Maharashtra and five in Gujarat. Brauch in Gujarat and Amravati in Maharashtra had more than half of total cropped area under this crop. Six districts of these two states had more than 40 per cent of GCA occupied by cotton.

On the other hand 54 drought prone districts had less than 10 per cent of GCA under cotton. Forty-three districts had less than 5 per cent of GCA under this crop. These low

Table 2.9

Spatial Distribution of Area under Cotton (1967-70)

Number of Districts

Percentage of Cotton area to GCA	Haryana	Gujarat	Maharashtra	Rajasthan	M.P.	A.P.	Karnataka	Tamilnadu	Total
20.0 and above	-	5	7	-	2	-	3	-	17
15.0 - 20.0	-	-	-	-	1	-	-	-	1
10.0 - 15.0	1	1	2	-	3	2	1	-	10
5.0 - 10.0	-	3	1	2	2	-	3	-	11
Below 5.0	1	3	5	17	5	4	5	3	43
Total	2	12	15	19	13	6	12	3	82

Table 3.0

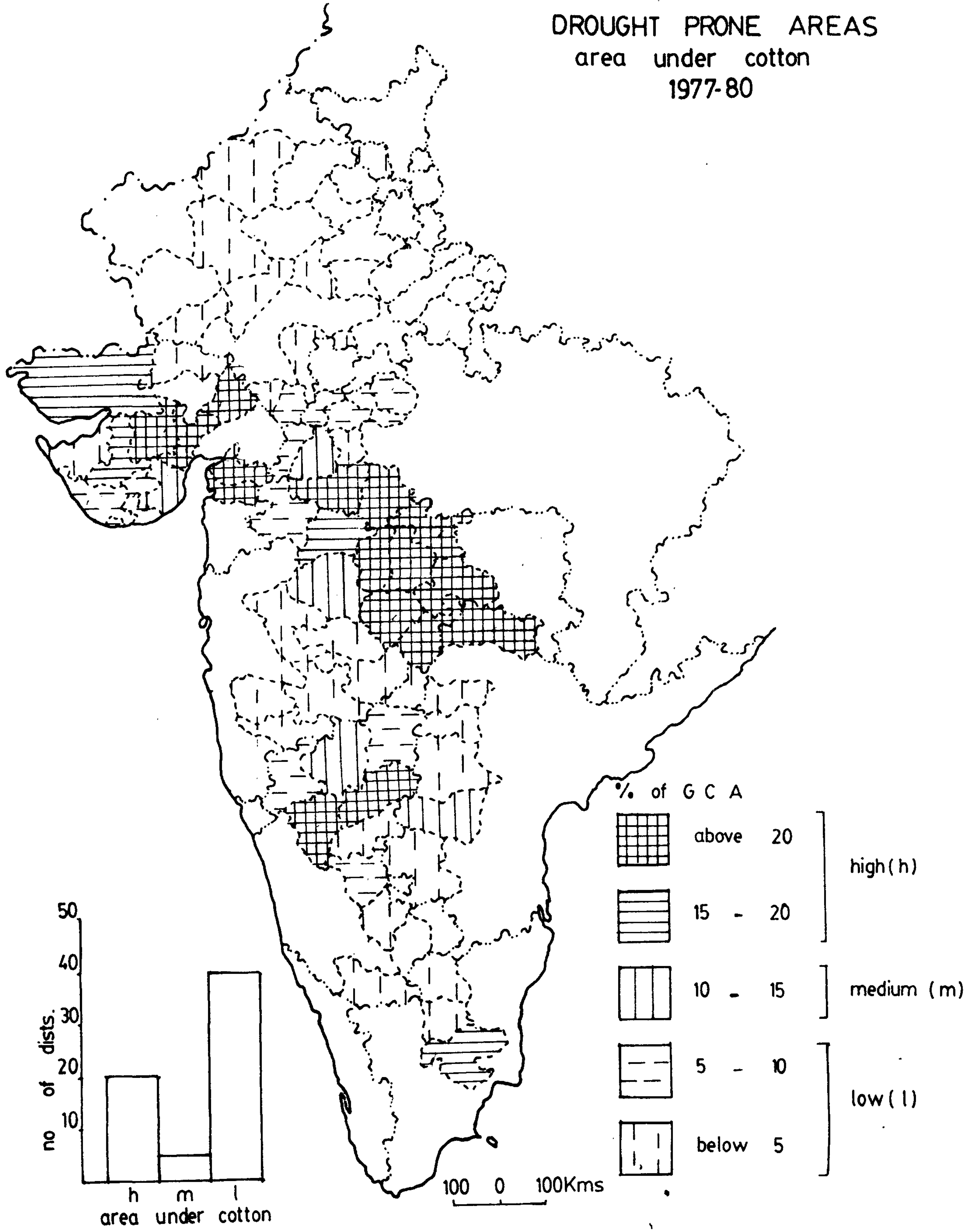
Spatial Distribution of Area under Cotton (1977-80)
No. of Districts

Percentage of Cotton area to G.C.A.	Haryana	Gujarat	Maharashtra	Rajasthan	M.P.	A.P.	Karnataka	Tamilnadu	Total
20.0 and above	-	5	6	-	2	-	2	1	15
15.0 - 20.0	-	2	1	-	-	1	1	-	5
10.0 - 15.0	-	1	1	-	1	1	1	-	5
5.0 - 10.0	-	2	1	1	5	-	3	-	12
Below 5.0	2	2	6	18	5	4	5	3	45
Total	2	12	15	19	13	6	12	3	82

cotton acreage districts are chiefly located in Rajasthan, south western Maharashtra, north western Madhya Pradesh, some parts of Karnataka plateau, western Andhra Pradesh, parts of Gujarat, Haryana and Tamilnadu. Twenty-nine districts had negligible cotton acreage (less than 1 per cent of GCA), fifteen of them are lying in Rajasthan.

In 1977-80 as depicted in table 3.0 and fig. 2.5 the pattern remains more or less the same. Twenty five drought prone districts, located in Maharashtra, Gujarat, Karnataka, Madhya Pradesh and Andhra Pradesh, have more than 10 per cent of their gross cropped area occupied by cotton. Twenty districts have more than 15 per cent of GCA under this crop. Fifteen districts, including six districts of eastern Marathwada and Vidarbha in Maharashtra, 5 districts of Gujarat and two each of Madhya Pradesh and Karnataka, have more than one-fifth of gross cropped area occupied by cotton. In Surendernagar district of Gujarat, cotton occupied 53.7 per cent of gross cropped area. Amravati and Yeotmal district of eastern Maharashtra also have more than 40 per cent of total cropped area under this crop.

Cotton occupies less than 10 per cent of GCA in fifty-seven districts of drought affected areas. Among them forty-five districts have low cotton acreage (less than 5 per cent of GCA). These low cotton acreage districts are spread over Rajasthan, Haryana, south west Maharashtra, north west


DROUGHT PRONE AREAS
area under cotton
1977-80
% of G C A
above 20
15 - 20
high (h)
10 - 15
medium (m)
5 - 10
below 5
low (l)
100 0 100Kms
50
40
30
20
10
no of dists.
h m l
area under cotton

Madhya Pradesh, Tamilnadu, western Andhra Pradesh and parts of Gujarat. Twenty five districts (most of which lie in Rajasthan) have negligible areas (less than 1 per cent of GCA) under this crop.

It is evident from the above discussion that cotton is an important crop grown in drought prone areas of eastern Maharashtra, Gujarat and some parts of Karnataka, Madhya Pradesh and Andhra Pradesh. It is insignificant in most districts of Rajasthan, Tamilnadu, Haryana, south west Maharashtra, north west Madhya Pradesh and parts of Karnataka and western Andhra Pradesh.

Comparison of tables 2.9 and 3.0 depict that proportion of cotton area in GCA is almost constant. In Maharashtra its share has declined in all districts, particularly in high acreage districts. In Gujarat proportion of cotton area declined in high acreage districts and increased in low acreage districts. Similarly in remaining state also it has marginally increased in some districts and decreased in others. Decline in cotton area in Bhiwani district of Haryana can be attributed to the fact that 1967-70 data pertains to Hissar district (of which Bhiwani was a part). Most of cotton growing areas have gone to Hissar after reorganization.

Summing Up

Five crops selected for study -- bajra, jowar, gram, groundnut and cotton -- together occupy 55.52 per cent of total cropped area of drought prone areas. Importance of these crops in the agriculture of drought prone areas can be imagined from the fact that except gram about two third of the area under remaining crops in the country is confined to this region (drought prone areas). Area under bajra and jowar has declined both in drought prone area and the country. However, decline rate of jowar area in drought prone area is very low. Cotton area has declined in drought prone areas, but has marginally increased in the country. Area under groundnut is constant both in drought prone areas and the country. Gram area has increased at slow rate in drought prone areas, however, it has declined in the country.

Jowar, which acquires about 20 per cent of gross cropped area, is widely grown crop in drought prone areas among the five crops selected for study. It is a dominant crop in the districts of Maharashtra, Madhya Pradesh, Andhra Pradesh, Karnataka and Tamilnadu. Normal annual rainfall in jowar belt ranges between 50 and 99 cm, and high moisture retention black soils form base of its cultivation in rabi season. Twenty four districts attribute more than 25 per cent of GCA to this crop. Percentage share of jowar area has declined except Maharashtra where it has increased and Karnataka where it is constant.

Bajra acquires about 13 per cent of GCA in drought prone areas and ranks second in the five crops. Its cultivation is confined to low rainfall and sandy areas of north western Rajasthan, Gujarat, western Haryana and parts of north western Maharashtra. Bajra cultivation is a monoculture in western most Rajasthan. Normal annual rainfall in bajra sowing region remains below 50 cm. Percentage share of area under bajra in GCA has declined in bajra growing areas, however, it has increased in some districts of Karnataka.

Gram cultivation is concentrated in eastern Rajasthan, south west Haryana and north west Madhya Pradesh. Because of soil moisture deficit and high temperature, rest of the parts of the drought affected areas do not provide congenial environment for gram cultivation. This crop acquires more than 15 per cent of GCA in 19 districts. Share of area under gram in GCA has increased in western Haryana and western Madhya Pradesh and is constant in eastern Rajasthan.

Groundnut region consists of the districts of Gujarat, Andhra Pradesh, Karnataka and Tamilnadu. Groundnut is a dominant crop in most of the low rainfall districts of Gujarat. Light clay well drained soils and moderate rainfall (50 cm to 75 cm) form congenial environment for the cultivation of this crop in Gujarat. Groundnut sowing region of south India has comparatively higher rainfall and, red and black soil. However, acreage of this crop in this region is low as compared to Gujarat. In Jamnagar, Rajkot, Amreli and Junagarh districts of Gujarat more than 50 per cent of total cropped area is occupied by this crop. Share of area under this crop in GCA has also increased.

Cotton is an important crop in drought prone districts of south central Gujarat, north east Maharashtra and adjoining districts of Madhya Pradesh, and some districts of Karnataka and Andhra Pradesh. Except a small area where rainfall is very low, drought prone area is potential area for cotton cultivation. But its cultivation is concentrated in black soil region of Maharashtra and Gujarat. Black soils are suitable for cotton cultivation as they are fertile, well drained and have high moisture retention capacity. Percentage share of area under cotton in GCA has declined in major cotton growing districts of Maharashtra and south Gujarat.

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CHAPTER III

SPATIAL VARIATIONS IN YIELD LEVELS AND GROWTH RATE OF BAJRA, JOWAR, GRAM, GROUNDNUT AND COTTON

Agriculture, which is a source of employment to majority of people in India, is largely of intensive subsistence type. Package technology, which was introduced in mid sixties, ushered the era of 'Green Revolution' in Indian agriculture. The 'Green Revolution', however, could not succeed in bringing about significant growth in dryland agriculture. Irrigation, spearhead of green revolution, could not be made available to drought prone areas. Cropping pattern of dryland remains traditional, as drought resistant crops still dominate it. These crops have to depend on erratic and insufficient monsoonic rainfall for supply of moisture. Moreover, there has not been significant breakthrough in seed technology of these crops, which could enable them to yield more under existing physical environment. Elements of physical environment, viz. climatic factors and soils vary in space in vast drought affected region of the country. It culminates into spatial variations in cropping pattern and yield of crops. This chapter analyses spatial pattern of variations in yield and growth of yield of bajra, jowar, gram, groundnut and cotton in drought prone areas.

During 1977-80, these five crops occupied 55.52 per cent of gross cropped area of drought prone districts. Food

TABLE 3.1

Production of some selected crops for the trienniums 1967-70 and 1977-80

(Output in tonnes)

S.No.	Crop	Drought prone districts			India			Share of drought prone area in total production of the country	
		1967-70	1977-80	Annual compound growth rate	1967-70	1977-80	Annual Compound growth rate	1967-70	1977-80
1.	Bajra	2547276	2412262	-0.54	4818537	4740750	-0.16	52.85	50.88
2.	Jowar	6127218	8082561	2.81	9850580	11792880	1.82	62.28	68.54
3.	Gram	1305457	1499395	1.39	5315760	4782948	-1.05	24.56	31.25
4.	Ground-nut	2989945	3753559	2.30	5151909	6245787	1.94	58.04	60.10
5.	Cotton	600324	703386	1.60	932160	1310031	3.46	64.40	53.69

TABLE 3.2

Yield levels of some selected crops and thier growth rates

(Yield in kg/he.)

S.No.	Crop	Drought prone areas			India		
		1967-70	1977-80	Annual Compound Growth Rate	1967-70	1977-80	Annual Compound Growth Rate
1.	Bajra	297	320	0.75	387	430	1.06
2.	Jowar	526	719	3.17	530	720	3.11
3.	Gram	633	635	0.03	690	633	-0.86
4.	Groundnut	635	785	2.14	707	843	1.77
5.	Cotton	101	125	2.15	120	163	3.11

grains, jowar and bajra are most important crops, acquired 19.82 and 13.29 per cent of gross cropped area in 1977-80. Cotton, groundnut and gram are respectively, third, fourth and fifth ranking crops in the present study.

Bajra

Spatial Variation in Yield Level

Bajra is an important cereal crop, particularly in dry areas of north western India. During 1977-80, 68.36 per cent of area under bajra of the country was concentrated in drought prone areas, while its contribution in total bajra production was 50.88 per cent. Yield level of bajra is low in drought prone areas as compared to other bajra growing areas of the country. As depicted in table 3.2 during 1977-80, bajra yield in drought prone areas was 320 kg/hactare, as compared to 430 kg/ha in the country. The difference in yield between the national average and drought prone region has increased from 90 kg. in 1967-70 to 110 kg in 1977-80.

As shown in fig. 3.1 and table 3.3, highest number of drought affected districts have low yield of bajra. These districts are spread, particularly, over Rajasthan, western Haryana, south western Madhya Pradesh and western Maharashtra. Yield of the crop is very low in western and north-western Rajasthan. High yield districts are spread over Gujarat.

TABLE 3.3

Spatial Distribution of yield level and Area of bajra

Yield (1977-80) (Kg/ha) (1)	(2) 35.0 & above	(3) 25.00-35.0	(4) 15.0-25.0	(5) 5.0-15.0	(6) Below 5.0	(7) Total
800 and above			1.Bhavnagar 2.Amreli	1.Junagarh	1.Vadodara 2.Dharmpuri	5(6.17)
600-800			1.Kutch 2.Bellary 3.Raichur	1.Jamnagar 2.Rajkot 3.Ahmedabad 4.Bhind 5.Salem 6.Tiruchirapalli.	1.Shivpuri 2Kolar	11 (13.58)
400-600		1.Banaskantha	1.Dhule 2.Bharatpur	1.Sabar-Kantha 2.Jalgaon 3.Beed 4.Anantpur 5.Bidar 6.Gulberga	1.Brauch 2.Parbhani 3.Nanded 4.Osmanbad 5.Buldhana 6.Akola 7.Ratlam 8.Ujjain 9.Mandsaur 10.Datia 11.Rajgarh 12.Shajapur 13.Kurnool 14.Hydrabad 15.Chitradurga 16.Dharwar 17.Kolar 18.Tumkur	27(33.33)

Table 3.3 (contd...)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
200-400	1.Sikar		1.Ahmednagar 2.Satara 3.Alwar 4.S.Madhopur 5.Bijapur	1.S.Nagar 2.Aurangabad 3.Ajmer 4.Mehboob-nagar. 5.Belgaum	1.Sholapur 2.Amravati 3.Yeotmal 4.Tonk 5.Indore 6.Dhar 7.Jhabua 8.East Nimar 9.Medak 10.Adilabad	21(25.93)
Below 200	1.Bhiwani 2.M.Garh 3.Barmer 4.Churu 5.Jaisalmer 6.Jalore 7.Jhunjhunu 8.Jodhpur 9.Nagaur.	1.Bikaner		1.Sangli 2.Pali	1.Banswara 2.Chittorgarh 3.Dungarpur 4.Kota 5.West Nimar	8(9.88)
Total	10(12.35)	2(2.47)	12(14.81)	20(24.69)	37(45.68)	81.(100)

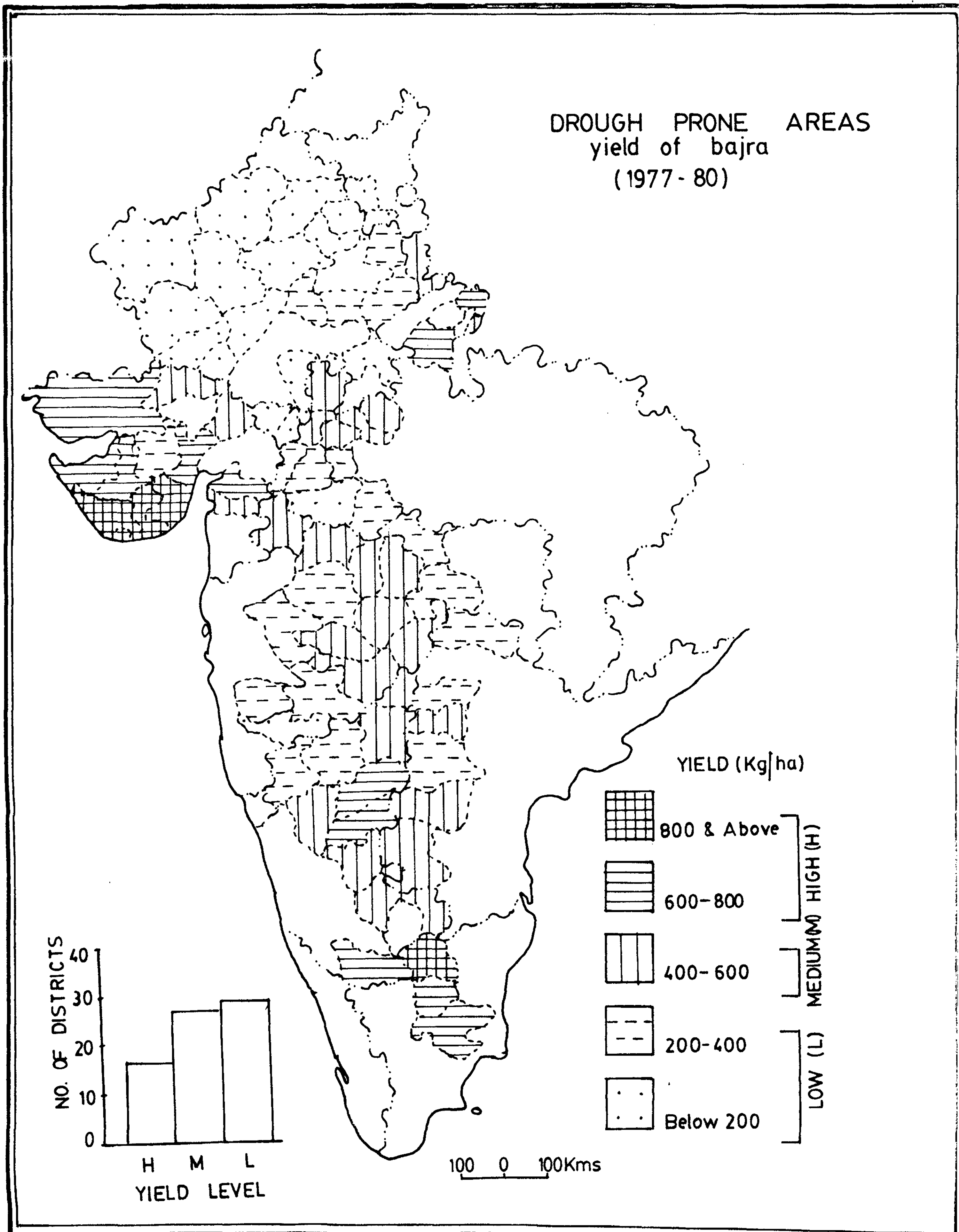

DROUGH PRONE AREAS
yield of bajra
(1977 - 80)
YIELD (Kg/ha)
800 & Above
600-800
400-600
200-400
Below 200
HIGH (H)
MEDIUM(M)
LOW (L)
NO. OF DISTRICTS
40
30
20
10
0
H M L
YIELD LEVEL
100 0 100Kms

Fig. 3.1

Yield is high in some districts of Tamilnadu, Karnataka and north eastern Madhya Pradesh too. Medium yield districts are spread all over drought prone region. Bajra yield is highest in Bhavnagar district of Gujarat (1538 kg/ha) and lowest in Jaisalmer district of Rajasthan (62 kg/ha) followed by Bikaner, Jhunjhunu and Churu districts of Rajasthan.

It is evident from table 3.3 that eleven out of twelve districts where bajra acquires more than one fourth of total cropped area, have low yield of bajra. These districts are located in Rajasthan and western Haryana. Medium acreage districts have very high to low yield level. Drought prone districts of Rajasthan account for 31.56 per cent of bajra acreage of drought prone region but it contributes 27.26 per cent of crop production of the region. Average bajra yield of drought prone districts of Rajasthan (300 kg/ha) is 20 kg less than the average of drought prone region. On the other hand, average bajra yield of drought prone districts of Gujarat is 805 kg/ha. 12.89 per cent of bajra acreage of drought prone areas is concentrated in Gujarat and it contributes 32.97 per cent of production of drought affected region.

Growth of Yield

Production of bajra in the country has declined by 0.16 per cent annually over the period 1967-70 to 1977-80. Decline rate has been rapid in drought prone area, -0.54 per cent. However, bajra yield, both in drought prone area

Table 3.4

Spatial Distribution of yield level of bajra and its growth rate

Yield 1967-70 (Kg/ha)	Annual Compound Growth Rate of yield (1967-70 to 1977-80)						
	10.0 and above.	6.0-10.0	3.0-6.0	0.0-3.0	-3.0-0.0	Above -3.0	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
800 and above						1.Sabarkanta	1 (1.23)
600-800		1.Bhavnagar. 2.Amreli 3.Janagarh.		1.Vadodara 2.Salem 3.Tiruchirapalli.	1.Ahmedabad 2.Brauch 3.Bhind		9(11.11)
400-600			1.Rajkot 2.Dhule 3.Rajgarh 4.Anantpur 5.Dharmapuri	1.Jamnagar. 2.Banastantha 3.Ujjain 4.Mandsaur 5.Shivpuri 6.Datia 7.Shajapur 8.Bidar.	1.Bharatpur 2.S.Madhopur 3.Kurnool	1.Bhiwani 2.Indore 3.EastNimar	19(23.46)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
200-400		1. Kutch 2. Mysore 3. Raichur	1. Jalgaon 2. Parbhani 3. Nanded 4. Bulchana 5. Akola 6. Amravati 7. Yeotmal 8. Ratlam 9. Hydrabad 10. Bellary 11. Chitrad-urga. 12. Gulberga 13. Kolar 14. Tumkur	1. Ahmednagar 2. Aurangabad 3. Beed 4. Osmanbad 5. Alwar 6. Dhar 7. Jhabua 8. Medak 9. Mahboob-nagar. 10. Adilabad 11. Belgaum 12. Bijapur 13. Dharwar	1. Satara 2. Ajmer 3. Dhungapur 4. Tonk	1. Mahender garh. 2. Banswara 3. Chittorgarh 4. Jhunjhunu 5. Kota 6. Sikar 7. West Nimar	41 (50.62)
Beow 200	1. Jaisalmer	1. Barmer 2. Jodhpur	1. Surender-nagar 2. Sangli 3. Bikaner 4. Pali	1. Shelapur 2. Jalore	1. Churu 2. Nagaur		11 (13.58)
TOTAL	1 (1.23)	8 (9.88)	23 (28.40)	26 (32.09)	12 (14.81)	11 (13.58)	81 (100.00)

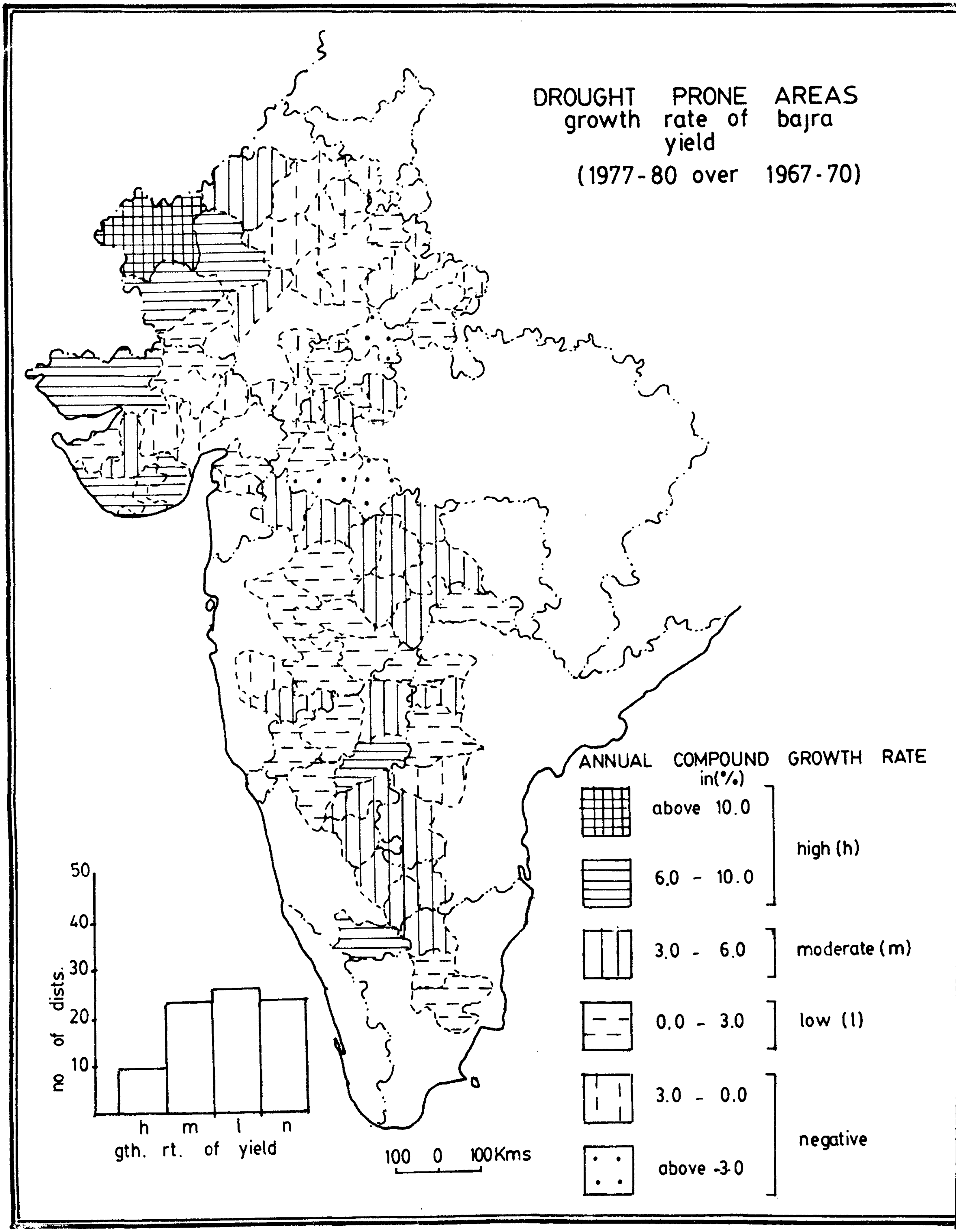

DROUGHT PRONE AREAS
growth rate of bajra yield
(1977-80 over 1967-70)
ANNUAL COMPOUND GROWTH RATE in(%)
above 10.0
6.0 - 10.0
high (h)
3.0 - 6.0
moderate (m)
0.0 - 3.0
low (l)
3.0 - 0.0
above -3.0
negative
50
40
30
20
10
no of dists.
h m l n
gth. rt. of yield
100 0 100Kms

Fig-3.2

and country as a whole, has not declined. It has improved marginally (0.75 per cent per annum) in drought prone area and (1.06 per cent per annum) in country as a whole. Yield has increased from 387 to 430 kg/ha in the country and 297 to 320 kg/ha in the drought prone areas. Because of sluggish growth in yield and falling acreage, bajra production has declined both at national and regional level. It may be noted that acreage and production of this crop have declined rapidly in drought affected regions which still remain a major producing region of bajra in the country.

Fig. 3.2 and table 3.4 depict spatial variation in growth rate of bajra yield. It is evident that twenty three districts have registered decline in yield. Decline in yield in eastern and north eastern Rajasthan and western Haryana, is a cause of concern. Yield has also declined in some districts of eastern Gujarat and south western Madhya Pradesh but it has witnessed high growth rate in western Rajasthan and western Gujarat. Because of severe drought, bajra yield was very low in western Rajasthan in 1967-70, it has increased at an annual compound growth rate of 20.0 per cent. In Gujarat, however, yield level was high in 1967-70. Most of the moderate growth rate districts ares apread over eastern Maharashtra, Karnataka plateau and Andhra Pradesh. Most of the districts with low growth rate are also spread over drought prone areas of peninsular plateau and Madhya Pradesh.

Table 3.4 depicts the relationship between yield levels during 1967-70 and growth rate of yield over the period 1967-70 to 1977-80. It is evident that except some districts of Gujarat, bajra yield has either declined or increased marginally in high yield districts. Yield has increased at low to medium growth rate in most of low yield districts. It has declined in some low yield districts of eastern Rajasthan. Majority of medium yield districts have registered low to medium growth in bajra yield.

Jowar

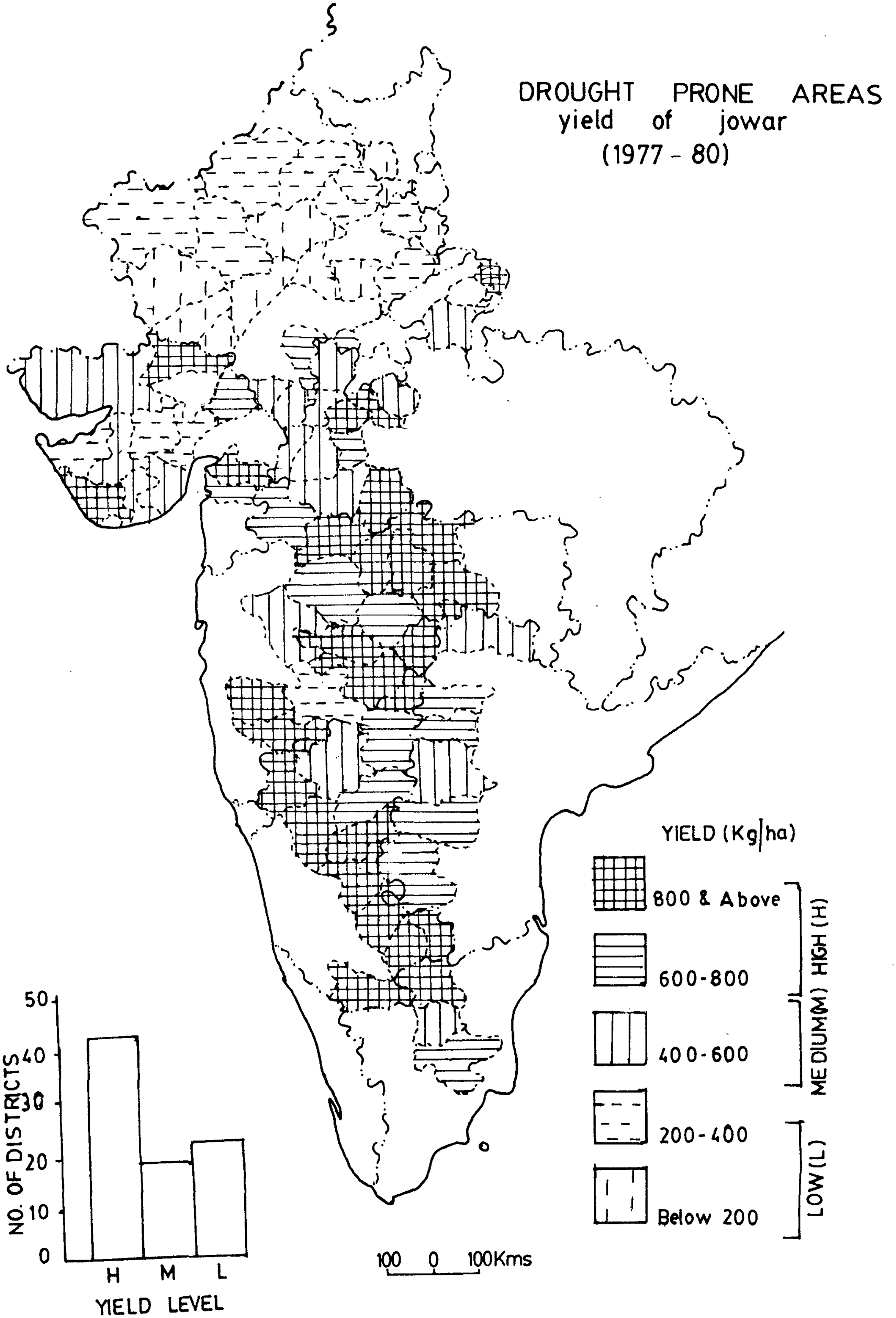
Spatial Variation in Yield

Jowar is an important crop in drought prone areas as it accounted for 19.82 per cent of gross cropped area during 1977-80. 68.64 per cent of jowar acreage of the country is concentrated in drought prone areas and the region contributes 68.54 per cent of jowar production of the country. Despite the fact that jowar acreage has declined, both in drought prone areas and country as a whole, its production has increased marginally. Growth rate of production is higher in drought prone area (2.81 per cent) in comparison to country as a whole (1.82 per cent). Moderate increase in yield, both in drought prone area (3.17 per cent) and country as a whole (3.11 per cent) is responsible for whatsoever increase in crop production. Yield level of jowar in drought prone areas

TABLE 3.5

Spatial distribution of yield level and area of jowar

Yield (1977-80) (Kg/ha)	Acreage (Percentage of Crop area to GCA) 1977-80					
(1)	(2) 35.0 & above	(3) 25.0-35.0	(4) 15.0-25.0	(5) 5.0-15.0	(6) Below 5.0	(7) Total
800 and above	1.Satara 2.Sangli 3.Beed 4.Nanded 5.Osmanbad	1.Jalgaon 2.Buldhana 3.Akola 4.Amravati 5.Yeotmal	1.Belgaon 2.Bellary 3.Bidar 4.Chitradurga 5.Dharwar 6.Mysore	1.Banaskantah 2.Vadodara 3.Tumkur 4.Dharmapuri	1.Junggarh 2.Ujjain 3.Bhind 4.Shajapur 5.Banglore 6.Kolar	26(31.71)
600-800		1.Aurangabad 2.Parbhani 3.Kurnool 4.Hydrabad 5.Medak 6.Gulberga	1.Brauch 2.Dhule 3.East Nimar 4.Datia 5.Raichur 6.Tiruchirapalli	1.Chuttorgarh 2.Indore 3.Anantpur	1.Sabarkantha	16.(19.51)
400-600	1.Ahmednagar 2.Adilabad	1.Rajgarh 2.Mehboobnagar 3.Bijapur	1.Kota 2.Maudsaur 3.West Nimar 4.Shivpuri 5.Salem	1.Rajkot 2.Amreli 3.Kutch 4 Ratlam 5.Dhar 6.Jhabua	1.Banswara 2.Dungarpur	18(21.95)
200-400	1.Sholapur			1.Jamnagar 2.Bhavnagar 3.Ahmedabad 4.S.Madhopur	1.Alwar 2.Bikaner 3.Churu 4.Jaisalmer 5.Jodhpur 6.Sikar	11(13.41)
Below 200			1.Ajmer 2.Tonk	1.S.Nagar	1.Bhiwani 2.M.Garh 3.Barmer 4.Bharatpur 5.Jalore 6.Jhanjhuna 7.Nagaur 8.Pali	11(13.41)
Total	8.(9.76)	14(17.07)	19(23.17)	18(21.95)	23(28.05)	82(100.00)


DROUGHT PRONE AREAS
yield of jowar
(1977 - 80)
YIELD (Kg/ha)
800 & Above
600-800
400-600
200-400
Below 200
HIGH (H)
MEDIUM(M)
LOW(L)
100 0 100Kms
NO. OF DISTRICTS
50
40
30
20
10
0
H
M
L
YIELD LEVEL

is almost equal to that of country as a whole (719 and 720 kg/ha respectively).

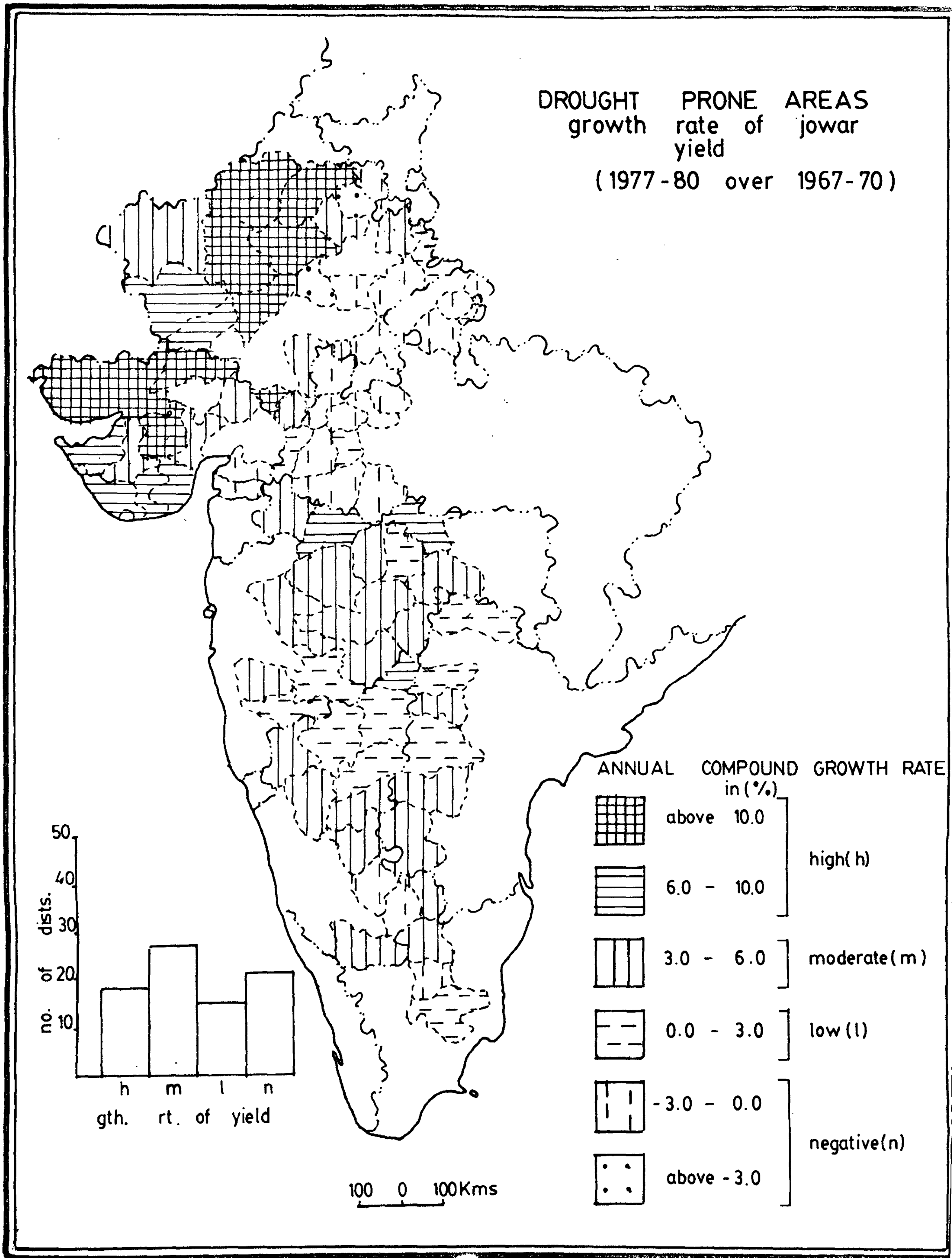
As it is evident from fig 3.3 and table 3.5 that highest numbers of drought affected districts have high yield level of jowar. These high yield districts are mostly spread over drought affected areas of Maharashtra, Karnataka, Andhra Pradesh and Tamilnadu. Drought prone districts of Maharashtra alone account for 53.25 per cent of jowar production of drought prone area. Per hectare yield of the crop in drought affected Maharashtra is 805 kg/ha. Drought prone areas of Maharashtra, Karnataka, Andhra Pradesh and Tamilnadu accounted for 84.17 per cent of jowar production of drought prone area as a whole. Low yield districts are spread over Rajasthan and western Haryana. Jowar is not an important crop in this part of drought prone area. It is a fodder crop, harvested before ripening stage to feed the cattles. Medium yield districts are concentrated in western Madhya Pradesh and Gujarat. Yield level of 30 districts which are located in peninsular parts of drought prone region, is above the average yield in the country as well as in drought prone areas.

Growth Rate of Yield

Jowar yield has increased in drought prone areas, except that of Haryana and Madhya Pradesh. Yield has increased sharply in Gujarat (6.92 per cent per annum). In Maharashtra

Table 3.6
Spatial Distribution of Yield level of jowar and its growth rate

Yield (1967-70) (Kg/ha) (1)	Annual compound Growth Rate of yield (1967-70 to 1977-80) (2) 10.0 & above	(3) 6.0-10.0	(4) 3.0-6.0	(5) 0.0-3.0	(6) -3.0-0.0	(7) Above -3.0	(8) Total
800 and above			1. Chitradurga 2. Dharwar 3. Kolar 4. Dharmapuri		1. Vadodera 2. Ujjain 3. Bhind 4. Shajapur 5. Banglore		9(11.11)
600-800		1. Jalgaon 2. Amravati	1. Satara 2. Nanded 3. Baldhana 4. Bellary 5. Mysore	1. Sangli 2. Akola 3. Indore 4. Datia 5. Tiruchira-palli	1. Ratlam 2. West Nimar 3. E. Nimar 4. Rajgarh 5. Tumkur 6. Salem		18(22.22)
400-600		1. Junagarh 2. Bidar	1. Dhule 2. Aurangabad 3. Parbhani 4. Beed 5. Osmanbad 6. Yectmal 7. Chittorgarh 8. Kurnool 9. Hydrabad 10. Belgaum.	1. Brauch 2. Jhabua 3. Medak 4. Mehboobnagar 5. Adilabad 6. Bijapur 7. Gulbarga 8. Raichur	1. Kota 2. Mandsaur 3. Dhar 4. Shivpuri		24(29.63)
200-400	1. Banaska-ntha.	1. Amreli 2. Dungarpur	1. Ahmednagar 2. Alwar 3. Banswara 4. Sikar 5. Anantpur	1. Sholapur	1. S. Madhopur 2. Tonk		11(13.58)
Below 200	1. Rajkot 2. Kutch 3. Bikaner 4. Churu 5. Jodhpur 6. Nagaur 7. Pali	1. Jamnagar 2. Bhavnagar 3. Barmer 4. Jalore	1. S. Nagar 2. Ahmedabad 3. Jaisalmer	1. Bharatpur	1. Bhiwani 2. M. Garh	1. Ajmer 2. Jhunjhunu	19(23.46)
Total:	8(9.88)	10(12.35)	27(33.33)	15(18.52)	19(23.46)	2(2.47)	81(100.00)



DROUGHT PRONE AREAS
growth rate of jowar yield
(1977-80 over 1967-70)
ANNUAL COMPOUND GROWTH RATE in (%)
above 10.0
6.0 - 10.0
high(h)
3.0 - 6.0
moderate(m)
0.0 - 3.0
low(l)
-3.0 - 0.0
above -3.0
negative(n)
no. of dists.
50
40
30
20
10
h m l n
gth. rt. of yield
100 0 100Kms

Fi

and Andhra Pradesh yield showed a moderate growth rate, above 3.0 per cent per annum. In Karnataka it was rather low (2.68 per cent per annum). It is evident from fig. 3.4 and table 3.6 that most districts of western Rajasthan and Gujarat have experienced high growth in jowar yield. Yield level of these districts is, however, very low. Most of the districts of Maharashtra, Karnataka, Andhra Pradesh and Tamilnadu have registered moderate growth rate. Some districts of north Karnataka, Andhra Pradesh and Maharashtra have increased yield at low growth rate. Yield has declined in most of the drought affected districts of Madhya Pradesh, eastern Rajasthan and western Haryana.

Table 3.6 shows relationship between yield level in 1967-70 and its growth rate over the decade 1967-70 to 1977-80. The growth rate of yield is generally high in low yield districts. Out of 18 high growth rate districts, 14 had low yield in 1967-70. On the other hand, out of 21 districts where yield has declined, 11 had high yield and 4 had medium yield in 1967-70. It is evident from fig. 3.4 also that growth rate of yield is high in low yield districts (Gujarat and western Rajasthan) and low to moderate in high yield districts (drought affected districts of peninsular India).

Gram

Spatial Variation in Yield

Gram is a 'rabi' pulse crop, sown with the help of conserved soil moisture. Because of moisture deficit even during south west monsoon season, large parts of drought prone areas do not provide congenial environment for the growth of this crop. Yet it is sown in comparatively high rainfall regions of drought affected area, north west India, i.e. eastern Rajasthan, north west Madhya Pradesh and western Haryana. Drought prone areas accounted for 31.27 per cent of area and 31.35 per cent of production of gram in India during 1977-80. Both area and yield of gram have declined in India over the period 1967-70 to 1977-80. Yield has declined from 690 kg/ha to 633 kg/ha, registering a decline rate of 0.86 per cent per annum. Consequently gram production in the country has gone down by -1.05 per cent per annum. But in drought prone areas, yield is stagnant (635 kg/ha) and acreage has increased marginally (1.37 per cent per annum). Hence, gram production has registered a very low growth rate (1.39 per cent per annum).

It is evident from fig. 3.5 and table 3.7 that high yield districts are concentrated, particularly in eastern Rajasthan, north west Madhya Pradesh and south western Haryana. Highest number of districts (46) have medium yield. Medium yield districts are spread almost all over drought prone areas,

TABLE 3.7

Spatial distribution of yield level and area of gram

Yield (1977-80) (Kg/ha) (1)	(2) 20.0 and above	(3) 15.0-20.0	(4) 10.0-15.0	(5) 5.0-10.0	(6) Below 5.0	(7) Total
800 and above.	1. Bhiwani 2. M. Garh 3. Alwar	1. Bharatpur	1. Jhunjhunu 2. S. Madhopur	1. Ajmer 2. Sikar		8 (9.76)
-800	1. Bhind		1. Banswara 2. Dungarpur 3. Kota	1. Pali 2. Shajapur	1. Barmer 2. Bikaner 3. Tiruchirapalli	9 (10.98)
400-600	1. Datia	1. Indore	1. Chittargarh 2. Tonk 3. Ratlam 4. Ujjain 5. Mandsaur 6. Dhar 7. Bidar	1. Jhabua 2. Shivpuri 3. Rajgarh	1. Jamnagar 2. Rajkot 3. S. Nagar. 4. Bhavnagar 5. Amreli 6. Junagarh 7. Kutch 8. Banaskantha 9. Sabarkantha 10. Ahmedabad 11. Vadadara 12. Brauch 13. Dhula 14. Jalgaon 15. Ahmednagar 16. Sangli 17. Jaisalmer 18. Jalore 19. Jodhpur 20. Nagaur 21. W. Nimar 22. E. Nimar 23. Kurnool 24. Hydrabad.	46 (56.10)

Table 3.7 contd...

(1)	(2)	(3)	(4)	(5)	(6)	(7)
400-600					25.Ban lore 26.Belgaum 27.Bellary 28.Chitradurga 29.Kolar 30.Mysore 31.Raichur 32.Tumkur 33.Salem 34.Dhamapuri.	
200-400				1.Osmanbad 2.Churu	1.Satara 2.Sholapur 3.Aurangabad 4.Parbhani 5.Beed 6.Nanded 7.Buldhana 8.Akola 9.Yeotmal 10.Anantpur 11.Medak 12.Mehboobnagar 13.Adilabad 14.Bijapur 15.Dharwar 16.Gulbarga	18(21.95)
Below 200					1.Amravati	1(1.22)
Total	5(6.10)	2(2.44)	12(14.63)	9(10.98)	54(65.85)	82(100.00)

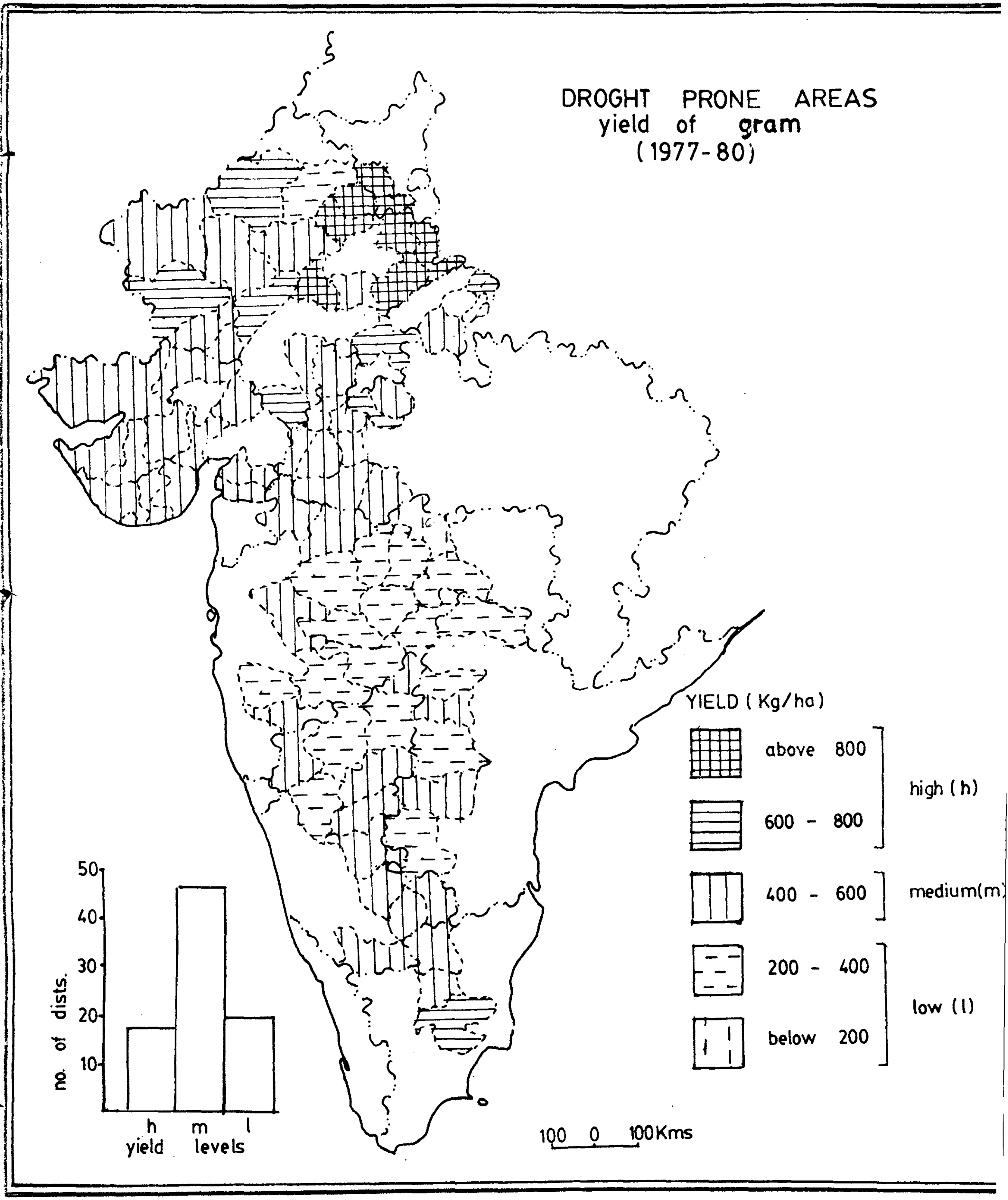

DROGHT PRONE AREAS
yield of gram
(1977-80)
YIELD (Kg/ha)
above 800
600 - 800
high (h)
400 - 600
medium(m)
200 - 400
below 200
low (l)
50
40
30
20
10
no. of dists.
h
m
l
yield levels
100 0 100Kms

Fig-3.5

concentrated in Gujarat, south western Madhya Pradesh, Karnataka and Tamilnadu. Medium yield districts are concentrated in Gujarat, south western Madhya Pradesh, Karnataka and Tamilnadu. Low yield districts are concentrated in Maharashtra and Karnataka plateau. Drought prone districts of Rajasthan, Haryana and Madhya Pradesh account for 85.43 per cent of gram production in drought prone areas. Rajasthan alone contributed 46.81 per cent of gram production of drought prone areas.

Growth Rate of Yield

As mentioned earlier, gram yield in drought prone areas remains stagnant over the period 1967-70 to 1977-80. Except Haryana and Gujarat, yield has increased in all other drought prone regions. However, its growth rate is very low in Madhya Pradesh, Rajasthan, Karnataka and Tamilnadu. It has increased by more than 4 per cent in Andhra Pradesh and by more than 2 per cent in Maharashtra. Annual compound growth rate of gram yield in drought prone areas is meagre, 0.03 per cent.

As shown in fig. 3.6 and table 3.8 only two districts (Jhunjhunu and Ajmer in Rajasthan) have registered high growth rate of yield. Growth rate is moderate in ten districts and eight of them are located in Maharashtra and Andhra Pradesh. Major parts of drought prone areas in

TABLE 3.8

Spatial distribution of yield level of gram and its growth rate

Yield (1967-7) Kg/ha (1)	(2) 10.0 & above	(3) 6.0-10.0	(4) 3.0-6.0	(5) 0.0-3.0	(6) -3.0-0.0	(7) Above -3.0	(8) Total
800 and above			1.Alwar	1.Bharat pur	1.Bhiwani 2.M.Garh	1.Kutch	5(6.10
600-800				1.Dungarpur 2.S.Madhopur	1.Amreli 2.Barmer 3.Bikaner 4.Jalore 5.Jodhpur 6.Nagaur 7.Pali 8.Bhind	1.Jaisalmer	12(14.63)
400-600		1.Jhunj-hunu	1.Kota	1.Jamnagar 2.Junagarh 3.Vadodara 4.Brauch 5.Banswara 6.Tonk 7.Indore 8.Mandsaur 9.Dhar 10.Jhabua 11.Datea 12.Shajapur 13.Banglore 14.Belgaum 15.Bellary 16.Bidar 17.Salem	1.Rajkot 2.S.Nagar 3.Bhavnagar 4.Banaskantha 5.Sebarkantha 6.Ahmedabad 7.Chittorgarh 8.Ratlam 9.Ujjain 10.W.Nimar 11.E.Nimar 12.Shivpuri 13.Rajgarh 14.Chitradurga 15.Gulberga 16.Kolar 17.Mysore		40(48.78)

Table 3.8 contd...

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				18.Dharmapuri 19.Tiruchira-palli	18.Raidhur 19.Tumkur		
200-400	1.Ajmer		1.Jalgaon 2.Ahmednagar 3.Aurangabad 4.Osmanbad 5.Kurnool 6.Anantpur 7.Hyderabad 8.Adilabad	1.Dhule 2.Satara 3.Sangli 4.Solapur 5.Parbhani 6.Beed 7.Buldhana 8.Yeotmal 9.Medak 10.Mehboobnagar 11.Bijapur 12.Dharwar	1.Nanded 2.Akola 3.Churu	1.Amravati	25(30.49)
Below 200							0(0.00)
Total	1(1.22)	1(1.22)	10(12.20)	35(42.68)	32(39.02)	3(3.66)	82(100.00)

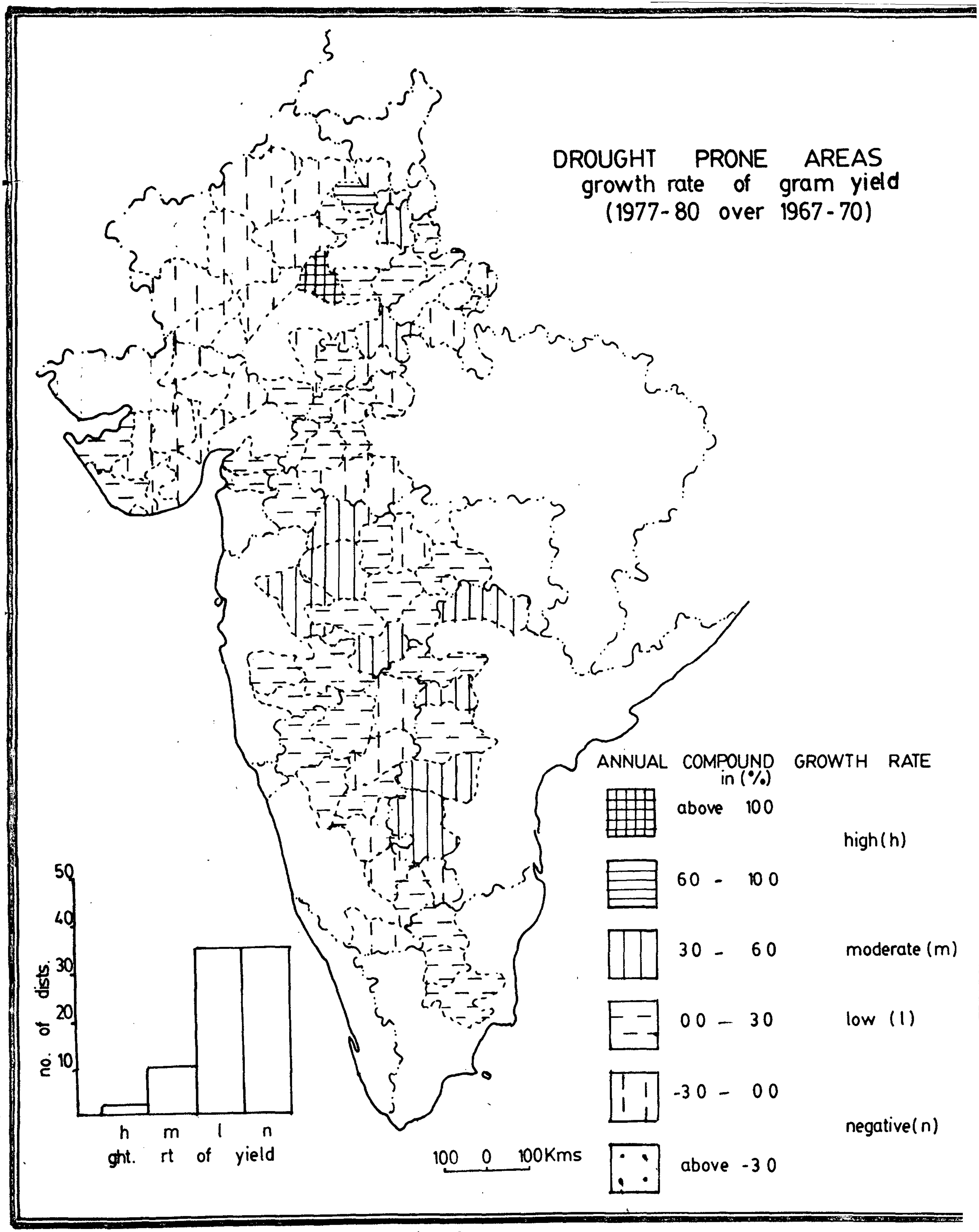

DROUGHT PRONE AREAS
growth rate of gram yield
(1977-80 over 1967-70)
ANNUAL COMPOUND GROWTH RATE
in (%)
above 100
high(h)
60 - 100
30 - 60
moderate (m)
00 — 30
low (l)
-30 - 00
negative(n)
above -30
100 0 100Kms
50
40
30
20
10
no. of dists.
h m l n
ght. rt of yield

Fig-3.6

peninsular India, eastern Rajasthan and west Madhya Pradesh have registered low growth rate of yield. Yield has rather declined in vast areas of Rajasthan, south west Haryana, Gujarat, Madhya Pradesh and some parts of south India.

Table 3.8 shows relationship between gram yield levels in 1967-70 and its growth rate over the period 1967-70 to 1977-80. Yield has either declined or increased marginally in high yield districts of drought prone areas. Out of 17 high yield districts, it has declined in twelve and increased in four. On the other hand, it has increased in twenty-one out of twenty-five low yield districts, through growth rate has been low in twelve districts.

Groundnut

Spatial Variation in Yield

Groundnut is an industrial crop of drought affected area of India. These areas accounted for 64.58 per cent of acreage and 60.10 per cent of production of groundnut in the country during 1977-80. Groundnut production in the country has increased at a slow rate (1.94 per cent) over the period 1967-70 to 1977-80. While the acreage is almost stagnant, yield has increased at an annual growth rate of 1.77 per cent. Hence increase in groundnut production is attributed mainly to increase in yield. Though, the growth rate of production is

TABLE 3.9

Spatial Distribution of yield level and area of groundnut

Yield (1977-80) (Kg/ha) (1)	Acreage (Percentage of Crop area to GCA) 1977-80 (2) 20.0 and above.	(3) 15.0-20.0	(4) 10.0-15.0	(5) 5.0-10.0	(6) Below 5.0	(7) Total
1000 and above	1.Bhavnagar 2.Junagarh 3.Salem	1.Dharmapuri	1.Tiruchira-palli	1.Bellary 2.Chitradurga 3.Mysore.	1.M.Garh 2.Banglore	10(12.50)
800-1000	1.Amreli 2.Anantpur	1.Kolar	1.Tumkur	1.Kutch	1.Hydrabad	6(7.5)
600-800	1.Jamnagar 2.Rajkot	1.Kurnool	1.Mehboobnagar 2.Belgaum 3.Raichur	1.S.Nagar 2.Jalgaon 3.Satara 4.Sangli 5.Chittorgarh 6.Shajapur.	1.Banaskantha 2.Vadodara 3.Brauch 4.Ahmednagar 5.Sholapur 6.Perbhani 7.Beed 8.Amravati 9.Barmer 10.Jalore 11.Ujjain 12.Bhind 13.Shivpuri 14.Datia 15.Medak.	27(33.75)
400-600		1.Sabarkan-tha.	1.Dhule 2.Dharwar	1.S.Madhopur 2.Tonk 3.Mandsaur 4.Dharwar	1.Ahmedabad 2.Aurangabad 3.Nanded 4. Osmanbad	

Table 3.9 contd..

(1)	(2)	(3)	(4)	(5)	(6)	(7)
				5.W.Nimar 6.E.Nimar 7.Rajgarh 8.Bidar 9.Bijapur 10.Gulberga	5.Akola 6.Yeotmal 7.Alwar 8.Banswara 9.Bharatpur 10.Churu 11.Dungarpur 12.Jhunjhuna 13.Jodhpur 14.Kota 15.Nagaur 16.Pali 17.Sikar 18.Indore 19.Ratlam 20.Adilabad	33(41.25)
Below 400				1.Ajmer 2.Jhabhua	1.Buldhana 2.Bikaner	4(5.00)
Total	7(8.75)	4(5.00)	7(8.75)	22(27.50)	40(50.00)	80(100.00)

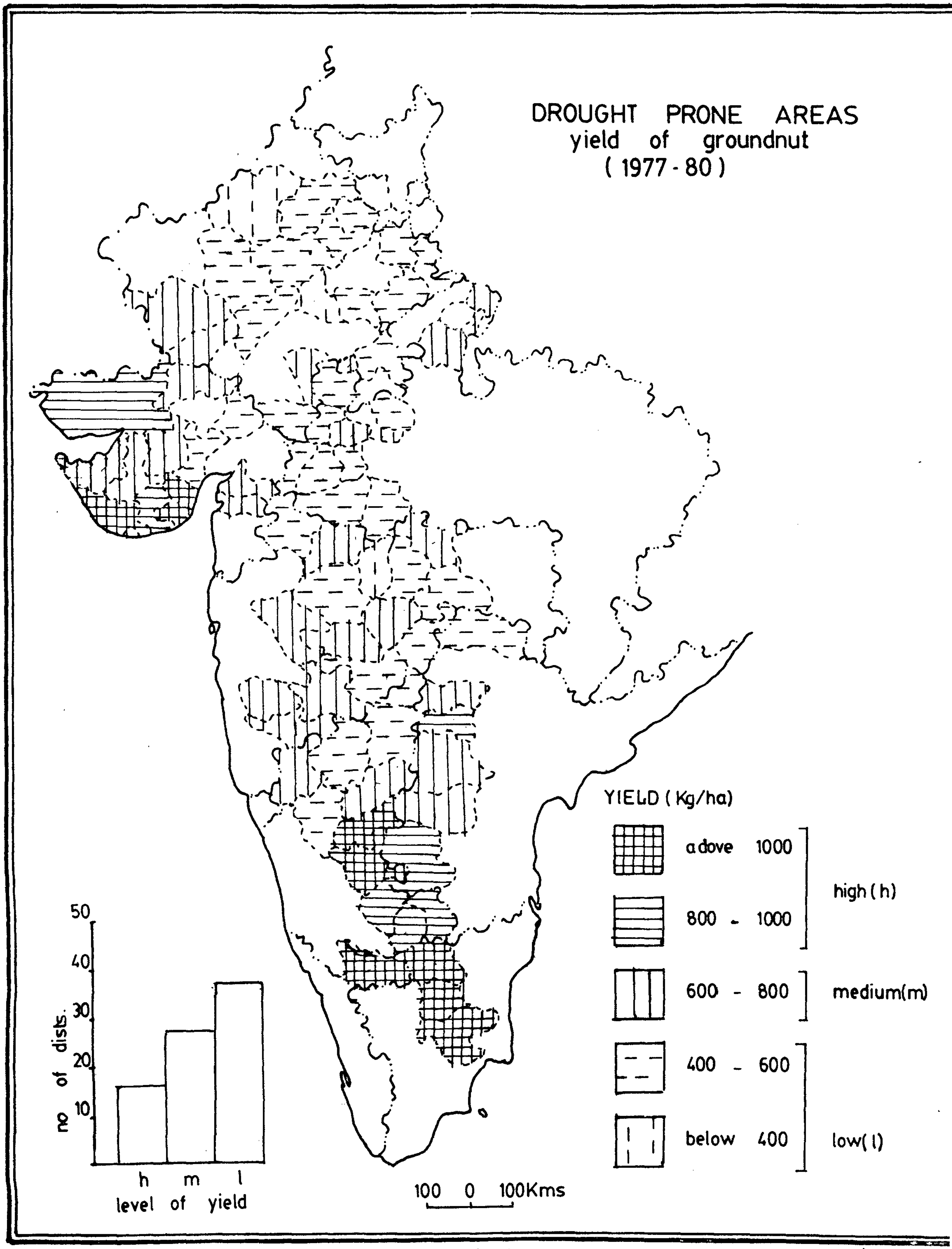

DROUGHT PRONE AREAS
yield of groundnut
(1977 - 80)
YIELD (Kg/ha)
adove 1000
800 - 1000
high (h)
600 - 800
medium(m)
400 - 600
below 400
low(l)
50
40
30
20
10
no of dists.
h m l
level of yield
100 0 100Kms

Fig- 3·7

low in drought prone areas (2.30 per cent per annum) but it is higher than that of the country. Acreage is almost stagnant (0.16 per cent per annum). Increase in yield (2.14 per cent per annum) is mainly responsible for increase in production of groundnut in drought affected areas.

Despite the fact that growth rate of yield in drought prone areas is higher than that of country as a whole, its yield level was 58 kg less than the yield lev el of country during 1977-80. Drought prone areas and country have 785 kg/ha and 843 kg/ha respectively groundnut yield during 1977-80. But groundnut yield is more than that of country as a whole in drought affected areas of Gujarat and Tamilnadu. Average yield in Tamilnadu and Gujarat is 1167 and 896 kg/ha respectively. Drought prone areas of Gujarat accounted for 45.89 per cent of groundnut production in drought prone areas. Drought prone areas of Gujarat, Andhra Pradesh, Karnataka and Tamilnadu account for 82.80 per cent of groundnut production of drought affected areas.

Fig. 3.7 and table 3.9 show spatial variations in yield levels of groundnut. It is evident that maximum numbers of drought affected districts have low yield level. Low yield districts are concentrated in Rajasthan, western Madhya Pradesh, eastern Maharashtra and north eastern Karnataka. High yield

Table 3.10

Spatial distribution of yield level of groundnut and its growth rate

Yield (1967-70) (Kg/ha) (1)	(2) 10.0 & above	(3) 6.0-10	(4) 3.0-6.0	(5) 0.0-3.0	(6) -3.0-0.0	(7) Above -3.0	(8) Total
1000 and above						1. Satra	1(1.35)
800-100			1. Bellary 2. Salem 3. Dharmapuri	1. Junagarh 2. Mysore	1. Parbhani 2. Kolar	1. Raichur	8(10.81)
600-800		1. Chitradurga	1. Banglore 2. Tumkur 3. Tiruchirapalli.	1. Kutch 2. Sangli 3. Amravati 4. E. Nimar 5. Kurnool 6. Anantpur 7. Medak	1. Sabarkantha 2. Dhule 3. Jalgaon 4. Beed 5. Osmanbad 6. Akola 7. Yeotmal 8. Alwar 9. Chittorgarh 10. Kota 11. Ratlam 12. Ujjain 13. Dhar 14. Westnimar 15. Shivpuri 16. Rajgarh 17. Shajapur 18. Adilabad.	1. Nanded 2. S. Madhopur 3. Mandsaur 4. Bidar	33(44.59)
400-600			1. Jamnagar 2. Rajkot 3. Bhavnagar 4. Amreli 5. Ahmednagar 6. Banswara 7. Dungarpur 8. Hydrabad	1. Banaska-ntha 2. Ahmedabad 3. Vadodara 4. Brauch 5. Shalapur 6. Aurangabad 7. Mehboobnagar 8. Belgaum 9. Gulberga	1. Buldhana 2. Indore 3. Bijapur 4. Kolar	1. Jhabua	22(29.73)

Table 3.10 contd..

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Below 400	1.Jhunjhuna 2.Jodhpur 3.Pali	1.Bharatpur 2.Jalore 3.Nagaur 4.Sikar	1.S.Nagar 2.Tonk	1.Ajmer			
Total	3(4.05)	5(6.76)	16(21.62)	19(25.68)	24(32.43)	7(9.46)	74(100.00)

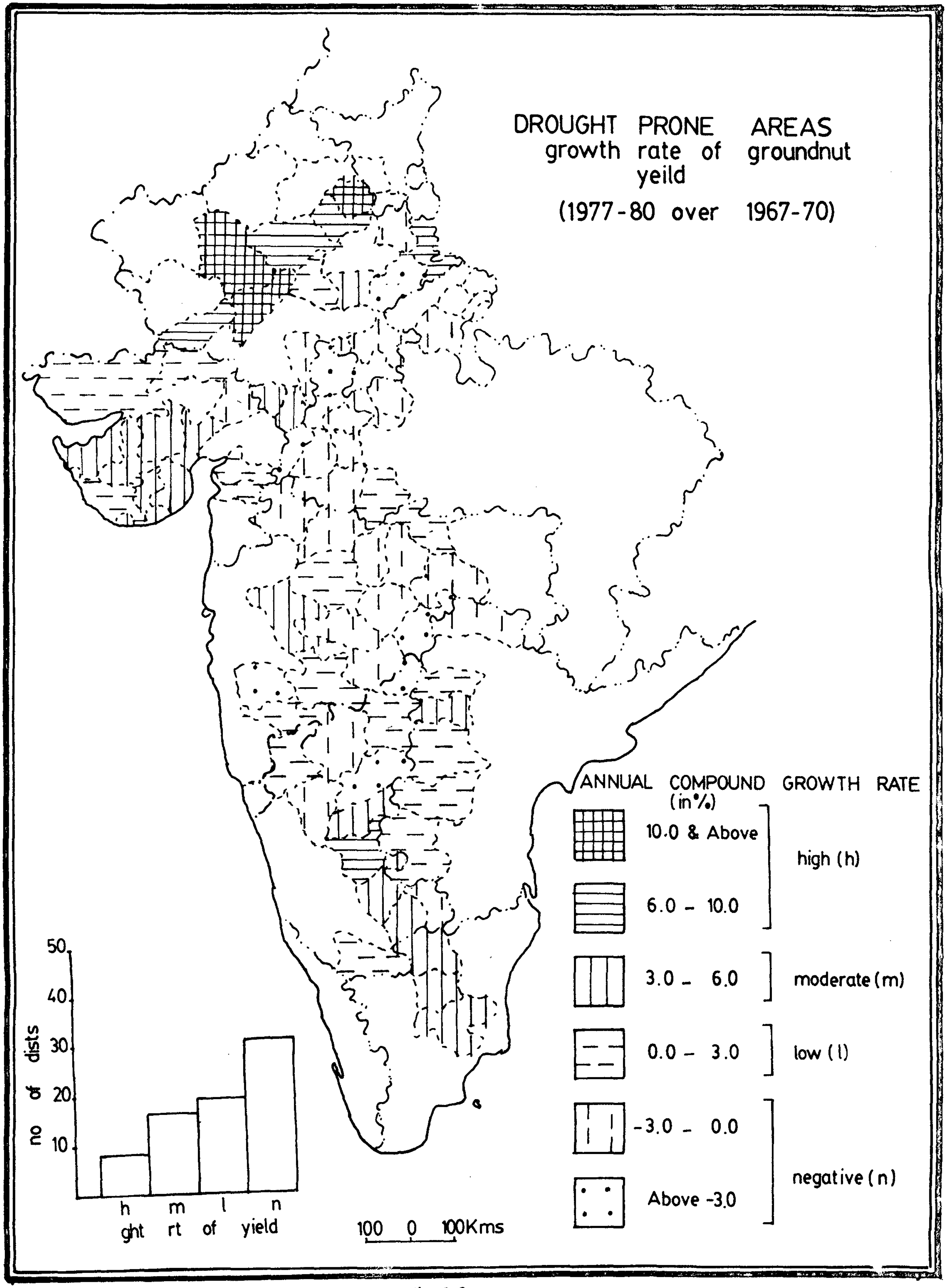

DROUGHT PRONE AREAS
growth rate of groundnut yeild
(1977-80 over 1967-70)
ANNUAL COMPOUND GROWTH RATE (in%)
10.0 & Above
6.0 - 10.0
high (h)
3.0 - 6.0
moderate (m)
0.0 - 3.0
low (l)
-3.0 - 0.0
Above -3.0
negative (n)
50
40
30
20
10
no of dists
h
m
l
n
ght rt of yield
100 0 100Kms

Fig-3.8

districts are less in numbers (16) and are spread over drought affected south western Gujarat, Tamilnadu, Andhra Pradesh and south Karnataka. Medium yield districts are spread all over India, particularly in western Maharashtra, Andhra Pradesh and Karnataka.

Growth Rate of Yield

As mentioned earlier, groundnut yield in drought prone areas has increased at an annual compound growth rate of 2.14 per cent. Looking at its spatial breakup, yield has increased in drought affected areas of Gujarat, Tamilnadu, Karnataka and Andhra Pradesh and has declined in rest of drought affected areas. Some districts of Rajasthan, Madhya Pradesh and Haryana have very large growth rate of yield. This is because of the fact that groundnut production in these areas was absent during earlier period, 1967-70. It is evident from fig. 3.8 and 3.10 that Chitradurga district of Karnataka and some districts of Rajasthan have registered high growth rate of groundnut yield. Maximum number of districts (31), particularly spread over Maharashtra and Madhya Pradesh, have registered decline in yield. Yield level is also low in most of these districts. Most of the drought affected districts of Gujarat, Tamilnadu and south Karnataka have experienced moderate growth in groundnut yield. Low growth rate districts are stretched over Andhra Pradesh, north Karnataka, Gujarat and Maharashtra.

It is evident from table 3.10 that out of eight high growth rate districts, seven had very low yield level during 1967-70. These low yield districts are concentrated in Rajasthan. Similarly out of 18 moderate growth rate districts, ten had low yield level. On the other hand, out of thirty-one districts where yield has declined, four had high and twenty-two had medium yield level. This implies that groundnut yield has increased in most of the districts where yield level was low during 1967-70.

Cotton

Spatial Variation in Yield Level

Cotton is an important industrial crop of drought affected areas of India. During 1977-80, drought affected areas accounted for 69.85 per cent of acreage and 53.69 per cent of production of cotton in the country. The yield level are comparatively low in these areas. Yield in drought affected areas was 125 kg/ha during 1977-80, which was 38 kg less than the average for the country. However, cotton yield of drought prone areas of Gujarat, Haryana and Tamilnadu is higher than average yield of the country. Average yield of cotton in drought affected areas of Haryana and Tamilnadu is 263 and 262 kg/ha respectively. On the other hand, yield is less than average yield of drought affected areas as a whole,

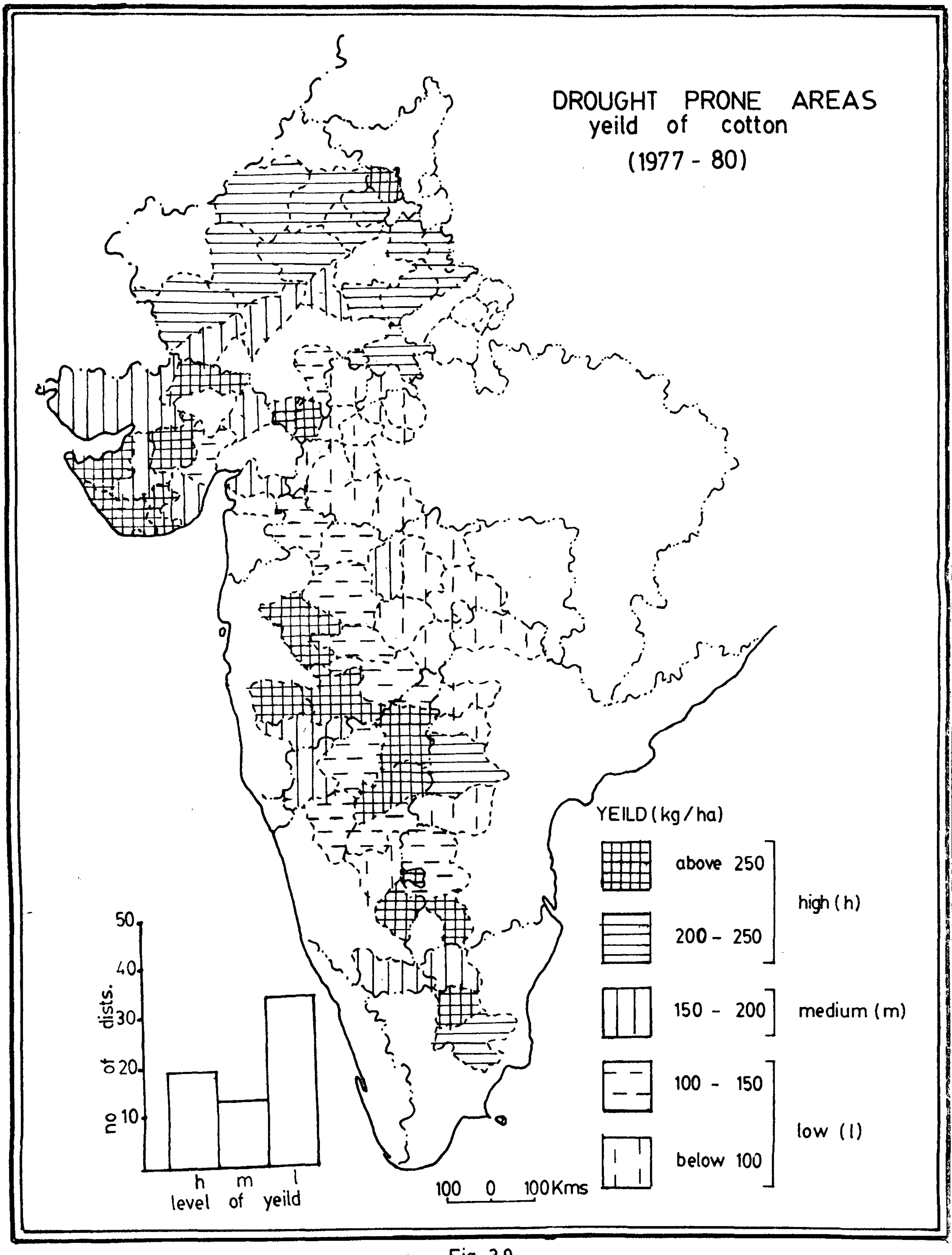
TABLE 3.11

Spatial distribution of yield level and area of cotton

Yield (1977-80) (Kg/ha) (1)	(2) 20.0 & above	(3) 15.0-20.0	(4) 10.0-15.0	(5) 5.0-10.0	(6) Below 5.0	(7) Total
250 & above.	1.Raichur	1.Rajkot		1.Amreli 2.Junagarah 3.Gulberga	1.Bhiwani 2.Jamnagar 3.Banaskantha 4.Ahmednagar 5.Satara 6.Sholapur 7.Kolar 8.Tumkur 9.Salem.	14(18.42)
200-250					1.Alwar 2.Barmer 3.Bharatpur 4.Bikaner 5.Churu 6.Dungaspur 7.Jhunjhunu 8.Jodhpur 9.Kota 10.Nagaur 11.S.Madhopur 12.Sikar 13.Tonk 14.Mehboobnagar 15.Tiruchirapalli	15(19.74)
150-200	1.S.Nagar 2.Sabarkantha 3.Vadodara 4.Buldhana	1.Kutch	1.Bhavnagar	1.Belgaum	1.Sangli 2.Ajmer 3.Jalore 4.Pali 5.Mysore 6.Dharmapuri	13(17.11)

TABLE 3.11 contd...

(1)	(2)	(3)	(4)	(5)	(6)	(7)
100-150	1.Ahmedabad 2.Brauch 3.Dharwar	1.Jalgaon 2.Bellary	1.Aurangabad 2.Bijapur	1.Dhule	1.Beed 2.Osmanbad 3.Chittorgarh 4.Anantpur 5.Bidar	13.(17.11)
Below 100	1.Parbhani 2.Nanded 3.Akola 4.Amravati 5.Yeotmal 6.W.Nimar 7.E.Nimar	1.Adilabad	1.Dhar 2.Kurnool	1.Banswara 2.Ratlam 3.Ujjain 4.Jhabua 5.Rajgarh 6.Shajapur 7.Chitradurga	1.Indore 2.Mandsaur 3.Hydrabad 4.Medak	21(27.63)
Total	15.(19.74)	5(6.58)	5(6.58)	12(15.79)	39(51.32)	76(100.00)



DROUGHT PRONE AREAS
yeild of cotton
(1977 - 80)
YEILD (kg / ha)
above 250
200 - 250
high (h)
150 - 200
medium (m)
100 - 150
below 100
low (l)
100 0 100Kms
50
40
30
20
10
no of dists.
h m l
level of yeild

Fig-3.9

in drought affected areas of Madhya Pradesh, Maharashtra and Andhra Pradesh.

It is evident from fig 3.9 and table 3.11 that most of the drought affected districts of Gujarat, Rajasthan, Haryana and Tamilnadu and some districts of Maharashtra and Karnataka have high yield level. Maximum number (34) of districts have low yield level. Low yield districts are concentrated particularly in Maharashtra, western Madhya Pradesh and Andhra Pradesh. Yield is very low in drought prone districts of eastern Maharashtra and Madhya Pradesh. Medium yield districts are concentrated in Gujarat, southern Rajasthan and some parts of Karnataka.

It is evident from table 3.11 that out of 29 high yield districts, acreage is less than 5 per cent of GCA in 24 districts. Most of these low acreage and high yield districts are located in Rajasthan and western Maharashtra. On the other hand, out of 34 low yield districts, 9 districts have acreage less than 5 per cent of GCA. Seven of these districts have less than 10 per cent of GCA under cotton.

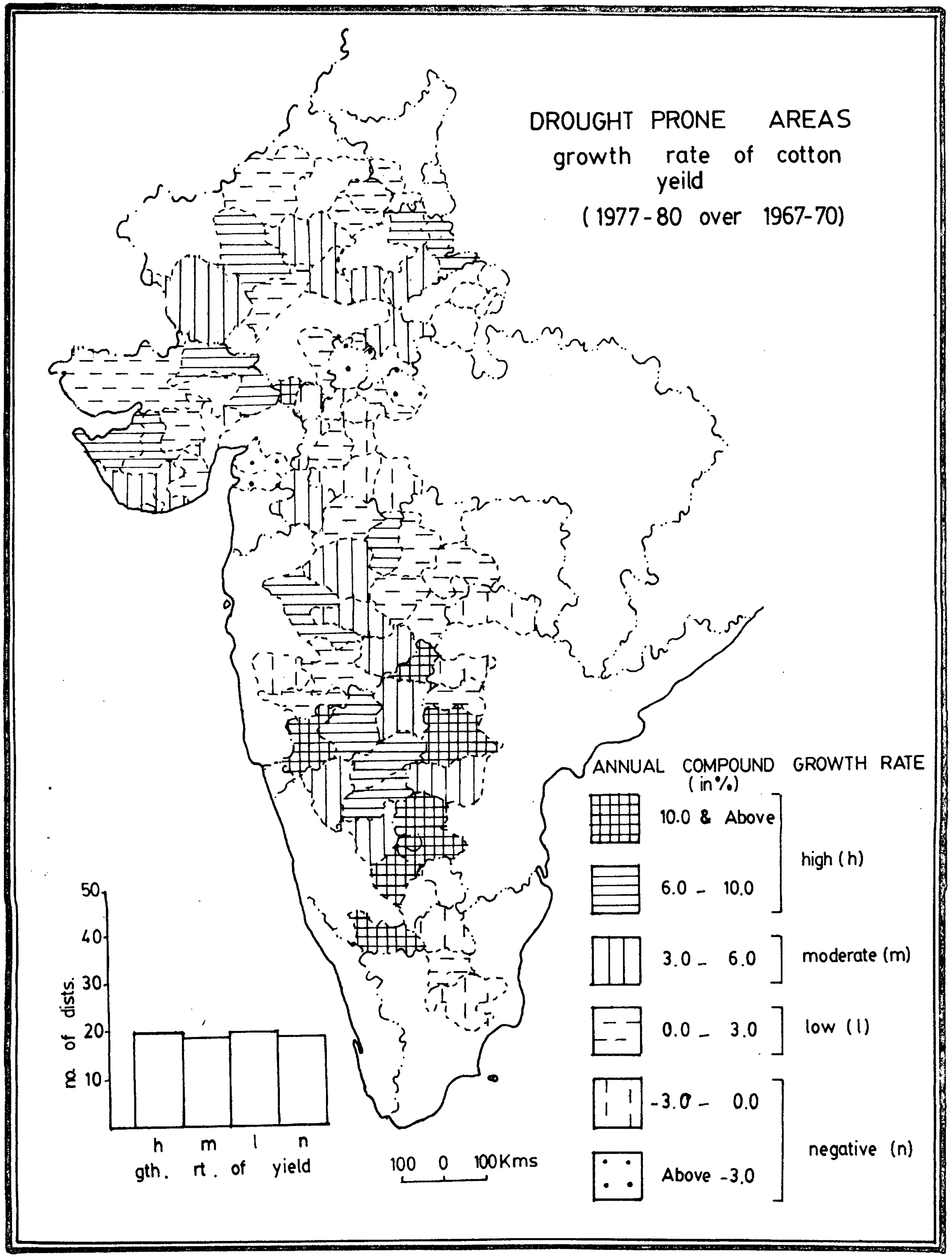
Growth Rate of Yield

Production of cotton in India, over the period 1967-70 to 1977-80, has increased at an annual compound growth rate of 3.46 per cent while in drought prone area it has increased comparatively at low growth rate (1.60 per cent).

TABLE 3.12

Spatial distribution of yield level of cotton and its growth rate

ield 1967-70) Kg/ha) (1)	(2) 10.0 and above	(3) 6.0-10.0	(4) 3.0-6.0	(5) 0.0-3.0	(6) -3.0-0.0	(7) Above -3.0	(8) Total
50 and bove.					1.Satara 2.Tiruchirapalli		2(2.70)
00-250				1.Bhiwani 2.Sholapur 3.Salem	1.Dhamapuri	1.Vadodara	5(6.76)
50-200		1.Jamnagar 2.Banaskan-tha	1.Rajkot 2.Amreli 3.Junagarh	1.Bhavnagar 2.Sangli 3.Bikaner 4.Jhunjuhunu 5.Sikar		1.Brauch	11(14.86)
100-150		1.Sabarkantha 2.Ahmednagar 3.Bharatpur 4.Dungarpur 5.Jodhpur	1.Ajmer 2.Barmer 3.Jalore 4.Kota 5.Nagaur 6.S.Madhopur 7.Tonk.	1.Kutch 2.Chittorgarh 3.Pali	1.Ahmedabad 2.W.Nimar 3.Medak	1.Rajgarh 2.Shajapur	20(27.03)
elow 100	1.Anantpur 2.Mehboob-nagar. 3.Belgaum 4.Bidar 5.Mysore 6.Tumkur	1.S.Nagar 2.Buldhana 3.Alwar 4.Bellary 5.Bijapur 6.Raichur	1.Dhule 2.Aurangabad 3.Beed 4.Osmanbad 5.Kurnool 6.Chitradurga 7.Dharwar 8.Gulberga	1.Jalgaon 2.Parbhani 3.Nanded 4.Akola 5.Yeotmal 6.Dhar 7.Ratlam 8.Hyderabad	1.Amravati 2.Banswara 3.Indore 4.Ujjain 5.Jhabua 6.E.Nimar 7.Adilabad	1.Mandsaur	36(48.65)
Total	6(8.11)	13(17.57)	18(24.32)	19(25.68)	13(17.57)	5(6.76)	74(100.00)



DROUGHT PRONE AREAS
growth rate of cotton yeild
(1977-80 over 1967-70)
ANNUAL COMPOUND GROWTH RATE (in %)
10.0 & Above
6.0 - 10.0
high (h)
3.0 - 6.0
moderate (m)
0.0 - 3.0
low (l)
-3.0 - 0.0
Above -3.0
negative (n)
50
40
30
20
10
no. of dists.
h m l n
gth. rt. of yeild
100 0 100Kms

Fig-3.10

Low growth rate of cotton production in drought prone areas is attributed to shrinkage of area and comparatively low growth rate of yield (2.15 per cent per annum). While acreage is constant (0.34 per cent) and yield has increased at an annual growth rate of 3.11 per cent in India.

Cotton yield has increased in drought affected areas of all states except Madhya Pradesh. Fig. 3.10 depicts spatial variations in growth rates of yield. It is evident that high growth rate districts from a contiguous belt in Karnataka, Andhra Pradesh and are also located in Gujarat and some parts of Rajasthan and Maharashtra. Cotton yield has declined in most of the drought affected districts of Madhya Pradesh, south eastern Gujarat and Tamilnadu. Moderate growth rate districts are scattered all over drought affected areas except Karnataka and Madhya Pradesh. Low growth rate districts are particularly located in parts of Maharashtra, Madhya Pradesh, Gujarat, Rajasthan and Haryana. Cotton yield has increased in most parts of drought affected areas of Karnataka, Andhra Pradesh, Gujarat and Rajasthan. It has declined in western Madhya Pradesh and adjoining region of Gujarat and Maharashtra.

Table 3.12 shows relationship between yield level of cotton during 1967-70 and its growth rate over the period 1967-70 to 1977-80. It is evident that out of 56 low yield districts, yield has increased in 43 and has declined in 13. Seven districts under this category have registered high and fifteen have registered moderate growth rate in yield. On the other hand, out of seven high yield districts, four have registered decline in yield. Yield has increased at a slow rate in remaining three districts. In most of the drought affected districts where yield level was low during 1967-70, it has further declined. It has declined or remained stagnant in high yield districts.

Summing Up

Bajra, which is a staple crop, is widely sown in drought affected areas of Rajasthan, western Haryana and Gujarat. Its yield is high in Gujarat but low in Rajasthan and western Haryana. Yield remains very low in areas which are frequented by drought, e.g. western Rajasthan. High yield level in Gujarat is because of adoption of modern technological inputs, e.g. high yielding varieties of seeds. These technological inputs have not been introduced in bajra cultivation in western Haryana and Rajasthan and crop yield depends on vagaries of weather. Gujarat has registered high growth rate of yield, while it has rather declined in eastern Rajasthan and western Haryana. High growth rate of yield in western Rajasthan is because of the fact that during the base period (1967-70) it was very low due to severe and continuous drought.

Jowar is a cereal crop in large portion of drought affected areas, viz. Maharashtra, Karnataka, Andhra Pradesh and Madhya Pradesh. Drought prone areas are doing better in terms of jowar yield and its growth. Yield level and its growth rate are equal in country and drought affected areas. Except Madhya Pradesh where yield level is medium, it is high in rest of jowar sowing areas (peninsular India). Jowar yield is low to medium in rest of drought affected areas where it is not a significant crop. Yield has increased at moderate to low growth rate in drought affected areas of peninsular India and declined in Madhya Pradesh. Gujarat and western Rajasthan where yield level was medium to low during base years have registered high growth rate.

Gram sowing area is confined to eastern Rajasthan, western Haryana and north-western Madhya Pradesh. Yield of the crop is high in eastern Rajasthan and south western Haryana, and medium in north western Madhya Pradesh. Yield level of gram is stagnant in drought prone areas. It has declined in western Haryana, increased at low rate in western Madhya Pradesh and eastern Rajasthan. It has marginally increased in peninsular India, where gram is not a significant crop.

Groundnut is an important oilseed crop of Gujarat, Andhra Pradesh, Karnataka and Tamilnadu. Its yield in drought prone areas continues to remain below the average of the country. It is high in Gujarat, south Karnataka, Tamilnadu and parts of Andhra Pradesh. It is medium in rest of groundnut sowing areas. Yield has increased at low rate in drought affected areas. It has increased at low to moderate growth rate in major groundnut producing areas and has rather declined in Maharashtra and Madhya Pradesh.

Cotton, a fibre crop, is important in Gujarat, Maharashtra and Karnataka. Its yield is high to medium in Gujarat and some districts of western Maharashtra and Karnataka. Majority of districts in Maharashtra and Karnataka have registered low yield. Tamilnadu, western Haryana and parts of Rajasthan have registered high yield. High yield level in Tamilnadu and Haryana is because of the fact that it is an irrigated crop. Yield has increased at moderate to high growth rate in Gujarat, Maharashtra and Karnataka. It has declined in Madhya Pradesh.

Except jowar and gram, yield of bajra, groundnut and cotton in drought prone areas is less than the average of the country. Yield level of jowar and gram in drought prone area is equal to the average of the country. Jowar yield has increased at moderate growth rate, while gram yield is stagnant. Yield of groundnut and cotton has also increased at a low rate. Bajra yield has also increased, though, at a very low rate.

It is evident from spatial and temporal pattern of yield levels of selected five crops that drought prone area of Gujarat is doing better, having high yield level of bajra, groundnut and cotton, and medium yield level of jowar and gram. The condition in western Rajasthan is depressing where yield of even bajra is very low. Bajra yield is low in eastern Rajasthan too, however, gram yield is high in this region. Madhya Pradesh is also a depression in terms of yield levels of the five selected crops. Except jowar and gram which have medium yield level in the region, yield of bajra, groundnut and cotton is low. Yield level of the four crops is low in Maharashtra except jowar. In Karnataka too, yield levels of important crops, groundnut and cotton, are low. However, jowar yield is high in this region. Yield of jowar is medium to high in Andhra Pradesh. Groundnut and cotton yield are medium and low respectively. Yield of all the crops is high in Tamilnadu except gram. South western parts of green revolution state, Haryana, also show a dismal performance in terms of yield of selected crops. Bajra and gram are important crops in this region. Bajra yield is low, but gram yield is high. Yield of both the crops has declined over the period of study.

Drought prone areas of India offer great potentiality in the above mentioned crops. Jowar yield is comparatively high, but still it can be increased in drought affected areas of Maharashtra, Madhya Pradesh, Karnataka and Andhra Pradesh. The manipulation of seeds technology is an imperative as the extension of net sown area is constrained. More judicious use of available moisture and further conservation strategies may deliver the good in future.

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CHAPTER IV

RAINFALL PARAMETERS AS DETERMINANTS OF AREA UNDER SELECTED CROPS AND THEIR YIELD IN DROUGHT PRONE AREAS

Agricultural productivity and cropping pattern of a region are functions of various factors such as physical phenomenas, socio-economic conditions, technology and institutional factors. Advancement in science and technology and progressive changes in socio-economic conditions in twentieth century have been able to pull out to some extent, the agriculture along with other sectors of economy, of the crisis of stagnation. Technological break through, in terms of mechanization, irrigation facilities, new seeds (HYV and quick ripening varieties), chemical fertilizers, insecticides and pesticides, have been able to increase agricultural production in accordance with demand. But still major parts of the developing countries, have not been successful to acquire a significant technological breakthrough in agricultural sector either because of underdevelopment of science and technology or various socio-economic problems. Physical factors, particularly climatic factors, still dominate the agriculture of these countries. Vast majority of third world population depend on agriculture to earn their livings.

Talking about the measures to protect the crops from climatic vagaries and ensure food for human beings, the Director General of Food and Agriculture Organisation of United Nations made a statement of Press on 1 February 1973: "It is intolerable that this world of 1970's with all its scientific progress and its slowly growing sense of common purpose, should go on enduring a situation in which the chances of enough decent food for millions of human beings may simply depend on the whim of one year's weather."[1]

New technological inputs in agriculture have been partially successful in reducing adverse effects of climatic factors on agricultural development. Assured water supply through irrigation, spray of insecticides and pesticides to counter meanance of crop diseases and pests, drought resistant and quick ripening varieties of seeds and improved agronomic practices have been able to mould the agricultural scene and reduce the risks imposed by climate. Still climatic factors remain responsible for variations in agricultural production up to a great extent in different parts, bec ause the adoption of technology is not an ubiquitious phenomena. If not dominate it, these factors indicate the direction of agricultural development of a region. "It is generally estimated that

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1 Quoted from the Report of National Commission on Agriculture, 1978, part 4, Ministry of Agriculture and Irrigation, Government of India, New Delhi, p. 1.

weather as a single factor could be responsible for a much as 50 per cent of variations in yield which occur from year to year, the remaining 50 per cent being due to other factors like irrigation, manuring and plant protection measures etc."[2] Influence of climatic factors is much pronounced in developi ng countries where new agricultural technology is either not available or is scale-biased.

Influence of weather phenomenon on agricultural production is obvious as crops are grown on open fields, involve biological growth and bear fluctuations in weather. For its sound growth and successful production, a crop requires optimal temperature, soil moisture and sunshine. Requirement of these factors, however, varies for various stages of a crop growth, and different crops require different optimal levels of these factors. So, excesses or shortages of solar radiation, temperature, precipitation and wind velocity from the optimal levels have adverse effects on crop production. Crop production involves metabolic process where growth of plant tissues depends on photosynthesis which is a function of solar radiation, carbandioxide, soil moisture and soil nutrients. In such a situation, climatic factors have major effect on crop production and technological intervention has been partially successful in reducing it.

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2 Ibid., p. 23.

In the above mentioned climatic factors, rainfall is dominant as it is the natural source of soil moisture for a vast area under cultivation. "Rainfall is the most important climatic factors as it determines the potential of any region in terms of crops to be raised, farming system to be adopted, the nature and sequence of farming operations to be followed, and targets to be achieved in agricultural productivity."[3] Availability of soil moisture depends on rainfall received, its parameters and fluctuations in occurance. These parameters have direct bearing on area and yield of crops. Rainfall is the most dominant climatic factor, which caused variations in agricultural production in tropical and subtropical regions of the world where sunshine and temperature are not limiting factors. Despite continuing efforts to meet the soil moisture demand of crops with the help of irrigation, a vast tract of globe, particularly arid and semi-arid zones, has to depend on rainfall parameters to raise the crops and rear the cattles. "Rainfall has a dominating influence in crop production for nearly two third of a world area.... In arid and semi-arid regions it becomes the limiting factor, superseding all other factors of crop production due to total and seasonal

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3 Jasbir Singh and S.S. Dhillon (1984), Agricultural Geography, New Delhi, p. 71.

amounts, frequencies, short time intensities, drought spells, wet spells and other variabilities.[4]

In India too, rainfall is a dominant factor, responsible for variations in cropping pattern and agricultural productivity in space and time. "Of the major weather elements affecting crop production, such as temperature, sunlight, moisture and wind, moisture is by far the most important single factor in Indian agro-climatology."[5] Temperature and sunshine do not have much influence on agriculture except Himalayan land, where temperature remains low throughout the year and drops even below freezing point during winter. North western parts of Indian plain also experience severe cold. Air and soil moisture temperature in December and January is likely to fall below 0°C. Frost and cold waves are harmful for rabi crops in north western Indian plain. High humidity, long standing cloudiness and lack of sunshine are sometimes responsible for crop diseases and pests. Otherwise it has got an endless crop seasons. "In India, however, temperature and sunshine do not act as limiting factors in a given part for the crops which are commonly grown.... It is either the rainfall or the moisture deficit

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4 J.R. Kakde (1985), Agricultural Climatology, New Delhi, pp. 116-17.

5 A. Ahmed and M.H. Qureshi (1979), "Some Aspects of Indian Agro-Climatology", Occasional Paper No. 22, CSRD, SSS, New Delhi, p. 5.

which comes out as the most important factor influencing the crop growth".[6]

Development of irrigation has been so meagre in India that more than 70 per cent of total cropped area has to depend on rainfall for soil moisture. In large parts of the country bulk of rainfall occurs between June and September, during south west monsoon season. Littoral parts of Tamilnadu and north western India, however, receive rainfall during winter. Rainfall also has a great deal of spatial variability, as Assam, other parts of eastern India and western Ghats receive annual rainfall above 250 cm. and western Rajasthan and Gujarat receive annual rainfall less than 50 cm. Rainfall in India, which is by and large confined to south west monsoon season in most parts of the country, is characterized having temporal fluctuations, which are more evident in drought prone or scanty rainfall areas. Hence dryland farming involves much risks than wet land. "The moisture content of the soil, in the growing season particularly, becomes important factor in the dry areas. It is not the temperature but the moisture which is limiting factor in the drylands of the tropics. Most of the dry farming techniques are adopted to conserve and use the moisture optimally."[7] Rainfall is dominant factor responsible

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6 Report of the National Commission on Agriculture, op. cit., p. 24.

7 M.H. Qureshi, "Area and Yield of Some Selected Crops in Dry Area - An Evoluation of Water as a Determinant", Proceedings of the Symposium on Dryland Farming, 29 March 1985, AMU, Aligarh, pp. 2-3.

for variations in yield and acreage of crops in drought affected areas of India.

Success of crop production not only depends on total amount of annual rainfall but also on the nature of distribution of this amount in time and space. The parameters which are crucial for the success of crop, besides the total amount of rainfall, are seasonal rainfall, number of rainy days, variability of rainfall, frequency of wet spells and frequency of dry spells."[8] Hence, while studying rainfall crop production relationship it is utmost important to examine nature of various rainfall parameters and their influence on crop yield and cropping pattern.

1. Annual Rainfall

It is the amount of rainfall received during an agricultural year. Annual rainfall has direct bearing on crop yield and cropping pattern of an agricultural region. It is evident from difference in yield levels and cropping pattern of wet and dry areas of India. Rice is a dominant crop in areas having annual rainfall more than 100 cm. Wheat is a dominant crop in irrigated tracts of northwest India. Dry farming is practised in rest of the country and coarse food grains, bajra, jowar and maize are main crops. There is remarkable difference between agricultural productivity of

8 Ibid., p. 23.

wet and dry areas. Keeping in view the amount of rainfall and its characteristics, farmers of dry or drought affected areas adjust cropping pattern in such a way, so that the risks posed by climatic factors are reduced. While shortage in annual rainfall invites drought resistant hardy crops, excess rainfall tempts the farmers to grow water intensive crops.

2. Seasonal Rainfall

Seasonal rainfall is amount of rainfall occuring during the crop growing season. It is the major source of soil moisture, however, role of residual soil moisture cannot be discarded. Residual moisture does not play very important role during kharif season in India, but its role cannot be undermined in success or failure of rabi crops. For example, gram, which is a rainfed rabi crop in most parts of north west and central India, grows on conserved or residual soil moisture of south west monsoon season. By and large success of this crop depends on rainfall occurred during last phase of south west monsoon and retreating monsoon. Light showers during 'rabi' season are also conducive for this crop. Adequate and timely south west monsoon rainfall which coincides with 'kharif' season, has positive influence on kharif crops production. Water requirement of crops varies from one stage of growth to another. Hence, seasonal rainfall should be adequate enough to meet its soil moisture requirement.

3. Onset and Withdrawal of Monsoon

Timely onset and withdrawal of south west monsoon has positive influence on crop performance. Late onset and insufficient rainfall in the beginning of the season not only shortens the crop season and hence have adverse affects on yield but also results in temporary shifts in cropping pattern. In such an eventuality, particularly in semi-arid areas, water intensive and long duration crops are replaced by drought resistant and short duration crops because "crops and their varieties vary greatly in their suitability in relation to their date of sowing and tolerance to droughts. Some crop varieties could withstand prolonged droughts while others are highly susceptible to moisture stress".[9] Late withdrawal of south west monsoon may have adverse influence on yield of kharif crops because of high susceptibility of crops to insects and pets in humid conditions which damage the crops during maturity stage. However, it has positive influence on acreage and yield of rainfed rabi crops which are grown on residual soil moisture. Early withdrawal of rainfall hampers yield of kharif crops, as moisture deficiency during maturity stage of plants results in production in grain size. It also has adverse affects on acreage and yield of rainfed rabi crops.

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9 P.C. Ashok Raj (1979), Onset of Effective Monsoon and Critical Dry Spells - A Computer based Forecasting Technique, New Delhi, IARI, p. 6.

4. Rainfall Reliability

Consistent and adequate supply of soil moisture is basic requirement for balanced growth of a crop. "Steady and moderately moist conditions are more favourable to crop growth than an erratic alternation of very wet and very dry spells".[10] South west monsoon, which is characterized by erratic and unreliable behaviour, does not grant adequate and timely supply of soil moisture in vast tracts of the country. "Though it is expected to occur during a cropping season and be useful to plants, the fainfall does not occur with a fixed schedule in frequency, duration and intensity in any region showing effects of wide fluctuations in crop performance."[11]

It is not only variations in amount of annual or seasonal rainfall but also rainfall variability in time and space are responsible for variations in acreage and yield of crops. Variability of rainfall in space for a long period of time, however does not have much importance because cropping pattern of a region gets adjusted with soil moisture availability. But temporal variations in annual and seasonal rainfall have impact on yield and acreage of the crops. Its impact on crop

10 J.E. Hobbs (1980), Applied Climatology : A Study of Atmospheric Resources, London, p. 115.

11 Kakde, (1985), op. cit., p. 117.

performance becomes more pronounced in drought affected or dry areas where high rainfall variability is associated with scanty rainfall. "Normally, it is seen that variability is usually of least magnitude over areas of high rainfall and greater over those of low rainfall."[12] It is also evident from the fact that correlation coefficient between annual rainfall and its variability in drought affected areas is -0.60. This highly unreliable and scanty rainfall of drought affected areas poses risks in agricultural development. "Variations in rainfall from year to year and even from season to season, when frequently marginal in amount for agriculture, becomes more critical."[13] In such a situation drought resistant crops dominate the cropping pattern of the region and crop yield is subject to variation with fluctuations in rainfall occurance.

Variability of seasonal rainfall has more influence on crop performance than that of annual rainfall. Variations in weekly and monthly rainfall during crop season exert even more influence on crop production. Crop yield may fall down in case of inadequate soil moisture supply during maturity stage. "Variability in time towards the end of kharif rainy season is much more and hence of great significance not only for

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12 Jasbir Singh and S.S. Dhillon (1984), op. cit., p. 72.

13 Ibid., p. 71.

kharif crops but also for rabi crops that grow primarily on residual soil moisture gained from rain received earlier."[14] Hence, rainfall variability is inversely related with rainfall reliability. Crop yield remains considerably low in highly unreliable rainfall zones and vice versa.

5. Frequency of Wet and Dry Spells

Wet spell is a rainy period when rainfall is adequate enough to meet the water demand of the crops in a region. But wet spell does not continue throughout rainy season and sometimes rainfall does not occur for a considerable period of time. In such a situation, evapotranspiration exceeds available soil moisture. This period of soil moisture stress is called as dry spell. Prolongation of dry spell causes stress and strains on crop growth and is termed as 'critical dry spell'. Occurance of dry spells is a common phenomena during south west monsoon season. Monsoon depressions, which originate in northern Bay of Bengal and move north west-ward bring rainfall in most parts of north and central India. These depressions are associated with moderate to heavy rainfall and presence of these depression in any region marks wet spell. Time gap between the two successive depressions is marked as a dry spell. Hence, success of crop production and acreage depend on frequency of dry and wet spells. The region characterized by having

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14 Kakde (1985), op. cit., p. 118.

frequent dry spells has low crop yield in comparison to other regions where dry spells are not so frequent.

6. Rainy days and Intensity of Rainfall

Effectiveness of rainfall, which depends on intensity of rainfall, land slope, soil texture and temperature, also plays an important role in crop production. High rainfall in a region might be concentrated to a few rainy days and have high intensity of rainfall. In such a situation rainfall has poor effectiveness because rain water flows down the slope and results into soil erosion and floods. Crop yield remains lower in such a region in comparison to others where rainfall being low but has higher effectiveness. South west monsoon rainfall in India is characterized by heavy showers occuring during a small period. "Rainfall intensity studies in India show that storms of 25 mm/hr or more intensities are received on a few days (about 7 to 15 per cent of total rainy days) and account for 30 to 70 per cent of total seasonal rainfall in low and moderate rain zones. Such rainfall also accounts for most of the run-off giving poor rainfall effectiveness, high soil erosion, erratic daily variations in river flows and pounding of water on land."[15] Hence, for better crop yield, rainfall should not only be high

15 Ibid., pp. 123-4.

but also fairly distributed with neither too high nor too low rainfall effectiveness.

Because of certain limitations, non-availability of data, effect of all the aforementioned rainfall parameters on yield and area of some selected crops, has not been examined. Present study analyses influence of annual rainfall, seasonal rainfall and variability of annual rainfall (C.V.) on acreage and yield of bajra, jowar, gram, groundnut and cotton in drought prone areas with the help of step-wise linear regression. Two independent variables, annual rainfall and seasonal rainfall, create the problem of multi-collinearity as correlation between these two variables is +0.97 for both periods of time, 1968-69 and 1978-79. In order to avoid the problem of multi-collinearity two sets of equation Y = f (X_1 and X_3) and Y = f (X_2 and X_3), have been tried for stepwise regression. The set having higher explanatory power has been chosen for explanation.

Rainfall Parameters as Determinants of Crop Acreage

Rainfall Parameters and Area Under Bajra

Correlation Matrix: Correlation matrix for 1968-69 shows that bajra acreage is inversely correlated with annual rainfall and seasonal rainfall and positively with variability of annual rainfall. Values are high and significant at 1 per cent level

Table 4.1

Bajra Area

Correlation Matrices

1968-69

	Y_1	X_1	X_2	X_3
	1.000	-.742*	-.699*	.672*
		1.000	.969	-.600
			1.000	-.472
				1.000

1978-79

	Y_1	X_1	X_2	X_3
	1.000	-.574*	-.548*	.622*
		1.000	.970	-.488
			1.000	-.397
				1.000

Y = Area under crop
X_1 = Annual rainfall
X_2 = Seasonal rainfall
X_3 = C.V. of annual rainfall

* Significant at 1 per cent level of significance
** Significant at 5 per cent level of significance

of significance for all these parameters. Annual rainfall has highest correlation coefficient -0.742 followed by seasonal rainfall -0.699 and C.V. of rainfall -0.672.

After a decade, in 1978-79 also bajra acreage had moderate to high correlation with annual rainfall, seasonal rainfall and C.V. of rainfall. C.V. of rainfall has highest correlation among these parameters (+0.62). Both, annual and seasonal rainfall have negative correlation with bajra area. r values for all three parameters are significant at 1 per cent level of significance.

It is evident from the above mentioned facts that variations in rainfall parameters lead to variations in area under bajra. In the rainfed agriculture of drought affected areas, area under bajra decrease with increase in annual and seasonal rainfall and increase with increase in rainfall variability. Bajra acreage is higher in scanty and less reliable rainfall areas. Research hypothesis that area under bajra increases with increase in annual and seasonal rainfall and decreases with increase in C.V. of rainfall is rejected and alternate hypothesis is accepted.

Stepwise Regression Analysis

Seasonal rainfall enters at step 1, in the regression analysis during the period 1968-69. It explains 48.86 per cent of variations in area under bajra. Seasonal rainfall along with

Table 4.2

Bajra Area

Stepwise Regression Analysis

	Variable	R	R^2x100	Increase in R^2x100	$\bar{R}^2$	F	Regression Coefficient	S.E. of Reg.Coef.	t	Intercept
1968-69										
Step 1	X_2	.699	48.86	-	.489	76.242*	-.626	.072	-8.732*	48.76
Step 2	X_2	.799	63.84	14.98	.634	69.885*	-.439	.069	-6.391*	9.33
	X_3						.844	.147	5.746*	
1978-79										
Step 1	X_3	.622	38.69	-	.387	50.591*	.899	.126	7.113*	-19.49
Step 2	X_3	.704	49.56	10.87	.489	38.758*	.694	.126	5.518*	2.54
	X_2						-.214	.052	-4.109*	

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

C.V. of rainfall explain 63.84 per cent of variations in bajra acreage, in which C.V. of rainfall has a contribution of 14.98 per cent. F values for both steps shows that R values are significant at 1 per cent level of significance. Per unit increase in seasonal rainfall and C.V. of rainfall cause, respectively, 0.44 unit decrease and 0.84 unit increase in area under bajra. Regression coefficients for both steps are significant at 1 per cent level of significance.

Rainfall variability explained 38.69 per cent of variations in bajra area in 1978-79. R value is significant at 1 per cent level of significance. Regression coefficient (+0.90) is also significant at 1 per cent level of significance. Variability of rainfall alongwith seasonal rainfall explains 49.56 per cent of variations in bajra area. Seasonal rainfall, which joins C.V. of rainfall at step 2, explains 10.87 per cent of variations in bajra acreage. R value is significant at 1 per cent level of significance. Regression coefficient with both the parameters of rainfall are also significant at 1 per cent level of significance.

Bajra acreage is inversely correlated with annual and seasonal rainfall and positively with variability of rainfall. It is a drought resistant, hardy crop and its cultivation is confined to scanty and less reliable rainfall zones of western Rajasthan northwestern Gujarat and western Haryana. In comparatively higher rainfall areas this crop has to compete with jowar, maize and ragi. Rainfall parameters have significant influence on bajra acreage, as only two parameters, seasonal rainfall and variability of rainfall explain 63.84 per cent and 49.56 per cent of variations in area under crop in 1968-69 and 1978-79 respectively.

Rainfall Parameters and Area under Jowar

Correlation Matrix: It is evident from table 4.3 that area under jowar in 1968-69 had moderate correlation with annual rainfall, seasonal rainfall and variability of rainfall. r value is -0.45 for rainfall variability, which is significant at 1 per cent level of significance. Annual and seasonal rainfall, on the other hand are positively correlated with area, however, their degree of association is considerably low, +0.38 and +0.37 respectively. r values for these variables are significant at 1 per cent level of significance.

In 1978-79, variability of rainfall exhibits negative correlation (-0.50) with area under jowar, which is significant at 1 per cent level of significance. Correlation of jowar acreage with annual rainfall is positive and low (.20) which is significant at 5 per cent level of significance. Seasonal rainfall exhibits very low and insignificant positive correlations with jowar acreage. One of the possible reason for low correlation with

Table 4.3

Jowar Area

Correlation Matrices

1968-69

	Y_1	X_1	X_2	X_3
	1.000	.377*	.369*	-.453*
		1.000	.969	-.600
			1.000	-.472
				1.000

1978-79

	Y_1	X_1	X_2	X_3
	1.000	.203**	.097	-.500*
		1.000	.970	-.488
			1.000	-.397
				1.000

* Significant of 1 per cent level of singificance

** Significant at 5 per cent level of significance

seasonal rainfall might be the fact that seasonal rainfall pertains to rainfall occurred between June and September, but jowar is also grown in rabi as an irrigated crop in Maharashtra and south India.

Stepwise Regression

Rainfall variability which enters at first step explains 20.52 per cent of variations in area under jowar in 1968-69. R value is significant at 1 per cent level of significance. Seasonal rainfall which is introduced at second step, together with rainfall variability, explains 23.62 per cent of variations in area under jowar. Contribution of seasonal rainfall is very low, i.e. 3.10 per cent. R value at second step (0.49) is significant at 1 per cent level of significance. Regression coefficient of rainfall variability on areas is -0.59 which is significant at 1 per cent level of significance at step one. Regression coefficient for rainfall variability is negative and significant at 1 per cent level of significance, but it is positive and insignificant for seasonal rainfall at the second step. In 1978-79, rainfall variability is introduced at first step and explains 25 per cent of variations in areas under jowar. R value is also significant at 1 per cent level of significance. Variability of rainfall combined with seasonal rainfall explain 26.21 per cent of variations in jowar acreage. In this case also R value (0.51) is significant at 1 per cent

Table 4.4

Jowar Area

Stepwise Regression Analysis

	Variable	R	R^2x100	Increase in R^2x100	$\bar{R}^2$	F	Regression Coefficient	S.E. of Reg. Coef.	t	Intercept
1968-69										
Step 1	X_3	.453	20.52	-	.205	20.610*	-.588	.130	-4.540*	39.86
Step 2	X_3	.486	23.62	3.10	.227	12.199*	-.466	.144	-3.211*	29.04
	X_2						.122	.068	1.793	
1978-79										
Step 1	X_3	.500	25.00	-	.250	26.709*	-.644	.125	-5.168*	39.98
Step 2	X_3	.512	26.21	1.21	.253	14.060*	-.705	.135	-5.206*	46.59
	X_2						-.064	.056	-1.143	

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

level of significance, however F value in second step has declined sharply. Seasonal rainfall provides explanation for 1.21 variation in area under jowar. Values of R^2 suggest to retain seasonal rainfall in the explanatory variables. Coefficient of slope of variability of rainfall on area under jowar is negative and significant at 1 per cent level of significance for both steps. Regression coefficient of seasonal rainfall is negative and insignificant at step 2.

Preceding discussion implies that variation in area under jowar is function of variations in annual rainfall, seasonal rainfall and variability of rainfall. Research hypothesis that jowar acreage increases with increase in annual rainfall and seasonal rainfall and decrease in coefficient of variation of rainfall holds true. Variability of rainfall has comparatively higher explanatory power. Correlation with annual and seasonal rainfall is also significant. However, correlation coefficient with seasonal rainfall is very low and insignificant in 1978-79. Apart from explanation given earlier, this might be because of other rainfall parameters, particularly on set and withdrawal of monsoon etc.

<u>Rainfall Parameters and Area Under Gram</u>

<u>Correlation Matrix:</u> Table 4.5 shows that all three parameters of rainfall had low and insignificant correlation with area under gram in 1968-69. Annual rainfall has positive correlation

Table 4.5

Gram Area

Correlation Matrices

1968-69

	Y_1	X_1	X_2	X_3
	1.000	.171	-.199	.087
		1.000	.223	-.600
			1.000	-.565
				1.000

1978-79

	Y_1	X_1	X_2	X_3
	1.000	.161	-.247**	-.047
		1.000	.248	-.488
			1.000	-.579
				1.000

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

(+0.17) with area. Correlation is negative with remaining parameters, seasonal rainfall (-0.199) and variability of rainfall (-0.09).

In 1978-79, seasonal rainfall was only parameter which had significant correlation with area under gram. Association between these two variables is low and inverse. Annual rainfall exhibits low insignificant positive correlation with gram acreage. Rainfall variability shows negligible positive association.

Stepwise Regression

During 1968-69, seasonal rainfall which was introduced at first step, explained 3.96 per cent of variations in area under gram. R value 0.199 is insignificant. Together with seasonal rainfall, variability of rainfall explains 9.80 per cent of variations in gram acreage. Variability of rainfall, at second step, explains 5.84 per cent at variations in acreage of gram. F value shows that R value (0.31) is significant at 5 per cent level of significant. Regression coefficient at step one is also insignificant. But in step 2 it is significant at 1 per cent level of significance for seasonal rainfall and 5 per cent level of significance for variability of rainfall.

During 1978-79 also, seasonal rainfall entered at first step and explained 6.10 per cent of variations in gram acreage.

Table 4.6

Gram Area

Stepwise Regression Analysis

	Variable	R	R^2x100	Increase in R^2x100	$\bar{R}^2$	F	Regression Coefficient	S.E. of Reg. Coefficient	t	Intercept
1968-69										
Step 1	X_2	.199	3.96	-	.040	3.297	-.188	.103	-1.816	4.99
Step 2	X_2	.313	9.80	5.84	.087	4.292**	.344	.122	-2.815*	12.08
	X_3						-.180	.079	-2.262**	
1978-79										
Step 1	X_2	.247	6.10	-	.061	5.216**	-.173	.076	-2.284**	7.218
Step 2	X_2	.340	11.56	5.46	.105	5.170*	-.289	.091	-3.184*	15.68
	X_3						-.206	.093	-2.207**	

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

R value (0.250) is significant at 5 per cent level of significance. In second step, seasonal rainfall and variability of rainfall explain 11.56 per cent of variations in area under gram. Variability of rainfall explains 5.46 per cent of variations in acreage. R value (0.34) is significant at 1 per cent level of significance. Regression coefficient of seasonal rainfall on area under gram is significant at 5 per cent level of significance. It has improved in second step and is significant at 1 per cent level of significance. Regression coefficient of variability of rainfall is significant at 5 per cent level of significance.

Results of correlation matrices and step-wise regression analysis show that except seasonal rainfall no other rainfall parameter has significant influence on area under gram. This, however, does not imply that area under gram is indifferent to rainfall parameters. Various physical and socio-economic factors seem to be intervening to weaken the correlation between rainfall parameters and gram acreage. Gram acreage is concentrated in drought affected areas of north and central India (eastern Rajasthan, north western Madhya Pradesh and western Haryana) because of congenial environment. Gram is a rabi crop, requires low temperature as compared to kharif crops and is sown on retentive and conserved soil moisture. Hence, it is not sown in large parts of the drought affected areas. In large parts of drought prone areas of peninsular India rabi jowar and groundnut are preferred. Western Rajasthan and Gujarat experience soil moisture deficit even in kharif season. Hence, there is no question of soil moisture retention. Seasonal rainfall, particularly rainfall occuring at the beginning of seasons, has positive influence on gram acreage. But it shows negative correlation in the present exercise. This is because of the fact that seasonal rainfall in this exercise pertain to rainfall occurred during October-February. This season has a good amount of rainfall in Tamilnadu, Karnataka and Andhra Pradesh where gram acreage is very low. Hence, seasonal rainfall shows negative correlation with area under gram.

Rainfall Parameters and Area Under Groundnut

Correlation Matrix: Table 4.7 shows that none of rainfall parameters had significant correlation with area under groundnut during 1968-69. Correlation with independent variables, annual rainfall, seasonal rainfall and variability of rainfall is positive and very low.

After a decade, during 1978-79, annual rainfall and seasonal rainfall had low negative correlation with groundnut acreage. Correlation between annual rainfall and groundnut acreage is, significant at 5 per cent level of significance. Variability of rainfall is positively correlated with groundnut acreage. It is significant at 5 per cent level of significance.

Table 4.7

Groundnut Area

Correlation Matrices

1968-69

	Y_1	X_1	X_2	X_3
	1.000	.135	.150	.190
		1.000	.969	-.600
			1.000	-.472
				1.000

1978-79

	Y_1	X_1	X_2	X_3
	1.000	-.219**	-.168	.218**
		1.000	.970	-.488
			1.000	-.397
				1.000

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

Table 4.8

<u>Groundnut Area</u>

Stepwise Regression Analysis

	Variable	R	R^2x100	Increase in R^2x100	$\bar{R}^2$	F	Regression Coefficient	S.E. of Reg. Coefficient	t	Intercept
1968-69										
Step 1	X_3	.190	3.61	-	.036	2.991	.207	.120	1.729	1.44
Step 2	X_3	.365	13.32	9.71	.123	6.077*	.462	.143	3.237*	-19.20
	X_1						.198	.066	2.978*	
1978-79										
Step 1	X_1	.219	4.80	-	.048	4.039**	-.104	.052	-2.010**	17.01
Step 2	X_1	.254	6.45	1.65	.053	2.718	-.070	.059	-1.186	7.993
	X_3						.180	.154	1.173	

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

Stepwise Regression: Table 4.8 shows that for the period 1968-69, variability of rainfall which is introduced at first step, explains only 3.61 per cent variation in the area under groundnut. R value .0.19 and regression coefficient (+0.210) are insignificant. In second step together with annual rainfall, variability of rainfall explains 13.32 per cent variations in groundnut acreage. Hence, contribution of annual rainfall in variations in area is 9.71 per cent. Multiple correlation coefficient (R) .365 is significant at 1 per cent level of significance.

For the period 1978-79, annual rainfall enters at first step and explains 4.8 per cent of variations in area under groundnut. R value (0.219) is significant at 5 per cent level of significance. Regression coefficient is negative and low, th ough significant at 5 per cent level of significance. Variability of rainfall joins annual rainfall at second step and explains together with annual rainfall 6.45 per cent of variations in area under groundnut. Contribution of variability of rainfall is meagre (1.65 per cent) in the explanation. R value (0.25) is insignificant. Coefficients of slope of annual rainfall and variability of rainfall on crop acreage are also insignificant.

From the preceding discussion inference can be drawn that none of the rainfall parameters, annual rainfall, seasona rainfall and variability of rainfall, has strong relationship with area under groundnut. Significant but low and negative correlation with annual rainfall and low positive correlation with variability of rainfall for the period 1978-79, however, rejects the research hypothesis that groundnut acreage increase with increase in rainfall and decrease with increase in variability of rainfall. Alternate hypothesis is accepted which says that groundnut acreage is inversely correlated with annual rainfall and positively with variability of rainfall. Explanatory power of these rainfall parameters is weak. Seasonal rainfall has weak and insignificant association with groundnut acreage. This might be because of the fact that groundnut is also sown in rabi season in some parts of south India.

Weak correlations with annual rainfall and variability of rainfall is because of the fact that groundnut can be sown in most parts of drought affected areas where annual rainfall is more than 50 cm. Light clay soil of low rainfall areas of Gujarat is suitable for groundnut cultivation. It is fertile, well drained and does not hamper the pod development. Hence, about 40 per cent of the groundnut areas in drought prone areas is confined to Gujarat. Comparatively high rainfall districts of Andhra Pradesh, Karnataka and Tamilnadu also have high acreage of groundnut, though less than that in Gujarat. It is an insignificant crop in low rainfall zones of Rajasthan and western Haryana.

Rainfall Parameters and Area Under Cotton

Correlation Matrix: Table 4.9 depicts that seasonal rainfall is the only rainfall parameter which has significant correlation with area under cotton. However, r value (+0.286) is low but significant at 1 per cent level of significance. Annual rainfall also has positive association, but it is low and insignificant. On the other hand variability of rainfall exhibits negative, low and insignificant correlation with area under cotton.

None of the rainfall parameters has significant correlation with cotton acreage for the period 1978-79. Annual rainfall and seasonal rainfall have very low positive correlation while variability of rainfall has very low negative correlation.

Stepwise Regression: Seasonal rainfall, which got introduced at first step, explains 8.18 per cent of variation in area under cotton during 1968-69. R value 0.29 is significant at 1 per cent level of significance. Regression coefficient (+0.17) is also significant at 1 per cent level of significance. At step 2, seasonal rainfall and variability of rainfall explain 8.64 per cent of variations in area under cotton. Variability of rainfall has very low explanatory power, 0.46 per cent only. R value is significant at 5 per cent level of significance. However, $-\bar{R}^2$ value suggest not to include variability of rainfall in the model. Regression coefficient for seasonal rainfall is significant at 5 per

Table 4.9

Cotton Area

Correlation Matrices

1968-69

Y_1	X_1	X_2	X_3
1.000	.194	.286*	-.184
	1.000	.938	-.600
		1.000	-.426
			1.000

1978-79

Y_1	X_1	X_2	X_3
1.000	.148	.145	-.151
	1.000	.965	-.488
		1.000	-.372
			1.000

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

Table 4.10

Cotton Area

Stepwise Regression Analysis

	Variable	R	R^2x100	Increase in R^2x100	$\bar{R}^2$	F	Regression Coefficient	S.E. of Reg. Coefficient	t	Intercept
1968-69										
Step 1	X_2	.286	8.18	-	.082	7.103*	.171	.064	2.665*	.908
Step 2	X_2	.294	8.64	0.46	.075	3.728**	.152	.071	2.130**	5.35
	X_3						-.098	.154	-.637	
1978-79										
Step 1	X_3	.151	2.28	-	.023	1.860	-.183	.134	-1.364	15.89
Step 2	X_3	.179	3.20	0.92	.020	1.301	-.136	.145	-.942	10.72
	X_2						.051	.060	.865	

* Significant of 1 per cent level of significance

** Significant at 5 per cent level of significance

cent level of significance. It is insignificant for variability of rainfall.

For the second period of time, 1978-79 variability of rainfall enters at first step and explains only 2.28 per cent of variations in area under cotton. R value (0.15) is insignificant. Coefficient of slope of variability of rainfall on cotton acreage is also insignificant. At second step, variability of rainfall combined with seasonal rainfall explains only 3.20 per cent of variations. Seasonal rainfall explain only 0.92 per cent of the variations. R value is not significant. Regression coefficients for both the parameters of rainfall are insignificant.

Rainfall parameters, annual rainfall, seasonal rainfall and coefficient of variation of rainfall fail to explain variations in area under cotton. However, seasonal rainfall has low significant association with cotton acrceage for the period 1968-69. It shows that seasonal rainfall has positive influence on area under cotton. Areas receiving higher seasonal rainfall have higher cotton acreage. Though, it has not been examined in this exercise, but the factors which influence up on area under cotton seem to be onset of southwest monsoon, soils and irrigation. Black soils of Maharashtra and Gujarat form the cotton belt of India.

Combinations of seasonal rainfall and variability of rainfall explain higher variations in area under the selected crops in comparison to the combinations of annual rainfall and variability of rainfall except the case of groundnut, where latter set offers higher explanation. This speaks of the fact that seasonal rainfall exerts greater influence on crop acreage than the total amount of rainfall received in the year . Onset of rainfall and amount of rainfall received during sowing period may offer even better explanation for variations in area under a rainfed crop.

Rainfall Parameters as Determinants of the Crop Yield

This exercise attempts to assess the influence of rainfall parameters on the yield of five selected crops. Correlation matrix shows nature and degree of relationship between the concerned variables, while stepwise regression analysis shows explanatory powers of independent variables.

Rainfall Parameters and Yield of Bajra

Correlation Matrix: Table 4.11 shows that annual rainfall and seasonal rainfall have moderate positive correlation with yield of bajra. Correlation is significant at 1 per cent level of significance. Variability of rainfall had very low negative correlation in 1968-69 which is insignificant.

None of the rainfall parameters has significant correlation with yield of bajra during the period 1978-79.

Table 4.11

<u>Bajra Yield</u>

Correlation Matrices

1968-69

Y_2	X_1	X_2	X_3
1.000	.418*	.425*	-.118
	1.000	.969	-.600
		1.000	-.472
			1.000

1978-79

Y_2	X_1	X_2	X_3
1.000	-.100	-.047	.094
	1.000	.945	-.489
		1.000	-.384
			1.000

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

Y = Yield of the crop

X_1 = Annual rainfall

X_2 = Seasonal rainfall

X_3 = C.V. of annual rainfall

Table 4.12

<u>Bajra Yield</u>

Stepwise Regression Analysis

	Variable	R	R^2x100	Increase in R^2x100	$\bar{R}^2$	F	Regression Coefficient	S.E. of Reg.Coef.	t	Intercept
1968-69										
Step 1	X_1	.418	17.47	-	.175	16.920*	3.133	.762	4.113*	114.45
Step 2	X_1	.450	20.25	2.78	.192	10.00*	4.065	.942	4.315*	-56.40
	X_3						3.337	2.023	1.649	
1978-79										
Step 1	X_1	.100	1.00	-	.010	.815	-1.090	1.207	-.903	566.40
Step 2	X_1	.113	1.28	0.28	.0004	.511	-.776	1.391	-.558	482.27
	X_3						1.685	3.641	.463	

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

Correlation coefficients are very low. Annual rainfall and seasonal rainfall have negative and very low correlations with yield of bajra. While variability of rainfall exhibits very low positive correlation.

Stepwise Regression: Annual rainfall is introduced at first step for the period 1968-69. It explains 17.47 per cent of variations in the yield of bajra. R value (0.418) is significant at 1 per cent level of significance. Regression coefficient of annual rainfall on yield is also significant at 1 per cent level of significance. It shows that one unit increase in annual rainfall leads to 3 unit increase in yield of bajra. At second step annual rainfall and variability of rainfall together explain 20.25 per cent of variations in yield of bajra. Variability of rainfall explains only 2.78 per cent of variations in yield of bajra. Multiple correlation coefficient (0.45) is significant at 1 per cent level of significance. Regression coefficient of annual rainfall on yield is also significant at 1 per cent level of significance. But regression coefficient of variability of rainfall on yield is not significant.

Correlation coefficients with all the rainfall parameters are insignificant for second point of time, 1978-79. Rainfall parameters included in the exercise do not explain anything. All R values and regression coefficients are insignificant. This could be explained in two ways. Details of the other rainfall parameters such as onset and withdrawal of rainfall, frequency of wet and dry spells, number of rainy days and rainfall intensity are not available which might have dominant influence on yield of bajra. Second possible explanation can be that relationship may not be linear. Annual rainfall in 1978-79 exceeded to normal annual rainfall in 68 of 82 districts. Hence, relationship could not be explained by linear regression for the period 1978-79.

Rainfall Parameters and Yield of Jowar

Correlation Matrix: Table 4.13 shows that two of the rainfall parameters, annual rainfall and seasonal rainfall had positive and variability of rainfall had negative correlation with yield of jowar. Annual rainfall has moderate correlation with yield of jowar which is significant at 1 per cent level of significance. Seasonal rainfall has low correlation but it is significant at 1 per cent level of significance. Variability of rainfall has inverse moderate correlation with yield of jowar which is significant at 1 per cent level of significance.

Variability of rainfall had inverse correlation while annual rainfall and seasonal rainfall had positive correlation with yield of jowar during 1978-79. Variability of rainfall has moderate correlation, which is significant at 1 per cent level of significance. Annual rainfall has low correlation with the yield, which is significant at 1 per cent level of significance. Seasonal rainfall has even lower correlation. It is, however, significant at 5 per cent level of significance.

Table 4.13

Jowar Yield

Correlation Matrices

1968-69

Y_2	X_1	X_2	X_3
1.000	.414*	.296*	-.484*
	1.000	.969	-.600
		1.000	-.472
			1.000

1978-79

Y_2	X_1	X_2	X_3
1.000	.315*	.245**	-.557*
	1.000	.970	-.488
		1.000	-.397
			1.000

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

Table 4.14

Jowar Yield

Stepwise Regression Analysis

	Variable	R	R^2x100	Increase in R^2 x100	$\bar{R}^2$	F	Regression Coefficient	S.E. of Reg. Coef.	t	Intercept
1968-69										
Step 1	X_3	.484	23.43	-	.234	24.504*	-26.589	5.371	-4.950*	1426.74
Step 2	X_3	.508	25.81	2.38	.249	13.773*	-20.192	6.652	-3.035*	913.55
	X_1						4.961	3.098	1.601	
1978-79										
Step 1	X_3	.557	31.02	-	.310	35.934*	-20.555	3.429	-5.994*	1413.41
Step 2	X_1	.559	31.24	0.22	.303	17.950*	-19.524	3.945	-4.949*	1312.02
	X_1						.811	1.516	.535	

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

<u>Stepwise Regression:</u> It is evident from table 4.14 that variability of rainfall explained 23.43 per cent of variations in yield of jowar. R value is significant at 1 per cent level of significance. Regression coefficient (-26.59) is also significant at 1 per cent level of significance. Variability of rainfall and annual rainfall together explain 25.81 per cent of variation in yield of jowar. Annual rainfall adds only 2.38 per cent in the explanatory power of variability of rainfall. Multiple correlation coefficient (0.508) is significant at 1 per cent level of significance. Regression coefficient of variability of rainfall is significant at 1 per cent level of significance. But regression coefficient of annual rainfall is not significant.

During the period 1978-79, variability of rainfall provided explanation for 31.02 per cent of variation in yield of jowar. R value 0.557 is significant at 1 per cent level of significance. Regression coefficient is also significant at 1 per cent level of significance. Variability of rainfall and annual rainfall together explain 31.24 per cent of variations in yield of jowar. Contribution of annual rainfall is meagre in the explanation, 0.22 per cent. R (0.559) is significant at 1 per cent level of significance. Regression coefficient (-19.52) of variability of rainfall on yield is also significant at 1 per cent level of significance. However, regression coefficient of annual rainfall is insignificant.

It is evident from the preceding discussion that annual rainfall and seasonal rainfall are positively associated and variability of rainfall is negatively associated with yield of jowar. Hence, research hypothesis is accepted. But explanatory power of annual and seasonal rainfall is very weak. Other rainfall parameters may better explain variation in yield of jowar. Explanatory power and correlation with seasonal rainfall is less than that of annual rainfall. This may be because of the fact that jowar is also a rabi crop in some parts of drought affected areas.

Rainfall Parameters and Yield of Gram

Correlation Matrix: Annual rainfall is the only parameter of rainfall which had significant correlation with yield of gram during 1968-69. It is low (+0.269), positive but significant at 5 per cent level of significance. Correlation between seasonal rainfall and yield of gram is negligible. Correlation with variability of rainfall is negative, very low and insignificant.

During 1978-79, except annual rainfall, correlation between other two rainfall parameters and yield of gram was significant. Seasonal rainfall has negative and low correlation (-0.32) with yield of gram which is significant at 1 per cent level of significance. Variability of rainfall also has low (+0.371) but significant correlation. Annual rainfall exhibits

Table 4.15

<u>Gram Yield</u>

Correlation Matrices

1968-69

Y_2	X_1	X_2	X_3
1.000	.258**	.021	-.114
	1.000	.222	-.600
		1.000	-.565
			1.000

1978-79

Y_2	X_1	X_2	X_3
1.000	-.188	-.320*	.371*
	1.000	.257	-.491
		1.000	-.579
			1.000

* Significant of 1 per cent level of significance

** Significant at 5 per cent level of significance

Table 4.16

<u>Gran Yield</u>

Stepwise Regression Analysis

	Variable	R	R^2x100	Increase in R^2x100	$\bar{R}^2$	F	Regression Coefficient	S.E. of Reg. Coef.	t	Intercept
1968-69										
Step 1	X_1	.258	6.66	-	.067	5.705**	1.178	.744	2.388**	295.37
Step 2	X_1	.263	6.92	0.16	.058	2.933	2.039	.935	2.181**	247.4
	X_3						.936	2.008	.466	
1978-79										
Step 1	X_3	.371	13.76	-	.138	12.801*	8.068	2.255	3.578*	276.76
Step 2	X_3	.393	15.44	1.68	.144	7.225*	6.076	2.756	2.204**	382.99
	X_2						-3.345	2.679	-1.248	

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

low negative correlation with gram yield which is insignificant too.

Stepwise Regression: Annual rainfall which is introduced at first step explained 6.66 per cent of variations in yield of gram in 1968-69. R value is significant at 5 per cent level of significance. Regression coefficient is also significant at 5 per cent level of significance. Variability of rainfall is introduced at second step. It does not provide significant explanation for the variation in yield. At second step these two variables explain only 6.92 per cent of variation in yield of gram which is insignificant. $\bar{R}^2$ values also suggest not to include variability of rainfall in the exercise. Regression coefficient of annual rainfall is significant at 5 per cent level of significance but regression coefficient of variability of rainfall is insignificant.

Variability of rainfall which had insignificant correlation with the yield in 1968-69, explained 13.76 per cent of variation in gram yield in 1978-79. R value is significant at 1 per cent level of significance. Regression coefficient of variability of rainfall is significant at 5 per cent level of significance. But regression coefficient of seasonal rainfall on yield is insignificant.

It is evident from correlation and regression analysis that annual rainfall which had significant positive correlation with the yield of gram in 1968-69, had insignificant negative correlation a decade later, in 1978-79. Seasonal rainfall and variability of rainfall had significant negative and positive correlations respectively, in 1978-79. These rainfall parameters had no correlation with yield of gram in 1968-69. Degree of relationship with all rainfall parameters is, however, low. Positive correlation between annual rainfall and yield of gram is justified because surplus soil moisture in high rainfall zone can be conserved for the gram cultivation. However, in drought affected areas of south and south west India, conserved surplus soil moisture is utilized to sow some other crops such as jowar and groundnut. Negative correlation with seasonal rainfall may be because of the fact that seasonal rainfall for gram pertains to the period October to February. This season has considerably higher rainfall in Tamilnadu, Andhra Pradesh and Karnataka where gram is not only an insignificant crop, but its yield is also low. Exclusion of these districts may show positive correlation between yield and seasonal rainfall.

Rainfall Parameters and Yield of Groundnut

Correlation Matrix: Variability of rainfall had moderate (-0.529) negative correlation with yield of groundnut which is significant at 1 per cent level of significance. Both annual rainfall and seasonal rainfall had positive correlation with yield of groundnut in 1968-69. Correlation with annual rainfall is significant at 1 per cent level of significance. Though, seasonal rainfall has low correlation but it is significant at 1 per cent level of significance.

Table 4.17

Groundnut Yield

Correlation Matrices

1968-69

Y_2	X_1	X_2	X_3
1.000	.473*	.341*	-.529*
	1.000	.969	-.600
		1.000	-.472
			1.000

1978-79

Y_2	X_1	X_2	X_3
1.000	-.083	-.074	-.105
	1.000	.970	-.488
		1.000	-.397
			1.000

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

Table 4.18

<u>Groundnut Yield</u>

Stepwise Regression Analysis

	Variable	R	R^2x100	Increase in R^2x100	R^2	F	Regression Coefficient	R.E. of Reg. Coef.	t	Intercept
1968-69										
Step 1	X_3	.529	27.98	-	.280	31.107*	-15.524	2.783	-5.577*	998.94
Step 2	X_3	.564	31.81	3.83	.309	18.396*	-11.244	3.409	-3.298*	655.50
	X_1						3.321	1.588	2.091**	
1978-79										
Step 1	X_3	.105	1.10	-	.011	.855	-2.761	2.936	- .941	753.66
Step 2	X_3	.186	3.46	2.36	.023	1.415	-5.030	3.343	-1.505	981.94
	X_1						-1.788	1.285	-1.391	

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

None of the rainfall parameters had significant correlation with yield of groundnut in 1978-79. All of them had very low negative correlations.

Stepwise Regression: Variability of rainfall which is introduced at step 1 explained 27.98 per cent of variation in yield of groundnut in 1968-69. R value 0.53 is significant at 1 per cent level of significance. Regression coefficient of variability of rainfall on the yield of groundnut is also significant at 1 per cent level of significance. Annual rainfall which is introduced at second step offers 3.83 per cent of explanation for variation in the yield of groundnut. Variability of rainfall and annual rainfall together explain 31.81 per cent of variation in groundnut yield. Multiple correlation coefficient (0.564) is significant at 1 per cent level of significance. Regression coefficients for both, variability of rainfall and annual rainfall, are significant at 1 per cent and 5 per cent levels of significance respectively.

Rainfall parameter, viz annual rainfall, seasonal rainfall and variability of rainfall, failed to explain variation in yield of groundnut in 1978-79. Relationship shown by correlation and stepwise linear regression is very low and insignificant.

It is evident from the preceding discussion that rainfall parameters, viz. annual rainfall, seasonal rainfall and variability of rainfall, had moderate correlation with the yield of groundnut in 1968-69. Only two parameters, annual rainfall and variability of rainfall explained about one-third of variation in the yield of groundnut. Inclusion of some other important rainfall parameters in the exercise may even increase the explanatory power. But these variables could not explain anything in 1978-79. There may be non-linear relationship between rainfall parameters and yield of groundnut and hence linear regression could not be an adequate tool of analysis.

Rainfall Parameters and Yield of Cotton

Correlation Matrix: Table 4.19 shows that rainfall parameters, viz.annual rainfall, seasonal rainfall and variability of rainfall, did not have any relationship with yield of cotton in 1968-69. Correlation coefficients are very low and insignificant.

However, these parameters of rainfall had significant relationship with yield of cotton in 1978-79. Annual rainfall and seasonal rainfall have negative low correlations, significant at 1 per cent level of significance. Variability of rainfall has positive low correlation. It is significant at 1 per cent level of significance.

Stepwise Regression: As shown in table 4.20 rainfall parameters did not explain any variation in the yield of cotton in 1968-69. Correlation coefficient and regression coefficient are insignificant and very low.

Table 4.19

Cotton Yield

Correlation Matrices

1968-69

	Y_2	X_1	X_2	X_3
	1.000	-.003	-.106	.085
		1.000	.938	-.600
			1.000	-.426
				1.000

1978-79

	Y_2	X_1	X_2	X_3
	1.000	-.365*	-.375*	.286*
		1.000	.965	-.488
			1.000	-.373
				1.000

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

Table 4.20

Cotton Yield

Stepwise Regression Analysis

	Variable	R	R^2x100	Increase in R^2x100	$\bar{R}^2$	F	Regression Coefficient	S.E. of Reg. Coef.	t	Intercept
1968-69										
Step 1	X_2	.106	1.12			.906	-.302	.318	-.952	114.17
Step 2										
1978-79										
Step 1	X_2	.375	14.06		.141	13.069*	-1.555	.430	-3.615*	267.16
Step 2	X_2	.407	16.56	2.56	.155	7.825*	-1.292	.460	-2.808*	189.30
	X_3						1.712	1.114	1.536	

* Significant at 1 per cent level of significance

** Significant at 5 per cent level of significance

Seasonal rainfall is introduced at first step and explains 14.06 per cent of variation in yield of cotton in 1978-79. R value is significant at 1 per cent level of significance. Regression coefficient (-1.56) is also significant at 1 per cent level of significance. Variability of rainfall joined seasonal rainfall at second step and together explain 16.56 per cent of variation in yield of cotton. Variability of rainfall raises the explanatory power by 2.56 per cent. R value is significant at 1 per cent level of significance. Regression coefficient of seasonal rainfall on yield of cotton is significant at 1 per cent level of significance. But regression coefficient of variability of rainfall on yield of cotton is insignificant.

It is evident that rainfall parameters included in the study failed to explain variation in yield of cotton during 1968-69. However, during 1978-79, these parameters have significant correlation with cotton yield and seasonal rainfall and variability of rainfall together explain one sixth of variation. Yield of cotton has inverse correlation with annual rainfall and seasonal rainfall and positive correlation with variability of rainfall. Thus the research hypothesis stands rejected and implies that higher annual rainfall or seasonal rainfall has adverse effects on cotton yield and it can give higher yield even in badly drought affected areas.

Except the case of cotton and gram (1978-79) combination of annual rainfall and variability of rainfall offer higher explanation than that of seasonal rainfall and variability of rainfall. It may be possible in the case of jowar and groundnut, because these crops are sown in rabi season too in Maharashtra and other parts of south India. Hence, rainfall concentrated in the period, June to September, may not explain much variation in yield.

Summing Up

It is evident that area under bajra in drought affected areas of the country is concentrated in low rainfall and badly drought affected areas. Its acreage decline with increase in rainfall and rainfall reliability. Amount of seasonal and annual rainfall has positive influence on yield of bajra. Correlation and regression exercises for 1978-79 indicate possible non-linear relationship between crop yield and rainfall parameters. Explanatory power of rainfall parameters is high to explain variation in area under this crop. Area under jowar is positively influenced by amount of annual and seasonal rainfall and inversely by variability of rainfall, though their explanatory power is not high. Annual and seasonal rainfall have positive influence on the crop yield. Yield is low in highly unreliable rainfall zones. These rainfall parameters explain one-third to one-fourth of variation in yield of jowar. Seasonal rainfall, October to February, has adverse affects on the area under gram because farmers of south India, which have higher rainfall, during this seas n prefer to sow crops other than gram because of prevailing agro-climatic conditions. Annual rainfall and variability of rainfall do not influence crop acreage. Explanatory power of rainfall parameters is low. Gram yield is inversely related with seasonal rainfall. Its yield is considerably higher where occurance of rainfal is less reliable. Rainfall parameters, however, have low explanatory power. Annual rainfall has adverse effects on area under groundnut. Area under groundnut is higher in unreliable rainfall zones. Rainfall parameters offer low explanation for variation in area under groundnut. Amount of annual and seasonal rainfall have positive effect on yield of groundnut. Its yield is low in the areas where rainfall is unreliable. Correlation and regression for 1978-79, however, is insignificant. This might be because of non-linear relationship. Rainfall parameters do not have much influence on area under cotton. Only seasonal rainfall has positive influence on cotton acreage. Its explanatory power is, however, low. Amount of annual and seasonal rainfall has adverse effect on yield of cotton. It gives better yield even in scanty and unreliable rainfall zone.

This study could be strengthened by inclusion of some of other important rainfall parameters, as onset and withdrawal of rainfall, frequency of wet and dry spells, number of rainy days, and intensity of rainfall. There might be possibility of non-linear relationship, particularly in the case of yield of bajra and groundnut in 1978-79.

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CHAPTER V

SUMMARY OF CONCLUSION

Agriculture still remains the dominant sector in the economy of India, as it provides employment to the vast segment of population, food to masses and raw material to agro-based industries. One time flourishing agricultural economy of the country experienced severe colonial exploitation. Downward trend in foodgrains production during pre-independence period was reversed after independence. But initially, not much emphasis was laid on agricultural development owing to greater emphasis on developing industrial infrastructure. Agriculture production increased because of physical extension of cultivated land. Severe and consecutive droughts in 1965-66 and 1966-67 proved the vulnerability of agriculture to climatic vagaries. Consequently new agriculture technology, which was initially tried as a pilot project in seven Intensive Agricultural District Programmes (IADP) districts in 1960-61, was extended for the entire country in mid sixties added with high yielding varieties of seeds. But this package technology could not influence the rainfed agriculture which accounts for about 70 per cent of cultivated land in the country. Punjab, Haryana, western Uttar Pradesh and coastal areas of Andhra Pradesh and Tamilnadu have benefitted by green revolution.

Drought prone or dry areas are still lagging far behind. Agricultural productivity is not stable and traditional drought resistant crops continue to occupy major proportion of cultivated land in these areas. Level of yield and cropping pattern are largely influenced by climatic conditions, particularly rainfall parameters. Irrigation, which forms the base for introduction of modern technological inputs in agriculture has made very little progress. Hence, rainfall parameters are very important in creating differences in agricultural productivity in drought prone areas.

A universally acceptable definition of drought could not be evolved because of diversity of drought as a phenomena in space. However, it is generally accepted that drought is caused due to negative deviation of rainfall from the mean. In India, drought prone areas occupy vast areas in Rajasthan, Gujarat, Madhya Pradesh, rainshadow areas of Maharashtra and Karnataka, and parts of Tamilnadu, Andhra Pradesh and south west Haryana. Eighty-two districts, spread over these eight states, have been identified as drought prone. These drought prone districts fulfil the criteria of annual rainfall less than 100 cm., share of gross irrigated area in gross cropped area less than 30 per cent (1976-77) and coefficient of variation of annual rainfall more than 20 per cent. This study, however, does not lay much emphasis on problems of definition and criteria of identification of drought prone areas. Objective of this study, as expressed earlier, is to examine spatio-temporal variations in yield level and area of some selected rainfed crops (bajra, jowar, gram, groundnut and cotton) and influence of rainfall parameters on them in drought affected areas. Linear stepwise regression technique has been used to examine degree and nature of relationship as envisaged in the hypothesis.

The five crops selected for the study are major crops of drought prone areas, as they occupied 55.52 per cent of gross cropped area in 1977-80. Except gram, more than two-third of the acreage under these crops in the country lies in drought prone areas.' About one-third of area under gram lies in this region.

Drought prone area is the major bajra growing region. It accounted for 68.36 per cent of area and 50.88 per cent of production of crop in the country. Bajra cultivation is mainly confined to low rainfall areas of western and north western Rajasthan, north western Gujarat and south western Haryana which account for 71.3 per cent of area under this crop. In fact, drought prone districts of Rajasthan account for more than 50 per cent of the area and 27.26 per cent of production of this crop. Bajra is a monoculture in western parts of Rajasthan, i.e. Jaisalmer and Barmer districts. Arid climate of this region, having annual rainfall less than 50 cm., is agronomically suitable for cultivation of this drought resistant crop. However, yield level of bajra is very low in this moisture deficit region. Its yield level in drought prone areas is much less than the average yield in the country. There are wide variations in yield level of the crop in the region. Apart from Rajasthan, south west Haryana also has low yield of bajra. Bajra growing districts of Gujarat, Tamilnadu and districts of Karnataka and Madhya Pradesh have high yield level. Bhavnagar district of Gujarat has highest yield in the region, i.e. 1538 kg/ha. High yield level in Gujarat can be attributed to the adoption of high yielding varieties of seeds. Gujarat has registered high growth rate of yield, while it has declined in eastern Rajasthan and south west Haryana. The low base (1967-70) is the cause for high growth rate of yield registered in western Rajasthan.

Drought prone areas occupied 68.64 per cent of area and contributed 68.54 per cent of jowar production in the country. Jowar occupies about 20 per cent of GCA in drought prone areas. Maharashtra, south east Rajasthan, south west Madhya Pradesh, uplands of Andhra Pradesh, Karnataka plateau and uplands of Tamilnadu are jowar growing regions. Drought prone districts of Maharashtra, Karnataka and Andhra Pradesh account for 75.31 per cent of area under this crop. Drought prone region of Maharashtra is major jowar growing area, as it accounts for 47.3 per cent of crop acreage in drought prone areas. Crop acreage has declined both in drought prone areas and country over the period 1967-70 to 1977-80, however, it is rapid in case of latter. Percentage share of the crop in GCA has also declined except in Maharashtra and Karnataka. Yield level of crop in drought prone areas is almost the same as in the country. Most of the jowar producing areas of peninsular India have registered high yield level. Maharashtra which accounts for 53.25 per cent of the crop production in drought prone areas has high yield level, 805 kg/ha. Yield level is medium in Madhya Pradesh and low in Rajasthan and south west Haryana. Yield has witnessed moderate growth rate in peninsular areas but has declined in Madhya Pradesh. Gujarat and western Rajasthan have registered high growth rate in yield level.

Drought prone areas accounted for 31.27 per cent of area and 31.35 per cent of production of gram in India during 1977-80. This crop occupies only 4.08 per cent of GCA in drought prone areas. Gram acreage is concentrated in eastern Rajasthan, south-west Haryana and north west Madhya Pradesh. Drought prone districts of these states account for 76.09 per cent of area and 85.43 per cent of production of gram in drought prone areas. Gram acreage has declined in the country (by -0.19 per cent per annum) over the period 1967-70 to 1977-80, however, it has increased slowly in drought prone areas (by 1.36 per cent per annum). Proportion of area under gram in GCA has increased in western Haryana and north west Madhya Pradesh and it is constant in eastern Rajasthan. Gram growing areas of eastern Rajasthan and south west Haryana have high yield level of the crop. Yield level of the crop is medium in north west Madhya Pradesh. Eastern Rajasthan has registered moderate growth in yield level, while it has declined in south west Haryana and north west Madhya Pradesh. Drought prone areas of peninsular India, where gram is not a important crop, have registered low growth rate of yield.

Groundnut which is a rainfed crop, is a major oilseed crop in drought prone areas of the country. Drought prone areas account for 64.54 per cent of area and 60.10 per cent of production of groundnut in the country. 8.43 per cent of GCA in the region has been devoted to this crop. Drought prone districts of Gujarat, Andhra Pradesh and Karnataka are major groundnut sowing areas, occupy 72.07 per cent of crop acreage in the region. Drought prone districts of Gujarat alone account for 40.17 per cent of the crop acreage in the region. Groundnut growing areas of Gujarat have light clay well drained soils and moderate rainfall (50 cm to 75 cm). While in south it is sown in red and black soils region, having comparatively higher rainfall. yield level of the crop in the region is 68 kg/ha less than its average yield in the country. It is high in Gujarat, south Karnataka, Tamilnadu and parts of Andhra Pradesh. It is medium in most parts of rest of the region. Yield has increased at low growth rate in the region. It has increased at moderate growth rate in major groundnut producing areas and declined in Maharashtra and Madhya Pradesh.

Cotton, a major industrial crop in India, occupies 9.90 per cent of GCA in drought prone areas. 69.85 per cent of cotton acreage of the country lies in this region and it accounts for 53.69 per cent of the crop production. There are wide spatial variations in terms of area and yield of this crop. It is an important crop in south central Gujarat, north east Maharashtra, adjoining districts of Madhya Pradesh, and some districts of Karnataka and Andhra Pradesh. Black soil region of Maharashtra and Gujarat is famous cotton region in the country. Black soils are suitable for cotton cultivation as they are fertile, well drained and have high moisture retention capacity. 82.51 per cent of area under cotton in drought prone areas is confined to Maharashtra, Gujarat and Karnataka. Area under this crop has declined in drought prone areas, though it is constant in the country. Percentage share of area under cotton in GCA has declined in major cotton growing districts of Maharashtra and Gujarat. Yield level of this crop in drought prone areas is 38 kg/ha less than the average yield in the country. Among cotton growing areas, yield level of the crop is high in Gujarat, parts of south west Maharashtra and Karnataka. By and large yield level of the crop is low in drought prone areas of Maharashtra, Karnataka, Andhra Pradesh and Madhya Pradesh. Yield level of the crop is high in most of the drought prone districts of Tamilnadu, Haryana and Rajasthan where it is not an important crop. Cotton yield has increased at high growth rate in most of drought prone districts of Karnataka and some districts of Gujarat, Andhra Pradesh and Maharashtra. Drought prone areas of Gujarat and Maharashtra as a whole have registered low growth rate in yield, while it has witnessed decline in Madhya Pradesh.

It is evident from spatial pattern of yield and area of five selected crops that drought prone areas of Gujarat and Tamilnadu are doing better. Widely grown crops in these areas have witnessed high yield level. In western Rajasthan, where bajra is a dominant crop, yield level is very low. Yield level of this crop is low in eastern Rajasthan too, but gram yield is high. Except jowar and gram which have high yield level, yield is low for bajra, groundnut and cotton in drought prone area of Madhya Pradesh. Yield of all the five crops has declined in this state. Except jowar, yield of remaining crops is low in Maharashtra. Jowar has registered high yield level in Karnataka, however, groundnut and cotton have low yield. Drought prone areas of Andhra Pradesh have high yield of jowar, medium yield of groundnut and low yield of cotton. South west Haryana has registered low yield level in bajra but high yield level in gram. Yield of both the crops has declined over the period 1967-70 to 1977-80.

Area under bajra is inversely correlated with amount of annual and seasonal rainfall and positively with rainfall variability. Correlation coefficients between rainfall parameters and area under bajra are high. Hence, bajra is a dominant crop in scanty rainfall and drought frequented areas of western and north western Rajasthan and south western Haryana. Seasonal rainfall and variability of annual rainfall explained 63.84 per cent and 49.56 per cent of variation in area in 1968-69 and 1978-79 respectively. Increase in amount of annual and seasonal rainfall has positive influence on the yield of bajra. Annual rainfall and variability of rainfall explained 20.25 per cent of variation in yield in 1968-69. Low and insignificant correlation in 1978-79 indicates towards possible non-linear relationship between yield of bajra and rainfall parameters.

Area under jowar is positively influenced by increase in amount of annual and seasonal rainfall and inversely by variability of rainfall. Seasonal rainfall and variability of rainfall have low explanatory power as they explained 23.62 and 26.21 per cent of variation in area under jowar in 1968-69 and 1978-79. Amount of annual and seasonal rainfall exhibits positive and variability of rainfall exhibits negative correlation with jowar yield. Annual rainfall and variability of rainfall together explained 25.81 per cent and 31.24 per cent of variation in jowar yield in 1968-69 and 1978-79 respectively.

Seasonal rainfall occurring between October and February has negative correlation with area under gram. It is because of the fact that drought prone areas of south India receive comparatively higher rainfall during this season.

Because of unfavourable agro-climatic conditions for gram, other crops such as groundnut and jowar are preferred in this region. Gram growing areas of Rajasthan, Haryana and Madhya Pradesh receive very low rainfall during this season. Area under this crop is not influenced by annual rainfall and variability of rainfall. Explanatory power of these variables is rather low. Annual rainfall has been found to have positive influence on gram yield in 1968-69. While, seasonal rainfall had negative correlation with gram yield in 1978-79. Variability of rainfall is positively correlated with the yield. Variability of rainfall and seasonal rainfall explained only 15.44 per cent of variation in yield in 1978-79.

Rainfall parameters had insignificant correlation with area under groundnut in 1968-69. Variability of rainfall and amount of annual rainfall explain 13.32 per cent of variation in groundnut area. Annual rainfall had positive and variability of rainfall had negative correlation with the area under this crop in 1978-79. Yield of groundnut had positive correlation with amount of annual rainfall and negative correlation with variability of rainfall in 1968-69. 31.81 per cent of variations in the yield was explained by variability of rainfall and annual rainfall. Correlation with all rainfall parameters was, however, insignificant in 1978-79. This might be because of inherent non-linear relationship.

Annual rainfall and variability of rainfall have insignificant correlation with area under cotton. Seasonal rainfall had, however, significant correlation with crop acreage in 1968-69. Amount of seasonal rainfall and variability of rainfall offer a meagre explanation, 8.64 per cent, for variation in area under cotton. Cotton yield had insignificant correlation with rainfall parameters in 1968-69. Yield was positively correlated with variability of rainfall and negatively with amount of annual and seasonal rainfall in 1978-79. Seasonal rainfall and variability of rainfall explain only 16.56 per cent of variation in yield.

It is evident from the study that rainfall parameters (amount of annual and seasonal rainfall and variability of rainfall) owe major responsibility to cause variation in area and yield of selected crops in drought prone areas. However, these rainfall parameters do not offer adequate explanation for gram, groundnut and cotton. But this does not imply that rainfall parameters exert less influence on acreage and yield of these crops. This shortcoming can be overcome by taking in account other parameters of rainfall, choosing small area of study which has minimum diversity in terms of physical and socio-economic factors and trying non-linear regression techniques.

Other parameters of rainfall such as frequency of wet and dry spells, onset and withdrawal of monsoon, number of rainy days and intensity of rainfall could not be taken into account in the present study, because of non-availability of data. These parameters of rainfall have significant influence on cropping pattern and yield of crops in drought affected areas. Hence, inclusion of these rainfall parameters in the exercise may even strengthn the explanatory power.

Study area is comprised of 82 districts, spread over northern Rajasthan and western Haryana in north to Tamilnadu in south. This vast drought prone area of the country has diversity of environmental, socio-economic and institutional factors. These factors influence cropping pattern and yield of the crop. For example, gram cultivation is concentrated in eastern Rajasthan, south west Haryana and north western Madhya Pradesh because of the fact that this region has relatively higher rainfall in monsoon season which is conserved for gram cultivation in rabi season. This crop requires moderate temperature which is available in this region druing winter. Groundnut is sown on light clay soils of Gujarat, however, rainfall in this region is low as compared to south. Black soils of Maharashtra and Gujarat grow cotton. Hence, a region having more or less a uniform distribution of various environmental, socio-economic and institutional factors should be chosen for such a study.

Relationship between rainfall parameters, and area and yield of crops has been analysed with the help of linear regression. However, there may not be linear relationship. Hence, curvilinear regression should be tried for this kind of exercise.

Drought prone areas constitute a major part of arid and semi-arid land in the country. These areas offer a great potentiality for agricultural development. Yield level of major crops of drought prone areas is less than the average yield level in the country. Yield and cropping pattern in these areas by and large depend on various rainfall parameters. Climatic vagaries put hindrance in development of agriculture. Hence, climatic characteristics of these areas should be studied in depth and cropping pattern should be adjusted with the moisture availability. Seeds of the rainfed crops should be manipulated in such a way that these can bear stresses and strains of soil moisture deficit. Management practices should be evolved so that the available water resources in the region could be conserved and utilized judiciously.

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APPENDIX I

Drought Prone Districts of India

1 S.No.	2 Name of District	3 Normal Annual Rainfall (cm)	4 C.V.of Annual Rainfall	5 Irrigation percentage of GAI in GCA (1976-77
	Haryana			
1.	Bhiwani	43.57	34	19.7
2.	Mahendragarh	55.34	34	19.3
	Gujarat			
3.	Ahmedabad	62.58	40	15.2
4.	Amreli	50.09	45	7.2
5.	Kutch	32.22	62	9.9
6.	Jamnagar	47.11	55	9.3
7.	Junagarh	62.32	67	13.4
8.	Banaskantha	62.65	54	19.5
9.	Broach	94.97	35	7.8
10.	Bhavnagar	59.33	41	10.8
11.	Rajkot	59.43	45	13.6
12.	Baroda	91.66	35	19.2
13.	Sabarkantha	79.42	40	25.8
14.	Surendernagar	48.70	40	8.8
	Maharashtra			
15.	Dhule	67.40	32	10.2
16.	Jalgaon	74.40	29	13.4
17.	Ahmednagar	57.88	34	18.0
18.	Satara	80.32	24	17.6
19.	Sangli	62.48	27	12.7
20.	Sholapur	58.43	28	13.7
21.	Aurangabad	72.58	30	12.4
22.	Parbhani	82.10	31	5.1
23.	Beed	66.80	30	11.5
24.	Nanded	90.11	29	5.5
25.	Osmanbad	80.99	30	14.5
26.	Buldhana	80.28	27	3.9
27.	Akola	84.65	26	2.9
28.	Amravati	87.73	26	4.6
29.	Yeotmal	99.16	24	8.9
	Rajasthan			
30.	Ajmer	52.73	43	26.1
31.	Alwar	61.61	35	20.1
32.	Banswara	92.24	37	7.0

1	2	3.	4.	5
33.	Barmer	27.75	58	0.9
34.	Bharatpur	67.15	34	19.3
35.	Bikaner	26.37	50	2.0
36.	Chittargarh	85.21	36	26.0
37.	Churu	32.55	40	0.1
38.	Dungarpur	76.16	37	10.0
39.	Jaisalmer	16.40	68	0.0
40.	Jalore	42.16	56	15.2
41.	Jhunjhunu	44.45	36	5.5
42.	Jodhpur	31.87	58	3.1
43.	Kota	88.56	35	25.3
44.	Nagaur	38.86	45	3.4
45.	Pali	49.04	50	26.9
46.	Sawai Madhopur	68.92	38	19.3
47.	Sikar	46.61	38	9.38
48.	Tonk	61.36	41	16.96
	<u>Madhya Pradesh</u>			
49.	Indore	98.00	29	11.7
50.	Ratlam	89.59	36	9.2
51.	Ujjain	89.25	33	5.8
52.	Mandsaur	82.45	35	13.2
53.	Dhar	83.33	32	7.0
54.	Jhabua	82.80	34	3.3
55.	West Nimar	83.15	32	8.6
56.	East Nimar	88.00	30	6.2
57.	Bhind	66.83	32	27.4
58.	Shivpuri	81.63	33	15.5
59.	Datia	73.99	31	15.0
60.	Rajgarh	90.07	31	6.3
61.	Shajapur	97.72	31	7.4
	<u>Andhra Pradesh</u>			
62.	Kurnool	62.20	26	12.4
63.	Anantpur	54.40	31	18.0
64.	Hydrabad	77.3	29	20.1
65	Medak	88.60	27	26.1
66.	Mehboobnagar	70.50	26	16.2
67.	Adilabad	95.10	24	8.3
68.				
	<u>Karnataka</u>			
68.	Bangalore	77.73	22	20.1
69.	Belgaum	79.13	22	15.5

1	2	3	4	5
70.	Bellary	57.17	28	20.0
71.	Bidar	85.70	29	5.5
72.	Bijapur	56.99	30	7.9
73.	Chitradurga	56.68	26	19.0
74.	Dharwar	68.44	25	8.2
75.	Gulberga	71.77	29	2.6
76.	Kolar	72.09	24	26.1
77.	Mysore	75.75	22	16.0
78.	Raichur	57.93	30	16.5
79.	Tumkur	66.87	24	18.8
	Tamilnadu			
80.	Salem	84.24	24	25.5
81.	Dharmapuri	84.43	24	14.6
82.	Tiruchirapalli	86.78	25	28.6

Apd. II

DROUGHT PRONE DISTRICTS (INDIA)

Area under crop as proportion to Gross Cropped Area (Per cent)

S. No.	District/ State	Bajra (a) 67-70	Bajra (b) 77-80	Jowar (a) 67-70	Jowar (b) 77-80	Gram (a) 67-70	Gram (b) 77-80	Groundnut (a) 67-70	Groundnut (b) 77-80	Cotton (a) 67-70	Cotton (b) 77-80
1.	2	3		3		4		5		6	
	HARYANA										
1.	Bhiwani	24.0	40.1	2.5	0.6	25.1	35.5	0.0	0.0	11.0	1.8
2.	M.Garh	47.3	38.7	2.6	1.2	23.5	22.9	0.0	0.1	0.0	0.0
	GUJARAT										
3.	Jamnagar	16.5	9.8	18.1	10.7	0.1	0.1	51.7	63.3	3.1	4.5
4.	Rajkot	14.0	7.1	12.3	6.5	0.1	0.1	51.6	54.0	12.5	19.1
5.	S.Nagar	19.6	13.0	19.1	14.7	0.3	0.6	7.6	5.4	44.3	53.7
6.	Bhavnagar	30.4	19.1	16.7	13.1	0.1	0.1	29.1	31.7	6.5	14.9
7.	Amreli	24.5	15.7	12.4	10.6	0.0	0.1	44.2	55.3	3.7	7.6
8.	Junagarh	13.3	6.5	7.7	4.6	0.5	0.6	53.1	58.7	6.3	5.9
9.	Kutch	24.4	13.4	18.3	11.0	0.0	0.0	7.1	7.5	9.8	16.3
10.	Banaskantha	44.9	29.6	12.2	11.1	0.2	0.3	0.3	0.3	1.3	2.0
11.	Sabarkantha	15.0	10.6	4.4	1.7	0.6	1.0	18.6	16.4	34.7	25.1
12.	Ahmedabad	13.8	10.3	17.4	11.1	0.3	1.2	2.4	1.5	34.5	28.3
13.	Vadodara	4.0	3.4	10.8	10.2	0.3	0.4	3.4	3.1	45.6	39.8
14.	Brauch	2.2	1.5	17.9	21.9	0.1	0.3	2.1	3.1	50.9	31.6
	MAHARASHTRA										
15.	Dhule	23.1	16.7	17.3	24.1	1.2	1.3	13.6	13.2	10.6	7.4
16.	Jalgaon	10.6	9.3	18.9	25.4	0.7	0.8	6.3	8.6	28.8	17.5
17.	Ahmednagar	27.4	20.7	37.3	46.7	1.6	1.6	1.8	1.4	2.2	1.0
18.	Satara	15.5	15.5	19.2	35.4	1.2	2.0	6.9	9.7	0.6	1.1
19.	Sangli	21.8	14.9	31.7	35.2	1.5	2.4	13.9	7.7	0.4	0.4
20.	Sholapur	9.5	4.8	60.6	62.7	1.8	2.6	6.1	2.2	0.8	1.1
21.	Aurangabad	16.6	13.3	27.2	33.2	2.8	2.9	2.8	2.1	14.3	10.3

Appendix II contd...

22.	Parbhani	0.7	0.9	35.2	34.7	2.7	3.1	1.1	1.4	26.9	20.7
23.	Beed	15.0	14.1	36.7	43.3	3.6	3.8	5.8	2.5	5.4	3.7
24.	Nanded	00.3	0.3	36.6	38.1	2.5	2.1	4.1	2.5	26.9	25.5
25.	Osmanbad	2.6	2.0	36.9	41.8	4.7	5.0	11.5	4.8	4.1	2.4
26.	Buldhana	1.2	1.5	36.7	[illegible]	0.6	1.4	2.5	3.6	35.4	27.6
27.	Akola	0.8	0.7	31.9	30.9	1.3	1.9	3.0	3.2	41.7	37.8
28.	Amravati	1.0	1.0	24.8	25.4	0.8	1.6	3.4	4.6	50.9	44.5
29.	Yeotmal	1.4	1.3	34.8	32.3	0.6	0.8	3.5	3.9	42.2	41.8
	RAJASTHAN										
30.	Ajmer	13.2	8.7	26.0	21.4	5.0	9.4	4.2	6.2	3.3	4.1
31.	Alwar	25.2	23.4	3.0	1.3	23.6	22.1	0.2	0.2	0.0	0.0
32.	Banswara	0.0	0.0	6.0	0.6	12.2	13.2	2.6	1.0	8.0	8.4
33.	Barmer	77.7	60.0	0.2	0.1	0.5	0.2	0.0	0.0	0.0	0.0
34.	Bharatpur	21.7	23.5	5.3	2.7	24.9	17.8	3.1	3.1	0.0	0.1
35.	Bikaner	41.0	31.9	0.1	0.2	0.0	0.4	0.0	0.0	0.0	0.2
36.	Chittergarh	0.0	0.0	15.4	9.0	4.4	11.0	13.3	6.7	5.2	3.0
37.	Churu	37.5	35.1	0.0	0.0	2.6	6.9	0.0	0.0	0.0	0.0
38.	Dungarpur	0.1	0.0	1.8	0.2	8.7	12.1	0.2	0.1	0.2	1.0
39.	Jaisalmer	88.1	71.6	1.3	1.5	0.0	0.1	0.0	0.0	0.0	0.0
40.	Jalore	59.7	35.7	0.4	0.4	0.4	1.8	0.0	0.0	0.1	0.3
41.	Jhunjhunu	44.3	39.7	0.1	0.0	4.7	12.7	0.0	0.1	0.0	0.0
42.	Jodhpur	55.2	49.6	1.0	0.8	0.0	0.9	0.0	0.2	0.0	0.2
43.	Kota	0.5	0.3	35.3	24.2	13.3	13.6	0.9	1.0	0.0	0.0
44.	Nagaur	45.6	42.6	6.5	4.0	0.5	2.1	0.5	2.3	0.0	0.1
45.	Pali	23.1	13.2	9.5	3.9	1.6	5.7	0.5	0.7	1.6	3.3
46.	S.Madhopur	25.2	22.0	10.0	10.2	16.9	14.8	6.7	8.4	0.0	0.0
47.	Sikar	46.8	35.6	0.2	0.5	1.6	5.9	0.8	0.7	0.0	0.0
48.	Tonk	9.3	4.0	28.0	24.0	14.6	13.0	2.4	6.0	0.4	0.1
	MADHYA PRADESH										
49.	Indore	0.3	0.0	17.3	14.4	13.5	16.6	1.2	1.1	4.1	0.7
50.	Ratlam	2.5	1.5	21.4	13.1	7.6	12.1	6.4	2.9	12.1	9.7
51.	Ujjain	1.8	0.3	27.7	28.5	8.2	12.9	4.0	2.8	13.6	6.8

52.	Mandsaur	0.7	0.3	32.9	22.2	3.7	14.6	13.7	6.0	3.1	1.2
53.	Dhar	3.0	1.3	17.0	11.0	8.6	10.0	9.0	8.7	7.9	11.7
54.	Jhabua	4.6	1.5	11.8	6.1	4.1	6.9	7.7	6.7	7.2	7.5
55.	W.Nimar	8.3	4.8	30.8	21.7	0.8	1.7	6.5	8.9	20.0	25.3
56.	E.Nimar	1.3	0.8	27.1	23.8	1.2	1.6	3.4	5.4	30.7	32.4
57.	Bhind	11.0	10.5	7.4	6.1	29.2	23.0	0.0	0.0	0.0	0.0
58.	Shivpuri	1.2	1.3	12.4	17.2	26.7	26.7	0.0	0.1	0.0	0.0
59.	Datia	1.2	1.3	12.4	17.2	26.7	26.7	0.0	0.1	0.0	0.0
60.	Rajgarh	0.0	0.0	35.8	32.2	4.2	7.9	7.4	6.8	11.2	7.2
61.	Shajapur	0.2	0.1	38.1	26.5	5.1	9.3	8.4	7.7	19.7	9.9
	ANDHRA PRADESH										
62.	Kurnool	2.9	2.9	26.5	27.3	0.5	0.6	19.2	15.0	12.4	12.6
63.	Anantpur	7.3	5.7	17.0	12.5	0.3	0.2	25.1	35.3	3.8	2.7
64.	Hydrabad	2.4	2.5	30.3	34.6	2.3	1.7	2.0	1.6	0.1	0.0
65.	Medak	0.9	1.3	30.2	32.6	4.1	3.1	1.8	0.5	0.2	0.1
66.	Mehboobnagar	5.6	5.5	31.5	32.6	0.5	0.3	12.3	11.8	1.1	0.8
67.	Adilabad	0.0	0.0	38.1	41.0	0.8	0.6	2.1	0.8	14.0	17.8
	KARNATAKA										
68.	Banglore	0.0	0.0	0.9	0.0	0.7	0.1	2.6	4.5	0.0	0.0
69.	Belgaum	9.1	10.2	26.0	20.4	1.8	2.0	14.4	13.8	6.4	6.6
70.	Bellary	4.9	7.0	28.7	23.7	0.3	1.1	14.1	6.7	20.0	16.4
71.	Bidar	3.6	5.0	28.3	24.2	12.8	10.4	8.8	5.4	2.6	2.0
72.	Bijapur	15.3	17.4	42.3	33.9	1.5	1.7	9.5	7.7	12.7	12.3
73.	Chitradurga	5.0	4.3	17.0	16.2	0.5	0.9	6.3	9.9	8.0	6.8
74.	Dharwar	0.2	0.2	23.5	20.6	1.1	1.4	13.2	10.7	20.7	20.7
75.	Gulberga	8.1	11.3	40.4	25.1	2.6	3.6	9.7	8.4	6.1	8.3
76.	Kolar	2.4	1.5	1.5	0.9	0.3	0.1	13.8	19.9	0.0	0.1
77.	Mysore	0.3	0.4	18.1	17.2	0.7	0.5	6.3	6.1	0.7	1.5
78.	Raichur	5.2	5.7	26.3	22.0	1.4	0.9	10.9	13.4	23.5	25.7
79.	Tumkur	0.5	0.6	6.8	5.7	0.6	0.3	7.2	11.8	0.2	1.9
	TAMILNADU										
80.	Salem	10.2	8.3	17.4	16.6	0.0	0.1	22.3	21.2	2.0	4.8
81.	Dharmapuri	3.0	2.1	11.5	11.9	0.1	0.2	10.0	10.7	0.4	1.3
82.	Tiruchirapali	12.5	13.4	16.2	19.1	0.0	0.0	12.8	9.1	0.9	1.0

APPENDIX III

DROUGHT PRONE DISTRICTS (INDIA)
Yield of Selected Crops
(Yield in Kg/ha)

1	2	3		4		5		6		7	
S. No.	District	Bajra		Jowar		Gram		Ground nut		Cotton	
		a. 67-70	b 77.80	a 67-70	b 77-80	a 67-70	b 77-80	a 67-70	b 77-80	a 67-70	b 77-80
	HARYANA	389	155	190	146	908	823	1186	1000	237	263
1.	Bhiwani	482	150	199	158	914	831	1186	-	237	263
2.	M.Garh	217	165	156	146	886	802	-	1000	-	-
3.											
	GUJARAT	545	805	248	488	525	516	602	896	155	183
3.	Jamnagar	553	694	97	221	501	564	509	756	170	308
4.	Rajkot	522	706	145	429	529	524	482	760	183	282
5.	S.Nagar	178	304	83	113	552	523	384	637	81	153
6.	Bhavnagar	708	1538	144	338	522	500	595	1059	195	197
7.	Amreli	729	1348	278	543	665	562	584	954	172	255
8.	Junagarh	696	1516	461	892	505	524	893	1196	197	307
9.	Kutch	360	717	79	421	1000	433	633	821	169	189
10.	Banswara	463	535	225	809	538	516	578	642	138	304
11.	Sabar-kantha	832	439	342	609	532	523	654	562	96	198
12.	Ahmedabad	730	727	170	295	509	498	432	489	142	137
13.	Vadodara	694	923	841	805	512	523	555	644	243	161
14.	Brauch	701	599	540	700	471	530	553	649	17[illegible]	114
	MAHARASHTRA	282	356	552	805	283	351	664	610	83	99
15.	Dhule	443	599	540	777	376	438	618	559	90	124
16.	Jalgaon	355	581	756	1362	351	542	666	636	96	123
17.	Ahmednagar	240	252	372	504	304	410	501	772	114	256
18.	Satara	289	216	632	875	378	383	1132	789	265	264
19.	Sangli	127	189	642	803	333	441	608	706	162	186
20.	Sholapur	167	205	378	386	284	314	525	632	232	291
21.	Aurangabad	306	370	471	734	257	360	410	468	84	119
22.	Parbhani	330	466	538	772	256	294	822	616	76	99
23.	Bhir	359	438	566	831	303	352	671	601	77	127
24.	Nanded	303	492	736	1077	306	291	770	479	87	96
25.	Osmanbad	325	409	594	992	242	365	671	561	83	115
26.	Buldhana	278	420	761	1356	250	294	479	386	88	189
27.	Akola	281	404	726	856	264	255	621	554	66	78
28.	Amrovati	272	377	630	1176	291	192	669	728	89	82
29.	Yeotmal	289	398	591	925	277	346	676	514	71	93

1	2	3		4		5		6		7	
	RAJASTHAN	175	165	280	300	698	787	522	511	103	14
30.	Ajmer	399	305	81	53	314	474	297	353	112	197
31.	Alwar	365	395	208	340	868	1178	616	526	99	223
32.	Banswara	271	180	365	579	512	619	430	586	77	62
33.	Barmer	76	140	80	199	791	612	-	670	141	224
34.	Bharatpur	429	411	147	194	937	1087	224	437	119	221
35.	Bikaner	53	74	43	344	662	611	-	276	170	218
36.	Chittergarh	241	176	412	695	528	491	628	622	107	132
37.	Churu	113	96	46	386	399	398	-	582	-	221
38.	Dungarpur	240	177	312	583	650	721	404	559	121	222
39.	Jaisalmer	10	62	121	216	798	576	-	-	-	-
40.	Jalore	133	163	82	190	784	578	347	630	123	195
41.	Jhunjhunu	278	69	188	129	504	968	161	555	170	231
42.	Jodhpur	91	163	65	281	739	593	98	515	117	222
43.	Kota	253	176	528	493	507	713	557	577	135	237
44.	Nagaur	192	172	63	197	648	479	247	479	125	218
45.	Pali	128	175	46	172	749	615	159	546	129	162
46.	S.Madhopur	415	356	348	320	702	863	784	555	125	219
47.	Sikar	388	203	213	296	792	932	258	527	180	210
48.	Tonk	399	298	230	180	443	559	337	463	128	219
	MADHYA PRADESH	415	408	689	643	572	549	674	566	83	72
49.	Indore	505	360	771	796	475	572	588	558	66	65
50.	Ratlam	362	537	729	544	446	418	712	566	61	74
51.	Ujjain	403	536	832	821	505	460	780	666	70	54
52.	Mandsaur	417	534	561	512	504	538	715	474	71	51
53.	Dhar	341	383	505	453	454	482	612	549	89	94
54.	Jhabua	294	357	577	581	452	497	540	388	96	71
55.	W.Nimar	309	141	688	585	517	469	747	597	103	88
56.	E.Nimar	474	346	726	676	546	538	609	475	72	58
57.	Bhind	632	604	864	812	599	757	-	600	-	-
58.	Shivpuri	498	624	442	425	599	608	725	669	97	30
59.	Datia	462	580	604	799	463	526	-	672	-	-
60.	Rajgarh	307	476	708	582	538	477	628	468	90	65
61.	Shajapur	426	557	917	847	517	623	671	671	84	5[illegible]

1	2	3		4		5		6		7	
	ANDHRA PRADESH	393	463	470	640	259	390	621	763	62	82
62.	Kurnool	538	493	426	728	298	497	631	713	52	73
63.	Anantpur	410	559	378	626	217	367	640	816	38	123
64.	Hydrabad	308	432	479	714	260	451	581	800	92	95
65.	Medak	284	318	574	653	264	350	604	664	113	93
66.	Medak	303	370	458	574	263	331	573	688	45	207
67.	Adilabad	277	315	544	590	204	351	612	546	92	86
	KARNATAKA	312	446	600	782	410	423	650	721	59	129
68.	Banglore	304	-	2351	2060	406	414	724	1038	571	-
69.	Belgaum	221	236	574	812	433	479	529	612	46	169
70.	Bellary	394	600	689	1007	439	443	861	1169	64	158
71	Bidar	403	447	528	1016	486	522	662	420	56	147
72.	Bijapur	299	338	446	536	766	322	538	421	42	108
73.	Chittradurga	324	545	1122	1698	447	435	724	1459	61	103
74.	Dharwar	322	409	816	1398	292	309	572	564	65	95
75.	Gulberga	349	511	545	636	410	398	498	589	71	112
76.	Kolar	316	439	1093	1476	435	422	900	861	-	679
77.	Mysore	311	743	616	982	438	421	1021	1128	59	280
78.	Raichur	371	738	541	670	410	409	818	602	62	166
79.	Tumkur	309	498	1097	937	418	404	602	947	58	361
80											
	Tamilnadu	650	703	701	780	540	583	774	1167	257	262
80	Salem	634	634	779	594	541	586	818	1170	241	293
81.	Dharmapuri	582	980	813	1202	532	579	848	1267	235	190
82.	Tiruchirapalli	667	703	611	694	566	611	755	1076	282	214

Drought Prone Districts (India)
Annual Compound Growth Rate of Yield of Some Crop

(1967-70 to 1977-80)

1 S.No.	2 District/State	3 Bajra	4 Jowar	5 Gram	6 Groundnut	7 Cotton
	<u>Haryana</u>	-8.79	-2.60	-0.98	-	1.05
1.	Bhiwani	-11.02	-2.28	-0.95	-	1.05
2.	M.Garh	-2.70	-0.66	-0.99	-	-
	<u>GUJARAT</u>	3.98	7.0	-0.17	4.06	1.67
3.	Jamnagar	2.30	8.58	1.19	4.04	6.12
4.	Rajkot	3.09	11.46	-0.10	5.10	4.42
5.	S.Nagar	5.50	3.13	-0.53	5.19	6.57
6.	Bhavnagar	8.07	8.91	-0.43	5.88	0.10
7.	Amreli	6.35	6.92	-2.77	5.03	4.02
8.	Junagarh	9.00	6.82	0.37	2.96	4.54
9.	Kutch	7.13	18.21	-8.02	2.63	1.12
10.	Banswara	1.46	13.65	-0.42	1.06	8.22
11.	Sabarkantha	-6.19	5.94	-0.77	-1.50	7.51
12.	Ahmedabad	-0.04	5.67	-0.22	1.27	-0.36
13.	Vadodara	2.89	-0.44	0.21	1.50	-4.03
14.	Brauch	-1.56	2.63	2.43	1.61	-4.41
15.						
	<u>MAHARASHTRA</u>	2.36	3.84	2.18	-0.84	1.78
15.	Dhule	3.06	3.70	1.54	-0.10	3.25
16.	Jalgaon	5.05	6.06	4.44	-0.46	2.51
17.	Ahmednagar	0.49	3.08	3.04	4.46	8.42
18.	Satara	-2.87	3.31	0.13	-3.35	-0.04
19.	Sangli	4.06	2.25	2.85	1.51	1.39
20.	Sholapur	2.07	0.21	1.01	1.87	2.29
21.	Aurangabad	1.92	4.54	3.43	1.33	3.54
22.	Parbhani	3.51	3.68	1.39	-2.84	2.68
23.	Bhir	2.15	3.92	1.51	-1.10	5.13
24.	Nanded	4.97	3.88	-0.40	-4.64	0.99
25.	Osmanbad	2.32	5.26	4.20	-1.77	3.31
26.	Buldhana	4.21	3.33	1.63	-2.14	7.94
27.	Akola	3.70	1.66	-0.35	-1.13	1.68
28.	Amravati	3.32	6.44	-4.07	0.85	-0.82
29.	Yeotmal	3.25	4.58	2.25	-2.70	2.74
	<u>RAJASTHAN</u>	-0.59	0.69	1.21	-0.21	3.34
30.	Ajmer	-2.65	-4.15	14.10	1.74	5.81
31.	Alwar	0.79	5.03	3.10	-1.57	8.46
32.	Banswara	-4.01	4.63	1.92	3.14	-2.14
33.	Barmer	6.30	9.54	-2.53	-	4.74
34.	Bharatpur	0.43	2.81	1.50	6.92	6.39
35.	Bikaner	3.39	23.11	-0.80	-	1.93

1	2	3	4	5	6	7
36.	Chittorgarh	-3.09	5.37	-0.72	-0.10	2.12
37.	Churu	-1.62	23.70	-0.03	-	-
38.	Dungarpur	-3.00	6.45	1.04	3.30	6.26
39.	Jaislmer	20.00	5.97	-3.21	-	-
40.	Jalore	2.05	8.77	-3.00	6.15	4.72
41.	Jhunjhunu	-13.00	-3.70	6.74	13.20	2.53
42.	Jodhpur	6.00	15.77	-2.18	18.04	6.61
43.	Kota	-3.56	-0.68	3.47	-1.29	5.79
44.	Nagpur	-1.09	12.08	-2.98	7.29	5.72
45.	Pali	3.18	14.10	-1.95	13.10	2.30
46.	S.Madhopur	-1.52	-0.84	2.09	-3.40	5.77
47.	Sikar	-0.27	3.35	1.64	7.40	1.55
48.	Tonk	-2.88	-2.42	2.35	3.23	5.52
	MADHYA PRADESH	-0.17	-0.69	-0.41	-1.73	-1.41
49.	Indore	-3.33	0.32	1.86	-0.52	-0.15
50.	Ratlam	4.02	-2.88	-0.65	-2.27	1.95
51.	Ujjain	2.89	-0.13	-0.93	-1.57	-2.56
52.	Mandsaur	2.50	-0.91	0.65	-4.03	-3.25
53.	Dhar	1.17	-1.08	0.60	-1.08	0.55
54.	Jhabua	1.96	0.07	0.95	-3.25	-2.97
55.	W.Nimar	-7.55	-1.69	-0.97	-2.22	-1.56
56.	E.Nimar	-3.10	-0.71	-0.15	2.45	-2.14
57.	Bhind	-0.45	-0.62	-0.54	-	-
58.	Shivpuri	2.28	-0.39	-1.63	0.80	-
59.	Datra	2.30	2.84	1.28	-	-
60.	Rajgarh	4.48	-1.94	-1.14	-2.90	-3.20
61.	Shajapur	2.71	-0.79	1.18	-	-4.68
	ANDHRA PRADESH	1.65	3.14	4.18	2.08	2.84
62.	Kurnool	-1.57	5.51	5.25	1.29	3.45
63.	Anantpur	3.14	5.17	5.40	2.46	12.46
64.	Hydrabad	3.44	4.08	5.66	3.25	0.32
65.	Medak	1.14	1.28	2.86	0.95	-1.92
66.	Mehboobnagar	2.02	2.28	2.33	1.85	18.27
67.	Adilabad	1.29	0.82	5.58	-1.13	-0.67
	KARNATAKA	3.64	2.68	0.31	1.04	8.14
68	Belgaum	0.66	3.52	1.01	1.64	13.98
69.	Banglore	-	-1.31	0.20	3.67	-
70.	Bellary	4.45	3.87	0.09	3.11	9.45
71.	Bidar	0.92	6.77	0.72	-4.45	10.13
72.	Bijapur	2.37	1.86	1.93	-2.42	9.90
73.	Chitradurga	5.34	4.23	-0.27	7.26	5.38
74.	Dharwar	2.42	5.53	0.57	-0.14	3.87
75.	Gulberga	3.89	1.94	-0.30	1.69	4.66
76.	Kolar	3.34	3.05	-0.30	-0.44	-
77.	Mysore	9.13	4.77	-0.42	1.00	16.85
78.	Raichur	7.12	2.18	-0.02	-3.02	9.67
79.	Tumkur	4.80	-1.56	-0.29	3.65	20.06
	TAMILNADU	0.79	1.07	0.77	4.19	0.19
80.	Salem	0.0	-2.67	0.80	3.65	1.97
81.	Dharmapuri	5.35	3.99	0.85	4.26	-1.89
82.	Tiruchrapalli	0.53	1.2'	0.77	3.61	-2.72

APPENDICES V & VI

YIELD (kg/ha), AREA (per cent of GCA) OF SOME SELECTED CROPS, ANNUAL RAINFALL, SEASONAL RAINFALL (cms.) AND C.V. OF RAINFALL IN DROUGHT PRONE DISTRICTS OF INDIA

YIELD	AREA	RAINFALL PARAMETERS
Y_1 Bajra	A_1 Bajra	X_1 A. Rainfall
Y_2 Jowar	A_2 Jowar	X_2 S. Rainfall
Y_3 Gram	A_3 Gram	X_3 C.V. of Rainfall
Y_4 G.nut	A_4 G.nut	
Y_5 Cotton	A_5 Cotton	

APPENDIX V (1968-69) pp.223-32
APPENDIX VI (1978 79) pp. 333-42)

Y_1	A_1	X_1	X_2	X_3
245.00	27.40	18.77	10.33	36.00
111.00	65.60	35.82	30.33	34.00
436.00	15.50	37.65	37.52	55.00
485.00	13.60	58.94	56.57	45.00
131.00	19.00	25.78	25.78	40.00
522.00	30.80	72.03	71.98	41.00
607.00	23.80	40.40	40.40	45.00
626.00	13.10	89.58	89.09	67.00
353.00	23.30	8.00	7.64	62.00
639.00	45.70	56.05	56.05	54.00
417.00	12.00	51.81	51.81	40.00
478.00	12.90	38.66	38.66	40.00
461.00	3.90	51.30	50.92	35.00
462.00	2.00	81.51	81.50	35.00
466.00	22.50	70.64	66.78	32.00
398.00	10.30	70.82	70.70	29.00
244.00	26.50	50.93	42.72	34.00
262.00	14.00	62.48	41.08	24.00
126.00	21.70	57.00	40.38	27.00
235.00	9.20	51.58	43.99	28.00
345.00	16.50	63.35	53.91	30.00
333.00	.70	63.93	61.71	31.00
324.00	14.90	57.41	44.99	30.00
321.00	.40	79.99	77.77	29.00
342.00	2.40	64.07	58.09	30.00
152.00	1.30	76.59	74.55	27.00
156.00	.80	63.68	61.05	26.00
150.00	1.10	72.35	69.59	26.00
162.00	1.40	88.58	86.42	24.00
276.00	11.80	44.72	43.40	43.00
296.00	28.70	49.22	36.58	35.00
98.00	.00	93.78	93.78	37.00
.00	86.30	4.11	3.51	58.00
312.00	23.70	43.54	38.67	34.00
.00	44.00	3.87	2.52	50.00
95.00	.00	79.14	79.14	36.00
44.00	37.50	22.85	20.86	40.00
100.00	.50	78.98	78.98	37.00
.00	96.40	5.26	4.66	68.00
14.00	63.80	10.05	9.74	56.00
[illegible]	47.20	29.08	27.18	36.00
12.00	60.60	19.16	16.78	58.00
99.00	.50	60.05	59.54	35.00
94.00	43.50	21.71	21.39	45.00
106.00	22.30	16.35	16.35	50.00
436.00	26.00	84.54	82.05	38.00
146.00	46.50	50.70	47.14	38.00
277.00	8.60	36.20	33.24	41.00

Y_1	A_1	X_1	X_2	X_3
549.00	.30	92.56	85.44	29.00
333.00	2.30	79.27	78.99	36.00
441.00	1.20	78.33	76.28	33.00
353.00	.60	68.36	67.74	35.00
308.00	2.90	83.47	79.96	32.00
181.00	4.40	67.22	67.22	34.00
303.00	7.80	71.56	70.25	32.00
423.00	1.20	78.87	77.45	30.00
590.00	10.60	68.35	66.13	32.00
431.00	1.70	88.72	83.45	33.00
410.00	1.40	85.06	82.64	31.00
241.00	.00	82.20	79.22	31.00
412.00	.20	80.47	78.42	31.00
471.00	3.20	53.08	46.84	26.00
462.00	7.70	51.68	42.27	31.00
178.00	2.60	63.88	55.88	29.00
230.00	.90	69.24	66.15	27.00
222.00	5.80	59.27	55.28	26.00
231.00	.00	72.22	68.89	24.00
.00	.00	78.52	57.39	22.00
262.00	9.90	67.82	60.91	22.00
359.00	4.50	64.33	55.13	28.00
358.00	4.10	62.42	57.20	29.00
267.00	16.60	62.80	58.07	30.00
152.00	4.20	52.05	34.15	26.00
273.00	.10	60.31	51.84	25.00
359.00	7.70	64.36	62.88	29.00
333.00	1.80	62.93	48.35	24.00
341.00	.30	74.88	48.83	22.00
359.00	4.70	63.22	55.12	30.00
314.00	.50	66.15	52.67	24.00
590.00	10.20	72.51	59.97	24.00
500.00	2.90	72.71	61.08	24.00
670.00	13.20	66.42	63.46	25.00

Y_2	A_2	X_1	X_2	X_3
179.00	3.30	18.77	10.33	36.00
87.00	3.10	35.82	30.33	34.00
99.00	19.00	37.65	37.52	55.00
212.00	12.20	58.94	57.57	45.00
36.00	18.10	25.78	25.78	40.00
117.00	16.20	72.03	71.98	41.00
315.00	12.10	40.40	40.40	45.00
411.00	8.40	89.58	89.09	67.00
78.00	18.80	8.00	7.64	62.00
154.00	13.90	56.05	56.05	54.00
365.00	4.10	51.81	51.81	40.00
54.00	15.10	38.66	38.66	40.00
784.00	11.60	51.30	50.92	35.00
486.00	20.10	81.51	81.50	35.00
572.00	17.10	70.64	66.78	32.00
1064.00	20.10	70.82	70.70	29.00
336.00	41.90	50.93	42.72	34.00
711.00	17.20	62.48	41.08	24.00
684.00	31.60	57.00	40.34	27.00
362.00	60.70	51.58	43.99	28.00
415.00	26.80	63.35	53.91	30.00
500.00	35.40	63.93	61.71	31.00
591.00	38.10	57.41	44.99	30.00
745.00	35.80	79.99	77.77	29.00
664.00	36.40	64.07	58.09	30.00
841.00	38.20	76.59	74.55	27.00
828.00	32.50	63.68	61.05	26.00
721.00	25.20	72.35	69.59	26.00
626.00	35.40	88.58	86.42	24.00
14.00	25.90	44.72	43.40	43.00
104.00	1.30	49.22	36.58	35.00
180.00	3.70	93.78	93.78	37.00
3.00	.20	4.11	3.51	58.00
62.00	4.20	43.54	38.67	34.00
.00	.00	3.87	2.52	50.00
276.00	12.80	79.14	79.14	36.00
.00	.00	22.85	20.86	40.00
180.00	1.90	78.98	78.98	37.00
.00	.20	5.26	4.66	68.00
3.00	.30	10.05	9.74	56.00
~~70.00~~	.10	29.08	27.18	36.00
1.00	.30	19.16	16.78	58.00
430.00	33.90	60.05	59.54	35.00
.00	6.50	21.71	21.39	45.00
12.00	5.50	16.35	16.35	50.00
276.00	9.10	84.54	82.05	38.00
72.00	.10	50.70	47.14	38.00
32.00	27.70	36.20	33.24	41.00

Y_2	A_2	X_1	X_2	X_3
783.00	17.90	92.56	85.44	29.00
496.00	19.50	79.27	78.99	36.00
935.00	27.90	78.33	76.28	33.00
416.00	31.00	68.36	67.74	35.00
376.00	17.10	83.47	79.96	32.00
380.00	10.40	67.22	67.22	34.00
652.00	30.80	71.56	70.25	32.00
799.00	28.70	78.87	77.45	30.00
916.00	6.80	68.35	66.13	32.00
429.00	22.60	88.72	83.45	33.00
502.00	13.70	85.05	82.64	31.00
717.00	34.10	82.20	79.22	31.00
923.00	35.60	80.47	78.42	31.00
340.00	29.00	53.08	46.84	26.00
366.00	19.00	51.68	42.27	31.00
415.00	31.10	63.88	55.88	29.00
566.00	31.10	69.24	66.15	27.00
325.00	32.40	59.27	55.28	26.00
327.00	38.50	72.22	68.89	24.00
4636.00	1.20	78.52	57.39	22.00
673.00	26.70	67.82	60.91	22.00
763.00	29.00	64.33	55.13	28.00
607.00	30.70	62.42	57.20	29.00
580.00	42.00	62.80	58.07	30.00
1758.00	15.60	52.05	34.15	26.00
839.00	23.60	60.31	51.84	25.00
548.00	45.60	64.36	62.88	29.00
318.00	1.70	62.93	48.35	24.00
584.00	19.00	74.88	48.83	22.00
574.00	25.80	63.22	55.12	30.00
1434.00	7.20	66.15	52.67	24.00
700.00	15.50	72.51	59.97	24.00
800.00	10.20	72.71	61.08	24.00
600.00	15.10	66.42	63.46	25.00

Y_3	A_3	X_1	X_2	X_3
512.00	17.90	18.77	3.01	36.00
214.00	8.80	35.82	3.42	34.00
428.00	.00	37.65	.13	55.00
400.00	.10	58.94	2.38	45.00
471.00	.20	25.78	.00	40.00
500.00	.10	72.03	.06	41.00
100.00	.00	40.40	.00	45.00
459.00	.60	89.58	.35	67.00
.00	.00	8.00	.00	62.00
500.00	.10	56.05	.00	54.00
588.00	.50	51.81	.00	40.00
435.00	.40	38.66	.00	40.00
500.00	.20	51.30	.38	35.00
400.00	.10	81.51	.00	35.00
429.00	1.20	70.64	3.86	32.00
424.00	.70	70.82	.12	29.00
340.00	1.60	50.93	8.21	34.00
390.00	1.20	62.48	9.86	24.00
354.00	1.50	57.00	13.96	27.00
285.00	1.80	51.58	6.76	28.00
297.00	2.80	63.35	9.44	30.00
261.00	2.70	63.93	1.56	31.00
338.00	3.60	57.41	12.18	30.00
357.00	2.50	79.99	1.88	29.00
301.00	4.70	64.07	5.86	30.00
333.00	.60	76.59	2.04	27.00
385.00	1.30	63.68	2.63	26.00
308.00	.80	72.35	1.78	26.00
318.00	.60	85.58	1.72	24.00
394.00	3.60	44.72	1.32	43.00
588.00	16.00	49.22	4.98	35.00
414.00	9.40	93.78	.00	37.00
500.00	.00	4.11	.00	58.00
838.00	23.50	43.54	.00	34.00
.00	.00	3.87	.51	50.00
564.00	4.20	79.14	.00	36.00
26.00	1.20	22.85	.61	40.00
556.00	6.00	78.98	.00	37.00
.00	.00	5.26	.00	68.00
515.00	.00	10.05	.31	56.00
210.00	1.20	29.08	.25	36.00
515.00	.10	19.16	1.34	58.00
530.00	15.50	60.05	.51	35.00
516.00	.70	21.71	.00	45.00
515.00	.60	16.35	.00	50.00
542.00	18.30	84.54	2.37	38.00
613.00	1.10	50.70	.47	38.00
344.00	15.90	36.20	2.36	41.00

IV.

Y_3	A_3	X_1	X_2	X_3
447.00	12.20	92.56	7.12	29.00
370.00	7.10	79.27	.28	36.00
453.00	7.60	78.33	2.05	33.00
381.00	3.10	68.36	.62	35.00
460.00	8.40	83.47	3.51	32.00
290.00	4.20	67.22	.00	34.00
442.00	.70	71.56	1.31	32.00
472.00	1.10	78.87	1.37	30.00
648.00	29.40	68.35	.95	32.00
529.00	9.80	88.72	5.09	33.00
413.00	28.30	85.06	2.32	31.00
428.00	3.70	82.20	2.98	31.00
435.00	4.50	80.47	2.05	31.00
280.00	.50	53.08	14.75	26.00
196.00	.30	51.68	13.59	31.00
252.00	2.30	63.88	8.50	29.00
252.00	4.20	69.24	10.36	27.00
227.00	.50	59.27	7.88	26.00
194.00	.80	72.22	4.22	24.00
451.00	.70	78.52	15.37	22.00
344.00	2.10	67.82	18.65	22.00
526.00	.30	64.33	13.60	28.00
463.00	13.50	62.42	3.80	29.00
43.00	1.50	62.80	16.34	30.00
603.00	.30	52.05	10.76	26.00
388.00	1.20	60.31	12.06	25.00
468.00	2.60	64.36	8.17	29.00
462.00	.10	62.93	15.96	24.00
517.00	.70	74.88	17.68	22.00
466.00	1.50	63.22	11.26	30.00
452.00	.70	66.15	13.93	24.00
532.00	.00	72.51	22.73	24.00
532.00	.10	72.71	25.90	24.00
526.00	.00	66.42	32.11	25.00

Y4	A4	X1	X2	X3
.00	.00	18.77	10.33	36.00
.00	.00	35.82	30.33	34.00
330.00	48.60	37.65	37.52	55.00
394.00	53.30	58.94	56.57	45.00
168.00	8.20	25.78	25.78	40.00
289.00	30.60	72.03	71.98	41.00
527.00	45.30	40.40	40.40	45.00
876.00	53.40	89.58	89.09	67.00
519.00	7.30	8.00	7.64	62.00
296.00	.30	56.05	56.05	54.00
164.00	21.70	51.81	51.81	40.00
301.00	2.90	38.66	38.66	40.00
300.00	3.40	51.30	50.92	35.00
302.00	2.10	81.51	81.50	35.00
532.00	14.90	70.64	66.78	32.00
549.00	7.10	70.82	70.70	29.00
559.00	1.80	50.93	42.72	34.00
1347.00	6.10	62.48	41.08	24.00
511.00	13.80	57.00	40.34	27.00
608.00	6.30	51.58	43.99	28.00
391.00	3.00	63.35	53.91	30.00
872.00	1.00	63.93	61.71	31.00
705.00	5.20	57.41	44.99	30.00
705.00	4.10	79.99	77.77	29.00
722.00	11.60	64.07	58.09	30.00
618.00	2.30	76.59	74.55	27.00
775.00	2.80	63.68	61.05	26.00
822.00	3.30	72.35	69.59	26.00
811.00	3.30	88.58	86.42	24.00
55.00	6.00	44.72	43.40	43.00
701.00	.20	49.22	36.58	35.00
186.00	4.10	93.78	93.78	37.00
.00	.00	4.11	3.51	58.00
233.00	3.00	43.54	38.67	34.00
.00	.00	3.87	2.52	50.00
346.00	14.20	79.14	79.14	36.00
.00	.00	22.85	20.86	40.00
135.00	.40	78.98	78.98	37.00
.00	.00	5.26	4.66	68.00
.00	.10	10.05	9.74	56.00
68.00	.00	29.08	27.18	36.00
.00	.00	19.16	16.78	58.00
750.00	1.00	60.05	59.54	35.00
97.00	.70	21.71	21.39	45.00
139.00	.80	16.35	16.35	50.00
100.00	7.20	84.54	82.05	38.00
120.00	.80	50.70	47.14	38.00
125.00	3.00	36.20	33.24	41.00

Y_4	A4	X_1	X_2	X_3
483.00	1.50	92.56	85.44	29.00
429.00	7.20	79.27	78.99	36.00
664.00	5.60	78.33	76.28	33.00
428.00	15.30	68.36	67.74	35.00
416.00	10.10	83.47	79.96	32.00
218.00	9.90	67.22	67.22	34.00
630.00	7.70	71.56	70.25	32.00
430.00	3.80	78.87	77.45	30.00
.00	.00	68.35	66.13	32.00
417.00	1.60	88.72	83.45	33.00
.00	.00	85.06	82.64	31.00
448.00	9.40	82.20	79.22	31.00
470.00	10.80	80.47	78.42	31.00
586.00	17.70	53.08	46.84	26.00
737.00	27.40	51.68	42.27	31.00
450.00	1.80	63.88	55.88	29.00
522.00	1.90	69.24	66.15	27.00
429.00	12.90	59.27	55.28	26.00
521.00	2.50	72.22	68.89	24.00
729.00	2.90	78.52	57.39	22.00
580.00	14.20	67.82	60.91	22.00
1126.00	12.90	64.33	55.13	28.00
632.00	8.60	62.42	57.20	29.00
464.00	9.20	62.80	58.07	30.00
623.00	7.90	52.05	34.15	26.00
558.00	12.40	60.31	51.84	25.00
632.00	11.60	64.34	62.88	29.00
623.00	12.70	62.93	48.35	24.00
1101.00	6.70	74.88	48.83	22.00
1126.00	9.90	63.22	55.12	30.00
623.00	7.60	66.15	52.67	24.00
816.00	19.60	72.51	59.97	24.00
809.00	8.80	72.71	61.08	24.00
792.00	11.60	66.42	63.46	25.00

Y5	As	X1	X2	X3
228.00	13.60	18.77	10.33	36.00
.00	.00	35.82	30.33	34.00
158.00	3.50	37.65	37.52	55.00
192.00	12.00	58.94	56.57	45.00
58.00	45.10	25.78	25.78	40.00
158.00	4.60	72.03	71.98	41.00
159.00	2.90	40.40	40.40	45.00
159.00	5.50	89.58	89.09	67.00
124.00	11.30	8.00	7.64	62.00
159.00	1.90	56.05	56.05	54.00
102.00	20.60	51.81	51.81	40.00
136.00	37.50	38.66	38.66	40.00
247.00	45.50	51.30	50.92	35.00
161.00	49.00	81.51	81.51	35.00
95.00	9.50	70.64	66.78	32.00
116.00	27.50	70.82	70.70	29.00
123.00	1.90	50.93	42.72	34.00
297.00	.60	62.48	41.08	24.00
167.00	.40	57.00	40.34	27.00
228.00	.80	51.58	43.99	28.00
84.00	14.50	63.35	53.91	30.00
76.00	26.80	63.93	61.71	31.00
98.00	4.90	57.41	44.99	30.00
107.00	28.10	79.99	77.77	29.00
98.00	4.30	64.07	58.09	30.00
90.00	34.40	76.59	74.55	27.00
72.00	41.20	63.68	61.05	26.00
97.00	51.10	72.35	69.59	26.00
88.00	41.90	88.58	86.42	24.00
101.00	3.60	44.72	43.40	43.00
129.00	.00	49.22	36.58	35.00
53.00	8.00	93.78	93.78	37.00
116.00	.00	4.11	3.51	58.00
118.00	.10	43.54	38.67	34.00
.00	.00	3.87	2.52	50.00
101.00	5.80	79.14	79.14	36.00
.00	.00	22.88	20.86	40.00
118.00	.20	78.98	78.98	37.00
.00	.00	5.26	4.66	68.00
118.00	.10	10.05	9.74	56.00
.00	.00	29.08	27.18	36.00
115.00	.00	19.16	16.78	58.00
120.00	.00	60.05	59.54	35.00
118.00	.00	21.71	21.39	45.00
148.00	1.90	16.35	16.35	50.00
113.00	.00	84.54	82.05	38.00
.00	.00	50.70	47.14	38.00
118.00	.40	36.20	33.24	41.00

Y_5	As	X_1	X_2	X_3
76.00	4.30	92.56	85.44	29.00
52.00	12.00	79.27	78.99	36.00
61.00	12.90	78.33	76.28	33.00
75.00	2.60	68.36	67.74	35.00
81.00	9.30	83.47	79.96	32.00
81.00	6.70	67.22	67.22	34.00
127.00	19.90	71.56	70.25	32.00
69.00	29.30	78.87	77.45	30.00
.00	.00	68.35	66.13	32.00
120.00	.00	88.72	83.45	33.00
.00	.00	85.05	82.64	31.00
95.00	10.10	82.20	79.22	31.00
80.00	18.30	80.47	78.42	31.00
61.00	11.50	53.08	46.84	26.00
33.00	3.70	51.68	42.27	31.00
60.00	.10	63.88	55.88	29.00
60.00	.20	69.25	66.15	27.00
28.00	1.10	59.27	55.28	26.00
64.00	14.50	72.22	68.89	24.00
.00	.00	78.52	57.39	22.00
35.00	6.50	67.82	60.91	22.00
84.00	19.70	64.33	55.13	28.00
64.00	3.00	62.42	57.20	29.00
35.00	12.60	62.80	58.07	30.00
84.00	6.80	52.05	34.15	26.00
68.00	20.40	60.31	51.84	25.00
80.00	4.20	64.36	62.88	29.00
.00	.00	62.93	48.35	24.00
64.00	.90	74.88	48.83	22.00
80.00	22.60	63.22	55.12	30.00
64.00	.20	66.15	52.67	24.00
220.00	2.00	72.51	35.24	24.00
224.00	.30	72.71	37.53	24.00
262.00	.90	66.42	35.19	25.00

Y_1	A_1	X_1	X_2	X_3
216.00	35.90	65.20	55.15	36.00
269.00	34.70	66.78	52.12	34.00
721.00	9.60	59.78	58.77	55.00
944.00	6.30	61.33	61.33	45.00
332.00	12.80	35.70	30.80	40.00
1560.00	19.80	49.60	46.30	41.00
1313.00	18.50	43.62	31.92	45.00
1570.00	6.80	70.46	67.21	67.00
606.00	15.70	34.20	30.60	62.00
582.00	26.90	79.30	73.20	54.00
509.00	9.90	87.92	87.14	40.00
689.00	10.10	70.13	65.16	40.00
851.00	3.50	107.41	96.89	35.00
661.00	1.30	83.00	74.43	35.00
511.00	16.00	34.10	34.10	32.00
599.00	9.40	73.62	66.30	29.00
147.00	25.30	32.22	22.75	34.00
233.00	16.70	65.38	55.41	24.00
214.00	16.30	53.28	26.58	27.00
208.00	5.80	77.93	51.93	28.00
317.00	13.00	74.93	64.93	30.00
512.00	.70	61.00	48.20	31.00
367.00	17.00	74.16	63.66	30.00
538.00	.30	98.88	78.12	29.00
430.00	2.10	85.05	64.36	30.00
458.00	1.40	78.93	65.38	27.00
452.00	.70	98.30	82.46	26.00
423.00	.90	128.37	90.91	26.00
441.00	1.20	112.25	89.43	24.00
502.00	10.00	65.98	49.96	43.00
667.00	23.50	75.09	67.61	35.00
.00	.00	163.40	154.64	37.00
184.00	62.00	38.05	29.12	58.00
677.00	23.10	63.16	56.26	34.00
81.00	34.40	40.06	30.81	50.00
285.00	.00	76.83	72.77	36.00
110.00	31.10	85.74	81.10	40.00
250.00	.00	128.56	118.94	37.00
59.00	74.30	24.60	20.30	68.00
260.00	39.00	60.37	46.09	56.00
123.00	36.70	70.35	64.20	36.00
170.00	52.80	41.76	35.81	58.00
254.00	.30	89.62	81.90	35.00
190.00	43.60	52.00	42.40	45.00
283.00	14.40	46.98	41.20	50.00
580.00	21.60	82.70	73.30	38.00
306.00	33.80	103.97	95.47	38.00
502.00	4.30	61.56	53.20	41.00

IX

Y_1	A_1	X_1	X_2	X_3
600.00	.00	78.95	70.51	29.00
596.00	1.20	112.39	107.50	36.00
548.00	.30	101.19	91.29	33.00
573.00	.40	89.07	80.12	35.00
385.00	1.20	99.84	90.90	32.00
347.00	2.00	100.99	94.32	34.00
124.00	4.60	78.94	70.48	32.00
342.00	.30	102.99	93.58	30.00
857.00	10.10	71.10	56.96	32.00
788.00	.90	88.78	80.06	33.00
712.00	1.30	119.97	98.62	31.00
250.00	.00	127.29	107.57	31.00
540.00	.10	100.23	84.14	31.00
660.00	3.20	89.40	76.80	26.00
468.00	5.90	52.40	46.40	31.00
428.00	2.60	122.40	111.00	29.00
283.00	1.30	128.40	116.60	27.00
332.00	5.10	112.20	85.10	26.00
283.00	.00	138.30	127.90	24.00
.00	.00	94.27	72.89	22.00
227.00	10.40	81.99	68.93	22.00
461.00	5.70	71.40	63.20	28.00
426.00	4.40	121.16	102.02	29.00
435.00	17.00	75.81	63.32	30.00
622.00	5.60	59.45	48.86	26.00
429.00	.10	90.10	73.13	25.00
509.00	13.50	112.56	97.40	29.00
418.00	2.00	81.17	69.54	24.00
798.00	.40	84.42	63.23	22.00
885.00	5.60	78.43	67.76	30.00
369.00	.70	71.26	56.28	24.00
694.00	7.40	89.26	77.74	24.00
946.00	2.10	75.20	69.88	24.00
731.00	12.70	81.58	74.69	25.00

Y2	A2	X1	X2	X3
120.00	.60	65.20	55.15	36.00
180.00	1.20	66.78	52.12	34.00
255.00	11.30	59.78	58.77	55.00
397.00	5.70	61.33	61.33	45.00
143.00	15.70	35.70	30.80	40.00
199.00	11.70	49.60	46.30	41.00
496.00	11.00	43.62	31.92	45.00
889.00	4.40	70.46	67.21	67.00
423.00	8.80	39.20	30.60	62.00
655.00	9.80	79.30	73.20	54.00
675.00	1.60	87.92	87.14	40.00
390.00	14.40	70.13	65.17	40.00
964.00	10.00	107.41	96.89	35.00
736.00	21.20	83.00	74.43	35.00
678.00	25.70	34.10	34.10	32.00
1253.00	24.30	73.62	66.30	29.00
361.00	46.40	32.22	22.75	34.00
778.00	34.00	65.38	55.41	24.00
841.00	34.40	53.28	26.58	27.00
490.00	60.70	77.93	51.93	28.00
712.00	31.40	74.93	64.93	30.00
677.00	34.10	61.00	48.20	31.00
833.00	41.50	74.16	63.66	30.00
881.00	37.80	98.88	78.12	29.00
1046.00	42.00	85.05	64.36	30.00
1245.00	33.60	78.93	65.38	27.00
700.00	29.30	98.30	82.46	26.00
1254.00	24.90	128.37	90.91	26.00
961.00	31.80	112.25	89.43	24.00
100.00	21.90	65.98	49.96	43.00
386.00	2.70	75.09	67.61	35.00
803.00	.60	163.40	154.04	37.00
231.00	.10	38.05	29.12	58.00
394.00	3.00	63.16	56.26	34.00
400.00	.40	40.06	30.81	50.00
1015.00	9.70	76.83	72.77	36.00
400.00	.00	85.74	81.10	40.00
805.00	.10	128.56	118.94	37.00
231.00	1.80	24.60	20.30	68.00
231.00	.30	60.37	46.09	56.00
644.00	.00	70.35	64.20	36.00
196.00	1.30	41.76	35.81	58.00
477.00	21.90	89.62	81.90	35.00
219.00	4.20	52.00	42.40	45.00
282.00	3.50	46.98	41.20	50.00
506.00	10.70	82.70	73.30	38.00
305.00	1.50	103.97	95.47	38.00
309.00	27.80	61.56	53.20	41.00

Y_2	A_2	X_1	X_2	X_3
802.00	14.20	78.95	70.51	29.00
719.00	14.30	112.39	107.50	36.00
722.00	27.80	101.19	91.29	33.00
594.00	22.80	89.07	80.12	35.00
420.00	11.10	99.84	90.90	32.00
608.00	6.20	100.99	94.32	34.00
695.00	22.10	78.94	70.48	32.00
809.00	23.70	102.99	93.58	30.00
975.00	6.50	71.10	56.96	32.00
540.00	13.90	88.78	80.06	33.00
743.00	16.20	119.97	98.62	31.00
710.00	31.20	127.29	107.57	31.00
964.00	25.20	100.23	84.14	31.00
739.00	27.00	89.40	76.80	26.00
730.00	12.30	52.40	46.40	31.00
656.00	32.70	122.40	111.00	29.00
427.00	29.90	128.40	116.60	27.00
615.00	32.50	112.20	85.10	26.00
549.00	40.60	138.30	127.90	24.00
2207.00	.00	94.27	72.89	22.00
940.00	19.40	81.99	68.93	22.00
1261.00	20.10	71.40	63.20	28.00
1042.00	27.70	121.16	102.02	29.00
575.00	33.80	75.51	63.32	30.00
1814.00	19.50	59.45	48.86	26.00
1492.00	20.60	90.10	73.13	25.00
672.00	24.60	112.56	97.40	29.00
1623.00	.60	81.17	69.54	24.00
1126.00	17.70	84.42	63.23	22.00
822.00	21.00	78.43	67.76	30.00
852.00	6.90	71.26	56.28	24.00
584.00	16.00	89.26	77.74	24.00
1198.00	11.40	75.20	69.88	24.00
784.00	18.40	81.58	74.69	25.00

Y_3	A_3	X_1	X_2	X_3
998.00	39.40	65.20	5.43	36.00
1053.00	26.40	66.78	6.37	34.00
750.00	.10	59.78	.41	55.00
750.00	.10	61.33	.00	45.00
649.00	.60	35.70	4.90	40.00
750.00	.10	49.60	3.30	41.00
667.00	.10	43.62	11.70	45.00
625.00	.60	70.46	3.79	67.00
500.00	.00	34.20	3.60	62.00
643.00	.30	79.30	6.10	54.00
635.00	1.10	87.92	.76	40.00
634.00	.70	70.13	4.86	40.00
632.00	.30	107.41	6.99	35.00
667.00	.20	83.00	8.57	35.00
414.00	1.10	34.10	.00	32.00
484.00	.70	73.62	7.32	29.00
477.00	1.40	32.22	8.08	34.00
421.00	2.00	65.38	8.82	24.00
606.00	2.70	53.28	19.00	27.00
346.00	2.60	77.93	22.16	28.00
352.00	2.80	74.93	7.58	30.00
306.00	3.00	61.00	11.40	31.00
337.00	3.80	74.16	8.02	30.00
212.00	2.00	98.88	17.73	29.00
410.00	4.90	85.05	15.09	30.00
251.00	1.70	78.93	10.51	27.00
234.00	1.90	98.30	14.46	26.00
282.00	1.50	128.37	29.09	26.00
437.00	.80	112.25	12.63	24.00
359.00	9.00	65.98	4.42	43.00
1293.00	24.70	75.09	1.87	35.00
694.00	12.50	163.40	4.98	37.00
573.00	.10	38.05	3.50	58.00
1204.00	20.60	63.16	1.60	34.00
870.00	.30	40.06	.90	50.00
503.00	8.10	76.83	1.30	36.00
461.00	8.30	85.74	.50	40.00
911.00	11.70	128.56	9.90	37.00
577.00	.10	24.60	.70	68.00
577.00	.80	60.37	3.99	56.00
574.00	13.90	70.35	1.25	36.00
1073.00	.10	41.76	.95	58.00
574.00	12.40	89.62	4.12	35.00
834.00	.90	52.00	2.60	45.00
309.00	3.30	46.98	1.30	50.00
706.00	14.90	82.70	.20	38.00
1084.00	6.50	103.97	3.60	38.00
574.00	13.40	61.56	.90	41.00

Y3	A3	X1	X2	X3
704.00	15.20	78.95	8.39	29.00
549.00	11.20	112.39	4.89	36.00
576.00	11.60	101.19	9.69	33.00
696.00	12.30	89.07	8.71	35.00
564.00	9.70	99.84	8.65	32.00
519.00	6.40	100.99	6.67	34.00
464.00	1.90	78.94	7.44	32.00
513.00	1.60	102.99	8.15	30.00
898.00	20.90	71.10	8.58	32.00
575.00	8.70	88.78	5.94	33.00
574.00	25.40	119.97	13.50	31.00
604.00	8.40	127.29	13.68	31.00
628.00	9.20	100.23	14.64	31.00
329.00	.50	89.40	12.30	26.00
429.00	.20	52.40	16.60	31.00
399.00	1.50	122.40	15.30	29.00
132.00	2.90	128.40	11.90	27.00
343.00	.30	112.20	12.80	26.00
334.00	.60	138.30	12.20	24.00
405.00	.10	94.27	25.18	22.00
600.00	2.00	81.99	14.21	22.00
403.00	1.40	71.40	17.73	28.00
552.00	9.20	121.16	23.45	29.00
291.00	1.80	75.51	16.80	30.00
406.00	1.00	59.45	22.55	26.00
238.00	1.30	90.10	25.32	25.00
363.00	3.60	112.56	12.02	29.00
406.00	.10	81.17	25.09	24.00
406.00	.60	84.42	27.92	22.00
406.00	1.00	78.43	8.97	30.00
405.00	.30	71.26	22.72	24.00
575.00	.00	89.26	47.10	24.00
588.00	.20	75.20	46.30	24.00
600.00	.00	81.58	58.85	25.00

Y_4	A_4	X_1	X_2	X_3
.00	.00	65.20	55.15	36.00
1053.00	.20	66.78	52.12	34.00
857.00	63.70	59.78	58.77	55.00
783.00	55.10	61.33	61.33	45.00
562.00	5.90	35.70	30.80	40.00
739.00	28.80	49.60	46.30	41.00
778.00	55.40	43.62	31.92	45.00
1466.00	56.70	70.46	67.21	67.00
782.00	8.20	34.20	30.60	62.00
545.00	.30	79.30	73.20	54.00
458.00	17.40	87.92	87.14	40.00
563.00	1.80	70.13	65.17	40.00
560.00	3.00	107.41	96.89	35.00
563.00	2.90	83.00	74.43	35.00
391.00	12.40	34.10	34.10	32.00
455.00	8.00	73.62	66.30	29.00
800.00	1.70	32.22	22.75	34.00
871.00	10.10	65.38	55.41	24.00
802.00	7.50	53.28	26.58	27.00
579.00	2.50	77.93	51.93	28.00
457.00	2.30	74.93	64.93	30.00
509.00	1.50	61.00	48.20	31.00
464.00	2.60	74.16	63.66	30.00
354.00	2.50	98.86	78.12	29.00
580.00	4.40	85.05	64.36	30.00
279.00	3.70	78.93	65.38	27.00
274.00	3.60	98.30	82.46	26.00
461.00	5.10	128.37	90.91	26.00
334.00	4.10	112.25	89.43	24.00
507.00	7.20	65.98	49.96	43.00
619.00	.20	75.09	67.61	35.00
619.00	1.00	163.40	154.04	37.00
750.00	.00	38.05	29.12	58.00
463.00	3.60	63.16	56.26	34.00
615.00	.00	40.06	30.81	50.00
656.00	8.20	76.83	72.77	36.00
618.00	.00	85.74	81.10	40.00
620.00	.20	128.56	118.94	37.00
.00	.00	24.60	20.30	68.00
622.00	.00	60.37	46.09	56.00
619.00	.20	70.35	64.20	36.00
618.00	.30	41.76	35.81	58.00
619.00	1.30	89.62	81.90	35.00
567.00	3.30	52.00	42.40	45.00
619.00	1.10	46.98	41.20	50.00
562.00	10.70	82.70	73.30	38.00
619.00	.90	103.97	95.47	38.00
619.00	6.90	61.56	53.20	41.00

Y_4	A_4	X_1	X_2	X_3
67.00	1.00	78.95	70.51	29.00
81.00	2.60	112.39	107.50	36.00
76.00	2.60	101.19	91.29	33.00
62.00	6.10	89.07	80.12	35.00
111.00	8.50	99.84	90.90	32.00
75.00	6.60	100.99	94.32	34.00
89.00	8.60	78.94	70.48	32.00
53.00	5.30	102.99	93.58	30.00
.00	.00	71.10	56.96	32.00
.00	5.10	88.78	80.06	33.00
.00	.20	119.97	98.62	31.00
70.00	6.70	127.29	107.57	31.00
47.00	7.60	100.23	84.14	31.00
66.00	15.20	89.40	76.80	26.00
62.00	35.60	52.40	46.40	31.00
93.00	1.70	122.40	111.00	29.00
93.00	.50	128.40	115.70	27.00
241.00	11.50	112.20	85.10	26.00
50.00	.80	138.30	127.40	24.00
.00	4.90	94.27	72.89	22.00
180.00	14.20	81.99	68.93	22.00
153.00	7.60	71.40	63.20	28.00
107.00	6.50	121.16	102.02	29.00
109.00	8.30	75.51	63.32	30.00
114.00	10.60	59.45	48.86	26.00
110.00	10.40	90.10	73.13	25.00
119.00	8.80	112.56	97.40	29.00
.00	19.30	81.17	69.54	24.00
185.00	6.50	84.42	63.23	22.00
158.00	14.10	78.43	67.76	30.00
432.00	11.90	71.26	56.28	24.00
367.00	21.10	89.26	77.74	24.00
196.00	10.70	75.20	69.88	24.00
220.00	9.70	81.58	74.69	25.00

Ys	As	X1	X2	X3
251.00	1.60	65.20	55.15	36.00
.00	.00	66.78	52.12	34.00
332.00	4.90	59.78	58.77	55.00
320.00	19.60	61.33	61.33	45.00
150.00	52.70	35.70	30.80	40.00
251.00	13.10	49.60	46.30	41.00
311.00	7.60	43.62	31.92	45.00
332.00	6.10	70.46	67.21	67.00
209.00	14.40	34.20	30.60	62.00
332.00	1.30	79.30	73.20	54.00
184.00	24.90	87.92	87.14	40.00
153.00	28.80	70.13	65.17	40.00
172.00	42.90	107.41	96.89	35.00
161.00	33.70	83.00	74.43	35.00
120.00	7.30	34.10	34.10	32.00
106.00	19.90	73.62	66.30	29.00
294.00	1.40	32.22	22.75	34.00
405.00	1.30	65.38	55.41	24.00
258.00	.50	53.28	26.58	27.00
363.00	1.10	77.93	51.93	28.00
115.00	11.20	74.93	64.93	30.00
97.00	20.60	61.00	48.20	31.00
168.00	2.90	74.16	63.66	30.00
78.00	25.60	98.88	78.12	29.00
137.00	2.60	85.05	64.36	30.00
74.00	28.30	78.93	65.38	27.00
55.00	39.40	98.33	82.46	26.00
68.00	44.50	128.37	90.91	26.00
83.00	42.20	112.25	89.43	24.00
218.00	4.40	65.98	49.96	43.00
241.00	.00	75.09	67.61	35.00
77.00	9.10	163.40	154.64	37.00
240.00	.00	38.05	29.12	58.00
241.00	.10	63.16	56.26	34.00
241.00	.10	40.06	30.80	50.00
135.00	3.30	76.83	72.77	36.00
.00	.00	85.74	81.10	40.00
241.00	1.10	128.56	118.94	37.00
.00	.00	24.60	20.30	68.00
241.00	.40	60.37	46.09	56.00
242.00	.00	70.35	64.20	36.00
241.00	.20	41.76	35.81	58.00
243.00	.00	89.62	81.90	35.00
241.00	.20	52.00	42.40	45.00
175.00	4.10	46.98	41.20	50.00
238.00	.00	82.70	73.30	38.00
238.00	.00	103.97	95.47	38.00
241.00	.10	61.58	53.20	41.00

Y_5	A_5	X_1	X_2	X_3
581.00	.60	78.95	70.51	29.00
630.00	10.20	112.39	107.50	36.00
682.00	6.80	101.19	91.29	33.00
548.00	1.10	89.07	80.12	35.00
621.00	12.00	99.84	90.90	32.00
535.00	7.20	100.99	94.32	34.00
578.00	25.50	78.94	70.48	32.00
342.00	32.90	102.99	93.58	30.00
591.00	.00	71.10	56.96	32.00
625.00	.00	88.78	80.66	33.00
767.00	.00	119.97	98.62	31.00
505.00	6.50	127.29	107.57	31.00
494.00	9.80	100.23	84.14	31.00
790.00	11.70	89.40	76.80	26.00
791.00	2.70	52.40	46.40	31.00
935.00	.00	122.40	111.00	29.00
696.00	.10	128.40	116.60	27.00
798.00	.90	112.20	85.10	26.00
507.00	18.10	138.30	127.90	24.00
896.00	.00	94.27	72.89	22.00
673.00	7.10	81.99	68.93	22.00
1183.00	16.00	71.40	63.20	28.00
358.00	1.80	121.16	102.02	29.00
506.00	13.50	75.51	63.32	30.00
1499.00	8.70	59.45	48.86	26.00
517.00	20.60	90.10	73.13	25.00
659.00	9.10	112.56	97.40	29.00
856.00	.00	81.17	69.54	24.00
1224.00	1.40	84.42	63.23	22.00
670.00	25.40	78.43	67.76	30.00
1130.00	.20	71.26	56.28	24.00
1214.00	5.30	89.26	55.45	24.00
1455.00	1.60	75.20	55.59	24.00
1216.00	1.10	81.58	63.39	25.00