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AGRICULTURE IN ARID AND SEMIARID REGIONS OF INDIA

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ABSTRACT : The paper discusses the agroclimatic aspects of the arid and semi-arid areas of India, delimits these areas on the basis of moisture index and outlines the performance and problems of agriculture in the semi-arid tracts of the country. It also suggests the strategy for the development of agriculture in these moisture-deficient zones. These include tapping different sources of water, practising improved methods of irrigation, optimization of cropping pattern and the introducion of better suited social and institutional changes.

Regional disparities in the levels of agricultural development in an underdeveloped countary are due to a host of causes, the most important of them being, the environmental, institutional and technological factors. India has a predominantly agricultural and rural economy and the regional disparities in income, especially in rural areas, are due to disparities in agricultural progress. In recent decades, there has been an actual accentuation of the regional disparities in the levels of progress of the Indian agriculture. The coefficient of variation in agricultural productivity per hectare increased from 0·52 in 1960s to 0.66 in 1970s and agricultural productivity per worker increased from 0.51 to 0.70 in the same period (Moonis Raza, 1979). One of the important causes for the disparities in agricultural development is the diversity of agro-climatic conditions. The areas with high production levels in agriculture have high correlation with areas of high rainfall and assured levels of irrigation, while the areas with very low production levels belong to the low and unpredictable rainfall regions or areas where irrigation is almost non-existent (Bhalla and Alagh, 1979).

On the basis of mositure indices, the country is broadly divided into four macro agro-climatic regions viz., the arid zone where constant water deficit is typical, the semi-arid zone which periodically suffers from lack of water, the sub-humid zone which enjoys a seasonal water surplus and the humid zone which has a surplus of moisture almost for most part of the year. The present paper is an attempt to examine the problems and prospects of agriculture in arid and semi-arid areas.

The study is divided into five sections : the first being the introduction, the second dealing with the agro-climatic aspects of the arid and semi-arid areas, the third with problems of agriculture, the fourth with its performance in recent years, and the fifth with the strategy for the development of agriculture in these regions.

Agroclimatic Aspects of the Arid and Semi-arid Areas

The arid and semi-arid areas of India form two of the four macro-agricultural regions of India and constitute a distinct ecosystem. Aridity, which is a common denomination in this macro-region, is essentially a climatic phenomenon with meteorological, hydrological, biotic and agro-climatological implications. Deficiency of rainfall, the primary cause for aridity, is the basic feature of arid and semi-arid areas. Various other parameters like the number of rainy days, runoff, soil moisture, groundwater levels, surface water area, soil and vegetation cover show distinctive characteristics by their scantiness in an arid environment.

The arid and semi-arid areas, together often described as dry zone or dry-farming zone where rainfed agriculture is common, are characterised by low rainfall (76 cm), high coefficient of variation of rainfall,excess of evapotranspiration and low humidity for 6 to 9 months. The arid and semi-arid areas are often vulnerable to drought and hence agriculturally unstable. Agriculturally, these areas are marginal in character. The ecological balance in the arid and semi-arid ecosystem is delicate and gets easily disturbed. The effect of drought on the total ecosystem specially on vegetation, soil moisture regime, landuse, animal life and human habitation is profound and far-reaching.

Criteria employed for delimitation

Among the climatic classifications of India, Thornthwaite's climatic classification corresponds well with the actual vegetation types. Thornthwaite's moisture index value of -40 is taken for differentiating arid zone from semi-arid zone, and-20 is taken for differentiating semi-arid zone from dry sub-humid zone.

Table - I

Moisture Index	Agroclimatic zone
0 to -20	Dry sub-humid (Cd)
-20 to -40	Semi-arid (Dd)
-40 to -60	Arid (Ed)

Note : 'd' indicates little or no water surplus.

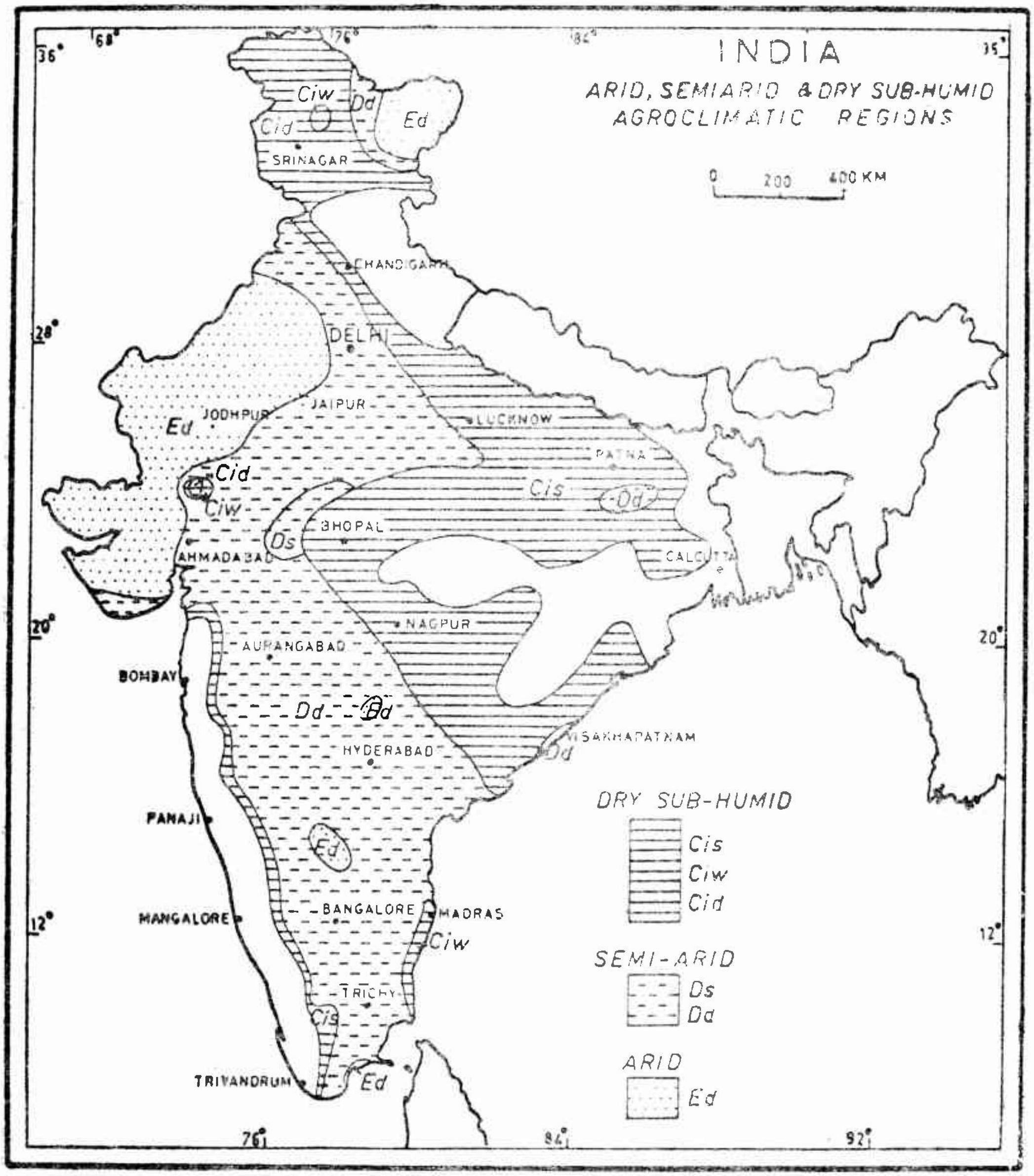
Schendel (1966) differentiated the arid and semi-arid zones by employing certain parameters like moisture index, precipitation, runoff, evapotranspiration, potential evaporation etc. The follwing table gives the parameters normally used for differentiating arid and semi-arid areas.

Spatial distribution of arid zone

The main arid zone which is situated in north western India accounts for 91 per cent of the total arid zone of the country. It comprises western Rajasthan, Saurashtra and Kutch of Gujarat, south westerna Punjab and western Haryana. In addition, there are small pockets of arid zone(30,120 Km^2) in Peninsular India comprising Anantapur

Table II : Criteria for Delineation of Arid and Semi-arid Areas

Climatic Zone	Mois-tur Index	PPT in mm	Run off in mm	Evapo-trans-piration in mm	5/3 in percen-tage	4/3 in percen-tage	Potential evaporation in mm
1	2	3	4	5	6	7	8
Semi-arid (D)	-20	401	40	361	90	10	2080
Arid (E)	-54	223	12	211	95	5	2153



Compiled from Agroclimatic Atlas of India,IMD, 1978.

TABLE III

Distribution of Arid Areas of India

State	Aridity Index*	No. of arid districts	Area under arid zone (Km²)	% in each state out of total arid zone of India
1. Rajasthan	78	12	196,150	61.9
2. Gujarat	76	7	62,180	19.6
3. Punjab	75	2	14,510	4,6
4. Haryana	74	2	12,840	4,0
5. Andhra Pradesh	68	3	21,550	6.8
6. Karnataka	68	4	8,570	2.7
7. Maharashtra	68	4	1,290	0,4
Total	—	34	317,090 *	100

Note :

* 1. Aridity Index $= \frac{\text{Annual moisture deficiency}}{\text{Annual water need}} \times 100$

* 2. The cold desert of Ladakh (70,300 Km) is excluded in the above table.

Source : A. Krishnan 1971.

Spatial distribution of semiarid zone :

The semi-arid zone is very extensive and comprises 104 districts covering 15 districts in Andhra Pradesh, 10 in Tamil Nadu, 8 in Karnataka, 15 in Maharashtra, 14 in Madhya Pradesh, 8 in Uttar Pradesh, 2 in Haryana, 2 in Punjab, 15 in Rajasthan, 13 in Gujarat and entire Delhi.

TABLE IV

Stateswise Distribution of Arid and Semi-arid Districts in India

State	No. of arid districts	No. of semi-arid districts	Total No. of arid and semi-arid districts
1	2	3	4
Rajasthan	11	15	26
Gujarat	3	13	16
Punjab	2	2	4
Haryana	1	2	3
Andhra Predesh	2	16	18
Karnataka	2	8	10
Maharashtra	-	15	15
Tamil Nadu	-	10	10
Madhya Pradesh	-	14	14
Uttar Pradesh	-	8	8
Delhi	-	1	1
Total for India	21	104	125

Note : Based on Agroclimatological Atlas of India, I. M. D., 1978

(67%), Kurnool (31%) and Cuddapah(9%) districts of Rayalaseema in Andhra Pradesh, Raichur (39%), Bellary (25%), Chitradurg (4%) and Dharwar (1%) districts of Karnataka, and Sholapur, Dhulia and Nasik districts of Maharashtra. The total number of the districts is 34. However, if the districts which have less than 25 per cent. of their respective areas under arid climate are excluded, then the total number of arid districts of India will be 21 only.

On the whole, the 125 arid and semi-arid districts of India constitute a little over 61 per cent. of the country's geographical aree and 40 per cent. of the cropped area (Jodha, 1979, P. 487).

In addition, there are some districts which are situated in the dry sub-humid zone which receive 75 - 85 cm. of rainfall and are vulnerable to drought. These districts account for another 9 per cent. of the cultivated area of the country.

Problems of Agriculture in the Dry Zone

The net sown area in the arid zone is much less than the total available area for cultivation. As the moisture holding capacity of the soil is limited and the rainy days are very few, large areas of land are left fallow. Sowing is often delayed for want of sufficient drought power during peak periods resulting in lower crop yield due to poor germination and poor cropstand. The problem of persistent dependence on monsoon and consequent instability of crop production is more severe in case of rainfed agriculture. In these areas, the overall precipitation is low and highly variable as indicated by the coefficient of variation of rainfall and related details. More importantly, evapotranspiration exceeds precipitation for 8 to 9 months of the year, which further restricts the scope for raising field crops. Further, the seasonal dstribution of rainfall is most unequal and erratic. The soils in these rengions range from sandy and shallow red to medium and black, and have varying degrees of deficiency of plant nutrients and are susceptible to erosion.

The Indian arid zone being one of the most densly populated deserts is a glaring example of desertification due to human activity (Mann et. al, 1979). The main factors of desertification within the desert are the escalation of human and livestock populations. The human population of Rajasthan desert has increased from 3.42 millions in 1901 to 8.84 millions 1971. To meet the needs of the additional population more sub-marginal and marginal lands have been brought under agriculture. In 1951 the net sown area in the arid zone was 25.6 % and it increased to 48.6% in 10 years (1951–61) and further increased to 51.4% in the next 10 years (1961–71) This substantial increase in net sown area has reduced the pasture and grasslands by about 25% and yet the livestock population in these areas increased from 9-4 millions in 1951 to 15.5 millions in 1972. The reduction in pasture land along with the increase in the livestock population had an adverse effect on the quality of livestock. The over-exploitation of groundwater resulted in the increase of salinity and water-logging. The net result of increased human activity in the desert ecosystem has been that 4.35% of the area of western Rajasthan was affected by the process of desertification. About 76.2% of the desert is moderately to highly vulnerable while 19.5% is slightly to moderately vulnerable to various froms of desertfication.

Droughts cause further deterioration of the desert ecosystem. During 1875–1972, there were more than 40 drought years when there was more than 25 per cent deficit of rainfall during the S. W. monsoon period. On an average, the region experiences drought every 2.5 years. However, since the frequency is not regular the occurrence of drought cannot be predicted.

The arid areas experience many hazards in addition to frequent droughts. In May-June months the Indian desert region experiences 5 to 8 dust storms. The occurrrence of these dust storms increases with the decrease of rainfall. The soil which is fine and fertile is removed in the process causing damage to the soil and crops.

The soils and climate of the arid areas are better suited for pasture development than for agriculture. Animal wealth is underenxploited in these regions despite the fact that the tract can boast of the best Indian dual purpose breeds of cattle. The iivestock of these areas is migratory in character mainly due to lack of year-round grazing and water. In years of drought, a large number of animals, both cattle and sheep, die due to malnutrition and deseases thus depleting a valuable resource.

The livestock rearing, similar to crop farming, is quite precarious in semi-arid areas. Unlike in the arid areas, animal population in semi-arid areas is dense and land for grazing is in short supply. The breeds are mostly non-descript, neither good as milch animals, nor good for drought purposes. The sheep are the coarse hairy type, with below average weights as mutton animals. In arid areas livestock population is an asset, in semi-arid areas a liability (Aurora, 1979). The concentration of livestock population in these areas have actually contributed to the decreasing productivity of land through over-grazing which results in erosion, unlimited movement of animals resulting in dwindling growth of forests, and feeding on crop remnants leading to grater compaction of soils.

The vegetation undergoes changes from edible perennial to unpalatable annuals due to high rate of evaporation and drought. Drought starts a chain of biological reactions in arid and semi-arid areas leading to deterioration and subsequent desertification. The removal of the scanty vegetation in these areas accelerates the process of soil erosion and causes further degradation of the environment.

Recharging of aquifers is so slow during the dry years that water table in wells falls resulting in scarcity of drinking water for human and livestock population. There will be no water for irrigation. Poor recharge also leads to manifold increase in salinity of water. In case of continuous drought years, the land becomes permanently damaged by the increase of salinity.

Droughts lead to scarcity of food-grains, water and fodder, and the people are forced to migrate. The livestock often perish. Prevalence of such high risks has made the farmers cultivate traditional crops although they are aware of the fact that the yields are lower than the potential. In the face of a high risk, the farmers feel reluctant to make new ventures such as growing HYVs which need heavy investment.

Two types of crops are grown in these regions : dry crops which are best suited to the soils and the prevailing agroclimatic conditions of the region, e. g., jowar (Sorghum), Bajra (Pearl millet), finger millet, pulses, oil seeds, cotton as well as wheat in some areas; and wet crops which yield high income are grown in the irrigated tracts, but they are limited in extent.

The arid and semi-arid regions of India account for the major portion of the cropped land under certain specific dry crops. Yet, het overall contribution of these areas to the country's total crop production is disproporionately low. This is due to the low and unstable yields of the crops under precarious rainfed conditions. The weather-induced problem of low and unstable crop production is the chief factor responsible for the continued economic stagnation of these areas.

Pearl millet and jowar are the main crops grown in arid areas. In the arid tracts of Rajastan, these crops account for about 45 per cent of the sown areas. In Gujarat, both jowar and pearl millet are equal in importance. In the arid areas of Andhra Pradesh and Karnataka, jowar is grown in larger areas than pearl millet. Yield of both jowar and pearl millet in all these areas, except

Kurnool and Anantapur districts of Andhra Pradesh, are lower than the all India average.

Groundnut is the next important crop in arid areas; but it is confined to Gujarat where the yield is medium and Andhra Pradesh where the yield is good. It is not grown in any appreciable extent in the arid zone of Rajasthan, Punjab and Haryana. Wheat and pulses are the two predominant crops in the arid tracts of Punjab and Haryana. Cotton is grown in all the three arid districts of Gujarat and in Ganganagar district of Rajasthan, but here the yields are low. In Punjab and Haryana dry tracts, cotton is grown in irrigated areas where the yields are high.

Performance of Agrigulture in Arid and Semi-arid Regions of Indla

The arid and semi-arid regions, as pointed out earlier, account for more than 61 per cent of the total geographical area and more than 40 per cent of the cropped area of the country (Jodha, 1979). These regions play an important role in the agrarian economy of India as is evidenced from the fact that they account for 30 per cent of wheat production, 60 per cent of maize, ragi and cotton production and 80 per cent of sorghum (Jowar) and pearl millet (bajra) production,90 per cent of oil seeds and pulses and 100 per cent of small millets (Special Report, The Hindu, 25th February, 1980). The larger coverage, coupled with the instability of yield in these areas, have often been the main reason for the extreme fluctuations of the overall agricultural production in the country. There is no gainsaying the fact that India's surplus or deficit in most of the foodgrains depends upon the fluctuations in the performance of agriculture in arid and semi-arid areas (Aurora, 1979).

Performance of agriculture

An attempt is made here to review the performance of agriculture in arid and semi-arid areas with a view to assess the different levels of growth of agriculture within these regions and then to identify the factors facilitating growth vis-a-vis those which contribute to stagnation. The section draws heavily on the district-wise study of the performance of Indian agriculture by Bhalla and Alagh (1979).

The present analysis is confined to those arid areas and arid districts where agriculture is highly vulnerable to drought. Districts with an annual average rainfall of 75 cm and with an irrigated area of more than 50 per cent of the sown area are excluded from the present analysis. Thus a total of 70 districts (21 arid and 49 semi-arid) are covered in the analysis. It covers a period of eleven years starting with the triennium of 1962-65 and extending up to 1970-73. The performance of agriculture in the districts is assessed in terms of the value of yield per hectare and the exponential annual gowth rate of output. On the basis of the annual average value of yield per hectare during 1970-73,districts are classified into three groups : (i) those with more than Rs. 1300, (ii) those with Rs. 700 to Rs. 1300, and (iii) districts with less than Rs. 700. On the basis of annual exponential growth rate of output, districts are classified into four groups viz., (i) those with growth rate of more than 4.5%, (ii) those with 2.5 to 4.5% (iii) those with 0 to 1.5% and (iv) districis with a growth rate of less than zero.

It is clear from Table V that the yield level in arid areas in general, as could be expected, is very low. There is not a single arid district where the value of per hectare yield is more than Rs. 1300. Of the 21 arid districts, the value of per hectare yield in 15 districts is less than Rs. 700, and it is Rs 700 to Rs. 1300 in the remaining 6 districts. Though the yield levels are markedly low in arid districts compared to other areas, the same cannot be said about the rate of growth of agriculture between 1962-65 and 1970-73. During this period nine of the twenty-one districts registered an average annual growth rate of more than 4.5% while in six districts the growth rate is between 1.5% to 4.5% and in the remaining six districts it is less than

Table V : Performance of arid agriculture (1962–65 to 1970–75)

Yield level per hectare	Growth rate >4.5%	1.5 to 4.5%	0 to 1.5%	< 0	Total[1]
More than Rs. 1300	Nil	Nil	Nil	Nil	
Rs. 700 to Rs. 1300	Bhatinda (P)	Hissar (H)	Kurnool (AP)	Anantapur (AP)	
	2	2	1	1	6
Less than Rs. 700	Ganganagar (R) Raichur (K) Barmer (R) Jodhpur (R) Pali (R) Jamnagar (G) Kutch (G)	Nagam (R) Jhunjhum (R) Sikar (R) Surendra-nagar (G)	Churu (R) Jalor (R)	Bikaner (R) Jaisalmer (R)	
	7	4	2	2	15
Total	9	6	3	3	21

1.5%. Three districts actually show negative growth rates during which period Green Revolution is supposed to have been ushured–in elsewhere in the country.

On the basis of yield level and growth rates, the arid districts may be broadly classified into two groups viz., the ' growing districts ' and the ' lagging districts '. Districts with a growth rate of more than 1.5% regardless of the level of yield, and districts with per hectare yield of Rs. 700 and more with positive growth rate are classified as ' growing districts ', while districts with per hectare yield value of less than Rs 700 with annual growth rate of less than 1.5% or those with yield levels of Rs. 700 to Rs. 1300 but with negative growth rate are treated as ' lagging districts '. Accordingly, there are five lagging districts among the arid areas which show perpetuation and accentuation of the problem of inequaity even within the backward arid zone. The ' lagging areas ' of arid zone may be identified as the core of the problem districts. These hard core areas cover five districts, namely, Anantapur in Andhra Pradesh, and Chury Jalor, Bekaner and Jaisalmer in Rajasthan. It is necessary to identify the factors that have contributed to the precarious agricultural situation in these areas and then to devise a strategy for the development of these regions.

A study of Table VI reveals the performance of agiculure in the 49 semi-arid districts during the period from 1962–65 to 1970–73. On the basis of productivity, the semi – arid areas include six districts with a per hectare yield value of more than Rs. 1300 All these high productivity districts are confined to the southern states. Chittoor in Andhra Pradesh, Mandya in Karnataka and Tiruchi, Madurai, Coimbatore and Tirunelveli in Tamil Nadu. It may be noted, however, that none of these high productivity districts experienced an annual growth rate of more than 4.8% during the period 1962–65 to 1970–73. There are another fifteen semi–arid districts with a level of productivity of Rs. 700 to Rs. 1300 per hectare. These medium productivity districts are spread across the country from Tamil Nadu to Haryana. Majority of the semi–arid districts, 28 out of 49, are low productivity districts with per hectare value

Table VI : Performance of semiarid agriculture (1962–65 to 1970–73)

Yield level per hectare	Growth rate: More than 4.5%	1.5 to 4.5%	0 to 1.5%	Bess than zero	Total
1	2	3	4	5	6
More than Rs. 1300	Nil	Chittoor (AP) Mandya (K) Tiruchira-palle (TN) Madurai (TN)	Coimbatore (TN) Tirunelveli (TN)	Nil	
	–	4	2	–	6
Rs. 700–Rs. 1309	Sangrur (H)	Junagadh (G) Mysore (K) Mahendra-garh (A)	Amroli (G) Rajkot (G) Bangalore (K) Hassan (K) Kolar (K) Dharma-puri (TN) Salem (TN) Ramanatha-puram (TN)	Cuddapah (AP) Baroach (G) Sahgli (M)	
	1	3	8	3	15
Less than Rs 700	Mehsana (G) Chitradurga (K) Tumkur (K)	Bhavanagar (G) Banaskatha (G) Ujjain (MP) Datia (MP) Shajapur (MP) Ajmer (R)	Nalgonda (AP) Ahmedabad (G) Dewa (MP) Dharwad (K)	Hyderabad (AP) Mahaboob-nagar (AP) Jabun (MP) Bhar (MP) Betul (MP) Sholapur (M) Dhulia (M) Nasik (M) Poona (M) Ahmadnagar (M) Aurangabad (M) Bir (M) Osmanabad (M) Gulbarga (K) Bijapur (K)	
	3	6	4	15	28
Total	4	13	14	15	49

of annual output of less than Rs. 700. These low productivity districts show extreme variations in their performance, ranging from an exponential annual growth rate or 6.91 of Chitradurga in Karnataka to -8.89 of Bhir in Maharashtra. With the exclusion of low productivity districts which have been consistently experiencing a growth rate of more than 1.5% and inclusion of medium productivity districts which have been registering a negative rate of growth, we will have 22 districts which come under 'lagging' group according to the classification described earlier. These 22 districts are confined to Andhra Pradesh (4), Karnataka (3), Madhya Pradesh (4), Maharashtra (9) and Gujarat (2). This implies that semi-arid agriculture as a major problem is faced by only these five states in India. An analysis of the causes for the perpetual low productivity in agriculture in these areas will be useful in devising an appropriate strategy for their development. Unfortunately, there is relatively little information about the progress and problems of agriculture in the agriculturally poorer parts of the country (Harris, 1980).

It may be pointed out that all the six semi-arid districts with productivity level exceeding Rs. 1300 per hectare and with reasonable growth rates are the districts with relatively better irrigation facilities and a higher degree of industrialisation. On the contrary, the 27 districts where the agricultural productivity as well as growth rates have been dismal are the districts where not only the irrigation facilities are poor but the degree of iudustrialisation has also been negligible. From this, it looks that industrial deveiopment reinforces agricultural development in the arid and semiarid areas.

A STRATEGY FOR THE DEVELOPMENT OF AGRICULTURE IN ARID AND SEMI-ARID AREAS

Augmenting Water Supplies

The crux of the problem of arid and semi-arid areas lies in the deficiency of water. The most important solution centres around the availability of water for human and livestock population and for agriculture. The core areas of aridity, where drought is chronic, are confined to a small area comprising West Rajasthan and Kutch in Gujarat. These areas are sand dune-ridden and the scope for irrigation here is remote. In these hard core areas, first priority may be given to the provision of drinking water and the next priority may be given to growing fodder or pastures for livestock farming. The rest of the arid and semi-arid areas where drought is neither chronic nor endemic, there is scope for improvement in agriculture through expansion of irrigation facilities along with appropriate techniques of cultivation.

(a) Protectiye Irrigation ;

The British conceived of 'Protective irrigation' as a solution to the problem of unstable agriculture in dry farming areas which were ravaged by droughts and famines. The British irrigation policy in India classified public irrigation works into the categories viz., (i) 'Productive works' which had to satisfy minimum net return criterion and (ii) 'Protective works' which were undertaken mainly for affording protection to crops against drought. Commercial profitability in the latter case was only a secondary consideration. Upto 1945-46 a total of Rs. 450 million was spent on protective works and such works during the same year irrigated 2. 2 million hectares out of 11.4 million hectares served by public irrigation works in British India (Irrigation Commission, 1972. Vol. I, pp. 61-65).

Protection of drought-prone areas through irrigation continued to be the important concern of the Government after independence and during this period irrigation expanded by 75 per cent in dry areas compared to 35 per cent in the rest of the country (Jodha, 1979, p. 489). Protective irrigation works have been in the form of large scale and medium irrigation projects and inter-basin diversion of water from surplus areas. " Owing to hydrological and related location or inflexibilities imposed by their design conditions oriented to ensure irrigation on a continuous basis, the scope for using protective irrigation as a major strategy for developing rainfed agriculture is extremely limited " (Jodha, 1979, p. 489).

(b) Conjunctive Use of Ground and Surface Water

The main sources of irrigation over the wide range of dry areas are tanks and wells. Of late, there appears to be a neglect of tanks and as a consequence many tanks are reported to be under disuse because they had not been properly maintained. Some of the tanks were Zamindari tanks and with the abolition of Zamindaries, some of them were not properly maintained (Irrigation Commission, 1972). Besides irrigation tanks, a number of percolation tanks have been in a state of abandonment. Such a negligence would break the balance between the surface and groundwater resources. " Although percolation tanks and check dams on streams do not provide direct irrigation, their contribution in firming-up and augmenting supplies in nearby wells and thus facilitating irrigation has now been established ". (Irrigation Commission, 1972). Therefore, it is necessary that in arid and semi-arid areas where the groundwater level is low and irrigation from wells is precarious, special attention should be given to the construction of percolation tanks, check dams and other bunds so as to enable proper harvesting of the scarce rain water and thereby improve the surface water as well as recharge of groundwater.

(c) Water-harvesting

Water-harvesting is yet another method through which the supplies of water can be improved in dry areas. The technology of water-harvesting consists of collecting and storing water from land so treated as to increase the run-off of rainfall. Run-off from catchments can be utilised to a greater extent building contour ditches to collect hillside flows. It can be increased by modifying vegetation, as also by treating the soil surface with impermeable shoots etc. Cultivation techniques like growing crops in strips, and leaving areas of suitable size and shape on both sides of these strips to facilitate the flow of rain water to them have also been tried and found effective. The new water-harvesting techniques offer good possibilities for augmenting water availability in rain-fed areas (Irrigation Commission, 1972, Vol. I, P. 174).

(d) Ground-Water Exploitation

Reliable information about the irrigation potential in different areas is lacking. Of the dry regions, only Rajasthan, Haryana and Gujarat have been covered by ground-water surveys but other states such as Madhya Pradesh, Maharashtra, Mysore, Andhra Pradesh and Tamil Nadu have been either not surveyed or partly surveyed. It is needless to emphasise that comprehensive assessment of the ground-water potential and its proper exploitation is of vital importance to the dry regions. The best results could be obtained by (i) delineating macro-aquifers by studying Landsat Imageries and airphotos, (ii) examining the nature of the aquifers in detail by electrical resistivity surveys, well logs and geological structures, and (iii) making detailed field investigations at micro-level by sample drilling or drilling wells.

(e) Artificial Rain-making :

Artificial rain-making through cloud-seeding may have to be tried during extreme dry spells when human, animal and plant life is threatened by drought. A pre-condition for artificial rain-making is the presence of clouds of suitable type and adequate depth lasting for some duration over the affected areas. Clouds of suitable type and size cannot be ordered to appear just because the area is suffering from drought. However, it is reported that in certain dry regions, it often happens that during dry spells in the rainy season there is much convective cloud cover, but little or no rain. Occasions like these may prove suitable for rain-making and be of considerable benefit particularly if the period happens to coincide with an important stage in plant growth. Such climatic features often occur in the dry regions of Gujarat and south Rajasthan during the South West Monsoon and parts of Tamil Nadu and Andhra Pradesh during North-East Monsoon (Irrigation Commission, 1972, Vol. I, P. 126). Measures should be initiated at least on experimental basis to mitigate drought in these areas through artificial rain-making. The costs may appear prohibitive at this stage but in view of social benefits it may be well worth trying.

Augmenting the supplies of water for irrigation by the various measures listed above form only a part of the strategy for expansion of area under irrigation The other and equally important part involves the most economic use of available water so as to maximise the area under irrigation. A strategy for better use of water resources for irrigation consists of two important steps : (i) adoption of cropping pattern which would provide maximum coverage of crop per unit of water, and (ii) introduction of improved methods of irrigation like sprinkler and drip irrigation and lining of canals to minimise the loss of water due to evaporation transpiration and seepage.

Optimisation of Cropping Pattern

Provision of irrigation to dry areas through large-scale works has often degenerated into intensive irrigation works for restricted areas. Irrigation works intended to irrigate dry crops or low- water requiring crops on larger areas tended to concentrate on high-water requiring crops on smaller areas (Jodha,1979,p.490). The agroclimatic conditions of arid and semi-arid areas show that coarse grains like pearl millet, sorghum and pulses and groundnuts are more suited to these regions. Productivity of these crops per unit of water is far higher compared to wet region crops like rice. But the most disturbing feature in dry areas is that along with the expansion of irrigation facilities there has been shift in the cropping pattern from ' dry crops ' to ' wet crops '. For instance, in the arid district of Anantapur in Andhra Pradeshs, the proportion of irrigated area to the total cropped area increased from less than 10 per cent to about 20 per cent in the quarter century following Independence but during the same period the proportion of rice in the total cropped area almost doubled from 5 per cent. to 10 per cent (D. N. Reddy, 1979, P. 403). This amounts to not only squandering of the scarce water resource in these areas but alse aggravation of the problem of inequalities by creating small pockets of prosperity within poverty ridden dry areas. " Given the actual and potential water shortage in these all too drought–prone areas, there is thus a need to think of the productivity of water as more critical than the productivity of the land, to express yield in kg per cubic metre of water rather than per hectare of land " (Chambers, 1977). Therefore, what is required is a large-scale rationalisation of cropping patterns with the ultimate objective of growing crops which is appropriate as far as the climate and soil are concerned. The objective should be to select such varieties which would make the most economic use of water. But as long as dry crops continue to have low value, irrigation of these crops likely to be a less attractive proposition to farmers and any amount of legislation in a soft state like India is bound to frustrate implementation of a rational irrigation policy. Increasing people's participation in the planning and execution of irrigation facilities is essential to overcome some of these problems.

Improved Methods of Irrigation

Adoption of improved methods of irrigation can go a long way in minimising the water use for a crop and maximising the area irrigated. The often recommended

Improved methods of irrigation include sprinkler and drip or trickler irrigation. These methods have been extensively used in the dry regions of Israel and the USSR with great benefits to their agriculture. The experience of these countries, though important, may not be relevant to India because in these counries financial resources are not a constraint and the extent of State involvement is quite considerable. In India there is very limited experimentation with drip (Trickler) irrigation and there appears to be considerable expertise in sprinkler irrigation. The Irrigation Commission (1972, vol.I,p. 119) has estimated that the initial investment for sprinkler irrigation is about Rs. 1750 per hectare. Investment requirements apart, the extent to which water is saved through sprinkler system depends on the climatic conditions. Under high temperature and strong winds the heavy evaporation losses from the sprinkler sprays substantially reduce the saving in water. However, over large areas where the wind velocity is low and temperature is not severe, the sprinkler system may be encouraged through proper incentives like crop subsidies. Cement lining of canals in dry areas is another method through which percolation and evaporation losses can be considerably reduced.Therefore, in all canals and channels wherever costs are not prohibitive, lining should be made part of the programme of construction right in the beginning.

Even if all the irrigation potential is fully developed, the maximum cropped area that can be irrigated will only be 25 per cent of the total cropped area in arid and semi-arid areas as against 50 per cent for the country as a whole. This does not, however, mean that potential for expanding irrlgation in arid and sami-arid areas is likely to be exhausted soon. Until recently, only 13 per cent of the cropped area in arid and semi-arid areas was covered by irrigation and thus there is still a long way to go before reaching the potential.

Conservation of water, vegetation and Land

A comprehensive and integrated water-soil-forest conservation policy is required to improve the soil condition, crop yield and ecosystem of the arid and semi-arid regions. Soil-moisture conservation through contour bunding has a long history in India. Though there has been no comprehensive study of the benefits of soil conservation so far, the available information shows that there has been improvement in yields in the bunded fields as compared to unbunded fields (Jodha, 1979, p. 593). The contour bunding programme however did not offer a uniformly viabie and widely acceptable technology for dry land agriculture. "This happened largely because of three basic deficiencies in the approach namely: (i) over-emphasis on the engineering component, (ii) lack of strong biological component, and (iii) complete neglect of utilisational components (Jodha, 1979, p. 494). Further, contour bundiag as a strategy for improving the resource base of dry land agriculture is not useful in the case of deep black soil where neither farmers nor technical considerations favour it. Even in shallow and medium soils and low rainfall areas where bunding is technically favourable, institutional factors inhibit its implementation. Majority of the holdings in the arid and semi-arid tracts are small, with less than one hectare. Even these tiny holdings consist of three or four fragmented parcels. Under such conditions implementation of contiguous contour bunding requires appropriate institutional arrangement.

Technology for Dry land Farming

(a) Evolution of farm technology adapted to the agroclimatic conditions of the arid aud semi-arid areas is looked upon as one of the promising strategies. Introduction of suitable high yielding varieties, introduction of crop combinations which are likely to perform best in the given climatic conditions, and adoption of appropriate mix of crop and livestock farming are the main components of dry land farming technology.

High Yielding Varieties

The evolution of high yielding varieties are so far confined to wheat and rice and to a limited extent to pearl millet and sorghum; pulses, oilseeds, minor millets and and forage crops which play a significant role in the economy of dry areas still remaln largely neglected. The consequence has been stagnation or decline in the yield of some of these crops, particularly pulses and groundnuts (Jodha, 1979, P. 496). In the case of HYVs of pearl millet and sorghum, severe pests have been reported making their adoption in dry areas highly risky. 'The net situation is that HYVs have not so far been able to offer a viable technology for vast portions of dry areas' (Jodha, 1979, P. 498).

With the exception of protective irrigation measures and some soil conservation measures, not much attention was paid to the problems of agriculture in dry areas. With the impressive performance of HYVs well-endowed areas and the alarm created in by accentuated regional inequalites following the success of "Green Revolution" in irrigated areas in 1960s, the government was compelled to pay more attention to the problems of dry land agriculture. As a result, in 1970 the All India Co-ordinated Research Project for Dry Land Agriculture (AICRPDA) was initiated with focus on: (i) the identification of crop combinations which can perform efficiently within the constraints imposed by the natural resource-base; and (ii) evolution of crop and resource management systems including water-harvesting practices which may enhance the effective utilisation of the productive potential of the natural resource-base. The AICRPDA with a network of 24 centres holds lot of promise in developing location-specific technology for dry areas.

In the face of high-investment and hence high risk of HYVs in rain-fed farming, it is increasingly realised that the important prerequisite for msking HYV technology a success in dry areas is to "inject as much variability and flexibility in the technology as warranted by spatial and temporal agro-climatic variability which conditions cropping patterns and practices throughout dry areas".

Evolving of new geno-types which assure crop yield inspite of fluctuating rains would be a major break-through in dryland agriculture. This requires that "the new varieties must be tailored in such a way that their duration matches with the duration of monsoon", and thus the risk is eliminated to a considerable extent. It has been reported that the scientific observations of crop withering during 1972-73, one of the worst years of drought, had shown that only 30 per cent of variation in the yield was attributable to rainfall and the rest is managable through proper choice of the appropriate maturing varieties, time of sowing, use of fertilisere etc. (N. G. P. Rao 1976). Thus selection of right variety of crop, right time of sowing etc. are likely to minimise the risk even in the face of rainfall variability,

(c) Inter-Cropping

Further, there has been considerable progress in the direction of development of inter-cropping techniques in rainfed areas. Inter-cropping involves growing different species of crops together in rainfed areas so that if there is failure of rain at least one of the component crops can yield something and thereby minimise the risk of total loss.

Introduction of appropriate inter-cropping systems and demarcation of appropriate crop belts in dry areas also held some hope for stabilisation of agriculture in dry areas.

There is also need to explore the possibility of development of orchards or dry land plantations. It is suggested that the plantation of **Accacia Senegal**, gum trees, which withstand scanty rainfall can contribute substantially to the improvement of the economy of dry areas. **Accacia senegal** is a plantation with good demand on international market and presently 90 per cent of the crop is grown in Sudan under uncerniat and erratic rainfall conditions which are similar to arid and semi-arid areas of India (S. K. Sinha, 1275, P. 105).

(d) **Mixed-Farming**

In view of the very high temporal and spatial variability of agro-climatic conditions within dry zones, it may not be possible to have uniform strategy of agricultural development for all these areas. There are certain dry regions where adoption of moisture conservation methods or improved combination of crops are not liekly to raise the productivity to a level comparable to other advantageous wet regions. There is every need in these areas io give less emphasis to crop farming and encouragement to livestock farming which together are referred to as ' mixed farming '. These dry areas have a definite comparative advantage because of the availability of suitable grasses and land for pasture development, availability of excellent breeds of sheep and cattle well adopted to arid conditions, possibility of sustained increase in the productivity of grazing land through conservation and greater scope for economising the most scarce water (Jodha 1980). Mixed cropping may be extended even to semi-arid areas through less emphasis on open grazing and more importance to stable dairying and cultivation of grasses for indoor-feed.

The arid and semi-arid regions constute a distinct ecosystem. Here, the physical environment is so different from that of others that it produces a distinct human and biotic response. A study of the interaction between the ecosystem and its components as well as among the components themselves is necessary to gain insight into the problems and to evolve a strategy to solve them. Such a study could be attempted by employing ' systems approach ' or ' systems analysis '. The advantages of this technique springs up from the fact that it is amenable to computer analysis. Further, it helps to identify the significant variables or components which play an important role in the ecosystem, so that by manipulating the same it would be possible to optimise the functioning of it.

Taxonomy and Typology :

In view of the very high temporal and spatial variability of agroclimatic terrain and soil conditions within the arid and semi-arid areas, it is very difficult to generate a single package of practices which are relevant to the development of the entrie region. There is every need to classify these areas into different meso and micro units with a view to evolving location-specific solutions.

Monitoring of ecological changes by landsat :

The present information on different aspects of agoclimatic conditions of the entire dry zone is scanty. In this connection, recent advanees in the technology of remote sensing are likely to open new vistas. The study of LANDSAT imageries which are taken continuously at a nine-day interval will help a great deal in monitoring degradation of vegetation and plant species, degradation of land due to soil erosion, changes in agricultural pattern and other ecological changes that occur especially during dry or/and drought periods. Analysis of the information made available by the LANDSAT is likely to be of invaluable help to understand the ecological processes and changes that take place rather imperceptibly in the dry regions and thereby help to find location specific preventive and prophylactic solutions (Chakraborthy and Roy, 1979.)

Social and Institutional Changes :

The hope for the arid and semi-arid agriculture lies in the fact that there is scope for substantial improvement in the productivity of the resource-base. Resource management which more effectively conserves and utilises the rainfall and the fertility of the soil and new crop production systems which maintain productivity and assure dependable harvests are technologically possible. What is technologically possible must be made socially feasible and acceptable. But comprehensive and refined devices for land and water management and utilisation to elevate and stabilise farm production in dry areas are subject to a number of institutional constraints. For techniques like ridges and furrows, guided terraces, grassed water ways, farm ponds etc. for water-harvesting and supplementary irrigation, which constitute a new resource management approach, consideration of the 'watershed' or 'catchment' as an indivisible unit for resource management is an essential prerequisite. The new land and water management technologies cannot be effectively adopted on a part of the watershed or by only a portion of the landowners whose land parcels constitute part of the watershed However, in India with small and fragmented land holdings, the watershed is seldom treated as one management unit. Farmers use their lands and adopt practices according to their own discretion. Thus, there arises an incompatibility between the evolving technological possibilities, as a solution to the problems cf dry land agriculture and the existing institution of atomistic land holding pattern. The solution to overcome this tangle is shown in the form of 'group organisation and action'. Men of wisdom have expressed skepticism (Jodha 1979, p. 505) on the possibility of 'group action' offering a lasting solution to the problem of comprehensive watershed management. It is clear that problems of dry land agriculture, after all, are not the ones which can be overcome by mere technological solutions but require lasting institutional changes too.

ANNEXURE - I
Some of The Characteristics of Arid Areas

State	District	Percentage of arid area of the district	Mean Annual rainfall (cm)	Mean aridity Index (%)	Irrigated area in the district (%)
Rajasthan	Ganganagar	100	25.4	82	29.0
	Bikaner	100	26.4	81	–
	Jaiselmer	100	16.4	89	0.1
	Barmer	100	27.7	82	0.8
	Churu	100	32.5	78	–
	Nagaur	96	38.9	73	2.2
	Jodhpur	100	31.9	78	2.9
	Jhunjhum	69	44.5	72	2.1
	Siker	65	46.6	67	5.1
	Pali	48	49.0	66	27.6
	Jalor	88	42.2	70	8.1
Gujarat	Kutch	100	32.2	79	11.7
	Jamnagar	80	50.0	69	4.1
	Surendranagar	29	50.7	66	2.0
Punjab	Bhatinda	88	38.7	73	49.6
	Ferozopur	77	36.9	74	63.3
Haryana	Hissar	90	37.5	74	29.5
A. Pradesh	Anantapur	67	54.4	66	11.3
	Kurnool	31	62.2	64	6.7
Karnataka	Raichur	26	60.1	65	1,2
	Bellary	26	57.5	64	3.6

Source: Mukhtar Singh & Krishnan, A. 1968.

ANNEXURE – II
Performance of Agriculture in Arid Areas - 1962-65 to 1670-75

State/ District	Mean Aridity Index	Yield level[1]	Exponential Annual[2] Growth Rate
Andhra Pradesh			
1. Anatapur	66	B	-1.52
2 Kurnool	64	B	0.74
Gujarat			
1. Kutch	79	C	4.62
2. Jamnagar	69	C	5.28
3. Surendranagar		C	1.54
Haryana			
1. Hissar	74	B	4.16
Punjab			
1. Bhatinda	75	B	6.87
2. Ferozepur	74	B	7.14
Karnataka			
1. Bellary	64	B	2.40
2. Raichur	65	C	6.64
Rajasthan			
1 Ganganagar	82	C	8.54
2 Bikaner	81	C	-1.94
3. Jaisalmer	89	C	-9.89
4. Barmer	82	C	7.20
5. Churu	78	C	1.06
6. Nagaur	73	C	2.67
7. Jodhpur	78	C	10.76
8. Jhunjhun	68	C	2.91
9. Sikar	67	C	2.72
10. Pali	66	C	6.76
11. Jalor	70	C	1.17

Note : 1. Yield level refers to the value of annual average yield per hectare during 1970-73.

A = More than Rs. 1300
B = Rs. 700 to Rs 1300
C = Less than Rs. 700

2. For Period 1962-65 to 1970-73.

Source : Bhalla and Alagh (1979)

ANNEXURE - III

Performance of Agriculture in Semi-Arid Areas 1962-65 to 1970-73

State / District	Yield level[1]	Exponential Annual[2] Growth Rate
Andhra Pradesh		
1. Chittoor	A	2.82
2. Hyderabad	C	-3.72
3. Mahaboobnagar	C	-1.82
4. Nalgonda	C	1.22
5. Cuddapah	B	-1.26
Gujarat		
1. Baroach	B	-0.60
2. Bhawanagar	C	1.61
3. Amreli	B	0.35
4. Banaskantha	C	4.45
5. Mehsana	C	4.76
6. Ahmedabad	C	0.85
7. Rajkot	B	1.04
8. Junagadh	B	3.11
Madhya Pradesh		
1. Jhabua	C	-5.96
2. Dhar	C	-0.61
3. Dewas	C	0.81
4. Ujjain	C	2.95
4. Datia	C	2.35
6. Shajapur	C	2.29
7. Betul	C	-0.28
Maharashtra		
1. Sholapur	C	-8.48
2. Dhulia	C	-5.02
3. Nasik	C	-2.75
4. Poona	C	-5.04
5. Ahmadnasar	C	-5.29
6. Sangli	B	-5.21
7. Aurangabad	C	-8.89
8. Bhir	C	-8.89
9. Osmanabad	C	-7.41
Karnataka		
1. Chitradurga	C	6.91
2. Dharwar	C	0 49
3. Bangalore	B	1.16
4. Hassan	B	0.59
5. Gulbatga	C	0.26
6. Kolar	B	1.14

Anuexure III contd....

state / District	Yield level[1]	Exponential Annual[2] Growth Rate
7. Tumkur	C	4.53
8. Mysore	B	4.00
9. Manday	A	1.92
10. Bijapur	C	-1.65
Haryana		
1. Sangrur	B	7.38
2. Mahendragarh	B	4.16
Tamil Nadu		
1. Dharmapuri	B	1.08
2. Salem	B	1.08
3. Coimbatore	A	0 33
4. Tirichirapalli	A	1 91
5. Madurai	A	1.97
6. Ramanathapuram	B	0.88
7. Tirunelveli	A	1.38
Rajasthan		
1. Ajmer	C	2.63

Note ; 1. Yield level refers to annual average value of yield per hectare during 1970-73.
A = More than Rs 1300
B = Rs 700 to Rs 1300
C = Less than R s 700

2. For the period 1962-65 to 1970-73.

Source : Bhalla and Alagh (1979).

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