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Environmental Economics of Desert Agriculture in Relation to Natural Resources Management in Rajasthan

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ENVIRONMENTAL ECONOMICS OF DESERT AGRICULTURE IN RELATION TO NATURAL RESOURCE MANAGEMENT IN RAJASTHAN

(A Study Under The World Bank Aided India : Environmental Management Capacity Building Technical Assistance Project)

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Udaipur **K.A. VARGHESE**

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EXECUTIVE SUMMARY

1. INTRODUCTION

The World Bank aided "India: Environmental Management Capacity Building" technical assistance project is an attempt to initiate research on various aspects related to environmental economics, in a developing country like India. The present study on environmental economics of desert agriculture is an attempt to locate the emerging environmental issues of this eco-fragile area in the state of Rajasthan.

In the perspective of economic growth and sustainable development it is required that the natural resources and the environment remain intact and its use is limited to the extent of its capability to regenerate naturally. Natural resources including natural environment perform the important functions in the process of economic growth. Firstly it provides inputs to production process and secondly it assimilate the waste generated in the process of production. Since earth is finite, closed and non-growing, there is a natural limit to both of these critical functions. In other words, the capacity of earth to provide inputs and to assimilate waste is limited. It implies that it is not possible to go on increasing production of goods and services using natural resources for ever. There are ecological and natural limits to economic growth and hence it cannot be sustained for ever. It is also being argued that the capacity of the resource system is amenable to augmentation through technological and managerial interventions. The proponents of sustainable development recognize this truth and advocate the middle path for development. In this context, the issues like land degradation, depletion of groundwater resources, deforestation, loss of biodiversity, climatic change, ozone layer or depletion etc are all important aspects associated to natural resources. Therefore, the sustainable agriculture that provides food security for the people without compromising ecological security is of paramount importance. For resource constrained areas like desert the magnitude of such challenges will be very high.

Economics aims to study the allocation of scarce resources among competing uses. The productive pattern of natural resources and the economic incentives that lead to the people for the best use of such resources are relevant considerations. The natural resource management addresses the use of these resources for economically

productive, socially equitable and environmentally sustainable purposes. The productivity, equity and sustainability of natural resources assume great relevance. Productivity is the criteria used to measure the efficiency of a resource. While economic efficiency is a value concept between output and input and the technical efficiency is a physical concept between input and output. Thus, economic efficiency is a follow up of technical efficiency. However, all technically efficient allocation of resources need not be economically efficient. Equity is a concept centered around distributional justice. For economists, equity implies `Pareto efficiency'. In the context of natural resources there can be conflict between efficient and equitable use of natural resources. Sustainability is an inter generational equity concept. It means that the present generation should not use the natural resources at the cost of future generation. Sustainability also means preservation of bio-diversity in the biological sense. Economic sustainability is used to mean the protection of natural resources from mindless over exploitation.

The perception of sustainability by the economists include the long term stability of economic parameters like income, consumption, production etc. On the other hand ecological sustainability relates to long term preservation of biosphere. Here comes the issue of preserving the biosphere and sustaining the human population within the available limits of natural resources. Thus, economic sustainability implies the preservation of natural capital which include natural resources and environment alongwith the production capital. On the other hand ecological sustainability is linked to the carrying capacity limits of natural system.

The environmental economics is concerned with the impact of the economy on the environment and the significance of the environment to the economy and suggest ways and means to regulate economic activity so that the required balance is achieved among environmental, economic and other social goals. Therefore, the desert area in general and desert based agricultural system in particular assume importance for indepth probing for assessing the sustainability of the system. As the concern for the environment is getting more and more importance, it is natural for the agricultural economists to focus their attention on aspects like desert agriculture where human and livestock pressure is on a steady increase where the fragile natural resources form the basis for their survival. If the natural resources are exploited beyond the replenishable

level in a desert based livelihood system, the perspective process of economic growth and sustainable development gets jeopardized. The further degradation of already degraded land resources may turn out to be a great threat to both human and livestock population. The ecological security in the desert belt is equally important to the sustainability of the agricultural system, which aims for the food security of the people and fodder requirement of the animals.

Therefore, the linkage between natural resource base and the economic activities which are centered around agriculture in the desert belt of Rajasthan including the externalities is a topic of vital importance. For a fragile eco-system like desertic condition, preserving the bio-diversity and also improving the natural resource base for sustaining the human population are significantly relevant.

2. OBJECTIVES

The specific objectives of the present study are as follows :

(i) to asses the pattern of temporal trend in different land use classes in the districts covered under the region.

(ii) to examine the extent of growing pressure of human and livestock population on the eco-fragile land base,

(iii) to study the nature and extent of changes taking place in the cropping pattern,

(iv) to measure the yield instability in various crop enterprises in the region,

(v) to examine the economics of desert agricultural practices/agricultural system in the context of environmental sustainability,

(vi) to work out the nature and extent of risk in various agricultural enterprises,

(vii) to identify the risk minimization strategies being adopted by the farmers,

(viii) to assess the divergence between private and social incentives and also the externalities of risk minimizing strategies of farmers on environmental settings,

(ix)* to trace the changes in property rights and status of land ownership due to government policies and development interventions*,

(x) to document community based economic institutions and resource conservation practices in desert agriculture.

* Later on dropped due to lack of data support.

3. STUDY AREA/METHODOLOGY

The study area is the Western Dry Region of India, one of the 15 agro-climatic regions delineated by the Planning Commission of India, for the purpose of decentralization of agricultural development planning in 1988. It consists of nine districts of western Rajasthan covered under the desert belt. These districts are Barmer, Bikaner, Churu, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Nagaur and Sikar. This region accounts for 51.2 per cent of the total geographical area of the state, 30.5 per cent of state's human population and 42.6 per cent of states' livestock population. The desertic condition prevalent in these districts made it necessary to delineate it as a separate zone to devise strategies and to implement programmes for developmental purposes on a bottom-up approach in view of the peculiar agro-climatic features of this zone.

The magnitude and direction of changes in the land use classes were assessed by working out the compound growth rates. The yield instability measures of crops were worked out using the coefficient of variation in yield after eliminating the trend effect. The risk in crop production was worked in terms of probability by using time series data of yield and comparing it with the break even yield level. Alternatively, the yield risk was worked out using cross sectional data also, by comparing the cost and return. The Economics of crop production and livestock rearing in the desert belt was worked out using farm management approach. The other issues causing concern to the environment due to agricultural activities were identified. Based on ten indicators

representing components of land, people, livestock and agricultural infrastructure, the composite indices of sustainable development for each of the districts were worked out. The findings of primary and secondary data analysis were put together to assess the sustainability of agricultural activities in the area of study.

4. DATA AND DATA ANALYSIS

The available secondary data on various aspects under study and also the primary data collected though structured questionnaire formed the data base for the study. The districtwise secondary data over the years for all the nine districts covered in the study area were collected. The primary data relates to 300 sample form households selected from the study area for the agricultural year 1999-2000.

The following districtwise data were collected for the period 1951-52 to 1997-98:

- Land use according to land use classes,
- Crop area, production and yield,
- Irrigated area (source wise)
- Fertilizer use
- Farm Energy Sources (Machines, draught animals)
- Infrastructure (Marketing, credits, input delivery)
- Social development (Schools, hospitals, colleges etc.)
- Communication facilities etc.
- Demographic data
- Livestock data.

The required secondary data were available from the following sources :

(i) Vital Agricultural Statistics (Published annually by the Dir. of Agriculture,

Govt. of Rajasthan, Jaipur).

(ii) Statistical Abstract of Rajasthan (Published Annually by the Directorate of Economics & Statistics, Govt. of Rajasthan).

(iii) Revenue Records available at District H.Q., State Revenue Board.

(iv) Agricultural Census of Rajasthan (Published periodically by the Agricultural Census (Revenue Deptt.), Govt. of Rajasthan

(v) Other official/non-official records.

The primary farm level data were collected through appropriate sample survey techniques by engaging qualified Field Investigators.

The farm household level data on the following aspects for 300 sample farmers for one agriculture year 1999-2001 were collected.

- Operational holding and tenancy system.
- Farm asset structure (physical & value) (land, buildings, wells/ tube wells, irrigation structure, farm animals, machines, implements etc.)
- Farm activitywise (crop, livestock, others) inputs (physical and labour) and also output (main & by-products).

The linear and exponential growth models of the following type were used to ascertain the pattern of trend in the time series data on area, production, yield of crops, land use pattern etc.

(i) $Y_t = a + bt$ - linear trend equation

(ii) $Y_i = Y_o b^t$ - exponential trend equation.

Besides the growth model of the following type were used to work out the compound growth rates in area, production and yield of rainfed crops.

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Where,

Y_t = Yield/area/production of the crop at t^{th} year.

a = Constant term in the equation.

r = Compound growth rate per annum.

The following indices of yield instability were worked out

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Where,

SD(Yc) = Standard deviation of yield of the crop-c for the specified period.

AM(Yc) = Arithmetic mean of yield of the crop-c for the specified period.

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Where,

$SD(Yc)^*$ = Standard deviation of detrended yield of the crop for the specified period.

$AM(Yc)^*$ = Arithmetic mean of detrended yield of the crop for the specified period.

3. Yield instability index 3 (I_3) = $CV^2(1-R^2)$

Where,

CV = Coefficient of variation of yield of the crop

R^2 = Coefficient of determination of the trend equation for the original time series data on yield.

The yield risk was assessed using the time series yield data as well as cross-sectional yield data. In both the cases the break-even yield concept was used.

The time series yield data of crop(s) were grouped into two.

(a) Number of years for which yield (Yt) was greater than breakeven yield (Yb). Let it be Ns.

(b) Number of years for which yield (Yt) was less than break even yield (Yb). Let it be Nf.

Ns + Nf + N

Probability of success (P) = Ns/N and

Probability of failure (q) = Nf/N where p+q = 1

The concepts and definitions as used in farm management surveys were used to assess economics of crop and livestock farming.

The composite index to assess sustainability of agricultural development was worked out. The set of n points may represent districts 1.2.... n for a group of k indicators 1. 2.... k. This can be represented by a matrix (X_{ij}) : i = 1.2.... n and j = 1.2... k. As the indicators of sustainable development included in the analysis are in different units of measurement and since the object was to arrive at a single composite index relating to the dimension in question, these indicators were standardized using the transformation formula :

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(Z_{ij}) denotes the matrix of standardized indicators. The best district for each indicator (with maximum/minimum standardized value depending upon the direction of the indicator) was identified and from this the deviations of the value for each district are taken for all indicators in the following manner :

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where Z_{oj} is the standardized value of the jth indicator of the best district and C_i denotes the pattern of sustainable development of ith district.

The pattern of development so arrived was useful in identifying the district which serve as `models' and it also helps in fixing the potential target of each indicator for a given district. The above composite indices helped to rank the districts in sequence in the context of sustainable development.

5. RESULTS

Barring Jhunjhunu and Sikar districts, the forest cover is remarkably low in the districts covered under this region. In districts like Barmer, Churu, Jaisalmer, Jodhpur and Nagaur, not even one per cent of the geographical area fall under forest. The share of area earmarked for non-agricultural use is less than that at the state level in all the districts covered under this region except Bikaner. The share of area falling under pasture and grazing land varies between 1.72 per cent of geographical area in Bikaner to 7.22 per cent of geographical area in Barmer. In the districts like Bikaner, Churu, Jaisalmer, Jalore and Nagaur the share of pasture land to geographical area is less than the state's share in this category of land. In fact a large chunk of area in Jaisalmer, Bikaner and Barmer is earmarked as culturable waste land. Water is the most limiting resource to bring these land under cultivation. The share of fallow land, current fallow and other fallow, is remarkably high in the districts of Barmer, Bikaner, Churu, Jalore, Jodhpur, Nagaur and Sikar. As far as the share of net sown area to geographical area is concerned, it varied from 8.75 per cent in Jaisalmer to 81.54 per cent in Churu. The large coverage of sown area in the desert belt in the districts like Churu (81.54%), Jhunjhunu (73.84%), Nagaur (70.57%) and Sikar (68.58%) is a matter of great concern.

The decadal growth rates of population in these districts have been very high during the decades ending 1981 as well as 1991. Except for Jalore in all other districts the decadal growth rates of population for the period ending 1991 were much higher to the state average growth rate of population. The female literacy in 1991 was as low as 6.12 per cent in Barmer.The low literacy level of the population in general and females in particular is indicative of limited scope to shift workforce from primary agriculture based

activities to other sectors. The work-force pattern revealed that the relative share of agricultural labourers to total workers increased in 1991 as compared to 1981 in all the 9 districts covered in this region. The increase in the marginal workers with sub-optional work days in a year (less than 183 days in a year) is also quite alarming in all the 9 districts.The relative share of cultivators to total workers was found less in 1991 over 1981 in districts such as Churu, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Nagaur and Sikar.

The large growth rate in the human population in almost all the districts covered under this region is yet another factor causing imbalance in the eco-system. The ever increasing need for generating income and employment opportunities is largely dependent on land based activities as the literacy rate of the rural population is remarkably low in this region. The increased burden on land arising from agriculture based activities is likely to adversely affect the efforts to arrest desertification in the belt. The large dependence of workforce on agriculture is likely to pose environmental problems in the eco-fragile area as a result of degradation of natural resources.

The animal population has gone up by more than double during the last 40 years in the districts like Barmer, Bikaner, Churu, Jaisalmer and Jodhpur. In fact, these districts are more arid with very high risk in crop farming. In the districts like Jalore, Jhunjhunu, Nagaur and Sikar crop based agriculture is equally dominant. In these districts also the livestock population has increased over the years. The current livestock density is more than human density in all the districts except Jhunjhunu and Sikar. The large number of human population in the eco-fragile region is a cause for problems related to food security and livestock population which is more than human population poses problems related to fodder security. Without improving the carrying capacity of land, the indiscriminate growth in the population of animals, particularly the exorbitant growth of large animals like cattle and buffalo and small ruminants like sheep and goat may lead to deterioration of the eco-system. The large risk in crop production prompts the farmers to resort on livestock based activities. The high growth and shifting composition of livestock population indicate the absence of herd planning in relation to carrying capacity of land.

The growth of oil engine, electric motor and tractors in the desert belt is really alarming.

The increase in oil engine in this region is about 33 times over the period 1966 to 1977. Similarly the increase in electric motor is about 240 times during this period. The number of tractors has gone us by 86 times. The over-exploitation of ground water resources is quite evident. The ground water exploitation is required to be restricted to the replinishable level by enforcing stringent laws in this belt. Similarly, there is a great need to restrict the indiscriminate use of tractors and other farm machines to minimize the problems due to shifting sand dunes in this area. In the absence of any policy restriction on groundwater exploitation, farmers resorted to digging of wells and mechanizing it with the credit availability through institutional and non-institutional sources. The adverse implication of such activities included drying of wells at a faster rate and the large investment made on wells, oil engine and electric motors become on a no return point.

The average gross cropped area has increased in all the nine districts over the years. The area under cereal crops in absolute terms has increased in all the nine districts. However, the relative share of area under cereal crops in relation to gross cropped area has come down in the districts of Barmer, Bikaner, Jaisalmer, Jalore and Nagaur. The area under pulse crops also increased in all districts except Jhunjhunu, Nagaur and Sikar. As far as area under oilseeds are concerned, large increase was observed in Bikaner, Churu, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Nagaur and Sikar. The area under guar which has fodder, food and commercial value was found to decline in Jhunjhunu, Jodhpur, Nagaur and Sikar.

The instability indices of yield of guar, moong and moth were quite high in Barmer district. In Bikaner, the instability indices of sesamum, bajra and guar have been very high. The instability measures of yield of crops in Jaisalmer district indicated that the inter-year yield fluctuations for bajra, moth, moong and guar has been very high. The inter-year yield fluctuations have been high for moth, moong and guar in Jhunjhunu district. The yield instability has been relatively high for moth, moong and sesamum in Jodhpur district. In Sikar district, guar and moong were found to have very high yield instability measures. Thus the yield of all the crops in all the districts is prone to high inter-year instability and the cropping pattern has undergone changes over the years. The crop production strategy seems to be guided by the traditional sequence determined by food and fodder requirement on the farm households. There is a great

need to devise appropriate crop mix strategy in this area, keeping in view the extent of risk in the production of various crops. There exists a wide gap between production and requirement of major commodities like cereals, pulses oilseeds in most of the districts in drought years. Even in normal years in this area, the production level of these commodities was short of actual requirement.

For bajra the probability of success at Cost A varied from 0.43 in Jaisalmer to 1.00 in Jhunjhunu, for guar it varied from 0.19 in Jaisalmer to 0.86 in Jodhpur. For moong and moth the ratio was relatively more in all the districts. However, for sesamum it varied from 0.44 in Bikaner to 0.89 in Jaisalmer. At the level of total cost which includes the paid or incurred cost as well as imputed cost, the situation was found quite different. For bajra only Jhunjhunu and Sikar districts were found to have higher chances of success. For guar crop, all the districts have either very low or zero chance of success at total cost. For moong the chance of success was higher over the chance of failure in Churu, Jaisalmer, Jalore, Jodhpur and Nagaur districts. As far as moth and sesamum crops are concerned, for all the nine districts, the chances of failure of these crops was higher over the chances of success at total cost. Thus, crop production in these districts is prone to very high risk which has lot of environmental and economic implications.

All the major crops which are grown by more number of farmers and taken up in more area are found to be loosing enterprises in the unirrigated desertic condition. The high risk in crop farming under the desertic situation is evident from the cost return analysis of major crop enterprises taken up in this region. It was found that 69 per cent of bajra growers, 74 per cent of guar growers 46 per cent of moth growers and 84 per cent of mixed crop growers could not realize the actual cost incurred for these crops during 1999-2000 crop year. The high risk in crop farming under unirrigated desertic situation is quite evident. The extent of risk is found to be more for mixed crops.

The intensive use of tractor for repeated deep ploughing is a threat for the process of sand stabilization in the desert belt. Remarkably, in the acute desert area the share of animal power is relatively more. However, it is on a decline over the years.

The grazing on land and browsing on trees by the animals for fodder requirement are common practice in this belt. The small ruminants like sheep and goat and large animals like cow and camel are taken in flock for grazing purposes. The plant spices

struggling for survival under drought condition, when disturbed by animals during the course of grazing, are further weakened and losses its potential to survive under moisture stress condition. The small ruminants, particularly sheep and goat which graze very close to the land, leads to the destruction of large number of plants. Thus, the process of sand stabilization being attempted through the natural growth of grasses and bushes in this belt is adversely affected by the privately owned animals. The animal husbandry practices in the desert belt pose adverse impact on the process of sand stabilization.

The extensive growth of vilayati babul (*Prosopis juliflora*) helps in developing vegetative cover and blocks fast movement of sand from field to roads etc. The adverse implication of this plant species is that it does not allow other plants to grow under it or even in its neighborhood. A large section of sample respondents realized that animal grazing, tracterisation, present cropping pattern, present animal husbandry practices and present land use pattern lead to desertification. The unreplinishable groundwater exploitation and indiscriminate tracterisation are the externalities emerging out of agricultural practices in the desert region.

Despite desertic condition in the area, the number of wells in all the districts in the region is increasing and so also the wells going out of use. In the year 1991-92, there were 1.88 lakh wells in this region out of which 1.39 lakh wells were in use and 0.49 lakh wells were out of use. In the year 1997-98 the total number of wells has increased to 2.31, lakh out of which 1.77 lakh wells were in use and 0.54 lakh wells were out of use. On one side the number of wells in this water scarce region is increasing tremendously and on the other side the number of wells going out of use is also increasing.

The mechanization of agriculture for various farm operations, for lifting of water from wells and also for transportation purposes is a follow up of green revolution in the country. The government credit policies in agriculture sector also prompted the farmers to go for purchase of tractor and other farm machines and implements on a large scale. There were only 955 tractors in this belt in 1966. Its number has gone upto 82409 in the year 1997. The rate of growth in the number of tractors during the period of last 30 years in the western dry region is much higher to that at state level.

The community based resource conservation practices include growing of Khejri (*Prosopis cinerasia*) trees which are multipurpose ecofriendly type and the indigenous water storage system including wells, baories, jhalaras for ground water and tanks, talab, tankas, khadins etc. for harnessing surface runoff.

The sustainability indices worked out for each of the districts covered under the western dry region using selected indicators on land resource, human population, livestock population and agricultural infrastructure revealed lack of sustainability in the processes of developmental efforts in this area. More specifically the indicators used for ascertaing sustainability included share of forest area, the size of net sown area per person, land-man ratio, decadal growth rate of population, literacy rate, share of workforce on primary sector, density of livestock, animal growth rate, extent of tracterisation, share of grazing land and extent of groundwater exploitation. On the basis of joint effect of all these factors the districts in the order of sustainability level are Bikaner, Barmer, Churu, Sikar, Nagaur, Jhunjhunu, Jodhpur, Jalore and Jaisalmer. On the basis of eleven indicators representing land resources, human and livestock population and created infrastructure for agricultural development the process of development in the districts of Barmer, Bikaner and Churu emerged as relatively more sustainable. In these districts the literacy rates are high, livestock density is less, livestock growth is less, net sown area per person is high, number of tractors and wells per unit of area is less. On the contrary, the development processes in districts like Jalore, Jaisalmer and Jodhpur are least sustainable. In these districts the population growth is high, literacy rate is low, livestock density and growth are high, share of forest area is the least, share of grazing land is low, number of tractors and wells per unit area is high. In short, in the western dry region where there is either accute desertic situation or where agricultural activities are intensively taken up, there exists lack of sustainability. On the other hand, in those districts where agricultural activities are relatively less intensive, the process of development is more sustainable. In any case traditional agriculture activities are going to continue in these districts until alternative livelihood means are generated. In such a situation two options emerge. Firstly, initiate and promote development programmes particularly social development activities like education so that part of workforce is shifted from agriculture to non-agriculture based activities. Secondly, a paradigm shift is needed in the approach for development. The development approach may be shifted

from "**component based**" to "**system based**".

The economy - environment interactions in the desert belt poses two types of problems. Firstly the economic activities adds to the severity of basic fragile nature of the eco-system. Secondly, the developmental efforts to improve the adverse situations are not allowed to bear results. Therefore, the question of sustainability of desert agriculture is of paramount relevance.

6. POLICY RECOMMENDATIONS

The policy recommendations emerged out of the study are summarized below:

(1) Effective land use planning keeping in view the strength and weakness of the land resources is advocated so as to keep proper balance between the area put under various land uses to avoid distortions and imbalances.

(2) Herd planning at household level is warranted in the desert belt to block the ever increasing growth of livestock population which in turn increases the demand for fodder and asserts pressure on land for fodder oriented crop production.

(3) Stress on social development programme including that on higher education to divert workforce from land based activities to other sector and also to check the exorbitant growth rate of population are very much required in this area.

(4) Stress on agricultural technologies to reduce the yield instability rather than that of yield increasing technology is the need of the area, as crop production is taken up under very high risk. Risk minimizing management strategies form the crucial aspect of agricultural production in this belt.

(5) The farm credit strategies will have to be given a new orientation keeping in view the exorbitant growth of tractors which may adversely effect the vegetative growth and sand stabilization process in this eco-fragile area. The large increase in the number of wells and tube-wells and also in the number of wells going out of use also stress the need to review the agricultural credit policy for this area.

(6) The growth of livestock population including draught animals on one side and the large stress on farm mechanization caused for diseconomics at the household level. Corrective measures are needed for the farm energy supply in this region.

(7) The large economic losses leading to high risk in crop and livestock based activities supports the need to evolve farm activities by integrating the capability of land resources and also the erratic nature of climatic factors, particularly the quantum and distribution of rainfall.

(8) The pressure of livestock and human population on land is to be kept in accordance to the land productivity to avoid indiscriminate use of land and natural resources.

(9) A shift in the development paradigm by devising strategies so as to have proper interface of agricultural activities with capabilities of resource base, particularly natural resources is very much warranted.

(10) The community based resource conservation practices like growing of multipurpose, ecofriendly tree species like `Khejri' and indigenous water storage system including wells, baories, jhalaras for ground water and tanks, talab, tankas, khadins etc. for harnessing surface runoff are to be promoted.

(11) The development strategies should follow a system approach rather than a `component approach' so that the ill-effects of one component on the development of other component is minimized.

1. INTRODUCTION AND BACKGROUND

This study is an attempt to assess the sustainability of economic activities of desert agriculture in the state of Rajasthan. While sustainability of desert agricultural is an implied aspect being addressed through this study, the key words apparently appearing in the title of the study are environmental economics, desert agriculture and natural resource management. Therefore, the understanding of concept and issues related to environmental economics, desert agriculture, natural resource management and sustainability/sustainable development is a prerequisite to carry out the proposed study. In the first part of this report, it is attempted to spell out these concepts, on the basis of review of literature carried out by the author, followed by the background of study area.

1.1 ENVIRONMENTAL ECONOMICS

The setting up of `Resource for the Future' - an environmental and resource economic research organisation in USA in the early 1950s by the Ford Foundation to address problems of material shortages may be considered as take off point of the field of environmental economics. The important contributions of this organisation in late 1950s and 1960s in the field made it possible for the booming of the field in the 1970s. With the emergence of environmental policies in the 1990s, the pay off has begun for the field of environmental economics. Environmental economics is concerned with the the impact of the economy on the environment, the significance of the environment to the economy, and the appropriate way of regulating economic activity so that balance is achieved among environmental, economic and other social goals (Charles D. Kolstad, 2000). Similar to other applied fields of economics like labour economics, monetary economics, development economics, industrial economics, agricultural economics etc., the environmental economic has also emerged as a major field of study. For the development of such applied areas of study in economics the basic theories of microeconomics were widely used. At the same time each of such fields has contributed to the body of knowledge in economics. The primary contribution that environmental economics made include the area of non-market valuation. Besides, environmental economic made it possible to adopt tools developed in other areas of economics to issues regarding the environment.

Environmental economics is different from ecological economics and resource economics. Environmental economics tends to involve economists who have extended their discipline and paradigm to consider the environment, whereas the ecological economics tends to involve ecologists who have extended their discipline and paradigm to consider humans and the economy. The combined treatment of environmental and resource economics is generally made since both has concern on the natural world. However, environmental economics involve questions of excessive production of pollution by the market or insufficient protection of the natural world due to market failure. Resource economics is concerned with the production and use of natural resources (Charles D. Kolstad 2000). The major environmental problems include the quality of the environment i.e. air pollution, water pollution, toxic chemicals etc. The important issues in environmental economics are (i) measuring the demand for non-market goods (ii) issues surrounding regulation of environmental goods (iii) international issues of environmental regulations.

The World Bank aided "India : Environmental Management Capacity Building" technical assistance project is an attempt to initiate research on various aspects related to environmental economics, in a developing country like India.

The present study on environmental economics of desert agriculture is an attempt to locate the emerging environmental issues of this eco-fragile area in the state of Rajasthan.

1.2 NATURAL RESOURCES ECONOMICS AND ENVIRONMENT

The natural resources are those resources that are not man-made, including all of the earth's natural elements and environmental forces. The major classes of natural resources are agricultural land; forest land and its multiple products and services; natural land areas preserved for aesthetic, recreational, or scientific purposes; the fresh and salt water fisheries; mineral resources including mineral fuels and nonfuels; renewable nonmineral energy sources of solar, tidal, wind, and geothermal systems; water resources; and the waste-assimilative capacities of all parts of the environment. More generally, natural resources fall into four categories:(i) basic natural resources

such as land, water, and air (ii) natural resource commodities such as timber and fish (iii) environmental amenities such as clean air and scenic views and (iv) environmental processes such as pollution, soil erosion, groundwater recharge, and species regeneration.

Natural resources have biological and physical characteristics that determine how people use them. Many are used directly - the air we breathe and the sun that warms us are good examples. Others must be transformed over time and space before they are useful to people. In this process, they usually are combined with other factors such as human labor to make them useful. Water, for example, is captured in the rainy season, stored until the dry season, and then transported from a reservoir to household, industrial, or agricultural consumers. Trees are harvested and then treated and refined in a variety of ways to make them useful for different purposes; they often are grown far from consumption centers and must be transported to market. The ways in which natural resources are used in the present often determine our options for using them in the future. Economists are interested in determining how to manage these natural resource commodities so that harvesting, extracting, reproducing, processing, transporting, storing, and using them take place in the most economically productive way. Population growth is a fundamental determinant of rising demand for natural resources.

In the perspective of economic growth and sustainable development it is required that the natural resources and the environment remain intact and its use is limited to the extent of its capability to regenerate naturally. Natural resources including natural environment perform the important functions in the process of economic growth (i) it provides inputs to production process and (ii) it assimilate the waste generated in the process of production. Since earth is finite, closed and non-growing, there is a natural limit to both of these critical functions. In other words, the capacity of earth to provide inputs and to assimilate waste is limited. It implies that it is not possible to go on increasing production of goods and services using natural resources for ever. There are ecological and natural limits to economic growth and hence it cannot be sustained for ever. It is also being argued that the capacity of the resource system is amenable to augmentation through technological and managerial interventions. The proponents of sustainable development recognize this truth and advocate the middle path for

development (Katar Singh 1998). In this context, the issues like land degradation, depletion of groundwater resources, deforestation, loss of biodiversity, climatic change, ozone layer or depletion etc are all important aspects associated to natural resources. Therefore, the sustainable agriculture that provides food security for the people without compromising ecological security is of paramount importance. For resource constrained areas like desert the magnitude of such challenges will be very high.

Economics aims to study the allocation of scarce resources among competing uses. The productive pattern of natural resources and the economic incentives that lead to the people for the best use of such resources are relevant considerations. The natural resource management addresses the use of these resources for economically productive, socially equitable and environmentally sustainable purposes. The productivity, equity and sustainability of natural resources assume great relevance. Productivity is the criteria used to measure the efficiency of a resource. While economic efficiency is a value concept between output and input and the technical efficiency is a physical concept between input and output. Thus, economic efficiency is a follow up of technical efficiency. However all technically efficient allocation of resources need not be economically efficient. Equity is a concept centered around distributional justice. For economists, equity implies `Pareto efficiency'. In the context of natural resources there can be conflict between efficient and equitable use of natural resources. Sustainability is an inter generational equity concept. It means that the present generation should not use the natural resources at the cost of future generation. Sustainability also means preservation of bio-diversity in the biological sense. Economic sustainability is used to mean the protection of natural resources from mindless over exploitation.

The present status of natural resource base of the desert region in the context of sustainable development assumes great importance. The study aims to assess the perspective of economic growth and sustainable development. Efforts have been made to analyse the compatibility of natural resource with agriculture based economic activities.

1.3 ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

Environment and sustainable development are two recent key issues received attention at international forums. The report entitled "Our Common Future" by the World Commission on Environment and Development (WCED) may be considered as the major international initiative to attract the attention of policy makers about the complicity of relationship between economic growth and environmental problems. The Conference on Environment and Development by the United Nations (UNCED) in Rio (1997) formed the follow up actions of the recommendations of the WCED. It gave rise to the global concern over various environmental problem and the need to search for strategies for sustainable development.

Environment including natural resources as well as the economic activities of a region are interlinked. The externalities of such economic activities, which can have harmful implications have its effect on environment. The interaction between economy and environment calls for the wise management of natural resources like land, water, forests, minerals and so on. Therefore wise use of these natural resources leading to protection of environment is needed to achieve sustainable economic development.

Conceptually, sustainability is the characteristic of a system, or a resource to remain intact for all the time. It was the World Conservation Strategy of the International Union for the Conservation of Nature and Natural Resources (1980) which focussed deeply on this concept. The agricultural sustainability emerged as a follow up. The World Commission on Environment and Development emphasized the importance of sustainability in agriculture. The perception of sustainability by the economists include the long term stability of economic parameters like income, consumption, production etc. On the other hand ecological sustainability relates to long term preservation of biosphere. Here comes the issue of preserving the biosphere and sustaining the human population within the available limits of natural resources. Thus, economic sustainability implies the preservation of natural capital which include natural resources and environment alongwith the production capital. On the other hand ecological sustainability is linked to the carrying capacity limits of natural system (Katar Singh, 1998).

The assessment of sustainability of the process of development initiated in the desert area also form part of this study.

1.4 CONCEPT OF SUSTAINABILTY AND SUSTAINABLE DEVELOPMENT

The origins of the concept of sustainability with special reference to sustainable development may be traced to the `World Conservation Strategy' developed by the International Union for the Conservation of Nature and Natural Resources, Worldwide Fund for Nature and the United Nations Environment Fund (Natarajan 1996). Some of its interpretation and implications are as given below :

* Sustainable development meets the needs of the present generation without compromising the ability of future generations to meet their own needs.

* An increase in (real) domestic product, duly allowing for the consumption of produced capital and the depletion and degradation of natural capital, taking into account the past trends of depletion and degradation that can be offset or mitigated by technological progress, substitution and new discoveries of natural resources, or new additions to them, and changes in consumption patterns (Environmental Accounting with an Operational Perspective].

* Keeping something going for an `indefinite' period of time. Thus, sustainable extraction of fossil fuels or sustainable farming employing chemical fertilizers are oxymorons.

* Conservation of living resources, or management of the biosphere for human needs and use. This represents an anthropocentric attitude, implying that animals and plants are all for human use.

* Wise use of nature and its resources; to provide the greatest sustainable benefit to present generations while maintaining the potential to meet the needs and aspirations of future generations.

* Living in harmony with nature.

* Lying off the income of nature, without eroding the capital.

* Must give back to the earth what use take from it.

* Living within the `carrying capacity' of the environment.

* Realization that the biosphere is both for us and for our descendants. `We have not inherited the earth from our parents; we have only borrowed it from our children".

Notwithstanding the several graphic descriptions cited above, the concept of sustainability is ambiguous, and its interpretation is a function of the user. It is often found fashionable to tag it on to several human activities, namely :(i) growth, (ii) development, (iii) agriculture, (iv) yields, and (v) power.

Thus, the concept of sustainabilty captures both economic and environmental dimensions of development and emphasizes the need for ensuring inter generational equity. In this respect it is very similar to the concept of sustainable livelihood which means assured access of both present and future generations to basic necessities of life such as food, clothes, shelters, freedom, basic literacy and health care on long term basis (Katar Singh, 1998). An operational definition of sustainable development that takes explicit account of economic, ecological and other standards and targets is given as "a set of development programmes that meets the target of human needs satisfaction without violating long-term natural resource capacities and standards of environmental quality and social equity" (Bartelmus, 1997).

Crop and livestock production are the major economic activities in the desert region which has its impact on the environment. Therefore, there is a great need to establish proper balance between environment, economics and the natural resource base of this ecofragile region. The rapidly increasing population in the desert belt is feared to adversely effect the desert environment. The pressure of population makes it necessary to over exploit the weak natural resource base limiting the scope for making a better environment through development strategies. The reality is that the struggle for survival of the people does not make it possible to protect the environment from further deterioration in the desert belt. Thus the preservation of natural environment is the major environmental task in the desert belt.

1.5 WORLD INITIATIONS ON ENVIRONMENT AND SUSTAINABLE

DEVELOPMENT

The document `Our Common Future' by the World Commission on Environment and Development (1987) could be the first major international initiative that prompted for the need to think aloud about the complexity of relationship between environmental problems, economic growth and also the aspirations of the people. The United Nations Conference on Environment and Development (UNCED) held in Rio in 1992 has ben an outcome of the growing concern on environment in the context of developmental efforts. The UNCED emphasized on the global concern over the deteriorating environment and the need to search for such strategies which could ensure sustainable development. The problems of deteriorating natural resources in developing countries could be attributable to both internal as well as external factors. The external factors may include the imbalances in international trade, indebtedness of developing countries, transfer of technologies to developing countries and so on. The internal factors may include population growth, imbalances between production activities and capacity of the natural resource base and also failure to address the environmental issues in the early process of development initiatives. Environment including natural resources and economy interact and are interdependent. However the policy interventions for devising development strategies could not adequately consider this reality. As a result the degradation of the natural resources and distortions in the resource base are required to be addressed on priority basis.

1.6 THE PRESENT STUDY

The environmental economics is concerned with the impact of the economy on the environment and the significance of the environment to the economy and suggest ways and means to regulate economic activity so that the required balance is achieved among environmental, economic and other social goals. Therefore, the desert area in general and desert based agricultural system in particular assume importance for indepth probing for assessing the sustainability of the system. As the concern for the environment is getting more and more importance, it is natural for the agricultural economists to focus their attention on aspects like desert agriculture where human and livestock pressure is on a steady increase where the fragile natural resources form the

basis for their survival. If the natural resources are exploited beyond the replenishable level in a desert based livelihood system, the perspective process of economic growth and sustainable development gets jeopardized. The further degradation of already degraded land resources may turn out to be a great threat to both human and livestock population. The ecological security in the desert belt is equally important to the sustainability of the agricultural system, which aims for the food security of the people and fodder requirement of the animals.

Therefore, the linkage between natural resource base and the economic activities which are centered around agriculture in the desert belt of Rajasthan including the externalities is a topic of vital importance. For a fragile eco-system like desertic condition, preserving the bio-diversity and also improving the natural resource base for sustaining the human population are significantly relevant.

1.7 THE STUDY AREA

Under the Agro-Climatic Regional Planning (ACRP) approach launched in 1988 by the Planning Commission, Govt. of India for the purpose of a reversal of the planning process from `top-down' to `bottom-up' the entire country was delineated into 15 separate agro-climatic zones (Fig.1). The state of Rajasthan is spread over four such zones. The zone 14 known as "Western Dry Region" consists of nine western districts of the state of Rajasthan (Fig. 2) which together cover 51.2 per cent of the total area of the state, 30.5 per cent of the state's total human population and 42.6 per cent of state's livestock population. The desertic condition prevalent in these districts made it necessary to delineate these 9 districts into a separate zone at the national level. The major desert cover of the state is confined to this zone. In all the districts covered under this zone, the decadal growth rate of population ranged between 28 to 43.2 per cent in relation to state's average growth of 28 per cent during the period 1981 to 1991. The livestock population in these districts also registered very high growth rates ranging from 15.12 per cent to 74.08 per cent as compared to the state average of 13.76 per cent for the period 1992 to 1997. The high growth rates in human population and livestock in this eco-fragile zone is a matter of severe concern, as the pressure on land, water and other natural resources is likely to increase tremendously. The process of

sand stabilization, the efforts to make more vegetative cover by enhancing forest coverage in this zone are likely to undergo severe set -back due to the exorbitant growth in human and livestock population.

The major factors for accentuation of the desertic conditions within the desert are the escalation of human and livestock population and their activities, besides the climatic and geo-morphological factors. The human population within the Western Dry Region has increased from 4.58 million in 1951 to 13.40 million in 1991. Agriculture and animal husbandry remain the major source of income and employment for the people in this region. The increasing human population is a serious stress, particularly on the vegetal resources of the desert. The trees and shrubs and even their roots are indiscriminately cut by the rural population for fuel, top feed, thorn fencing and the construction of thatched hutments.

The livestock population far exceeds human population in all the nine districts covered under the Western Dry Region. The livestock population has increased from 10.74 million in 1956 to 23.16 million in 1997. The dominance of small ruminants like sheep and goat in the livestock population limits the scope to enhance vegetative cover due to the continuous grazing habit of those animals. The goats and sheep are considered as the desert makers, eating every bit of green or dry vegetation. Because of continued cultivation of marginal lands and over grazing by the animals, the soil gets loosened to be carried away by strong desert winds which are frequent in the area. The over exploitation of ground water in the Western Dry Region is yet another important problems adding to the gravity of desertification in the area.

The peculiar village structure with limited number of households in each village and large inter-village distances stand in the way of regular socio-economic development process in this region.While the low literacy rates of the population in general and female population in particular may be the major factor for high population growth, the higher growth in livestock population may be attributable to the large yield risk involved in crop farming in this area. Under such a circumstance, it is relevant to make economic analysis of crop, livestock and other farm based activities in this eco-fragile region. It is also worthwhile to identify the factors leading to the large growth in human and livestock population and to assess the implication of the same in relation to natural resource

management and environment upgradation.

The present study is confined to the environmental economic aspects of the Western Dry Region delineated by the Planning Commission for the "bottom-up" approach of planning process under the Agro-climatic Regional Planning (ACRP) approach.

1.8 FARMING SYSTEM, NATURAL RESORUCES MANAGEMENT AND ENVIRONMENTAL UPGRADATION OF DESERT BELT IN RAJASTHAN

The compatibility of agricultural activities with natural resources including land is a crucial aspect of natural resoruce management and environmetnal upgradation. The land includes all natural resources including water in a wider perspective. The expansion of IGNP canal irrigation system in part of the desert belt in Rajasthan, the exorbitant grwoth in human population and livestock population and the limited scope to divert work force from land based activities to other sectors, add to the burden on land in this region. Over-exploitation of land and other natural resources may lead to more aggressive desertification. Frequent ploughing of land with tractors for crop production and deep ploughing of soil for commeercial crops may also prove to be hazardous towards the attempts being made for sand stabilization. The method of irrigation, wherever water resources are being made available, holds relevance to better management of land reosurces. In the absence of proper drainage system, flooding of the field may prove hazardous to land resources. The large increse in small ruminants, particularly sheep and goat and also animals like cattle, which require intensive grazing and camels which browse on the growing bushes and trees are likely to degrade the natural reosruces and also the environment. The canal irrigation without proper drainage system may also cause for salinization and other land based problems.

The migration of cattle breeders with animals for want of adequate resource base to sustain the human and livestock population is till not uncommon in this area. The poor literacy rate of the population limits the scope to divert the work force from land based activities to other sectors in this area. The slow process of social development and hte limited option for diversification of economic activities add to the importance of land based economic activiteis in this region.

The agro-forestry practice is very old in the dry region of Rajasthan. During the recent years it has taken a scientific approach with the work beign done by the Central Arid Zone Research Institute, Jodhpur and Arid Forest Research Institute, Jodhpur. The role of agro-forestry in setting a new direction for the on-going practices of mixed farming developed over the years, both for risk aversion and for meeting the food-fodder security in the area, is very relevant.

1.9 OTHER ENVIRONMENTAL ASPECTS

The ecological and economic interactions taking place with crop-livestock and tree species are also worth probing to ascertain the sustainable land management of this region. While pin-pointing the economic problems facing the farmers, identification of divergence between private and social incentives and quantification of losses from externalities also assume importance. The development activities/policies ignoring environmental damage may hit hardest the very people for whom the development projects are launched. The crop and livestock being the major land based economic activities, identification of divergence between private and social incentives as a result of growing pressure of these economic activities and the emerging externalities mostly as social cost form the major environmental economic component of the proposed study. The implications of the decisions of the farmers to reduce risk in the economic activities and the likely externalities towards environmental upgradation shall also form the focus of the study. Based on the experiences, both within the study area and outside, efforts will be made to identify the activities/technologies which are replicable under the existing natural resource base in the study area for its better management and environmental sustainability. The appropriate crop-livestock activity combinations for the effective and efficient natural resource management and environmental upgradation assume great significance for this area. Those activities which promote sand stabilization and vegetative cover for building up sustainable environment and those leading to degradation of the process are to be identified for suggesting required policy intervention by the State-Government and also to provide direction to the developmental agencies including Panchayat Raj Institutions and NGO's working in this area, so as to devise strategies for sustainable development of the area.

The growth oriented development strategies pursued in the past seem to have caused for some distortions in the resource base in this eco-fragile area. The inter-activity competition for sharing the resources also appears to be a limiting factor for ensuring sustainable development of this area. Therefore, indepth analysis of the resource base and also the agricultural activities has become a topic of paramount importance. The extent of compatibility between agricultural activities and agricultural resources also needs to be assessed. The present study is an attempt in this direction.

1.10 REVIEW OF STUDIES ON INDIAN DESERT ECO-SYSTEM AND DESERT AGRICULTURE IN RAJASTHAN

A good number of studies on desert eco-system and agricultural activities are available in edited hooks, proceedings etc. Some of the relevant studies reviewed are summarized in this section.

Mann (1977) has pointed out that the major factors of desertification (accentuation of the desert conditions) within the desert are the escalation of human and livestock population and their activities, besides the climatic and geo-morphological factors. The human population within the Rajasthan desert has increased from 3.42 millions in 1901 to 8.84 millions in 1971a growth rate of 158 per cent, and this rate is much more (125 per cent) in comparison with the whole of the Rajasthan State. It was further stated that the increasing human population is a serious stress, particularly on the vegetal resources of the desert. The trees and shrubs and even their roots are indiscriminately cut by the rural population for fuel, top feed, thorn fencing and the construction of thatched hutments. It has been estimated that the requirement of the people in the desert in respect of the woody biomass has increased from 1.85 million tonnes in 1951 to 3.33 million tonnes in 1971. The desert people have developed peculiar food habits. All the available air-dried seeds and pods of the trees are used as delicacies. The seeds of *Acacia senegal (kumat)*, the fruits of *Capparis decidua (karir)* and the pods of *Prosopis cineraria* are harvested. Almost all the fruits of *Zizyphus mummularia* (ber, jhadberi) growing in accessible parts of the desert are harvested for human consumption. The seeds of grasses, e.g. *Panicum turgidum, P. antidotale, Cenchrus biflorus and Echinochloa colonum*, are mixed with millet for making chapatis

(unleavened cakes) especially during drought years. On the growth of livestock population he stated that "Livestock population far exceeds human population in arid western Rajasthan. It increased from 9.4 millions in 1951 to 15.5 millions in 1972. The goat and sheep populations ranged from 57.1 to 69.3% during this period. Owing to continued droughts during 1967-71, with the consequent migration and mortality, the number of cattle fell heavily (10.8% decrease), but the number of hardy animals, e.g. the goat, increased substantially (34% increase). The goats are the desert-makers par excellence, eating every bit of green or dry vegetation. On the crop production in desert area he opined that because of cultivation of marginal lands, overgrazing, and the depredations of field rodents, the compact, stabilized sand over the inter-dunal and dune lands is loosened to be carried away by the strong desert winds. Referring to the recommendations by the National Commission on Agriculture at was indicated that it is important to work out a policy whether arid lands receiving rainfall lower than 300 mm per annum or so should be cultivated or used as rangelands for livestock. On the aspect of groundwater at was mentioned that the scientific exploitation of groundwater in the Indian desert is another important matter. The occurrence and the quality of the ground-water at a particular site are mainly dependent on the mode of formation and nature of the aquifer and its relation to the overlying beds.

In his paper on origin and History of Rajasthan Desert, **Mittre (1977)** concluded that the palaeobotanical evidence indicate an increasing trend in aridity since the Miocene times in western India. This trend was responsible for the increase in deciduous elements in the semi-evergreen forests with moist equable climate which had existed in the north-western and western India since Eocene times. It is during the early to mid-Quaternary most probably that the repeated fluctuations in temperature and precipitation caused the formation of the desert and overall aridity in western India. It is during this period that the Saharo-Sudanian and African floristic elements began to invade this region at the expense of decline and eventual extinction of the dense evergreen and semi-evergreen forests in western India and Rajasthan. The creation of the desert was indeed the result of natural phenomena, and the early man had settled here under the desertic environment, with the precipitation gradient much as at present. The migration of the sand-dune formation activity from the west to the east of the desert has continued and the palaeobotanical evidence has been found of such an activity as

recent as 5,000 years ago.

Misra (1977) on the evolution of the pattern of human settlement in the arid and semi-arid regions in India stated that as a result of relatively recent research done in Rajasthan, Gujarat and Haryana, we have a fairly good picture of the evolution of human cultures and of the pattern of human colonization in the arid and semi-arid regions of western India during pre-historic times. There is no true Neolithic period in western India, because by the time the food-producing way of life was introduced into this region, man had already learnt the use of copper and bronze. So the Mesolithic period in this entire region is succeeded directly by Chalcolithic Age and in some cases by the Bronze Age.

Relating the observation in the report of the Planning Commission of the Government of India in its first five year plan with evidences from other studies on climatic changes in the Indian desert, **Singh (1977)** expressed that in the early fifties, great concern was expressed over the reportedly rapid spread of the Rajasthan desert into the hitherto fertile tracts surrounding the region. "Recent topographical surveys show that the great Indian desert of Rajasthan has been spreading outwards in a great convex arc through Ferozepur, Patiala and Agra towards Aligarh and Kasganj at the rate of about half a mile per year for the last 50 years, and is encroaching upon approximately 50 square miles of fertile land every year" (Report of the Planning Commission of the Government of India in Its First Five Year Plan). The claim for the extension of the desert, however, did not find support from the large body of expert opinion, then available, as brought out in the Proceedings of the Symposium on the Rajputana Desert, organized by the National Institute of Sciences of India in 1952. Indeed, the meteorological record over the previous 70 years showed no significant change in rainfall, temperature, humidity and wind velocity over the desert areas and, therefore, no plausible case could be made to support the contention of the progressive spread of the Rajasthan desert in recent years as indicated in the report. Thus, on the deterioration of Indian desert condition he further stated that regarding the question whether the desert conditions had deteriorated gradually over a longer period, there was no precise information available. It was generally held that the desert conditions had deteriorated as compared with conditions obtaining during the period of the Harappan Culture (2300-1750 B.C.) and also to some extent in relation to some later cultures which flourished in north-

western India in the early centuries of the Christian Era.

On the basis of studies on geomorphology of the Rajasthan desert **Ghose *et al*. (1977)** made out their observation that the geomorphological evolutionary history of the region has revealed that the landforms of the Pre-Quaternary eras in the Rajasthan desert have evolved through long periods of subaerial degradation and aggradation, interrupted by short periods of tectonic activities. The major existing landforms have resulted owing to the climato-morphogenetic processes operating during the Late Quaternary period on various lithological formations and under different climatic phases. The fluvial and aeolian landforms of the region are polygenic and bear the imprints of the past climates.The vast alluvial plains were formed by the well-integrated drainage systems in the Pleistocene period and they form the backbone of the region. The sand-dunes, sandy plains and inland basins were created by intense aeolian activities during the prolonged arid phase of the Pre-Holocene period. These aeolian landforms were stabilized and dissected during the prolonged humid phase of the early Holocene period. The renewed aeolian activities of the late Holocene period created active barchan and shrub-coppice sand-dunes and sand sheets on the existing landforms of the region. In the Recent period, the increasing biotic activities have also become important in sculpturing the landforms. Taking into consideration all the geomorphological factors, such as the evolutionary history of the landforms, their slopes and forms characteristics, nature, size and depth of sediments and associated hazards, the Rajasthan Desert has been divided into fourteen major landform units. The distribution and geomorphological characteristics of these landform units have been analysed and mapped in their correct positions and mutual relationships. Each geomorphological nomenclature indicates the agricultural and water potentials of the region. These landform units, thus, have different production potentials and physical limitations which can be developed by suitable management techniques.

Mann *et al*. (1977) carried out detailed study on the land utilization of the arid zone comprising 12 Western districts of Rajasthan. They observed that with the increase in the working force, the diversification in adopting occupations other than cultivation has not occurred, as the region lacks a diversified base. The available proven technology on dryland management suggests that enormous potentialities exists in the arid areas to transform the existing subsistence or deficit-oriented farming into that with marketable

surplus through scientific land-crop management, consistent with the land-use capability and adoption of the recommended management practices for different land-resources units. Paradoxical as it may appear, there has been a shrinkage in grazing-lands, on the one hand, and an increase in the livestock population, on the other. This situation has led to excessive livestock pressure on grazing-lands and the people have often to resort to migration and nomadism for the survival of their livestock. Of the limiting factors in sheep production and animal husbandry in the arid region, inadequate forage and drinking -water are important because they impoverish the resource. The high biotic interference has considerably influenced the occurrence and distribution of vegetation. Also, valuable cow-dung, otherwise an excellent manure, has been always wastefully used as fuel. These existing problems cannot, however, be solved through technology alone. Social action and awareness are essential. Historically, religions have adapted themselves to the changing economic conditions and it is inevitable that adjustments in outlook, compatible with basic religious beliefs, but more in keeping with economic demands, must take place, if the resources of the arid areas are to be fully used for the benefit of the people.

On the silvicultural problems in the arid zone **Kaul *et al*.(1977)** stated that the most urgent practical problem in applied silviculture is the development of practical methods for afforesting different land types met within the arid zone, with utilizable species. Considering that livestock husbandry occupies the most important place in the economy of the arid region and that frequent droughts results in a loss of cattle wealth owing to the shortage of fodder resources, it is necessary that range improvement should be complemented with the raising of fodder tree and shrub species which not only give the much-needed forage during the scarcity periods, but also give shade and shelter to the grazing animals, thereby help to utilize forage uniformly on the range. In addition, fodder trees and shrubs will ameliorate the micro-climatic conditions and thereby create conditions conducive to the natural regeneration of grasses which are higher in succession.

Mann and Singh (1977) in their study on Crop Production in the India Arid Zone concluded that crop production in the rainfed areas, in general, and in the arid regions, in particular, is unstable and risky, leading to low and unremunerative yield levels. Bajra (*Pennisetum typhoides*), kharif pulses, jowar (*Sorghum vulgare*) and sesamum are the

principal crops grown. An analysis of the problems of crop production in the rainfed areas of the Indian arid zone revealed that an acute ecological imbalance of the components of productivity is responsible for limiting the consistency of a remunerative crop production in these regions. Harsh and unfavourable climatic conditions, coupled with wind-blown soils low in organic matter and poor in moisture retention are responsible for a sparse vegetative cover and low unstable yields of dryland crops. Although the conventional dryland crops, viz., pearl-millet or bajra (*Pennisetum typhoides*), sesamum and kharif pulses, particularly mung (*Vigna radiata*), guar (*Cyamopsis tetragonoloba*) and moth (*Phaseolus aconitifolius)* are adapted to the existing conditions of low soil fertility and moisture stress, the local varieties offer a limiting choice for increasing crop production under varying rainfall situations. They suggested water harvesting system to minimize risk and enhance production. Owing to low rainfall and its erratic distribution, the dryland crops encounter drought during critical growth periods, leading to low yields or to the total failure of crops. This problem can be overcome to a great extent by adopting an appropriate water-harvesting system which can provide for additional quantities of moisture.For the situations obtainable in the rainfed areas of the arid zone, two water-harvesting systems, viz., inter-plot and inter-row systems, have bee found to offer opportunities for in situ water -harvesting. Studies at the Central Arid Zone Research Institute, Jodhpur, have shown that the total production by cropping only two-thirds of the field (leaving one-third for micro-catchment) by adopting the run-off farming is the same as obtained from conventional cropping on a flat surface. The run off farming has been found to offer potentialities for increasing and stabilizing yields, thereby lowering the risk of crop failure and saving inputs required for crop production.

Stressing the need to develop arid horticulture **Pareek (1977)** suggested that the characteristic soil and climatological features of these regions are most favourable for the production of certain fruits and offer conditions for the development of a distinct fruit quality. These features, however, restrict the choice of fruit crops for such regions and also necessitate the use of special growing techniques for their successful cultivation. Fruit crops, e.g., the ber, pomegranate, guava, custard-apple, aonla and karonda, conform to this pre-requisite. These crops can be grown, with or without the use of runoff concentration or with water conservation systems or both depending upon the

average annual rainfall of the region.

Pareek *et al*. (1998) identified important fruits, vegetables, and medicinal plants of thar desert. The important fruit crops of thar desert are Ber (*Ziziphus mauritiana*), Boradi (*Z. mauritiana* var. *rotundifolia*), Jharber (*Z. nummularia*), Pomegranate (*Punica granatum*), Aonla (*Emblica officinalis*), Karonda (*Carissa carandas*), Ker (*Capparis decidua*), Khejri (*Prosopis cineraria*), Pilu (*Salvadora oleoides*), Gonda (*Cordia myxa*), Gondi (*Cordia gharaf*), Phog (*Calligomum polygonoides*), Woodapple (*Feronia limonia*), Datapalm (*Phoenix dectylifera*), Kumat (*Acasia senegal*) and Ganegran (*Grewia lenax*). The importnat identified vegetables are Mateera (*Citrullus lanatus*), Kachri (*Cucumis callosus*), Snapmelon (*Cuscumis melo* var. *momordica*), Arya (*Cucumis* sp.), Tinda (*Citrullus lanatus* var. *fistulosus*), Guarpata (*Aloe barbadensis*), Kheep (*Leptadenia pyrotechnica*), *Clusterean* (*Cyamopsis tetgonoloba*), Drum stick (*Moringa oleoides*), Kulfa (*Portulaca oleracea*), Bathua (*Chenopodium album*), Chaulai (*Amaranthus* sp.), Bittergourd (*Momordica charantia*) and Cowpea (*Vigna unguiclata*). The importnat medicinal plants of the desert are Tumba (*Citrullus cococynthis*), Gugal (*Comnifera wightii*), Neemgiloy (*Tinospora cordifolia*), Ak (*Calotropis procera*), Thor (*Euphorbia caducifolia*), Anantmool (*Hemidesmus indicum*), Menhdi (*Lawsonia inermis*), Tulsi (*Ocimum sanctum*), Perivincle (*Vinca rosea*), Ashwagandha (*Withania somnifera*), Hingota (*Balanites aegiptiaca*) and Gokharoo (*Tribulus terestris*).

Sharma and Sharma (1998) in their study on livestock resources and fodder requirement in western region of Rajasthan concluded that the main reason for low average production of livestock is deficiency of nutritive fodder. Highly degraded and over exploited pastures and increasing number of livestock causing pressure on ecological balance, especially in drought years. Even in a normal rainfall year there is 20 per cent shortage of fodder. Carrying capacity of pastures is very low i.e. 0.12 adult cattle unit per hectare, causing animals to divert to fallow and wastelands which are lacking in ground species and much of top feed. This results in more use of browsing shrubs as feed causing to ecological imbalance.

Solanki and Ajit (1998), in their study on management of agroforestry for economic gains reported that "Khejri" is the most important tree growing in combination with agricultural crops in the rainfall zone of 250 to 400 mm in Rajasthan. It's density in

agricultural fields varies with the rainfall and site conditions. Optimum density ranging from 80 to 120 trees per hectare can be observed in districts of Churu, Sikar, Jhunjhunu, and Naguar. Its suitability in agroforestry system stems from the amazing capacity of a well lopped Khejri tree to recover the full crown size in a period of nine months. The foliage is lopped to facilitate better growth of Kharif crop. In case, the fields are to be used for rabi crops like wheat and mustard, lopping continues upto the end of December. New growth initiates by February-March and continues slowly during summers and develops fast during monsoon. Various agroforestry system based on *Prosopis cineraria* has been suggested.

Singh (1998) while assessing the impact of goat population on ecology concluded that goats should not be categorized as animals responsible for the destruction of ecology. It is unwise to put the blame on goats for land degradation and desertification caused by activities of human and other livestock. It was suggested to maintain a balance between the number of goats and other livestock species and the quantity and type of feed resources, which are available for the combined population. In a developed three-tier silvi-pasture system, the goats should be introduced first followed by cattle and then sheep. After the sheep are out of the grazing area, the land should be given rest for regeneration/reseeding. This way the goat will go for bush, shrub and low set tree branches, cattle would utilize taller grasses and the sheep shorter and closer to surface vegetation resulting is most efficient and judicious utilization of the available feed resources.

Arya Ranjna *et al*. (1998) in their study on management of salt affected soils based on performance of bushes and trees in arid area concluded that *Salvadora persica* is better tree species for the shallow, degraded salty soils in long run as it is slow growing and tolerates the salinity as well as alkalinity and help in improving the soil qualities. *Prosopis juliflora* though performed well did not affect the soil pH as it is not a true halophyte. *Tamarix aphylla*, a halophyte by nature was not found to be suitable as its water requirements are high. Soil's physical as well as chemical properties were improved after five years of plant growth and the soil supports a galaxy of indigenous shrubs and grasses both annual and perenials as compared to negligible vegetation when planting was done.

In the edited book on `Arid Ecology in two volumes' which is a collection of papers on resources, hazards and rural development policies, **Harsh Vardhan (1999)** gives the description on the wildlife in the arid regions of India. According to him the presence of species like chital and hog deer, several centuries ago, in the desert, indicates the type of flora that would have been common then : dry deciduous for chital and moist deciduous for hog-deer. Some regions of the desert should have been aquatic too, to host the one-horned rhinoceros in olden times. This animal was reported in the Mohanjodaro terrain about 5,000 years ago. Moisture laden regime would have been possible because the Saraswati river had been flowing in this desert. However, the region underwent a long period of natural stress and developed arid conditions, which resulted in most large mammals getting extinct. This would have lasted for nearly a thousand years in which duration animals thrived in pockets only. Xerophytic flora took over from the one which survived here in the past to provide cover to animals and birds which could adjust to the gradual changes that occurred here.

According to him conservation renaissance took place in this desert during the fifteenth century when Lord Jambheshwar (born in 1452 AD at Pipasar near Nagaur) preached the 29 new principles of modest living. Conservation of flora and fauna formed prominent part of this philosophy. The people who followed them were popularly called Bishnoi (bees + noie 20 + 9 = 29 principles). The new sect flourished throughout the desert as Lord Jambheshwar toured places. His sojourn was marked by construction of tiny rest-house type of facilities which were later on accepted as Bishnoi temples. The attention in favour of green flora and wild animals was drawn in a religious manner and the desert received a conservation support, after a long gap. Yet spells of droughts and even famines were recurring features in this belt which caused widespread loss to wildlife, both flora and fauna. This continued after independence of the country also, almost until the seventies when benefits from the canal irrigation were received. The Indian gazelle is invariably present in this desert and can be observed at a short distance, often within close proximity of villages and agriculture fields. The black buck is another common wild animal in the desert which is also preserved by the Bishnoi community. The desert fox, the desert cat and the wolf are the only predators left in the desert today. The Indian hare is getting rarer in the desert. Its occurrence is reported in a section of the Desert National Park in Jaisalmer district. Rats, gerbils, skinks, snakes,

etc. proliferate extremely well in this desert. Eagles (Short-toed, snake eagle, tawny eagle, steppe eagle, imperial eagle), Harriers (pale harrier, pied harrier and montagu's harrier), Buzzards (long-legged buzzard, white-eyed buzzard, common buzzard), Eurasian kestrel, laggar falcon besides several species of vultures are observed here. Larks, sandgrouses and a vast variety of other terrestrial and arboreal birds are frequent to be encountered throughout this region. The Great Indian Bustard finds its home in the desert, preferring scrub and bushy terrain; it is the State Bird of Rajasthan.

Sinha and Sinha (1999) reported that the great Indian desert "Thar" occupying a 2.34 million sq.km area in the western part of India is not man-made desert as is often conceived. It is now well proved that it has resulted from geo-tectonic and climatic changes in the past, more than hundred thousand years ago. Thar desert of India are unique. They are the living representative of the races of plants and animals which have undergone a great evolutionary changes after entering the desert over long period of time. Thar desert is full of life. It is highly `generic' containing vast range of underlying dormant seeds which blooms into colourful ranges of herbs and grasses with the very first shower. Thar desert also has unique varieties of trees which during certain period of time blooms into colourful ranges abounding amazing variety of birds and animals. The density of certain wild animals like `black buck', `gazelle', `sand grouse', `wild boar', and a number of other animals was in the recent past so high that is must have been worthy of investigation as to how such large population of wild animals were sustained on the resource starved land! The wild animals inhabiting in the Thar desert are able to withstand climatic vagaries, extremes of temperature and paucity of water by adapting to `nocturnalism', by generating metabolic water to regulate water balance in the body and by structural and behavioural adjustment. The abundant population of wildlife in the desert may also be due to the love of desert dwellers for them, a feature which is unique in the Thar desert.

It is further stated that as a measure at bio-diversity for enhancing soil fertility and crop production in Thar desert farmers in the Thar desert of Rajasthan practice traditional agroforestry making use of biodiversity. Bordi (*Zizyphus glabarata*) is mostly grown with pearl millet. Right with the start of agricultural operations bordi plants are allowed to remain and are not taken out. Care is also taken that while ploughing and weeding bordi are not removed. Bordi sprout each year from the root stock, which are left in the fields

in the preceding year. The plants also, get established from the seeds which fall in the fields. Twenty to thirty years ago an area of field sown with bajra contained about 100-200 plants of bordi. However, with the introduction of tractor in modern agriculture majority of bordi plants got removed and the density per acre has reduced to only 25-30 bordi plants. Most knowledgeable farmers in the Thar desert lament about the reduced number of bordi plants, its excellent feed, fencing and food values. The leguminous tree khejri (*Prosopis cineraria), king* tree in the arid zones of Rajasthan grow well in combination with crops like pearlmillets, legumes and oil seeds. The density of this tree traditionally preferred and maintained in one acre area under crops, was about 25 to 35 trees. Introduction of tractor for cultivation has reduced the density of these trees in the field boundaries to 10-15. Khejri provides lives-stock feed (leaves), vegetables and timber. When not lopped (as among one of the Bishnoiu communities) the leaves that fall on the ground add fertility to the soil. Traditional agroforestry practiced by the farmers of Thar desert in Rajasthan reveal the importance of developing greater knowledge of the past and present activities in agriculture through biodiversity conservation.

On fodder crops in thar desert they reported that *Cenchrus cilaris* (`Marwar Anjan') is a selection from an entry in the germplasm received from Australia. It is a tall, thick stemmed, erect and drought hardy perennial grass. Leaves are broad, long, droopy and remains green up to maturity. It has wider adaptability, high tillering ability and is good in regeneration. It gives 2 and 3 cuttings per year. It yields 70 quintals of green fodder and 30 quintals of dry matter per hectare under arid conditions. It has 8 per cent protein and about 60 per cent digestibility. It produces 1 to 1.5 quintal/ha seed even after one cutting of fodder. It is a persistent and aggressive variety for grasslands and remain productive for 4 to 5 years.

Cenchrus setigerus locally known as Marwar Dhaman is a selection from exotic material and adapted well in arid and semi-arid regions of India. `Marwar Dhaman' is excellent for grazing purpose due to its thin stem and leafy foliage. It is a drought hardy perennial early maturing variety. It is better in regeneration and capable of giving 2 to 3 cuts per year. It provides an average yield of 40 quintal/hectare green fodder and 15 quintal/ hectare dry matter. It contains 9.5 per cent crude protein and pasture remain productive for 4 to 5 years. It is moderately resistant to major insect pests. For achieving

a breakthrough in the yield of different promising grasses and legumes, an exhaustive germplasm of over 1600 collection has been built up at CAZRI, Jodhpur and maintained in nursery. These varieties provide high and nutritive forage over a greater part of the year. They are drought hardy, salt-tolerant, stable, persistent and aggressive in rangeland and possess high seed yield ability, fast regeneration and good germination *Lasiurus sindicus* is particularly very highly nutritive fodder grass well adapted to the Thar desert and they grow extensively on the dry sandy soil. They also work as good sand-binder.

About the funa in Thar desert it was reported that 38 species of fish occur in the perennial lakes in the desert. In the larger lakes crocodile (*Crocodilus palustris*) was fairly abundant, but in the post independence period its number has reduced drastically partly due to drying of lakes during consecutive droughts and partly due to human persecution. Over 60 mammalian species inhabit the Thar desert including the larger carnivorous `flying bats' and `tiny rodents'. Rodents constitute one of the largest mammalian groups in the Thar desert. The Rajasthan desert is also fairly rich in its avian fauna. About 300 species of birds have been reported from Thar desert. The most important of all is the majestic bird godawan or the great Indian bustard (*Choriotes niriceps*) which breed in the area and migrate locally in different seasons.

A desert community of people called `Bishnois' occupies a distinctive position in world as far as human animal relationship is concerned. Bishnois nurse a peculiarly strong inhibition towards the killing of the animals. To a Bishnoi, the black-buck represents one of his ancestors and, as such, is an object of protection. It will be no exaggeration to say that but for the aggressive protection afforded by the Bishnois to this beautiful antelope species, it would have vanished from the Thar desert. They even provide grains and water to the animals during droughts and engage people to look after the needs of animals in remote areas. Cattle, sheep, goats and camel are the important livestock species of the Thar desert. The desert areas posses some of the best breeds of livestock. A large percentage of livestock in the desert are nondescript. There are some important dairy breeds, e.g., `Tharparkar', `Rathi' and `Gir', draft animals breeds, e.g., `Kankarej' and `Nagauri', and dual purpose breeds of cattle. The usual husbandry practices are still largely traditional. The important breeds of sheep in the region are `Chokla', `Pattanwadi', `Magra', `Marwari', `Nali', `Pugal' and `Jaisalmeri'. The goat

breeds of the Thar desert are reputed for high milk production potentials and are prolific breeders even under adverse conditions. The important breeds of goats in the area are `Marwari', `Jhankrana', `Sirohi', `Beetal', `Jamnapari' and `Barbari', `Jamanapari' and `Beetal' are heavier and taller breeds.

According to them, the important plants, which yield `fibres', `mats', `baskets' and `sirkis' for cottage industry, include bawli (*Acacia jacquemontii*), khimp (*Leptadenia pyrotechnica*), munj (*Saccharum bengalense*), and aak (*Calotropis procera*). Some desert plants like kumat (*Acacia senegal*) and babul (*Acacia nilotica*) yield gums which are in great demand for textile industry. Natural dyes are extracted from plants like dhok (*Butea monosperma), Arnebia hispidissima* and mehndi (*Lawsonia alba*). Several plants yield non-edible oil used in soap industry, particularly washing soap, e.g., jal (*Salvadora oleoides*), tumba (*Citrullus colocynthis*) and watermelon (*C. lanatus*). In desert of Rajasthan, famine food plants, e.g., *Cenchrus biflorus, Panjicum turgidum* and *P. antiodotale* which provide nutritive grains assume great importance. The fruits of *Capparis decidua* are pickled as well as used as vegetables. The fruits is of great medicinal value. The flowers of *Aerva pseudotomentosa* are cotton like and are used for stuffing pillows and mattresses.

On the threat to bio-diversity in the thar desert they reported that Thar desert biological diversity is subjected to intense population pressure. Trees, shrubs and even their roots are mercilessly removed by human beings for fuel, fodder, fencing and construction. The requirement of fuel wood has increased from 1.85 million tonnes in 1951 to about 4.0 million tonnes in 1991. *Prosopis cineraria*, *Acacia nilotica, acacia senegal* and *Calligonum polygonoides* (roots) are exploited for fuel purpose. *Commiphora wightii, Withania somnifera, Solanum surattense and urginea indica* are badly exploited for medicinal use.

The desert wildlife are facing immense biotic pressure from the growing human and livestock population which has increased from 3.4 millions in 1901 to 13.4 millions in 1981 and from 10.3 millions in 1951 to 23.2 millions in 1983, respectively. As a consequence of the biotic pressure, land under cultivation has substantially increased. Consequently the grazing lands for wildlife have not only proportionately shrunk but are overgrazed by the domestic animals. The wildlife animals have, therefore, been pushed

towards bare sand dunes where there is nothing to feed upon. The larger herbivores like blue bulls have turned to agricultural crops in certain areas causing immense damage to agriculture. The blue bull has an insatiable appetite. Its herds freely enter the crop fields of millet, wheat, barley, mustard, sesame and destroy them.

It was also reported that in the Thar desert about 10 per cent of the existing biological diversity is endangered. Among the flora the density of phog (*Calligonum polygonoides*), tumba (*Citrullus colocynthis*), rohida (*Tecomella undulata*), khejri (*Prosopis cineraria*), deshi babool (*Acacia nilotica*), bordi (*Zizyphus glabarata*), Nagauri ashgandh (*Withania somnifera*), guggal (*Commiphora wightii), Solanum surattense* are depleting and becoming endangered. Among the fauna chinkara (*Gazella gazella*), great Indian bustard (*Choriotes nigriceps*) and black buck (*Antelope cervicapra*) have already been declared endangered.

Deora (1999), describing on the origin of thar desert stated that the Rajputana desert' which is often called as `Thar desert' or `Little Great Desert of India' is not of very recent origin. Archaeologists generally believe that the Rajputana desert, which is a part of the Great Indian desert is atleast two millennial old and its nucleus might be older still. There is a general consensus that before the period of Greek invasions on India (327 B.C.), the desert conditions in Rajasthan were stabilized. But at the same time it is not certain to describe the exact or even estimated areas of the desert, Probably to define the limits of arid landscape is rather difficult as there is no generally accepted definition of arid lands. Moreover, both archaeologists and scientists assume that desert too expands with the progress of time. Even today it is marching. In other words the present boundaries of the Rajputana desert cannot be accepted as such for purpose of the study on the same in the historical context. The boundaries of it should be different in each phase of its movement.

Choudhary (1999) in his paper on desert ecology concluded that continuous ploughing, over grazing, cutting of the roots and stems of desert's biome in the last 3 decade have resulted in macro and micro nutrient deficiency in the soil which has resulted in low quality and quantity production of desert's grasses, bushes, trees and crops. This has resulted in low productivity in animals and suffering of animals due to deficiency of nutrient. It is suggested to introduce Agro-forestry, Agro-silviculture, Agro-silvi-

pastoralism, multi purpose forest tree production system and grazing forest micro-climate in this area for the welfare of animals.

According to him introduction of bio-gas and bio-manure production systems through social awakening is the need of time. Utilization of solar energy and bio-gas for cooking purposes instead of cow dung and wood is the only way by which desert can be preserved for the survival of its eco-system and the survival of the livestock population and man himself.

Pal *et al*. (1999) describe the importance of desert national park concept. National Parks are areas usually of great natural beauty and interest, now established in many countries and serve specially for conservation of native flora and fauna, as well as, for recreation of human beings - specially those interested in wild life. The desert national park extends into 3162 sq km partly in Jaisalmer and partly in Barmer distributes of Rajasthan. The Desert Park is under the administrative control of wildlife wing, for planned working. The entire area was notified as a sanctuary under the Wildlife Protection Act (1972) and still has natural landscape, original vegetation, landforms, traditional land use, animal husbandry, fewer people and it is large enough to be an effective conservation unit. The Desert National Park has no ecological boundary. Agricultural fields, pastures, revenue lands and sanctuary land all are conjoint and at some places barbed-wire fencing is the only significant marking of boundaries, making pillars to show its actual status.

In his paper entitled "Development potential and policy neglect of the Rajasthan desert" **Mathur (1999)** made out that "The Great Indian Desert" is, essentially, "The Rajasthan Desert" and this fact of natural ecology must become a prominent element of public consciousness of policy-makers in Rajasthan. He argued that the war against desertification must, therefore, begin in the minds of scientists and technologists of Rajasthan because the type of challenges posed and resource development opportunities offered by the "desert ecology" are, more or less, location-specific opportunities as far as india is concerned.

Encompassing 11 districts covering an area of 208,626 sq km or about 20 million hectares, the "Rajasthan Desert" is characterized by not merely physico-chemical monoformity but its most marvellous property is its great bio-technological capacity to

sustain a variety of life-forms. The 1971 Animal Census revealed a figure of nearly 16.28 million and the 1971 (Human) Census yielded a figure of 8.84 million giving one of the highest biotic concentrations for desert areas anywhere in the world.

It is further mentioned that the social scientists can play an important role not only by providing better research assessment of the biotic resources of western Rajasthan but their presence on the desert scene is vital in terms of the trade-offs inherent in the arid ecology of Rajasthan which is rich not only in biotic resources but also abounds in inputs like solar energy and wind power which can be successfully harnessed.

Ram *et al*.(1999) in their study on land use development of Jhunjhunu district, a district in the desert belt of Rajasthan concluded that during the past three decades, a significant but gradual change in land use in arid zone has been observed. However, these changes do not seem to have taken much note of dry harsh and inhospitable climatic conditions, meagre surface and ground water resources coupled with aeolian land scape and wind erosion hazards. The increased human population pressure not only brought more marginal land under plough, disregarding the land use capabilities but also brought under regular plough the land that was otherwise under long fallow, the practice that was more beneficial in arid areas, without achieving much stride in crop production.

Describing on Indira Gandhi Nahar project which is one of the largest canal system **Kapoor (1999)** pointed out that the purpose of this project was to transform the vast waste tract of the Great Indian Desert (the Thar) into a prosperous fully developed region humming with agriculture industry and commerce by irrigating an area of 15.79 lakh hectares annually in the district of Ganganagar, Churu, Bikaner, Jaisalmer, Jodhpur and Barmer. The project has been undertaken in one of the harshest environments of India where the inhabitants had, unfortunately for generations, accepted scarcity and famine as normal mode of existence. Now the virgin soil of the desert has been turning into prosperous and fully developed land, humming with agriculture, industry and commerce. The impact of canal irrigation on the socio-economic life of the people in this arid zone of Rajasthan can be viewed with particular reference to increase in household income, generation of employment opportunities, increase in standard of living, savings and investments in economic terms, changes in

occupation, structure and development of community facilities.

Bhattacharya (1999) in his paper entitled "IGN Project : Regional Development Plan-2001" describes the Rajasthan desert as a huge sandy waste tract known as the `Maru Desa' by the ancients or the "Rajasthan Desert" as it is known today. It covers approximately an area of 2 lakh sq kilometres occupying nearly 3/5th of total area of the state where conditions of living are extremely hard for man, animals and plants. Although arid areas have many advantages, as dry climate is good for health, pest control and off season crops, yet the environmental disadvantages, however, far out balance its few advantages.

The crop production in this region is described by him. A striking feature of agriculture in the region is high variability in the yields of principal crops, which causes a high degree of instability to the economy of the region as well as subsistence orientation to the cropping pattern. The existing cropping pattern is based on low rainfall and can be modified only after irrigation facilities are made available. Bajra, kharif pulses, jowar and sesamum are the principal crops of the region which jointly cover more than 90 per cent of the gross cropped area. Bajra is the main staple food crop which covers more than 50% of the cropped area (except in Ganganagar district). According to him the vegetation is dominated by theory species. The main floral series are (i) Colligonum polygonides series, (ii) Prospopis capparis Zizyphus series and (iii) Acacia capparis series. Open savannah consisting of grasses, mostly Sewan (*Lasiurus sindicus*), Anjan (*Cenchrus setigerus*) and Dhaman (Cenchrus ciliaris) with scattered trees and shrubs are commonly found throughout the region. *Acacia nilotica* (Babul) *Acacia senegal* (Kumta), *Prosopis cineraria* (Khejri) and Prosopis juliflora (Vilayati babul) are the most common trees of the region. Phog (*Calligonum polygcnoides*) is the most common shrub which is used mostly as fuel wood by the local population. Tree species like Eucalyptus (Safeda), *Acacia tortalis* (Israeli Babul), Dalbergia sissoo (Shisham), etc. have been found to be successful in the irrigation plantation along canals and roads of the region.

Sukhwal (1999) in his paper on afforestation in the IGNP area states that the canal region, characterized by desert topography, sandy soils, and sand dunes, is considered to be the most arid part of the country. The precipitation is scanty, unreliable, unevenly

distributed, and extremely periodic in nature. The evaporation and evapotranspiration rates are extremely high during the summer monsoon period between July and September.The strong south-west winds blow clouds of sand from the Rann of kutch and the Indus basin, causing to degrade the desert. The scanty desert vegetation is largely dominated by shrubs, grasses (*Cenchrus cillars, Elyonrus-cymbopogon jwarancusa, Dichanthium elyonurus)*, with a few widely spaced xerophytic trees (*Acacia arabica, Acacia senegal, Prosopis spicigera, and Acacia senegal balanites*). In general, the vegetation is sparce. The high percentage of vegetation consists of stunted, thorny, or prickly shrubs and perennial herbs capable of resisting the drought. Permanent vegetation is therefore xerophytic, showing various xeromorphic features like deep roots, dry hard rod-like thick or fleshy stems, spines and indumentum well developed, leaves either absent or much reduced, though usually with a casting of wax or hair to prevent excessive evapotranspiration. The bulk of vegetation appears after the first showers and dies out as soon as the soil gets dry, due to extremely high temperatures and excessive evaporation.

Singh and Khan (1999) on indigenous water harvesting system in arid ecosystem of Rajasthan indicated that the history of Rajasthan reveals that the local inhabitants have rich heritage of water management called indigenous systems some of which have survived over centuries.The dominant among them are wells, baories, jhalaras, reservoirs, tanks, talabs, nadis, tankas, khadins and roof water harvesting system. Some of these structures suggest that they are not only excellent feet of architectural and engineering design, but speak of the high degree of community sharing, social, moral and religious values built in the society. With the technological advancement in pumping and water supply, in many areas, these systems were neglected. However, with the increasing population trend and social advancement the importance of indigenous systems is being felt. Among the indigenous systems, the wells, baories, jhalaras depend on ground water aquifers, while reservoirs, tanks, talab, nadis, tankas, khadins, etc. are based on harnessing surface runoff.The latter fall under `water harvesting' schemes and have started getting attention of the people and developmental agencies once again but it is not true in the case of baories and jhalaras.

Pareek and Nath (1999) in their paper in potential of horticultural production in arid region indicated that these areas grow plants such as ker (*Capparis decidua), phog*

(Calligonum polygonoides), kheep (Leptidenia pyrotechnica), tumba (Citrullus colocynthis), mateera (Citrullus lanatus), clusterbean (*Cymopsis tetragonoloba*), etc. which yield fruits and vegetables.

Most of these studies indicate deterioration in the desert eco-system, large pressure of human and livestock population and lack of planned strategy to preserve the biodiversity in the desert eco-system.

The overview of available literature on desert agriculture system in Rajasthan brought to light some of the facts/issues listed below:

1. The major factors of accentuation of desertic condition in the area include escalation of human and livestock population and their activities besides the climatic and geomorphologic factors.

2. Increasing population is a serious stress on the vegetal resources of the desert area.

3. The continued cultivation of marginal land and overgrazing of the stabilized/ compact land lead to loosening the soils to be carried away by the strong desert winds.

4. With the increase in work force, the diversification in adapting occupations other than agriculture based activities has not occurred as the desert region lack a diversified resource base.

5. Potentialities for scientific land-crop management on the lines of dryland management consistent with the land use capability to transform the subsistence farming into marketable surplus were reported.

6. Shrinkage in grazing land on the one hand and gradual increase in livestock population causing excessive livestock pressure on grazing land has been reported as a threat to the desert eco-system. The resorting to migration and nomadism is reported as follow of this phenomenon.

7. The increased pressure for food for people and fodder for animal is prompting to put more and more land under plough causing problem in developing

afforesation programmes with utilizable species and befitting to different land types within the desert zone.

8. The range improvement was advocated to overcome the problems arising from frequent droughts resulting in the loss of cattle wealth due to shortage of fodder resources.

9. The crop production in the desert area was reported as unstable and risky.

10. The acute ecological imbalance of the components of crop productivity is reported as responsible for limiting the consistency of remunerative crop production system in the region.

11. Harsh and unfavourable climatic conditions coupled with wind blown soils, low in organic matter and poor in moisture retention, are responsible for the sparse vegetative cover as well as low and unstable yield of crops.

12. Setting apart-identified area of land for water harvesting has been suggested.

13. Potential fruit crops vegetables and medicinal plants of the desert area have been identified.

14. The low productivity of livestock was reported as due to deficiency of nutritive fodder.

15. The agroforestry system based on `Khejri' (*Prosopis cineraria*) is reported as useful to the crop production in this region.

16. Instead of blaming the goat for land degradation and desertification, keeping a balance of goat population in the livestock population has been suggested.

17. The widespread loss to wildlife, and also flora to and fauna is attributable to spells of drought and famine as recurring features in this belt. The desert wildlife has been reported as facing immense biotic pressure from the fast growth rate of human and livestock population.

18. The traditional practice of maintaining bio-diversity adopted by the farmers has been reported. Keeping bordi (*Zizyphus glabarata*) while growing pearl millet is

stated as an example. However, with the introduction of tractor, the bordi plants are getting removed. The density per hectare of bordi plants had come down from 100-200 to 25-30 per acre.

19. The role of `Bishnois Community' to live in harmony with animals and plants in desert area is reported as a positive factor to protect the eco-system from fast deterioration.

20. Continuous plough, overgrazing, cutting of roots and stems of desert's biome in the recent past have resulted in nutrient deficiency in the soil which in term has resulted in low quality and quantity of desert grasses, bushes, trees and crops.

21. The introduction of canal system in the area is reported as beneficial to transform the vast waste tract into a prosperous and developed region with the joint contribution of agriculture, industry commerce etc.

22. The rich heritage of indigenous water management systems in the desert belt speaks about excellent architectural and engineering design and community sharing practices followed by the people.

2. OBJECTIVES OF THE STUDY

The specific objectives stipulated for the present study are as follows :

(i) to asses the pattern of temporal trend in different land use classes in the districts covered under the region.

(ii) to examine the extent of growing pressure of human and livestock population on the eco-fragile land base,

(iii) to study the nature and extent of changes taking place in the cropping pattern,

(iv) to measure the yield instability in various crop enterprises in the region,

(v) to examine the economics of desert agricultural practices/agricultural system in the context of environmental sustainability,

(vi) to work out the nature and extent of risk in various agricultural enterprises,

(vii) to identify the risk minimization strategies being adopted by the farmers,

(viii) to assess the divergence between private and social incentives and also the externalities of risk minimizing strategies of farmers on environmental settings,

(ix) to trace the changes in property rights and status of land ownership due to government policies and development interventions,*

(x) to document community based economic institutions and resource conservation practices in desert agriculture.

* *Later on dropped due to lack of data support.*

3. METHODOLOGY

The available secondary data on various aspects under study and also the primary data collected though structured questionnaire formed the data base for the study. The districtwise secondary data over the years for all the nine districts covered in the study area were collected. The primary data relates to 300 sample form household selected from the study area for the agricultural year 1999-2000.

3.1 TYPE OF DISTRICTWISE DATA COLLECTED (1951-52 AND 1997-98)

- Land use according to land use classes,
- Crop area, production and yield,
- Irrigated area (source wise)
- Fertilizer use
- Farm Energy Sources (Machines, draught animals)
- Infrastructure (Marketing, credits, input delivery)
- Social development (Schools, hospitals, colleges etc.)
- Communication facilities etc.
- Demographic data
- Livestock data.

The changes taking place in the natural resources alongwith human and livestock population would be associated with the development process for examining the sustainability aspects.

3.2 SOURCES OF SECONDARY DATA

The required secondary data were available from the following sources :

(i) Vital Agricultural Statistics (Published annually by the Dir. of Agriculture, Govt. of Rajasthan, Jaipur).

(ii) Statistical Abstract of Rajasthan (Published Annually by the Directorate of Economics & Statistics, Govt. of Rajasthan).

(iii) Revenue Records available at District H.Q., State Revenue Board.

(iv) Agricultural Census of Rajasthan (Published periodically by the Agricultural Census (Revenue Deptt.), Govt. of Rajasthan

(v) Other official/non-official records.

The primary farm level data were collected through appropriate sample survey techniques by engaging qualified Field Investigators.

3.3 TYPE OF PRIMARY DATA

Farm household level data on the following aspects for 300 sample farmers for one agriculture year were collected.

- Operational holding and tenancy system.
- Farm asset structure (physical & value) (land, buildings, wells/ tube wells, irrigation structure, farm animals, machines, implements etc.)
- Farm activitywise (crop, livestock, others) inputs (physical and labour) and also output (main & by-products).

3.4 METHOD OF SAMPLE SELECTION

The sample for primary data was selected through three stages viz., (i) tehsil (ii) village (iii) farm households. From the list of tehsils in each district, one tehsil each was randomly selected from the nine districts covered under the study area. From each of the 9 selected tehsils, one village was randomly selected. The list of village given in the Census District Handbook (1991) was used for this purpose. From each of the selected villages 30 farm households were selected (while selecting the farm households the willingness to share the information and representation to the existing farming systems in the villages were considered). Thus in all 270 farm households were selected. One extra village was selected from the command area of IGNP passing through the region and from this village also 30 farmers were selected. The distribution of 300 sample farm households according to access to water resources is as under :

Unirrigated farm situation		-	255
Partially irrigated farm situation		-	15
Irrigated farm situation		-	30
	Total	-	300

4. DATA ANALYSIS

The secondary and primary data collected on various aspects on desert agriculture were analysed using appropriate statistical techniques and economic concepts.

4.1 GROWTH MODEL

Linear and exponential growth models of the following were used to ascertain the pattern of trend in the time series data on area, production, yield of crops, land use pattern etc.

(i) $Y_t = a + bt$ - linear trend equation

(ii) $Y_i = Y_o b^t$ - exponential trend equation.

4.1.1 Growth Rates

The growth model of the following type will be used to work out the compound growth rates in area, production and yield of rainfed crops.

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Where,

Y_t = Yield/area/production of the crop at t^{th} year.

a = Constant term in the equation.

r = Compound growth rate per annum.

4.1.2 Instability Measure

The following measures of yield instability can be worked out

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Where,

SD(Yc) = Standard deviation of yield of the crop-c for the specified period.

AM(Yc) = Arithmetic mean of yield of the crop-c for the specified period.

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Where,

$SD(Yc)^*$ = Standard deviation of detrended yield of the crop for the specified period.

$AM(Yc)^*$ = Arithmetic mean of detrended yield of the crop for the specified period.

3. Yield instability index 3 (I_3) = $CV^2(1-R^2)$

Where,

CV = Coefficient of variation of yield of the crop

R^2 = Coefficient of determination of the trend equation for the original time series data on yield.

Based on the consistency in the indices, the extent of yield instability will be assessed.

4.2 YIELD RISK

The yield risk was assessed using the time series yield data as well as cross-sectional yield data. In both the cases the break-even yield concept was used.

The time some yield data of crop(s) were grouped into two.

(a) Number of years for which yield (Yt) was greater than breakeven yield (Yg). Let it be NS

(b) Number of years for which yield (Yg) was less than break even yield (Yb). Let it be Nf.

Ns + Nf + N

Probability of success (P) = Ns/N and

Probability of failure (q) = Nf/N were P+q = 1

4.3 ECONOMICS OF CROP FARMING

Concepts and Definitions of Terms Used in Working Out Economic of Crop Farming:

1. Operational Holding : This includes area actually cultivated (including current fallows) by the farmer and his family, irrespective of title or location

2. Net Area Sown : The area sown with crops and counting the areas sown more than once in the same year once

3. Gross Cropped Area : This represents the sum total of area covered by all the crops, area sown more than once during the year being counted as separate area for each crop.

4. Intensity of cropping : Ratio of gross cropped area to farm area.

5. Man-day : Unit of work equivalent to 8 hrs.of male adult worker.

6. Bullock pair-day : Unit of work equivalent to 8 hrs. work by a pair of bullock. One camel was treated equivalent to a pair of bullock.

7. Value of Assets : Farm assets includes value of self-cultivated owned land, farm buildings, wells, livestock, implements and machinery.

8. Inputs : These included

   (i) Wages oh hired labour (cash & kind)

   (ii) Imputed value of the family labour

(iii) Value of hired & owned bullock labour

(iv) Value of owned & hired machine labour

(v) Values of seed, manures and fertilizers (farm produced and purchased) plant protection material etc.

(vi) Irrigated charges.

(vii) Depreciation of farm buildings, machinery and implements

(viii) Rent paid for leased in land

(ix) Rental value of owned land

(x) Interest on working capital

(xi) Interest on owned fixed capital

(xii) Land revenue & cess etc.

9. Output : The entire gross produce was evaluated at harvest prices prevailing at the village or nearest market (net of transport and marketing charges)

Procedure for Evaluation and Allocation of Costs

(a) Evaluation of Farm Assets (Inventory) :

1. Farm Lands : Self-cultivated land evaluated at rates prevalent in the village taking into account the differences in type of soil, distance from village, source of irrigation available etc.

2. Farm Building : Evaluated at prevailing prices in the village. Present value assessed at the existing condition.

3. Implements and Machinery :(i) Home produced ones evaluated at the market prices. Present value at par to resale prices.

(ii) Evaluated at prevailing market prices.

4. livestock : Original purchase price plus appreciation or less depreciation in the case of purchased animals. Home breed animals evaluated at market prices. Even if the age of the animal exceeded 13

years at which age the animal was supposed to have depreciated fully, the prevailing market value was taken.

(b) Farm Input :

1. Human Labour

(i)	Casual Hired	:	Actual amount paid both in cash & kind, the latter evaluated at harvest prices, prevailing in the village. Perquisites, included in kind payments evaluated at market price.
(ii)	Permanent (Hired)	:	Actual amount paid both in cash and kind, the latter evaluated at harvest prices.
(iii)	Family Labour	:(a)	The cost of family labour imputed at the wage rate of the hired farm labour
		(b)	For working out the rate of family labour in the case of women an children, the man equivalent of female (75%) and child labour (50%) were utilized.

2. Bullock Labour

(a)	Hired Bullock Labour	:	Actual amount paid in cash and/or kind, the latter evaluated at harvest/or retail price.
(b)	Owned Bullock Labour	:	The per day rate was evaluated at market rates for the same category

3. Machine Labour

(a)	Hired	:	At actual rates paid by the farmers for tractor/thresher
(b)	Owned	:	At market rate for similar type

4.	Seeds	:	Purchased seed value at actual cost plus transport charges, if any. Farm produced seeds evaluated at market price.
5.	Irrigation Charges	:(i)	Owned oil engine/electric motor charges evaluated at market rates
		(ii)	Irrigation charges paid to the Government.

6.	Manures and Fertilizers	:	Farm produced manure valued at prevalent market prices. In the case of purchased manures and fertilizers actual purchase cost was taken along with transportation cost, if any.
7.	Rental Value of Owned Land	:	Evaluated on the basis of rent paid to similar land in the villages/one third of gross output.
8.	Interest on Fixed Capital	:	10% rate on capital farm goods.
9.	Interest on Working capital	:(i)	12% rate was computed
		(ii)	The period of interest on working capital was 3 months for all crops.

(c) Evaluation of Farm Output :

1. Depreciation

(a)	Farm Building	:	Divided amongst crops in proportion to the area under crop to GCA.
(b)	Implements	:	Divided amongst crops in proportion to the area under crop to GCA.
2.	Manures	:	Total effects accounted for the crop on which applied.
3.	Interest on Fixed Capital	:	In proportion to area under crop to GCA.

(a) Cost of Cultivation (Cost A) = Cost for human labour (hired)

+ Cost for bullock labour (hired & owned)

+ Cost for machine labour (hired & owned)

+ Cost for seed

+ Cost for farm yard manure

+ Cost for fertilizer

+ Cost for insecticides

+ Cost for irrigation

+ Interest on working capital

+ Depreciation

+ Land revenue

+ Rent for leased in land

Cost B = Cost A + Interest for fixed capital

+ Rental value of owned led

Cost C = Cost B + Value of family labour

(b) Output :

Gross value (G.V.) = Qm x Pm + Qb x Pb

Qm = Quantity of main product

Qm = Price of main product

Qb = Quantity of by product

Pb = Price of by product

(c) Net Income Measures :

(1) Form Business Income = GV - Cost A

(2) Family Labour Income = GV - Cost B

(3) Net Income = GV - Cost C.

4.4 COMPOSITE INDEX OF SUSTAINABLE AGRICULTURAL DEVELOPMENT

The set of n points may represent districts 1.2.... n for a group of k indicators 1. 2.... k. This can be represented by a matrix (X_{ij}) : i = 1.2.... n and j = 1.2... k. As the indicators of sustainable development included in the analysis are in different units of measurement and since the object is to arrive at a single composite index relating to the dimension in question, there is a need for standardization of the indicators. Hence the indicators are standardized as shown below :

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(i = 1. 2.... n)

(j = 1. 2 ....k)

(Z_{ij}) denotes the matrix of standardized indicators. The best district for each indicator (with maximum/minimum standardized value depending upon the direction of the indicator) is identified and from this the deviations of the value for each district are taken for all indicators in the following manner :

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Where Z_{oj} is the standardized value of the jth indicator of the best district and C_i denotes the pattern of sustainable development of ith district. The pattern of development is useful in identifying the district which serve as `models' and it also helps in fixing the potential target of each indicator for a given district. The above composite index will help to rank the districts in sequence in the context of sustainable development.

5. RESULTS AND DISCUSSION

Keeping in view the stipulated objectives of the study, the results are presented under following sub-heads so as to assess the environmental aspects of desert agriculture in the Western Dry Region of Rajasthan.

- Land resources
- Status of land ownership over time
- Human resources
- Livestock population
- Socio-economic development and infrastructural facilities
- Changes in operational holdings
- Temporal dimensions of crop production
- Inter-year yield instability of crops
- Crop production risk
- Economics of desert agriculture
- Divergence between private and social institution
- Externalities of agriculture activities
- Community based economic institution and resource conservation practices.

5.1 LAND RESOURCES

The land use pattern of the 9 districts covered in the Western Dry Region of Rajasthan is given in Table 1.

The meagre coverage of area under forest in the district of western dry region is

evident. Barring Jhunjhunu and Sikar districts, the forest cover is remarkably low in the district covered under this region. In districts like Barmer, Churu, Jaisalmer, Jodhpur and Nagaur, not even one per cent of the geographical area fall under forest. The share of area earmarked for non-agricultural use is less than that at the state level in all the districts covered under this region except Bikaner. The share of area falling under pasture and grazing land varies between 1.72 per cent of geographical area in Bikaner to 7.22 per cent of geographical area in Barmer. In the districts like Bikaner, Churu, Jaisalmer, Jalore and Nagaur the share of pasture land to geographical area is less than the state's share in this category of land. In fact a large chunk of area in Jaisalmer, Bikaner and Barmer is earmarked as culturable waste land. Water is the most limiting resource to bring these land under cultivation. The share of fallow land, current fallow and other fallow, is remarkably high in the districts of Barmer, Bikaner, Churu, Jalore, Jodhpur, Nagaur and Sikar. As far as the share of net sown area to geographical area is concerned, it varies from 8.75 per cent in Jaisalmer to 81.54 per cent in Churu. The large coverage of sown area in the desert belt in the districts like Churu (81.54%), Jhunjhunu (73.84%), Nagaur (70.57%) and Sikar (68.58%) is a matter of great concern.
Sand stabilization

Table 1. Land Use Pattern of Districts in the Western Dry Region of Rajasthan (1996-97)

District	Share of area to geographical area (% to geo-area)									Geo area (Lakh ha)
	Forest	Non. Ag. use	Barren & Uncultivated land	Permanent pasture & grazing land	Land under Misc. trees	Culturable waste land	Other fallow land	Current fallow land	Net Sown area	
Barmer	0.88	2.56	4.66	7.22	0.01	8.53	13.82	10.02	52.29	27.37
Bikaner	2.77	8.79	1.40	1.72	Neg.	29.75	6.28	5.46	43.83	27.12
Churu	0.40	4.33	0.04	2.76	"	0.83	4.51	5.58	81.54	16.87
Jaisalmer	0.59	2.29	9.59	2.80	"	72.67	1.98	1.46	8.75	38.44
Jalore	1.77	3.49	8.40	4.33	0.01	2.31	10.95	9.49	59.23	11.70
Jhunjhunu	6.68	3.33	2.62	6.83	0.01	1.04	3.12	2.51	73.84	5.91
Jodhpur	0.31	3.32	6.48	5.55	0.01	1.22	14.85	12.59	55.67	22.72
Nagaur	0.87	4.72	3.47	4.06	0.02	0.67	4.58	11.03	70.57	17.83
Sikar	7.69	4.11	2.28	5.38	0.02	1.14	4.59	6.21	68.58	7.84
State Average	7.23	4.92	7.73	5.07	0.04	14.73	5.90	5.33	49.4	342.38

process to overcome the problem of shifting sand dunes on one side and the frequent tillage of the soil particularly with tractor for crop cultivation, are conflicting activities. In fact those areas which is not frequently ploughed for cultivation appear more stabilized with number of plant species having fodder, medicinal, oil and other uses. These plant species are locally known as `bhui', `sewan', `aakada', `murut', `ker', `ber', `khajri', `sanithra', `keep', `baker', `burant', `lanno', `gandia', `jhal', `kiroli', `thumpa`, `kaliblui', `dhamasa', `murada', `khandala', `jinjali' etc. Besides, tree, species like `khejri', `neem', `kikar', `pipal', `rohida', `bargad', `sisam' are also grown on farm and other type of land. However, wherever frequent ploughing is done under rainfed condition the shifting sand dunes are more common.

The increasing requirement of food grains for food security of the people and fodder for the fodder security of animals make it necessary to put more and more area under plough. The high risk in crop farming is also a factor compelling the farmers to put more area under crops.

The strategic approach pursued during the planned era for the development of agricultural sector included appropriate support through technologies, institutions and policies. The agricultural activities including crop and animal husbandry and also the land resources were covered under in the ambit of such strategic development. The changes taken place in the land use pattern in the nine districts covered under the Western dry region are given in Table 2. Though the forest coverage in the nine districts increased by 227 per cent during the last 30 years, still the forest cover is only 1.6 per cent of the geographical area. The increase in the land put under non-agricultural uses during the period is 41 percent. The drastic reduction in the land categorized as barren and uncultivated is mainly due to major changes in the classification of barren land to culturable waste land in Jaisalmer district during mid-seventies.The changes in the size of land categorized as permanent pasture and grazing land have only been marginal in most of the districts. However there has been substantial reduction in the size of culturable waste land in Bikaner, and this reduction has been gradual in nature. On the other hand the size of culturable waste land in Jaisalamer increased abruptly in mid-seventies due to shift of barren land to culturable waste land. While in districts like Barmer, Churu, Jalore, Jodhpur and Nagaur the old fallow land was found declined, the same in other districts was found increased over time. The net sown area has shown

remarkable increase in districts like Barmer, Bikaner, Churu, Jaisalmer, Jodhpur and Nagaur. The net sown area remained 41 per cent of the combined geographical area of 9 district in 1966-67 which increased to 49 per cent in 1997-98. In district Churu about 82 per cent of geographical area remained under plough in 1997-98. Similarly in Jhunjhunu 75 per cent and in Nagaur 73 per cent and in Sikar 70 per cent of geographical area remained under plough. The relatively higher share of sown area to geographical area in district like Churu, Jhunjhunu, Nagaur, Sikar is a matter of grave concern. On one side the seasonal ploughing of the area reduces the scope for sand stabilization process in these districts and in the other hand it stands in the way of sparing land for activities such as arid forestry, grazing etc.

The annual compound growth rates in various land use classes according to the temporal phases (i) 1956-67 (pre-green-revolution period) (ii) 1967-80 (Post-green revolution period (iii) 1980-97 (Recent period) are given in Table 3.

Table 2 Land Use Pattern of Districts Covered Under Western Dry Region 1966-67 & 1997-98
(Area : 000'ha)

District	Forest	Non. Ag. use	Barren & Uncultivated land	Permanent pasture & grazing land	Land under Misc. trees	Culturable waste land	Other fallow land	Current fallow land	Net Sown area	Geo area
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Barmer										
1966-67	11	55	157	200	1	381	423	324	1264	2816
1997-98	26	22	130	206	-	232	364	252	1535	2817
Bikaner										
1966-67	10	99	17	28	-	1736	135	87	621	2733
1997-98	77	241	398	45	-	792	224	119	1197	2734
Churu										
1966-67	1	88	1	28	-	117	138	130	1182	1685
1997-98	7	73	1	46	-	13	72	84	1390	1686
Jaisalmer										
1966-67	19	48	1635	77	-	1820	65	34	185	3883
1997-98	22	98	365	104	-	2784	82	55	328	3839
Jalore										
1966-67	5	35	94	51	-	19	85	102	666	1057
1997-98	19	40	84	46	-	29	101	83	657	1056
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Jhunjhunu										
1966-67	26	9	32	46	-	8	9	18	444	592

1997-98	40	20	15	40	-	6	17	13	441	592
Jodhpur										
1966-67	2	90	138	114	2	26	451	322	1105	2250
1997-98	7	75	146	126	-	46	344	269	1243	2256
Nagaur										
1966-67	1	74	78	82	-	9	105	233	1182	1764
1997-98	20	83	60	71	-	13	75	165	1280	1764
Sikar										
1966-67	10	22	61	50	-	19	22	52	539	775
1997-98	60	32	18	42	-	9	33	42	538	775
Total for 9 districts										
1966-67	85	520	2213	676	3	4135	1433	1302	7188	17555
1997-98	278	734	858	726	-	3924	1312	1082	8609	17519

Table 3. Compound Growth Rates in Land Use Classes According to Temporal Phases in the Western Dry Region of Rajasthan (1956-97)

(Percent/year)

District	Temporal phases	Forest	Non. Ag. use	Barren & Uncultivated	Permanent pasture & grazing land	Land under Misc. trees	Culturable waste	Other fallow land	Current fallow land	Net Sown area
Barmer	1956-67	-3.50	-1.33	-0.03	8.33	-	2.12	-2.35	-7.75	2.44
	1967-80	2.25	0.58	-1.05	0.62	-	-0.87	-3.98	-2.67	3.03
	1980-97	2.98	1.06	-0.34	-0.28	-	-2.31	0.69	0.11	0.32
Bikaner	1956-67	3.41	9.08	-0.80	16.56	-	-1.10	-3.26	-1.29	5.47
	1967-80	5.69	1.59	-	3.22	-	-1.84	1.34	1.74	3.83
	1980-97	3.93	5.99	5.58	0.97	-	-2.95	-0.80	0.61	1.97
Churu	1956-67	-	1.27	-	8.20	-	-4.80	-5.90	-2.49	2.17
	1967-80	16.95	-1.16	2.31	1.14	-	-6.47	-0.29	2.49	-0.37
	1980-97	0.98	0.11	-3.54	-0.15	-	-6.71	-3.73	-1.49	0.57
Jaisalmer	1956-67	0.69	-2.67	0.23	5.09	-	0.02	-9.68	16.45	9.98
	1967-80	11.67	-1.30	-14.17	1.34	-	5.41	-6.87	-9.65	6.89
	1980-97	-0.58	3.11	0.30	1.12	-	-0.25	-0.34	0.48	2.61
Jalore	1956-67	-13.46	-1.10	1.39	0.25	-	-3.86	-3.17	-5.08	1.93
	1967-80	11.95	0.26	-0.86	-0.06	-	-8.09	2.13	0.05	-0.07
	1980-97	0.63	0.46	0.26	-0.88	-	13.93	0.12	-0.01	0.19
Jhunjhunu	1956-67	-13.64	5.46	13.41	0.15	-	-4.85	-5.75	0.26	0.35
	1967-80	1.10	5.11	-3.87	-0.23	-	-3.77	7.99	6.16	-0.42
	1980-97	0.76	1.38	0.15	-0.83	-	-2.84	8.25	-2.29	0.02
Jodhpur	1956-67	-18.46	-3.95	3.10	10.71	-	-6.60	-2.65	-3.60	2.42
	1967-80	2.46	-0.41	-0.09	-0.05	-	2.98	0.27	-2.30	0.42
	1980-97	4.38	-0.08	0.004	0.26	-	-5.84	-1.80	-0.26	0.99
Nagaur	1956-67	-	1.01	-1.53	2.06	-	-6.12	-6.20	-1.35	1.35
	1967-80	18.57	1.26	-2.54	-0.66	-	-10.02	-0.37	2.43	-0.42
	1980-97	-0.61	0.32	0.49	-0.51	-	-4.49	-1.85	-1.94	0.57
Sikar	1956-67	5.24	0.36	-1.03	-0.24	-	-2.53	-1.53	-2.21	0.46
	1967-80	2.14	0.87	-0.35	-0.17	-	-2.72	6.63	5.21	-0.96
	1980-97	9.91	1.24	-8.15	-0.83	-	-3.25	-0.43	-2.49	0.34

The area under forest has shown consistent positive growth in Bikaner, Churu, and Sikar districts. The area under forest was found to have positive growth during 1967-80 in all the district showing that the afforestation programme launched during this period was having positive impact in all the districts. In Barmer, Jalore, Jhunjhunu, and Jodhpur the pre-green revolution period emerged with negative growth in forest area and in Jaisalmer and Nagaur the forest area was found declining from 1980. While in most of the districts the land put to non-agricultural uses was increasing, in Jodhpur the land earmarked for nonagricultural uses was found declining. In Sikar and Barmer districts the barren land has been consistently declining and as such land was being put under other purposes. It is remarkable to note that the barren land has been increasing in the recent past in the districts like Bikaner, Jaisalmer, Jalore, Jhunjhunu and Nagaur. Decline in pasture land during the recent past is evident in Barmer, Churu, Jalore, Jhunjhunu, Nagaur and Sikar as such land is being put under other uses.

The land earmarked as culturable waste land has been steadily declining in Barmer, Bikaner, Churu, Jhunjhunu, Nagaur and Sikar. Evidently such land has been diverted for cultivation purposes due to the growing pressure of human and livestock population in all these districts. The decline in other fallow land (one to five year duration) in most of these districts is also attributable to the growing pressure of human and livestock population. The net sown area showed positive growth in almost all the districts, particularly during the recent past.

5.2 HUMAN RESOURCES

The size, density and decadal growth rates of the population in the nine districts covered under the western dry region of the state are given in Table 4 and the literacy rates, and break-up of workforce for the year 1981 and 1991 in these districts are given in Table 5.

The decadal growth rates did not reveal any definite trend during the last five decades in any of these districts. However, the decadal growth rates of population in these districts have been very high during the decades ending 1981 as well as 1991. Except for Jalore in all other districts the decadal growth rates of population for the period

ending 1991 were much higher to the state average growth rate of population.

Table 4. Total Population, Density and Decadal Growth Rate of Population in the Districts Covered Under Western Dry Region of Rajasthan

Particulars	1951	1961	1971	1981	1991
BARMER					
1. Total Population (in lakh)	4.77	6.49	7.75	11.19	14.35
2. Density (No./Sq.Km.)	18	23	27	39	51
3. Decadal Growth Rate (%) (Year ending)	20.98	36.14	19.24	44.41	28.27
BIKANER					
1. Total Population (in lakh)	3.42	4.44	5.73	8.49	12.11
2. Density (No./Sq.Km.)	14	16	21	31	44
3. Decadal Growth Rate (%) (Year ending)	8.76	30.02	28.94	48.09	42.70
CHURU					
1. Total Population (in lakh)	5.23	6.59	8.74	11.79	15.43
2. Density (No./Sq.Km.)	84	39	52	70	92
3. Decadal Growth Rate (%) (Year ending)	14.97	25.94	32.68	34.88	30.84
JAISALMER					
1. Total Population (in lakh)	1.11	1.40	1.66	2.43	3.44
2. Density (No./Sq.Km.)	7	4	4	6	9
3. Decadal Growth Rate (%) (Year ending)	10.18	25.91	18.83	45.77	41.73
JALORE					
1. Total Population (in lakh)	4.24	5.47	6.68	9.03	11.43
2. Density (No./Sq.Km.)	40	52	62	85	107
3. Decadal Growth Rate (%) (Year ending)	NA	29.2	35.20	35.20	26.52
JHUNJHUNU					
1. Total Population (in lakh)	5.88	7.20	9.29	12.12	15.82
2. Density (No./Sq.Km.)	98	121	154	204	267
3. Decadal Growth Rate (%) (Year ending)	NA	22.30	29.10	30.39	30.61
JODHPUR					
1. Total Population (in lakh)	6.72	8.86	11.53	16.68	21.53
2. Density (No./Sq.Km.)	29	39	50	73	94
3. Decadal Growth Rate (%) (Year ending)	NA	31.88	30.15	44.68	29.12
NAGAUR					
1. Total Population (in lakh)	7.64	9.35	12.62	16.29	21.45
2. Density (No./Sq.Km.)	NA	137	71	100	121
3. Decadal Growth Rate (%) (Year ending)	NA	22.40	34.99	29.04	31.69
SIKAR					
1. Total Population (in lakh)	6.77	8.20	10.43	13.77	18.43
2. Density (No./Sq.Km.)	223	106	135	178	238
3. Decadal Growth Rate (%) (Year ending)	10.04	21.19	27.10	32.09	33.81

Table 5. Literacy Rates and Break-up of Work-force in the Districts Covered Under Western Dry Region of Rajasthan

Particulars		Barmer		Bikaner		Churu		Jaislmer	
		1981	1991	1981	1991	1981	1991	1981	1991
1.	Literacy (%)								
	Person	12.29	18.33	28.20	33.35	21.86	27.30	15.80	24.02
	Male	20.04	29.21	37.66	43.83	33.34	40.07	24.35	36.18
	Female	3.71	6.12	17.57	21.51	9.81	13.66	5.25	8.95
2.	Share of SC (% to total)	15.63	15.70	18.35	18.64	19.55	20.13	14.52	14.55
3.	Share of ST (% to total)	5.10	5.87	0.18	0.26	0.48	0.51	4.39	4.85
4.	Main Workers (in lakh)	3.56	4.82	2.48	3.62	3.48	4.63	0.78	1.02
	Cultivator (%)	78.29	79.18	52.88	53.69	73.17	71.41	58.49	46.18
	Ag. Labour (%)	2.83	3.65	2.60	5.51	3.16	4.62	3.34	8.28
	Other Workers (%)	18.88	17.17	44.43	40.79	23.66	23.97	38.17	45.54
5	Marginal Workers (in lakh)	1.06	1.55	0.32	0.72	0.64	1.32	0.10	0.25

Particulars		Jalore		Jhunjhunu		Jodhpur		Nagaur		Sikar	
		1981	1991	1981	1991	1981	1991	1981	1991	1981	1991
1.	Literacy (%)										
	Person	13.70	18.76	28.61	37.76	26.64	32.68	19.38	25.28	25.43	33.13
	Male	22.43	30.64	45.07	53.96	37.71	45.69	31.13	39.10	41.16	49.70
	Female	4.43	6.15	11.40	20.35	14.47	18.08	7.11	10.60	9.08	15.60
2.	Share of SC (% to total)	17.01	17.79	17.91	15.35	15.51	15.27	19.18	19.73	13.75	14.01
3.	Share of ST (% to total)	8.01	8.43	1.90	1.93	2.40	2.82	0.18	0.22	2.65	2.65
4.	Main Workers (in lakh)	2.66	3.65	3.03	3.86	5.10	6.61	5.39	7.17	3.39	4.62
	Cultivator (%)	69.25	68.72	49.27	55.51	58.93	53.37	71.86	68.46	61.82	57.36
	Ag. Labour (%)	11.47	13.63	4.78	8.76	5.44	6.82	5.63	8.10	4.40	6.99
	Other Workers (%)	19.28	17.65	45.95	35.73	35.63	39.81	22.50	23.44	33.78	35.65
5	Marginal Workers (in lakh)	0.39	1.06	1.13	1.43	0.54	1.25	0.77	1.35	0.86	1.21

The highest decadal (1981-91) growth was recorded in Bikaner with 42.7 percent. The high growth rate of population in the desert area could be attributable to low literacy rates of the population in general and female population in particular. The exorbitant growth in the population in the resource fragile area is going to increase the pressure on land through agriculture based activities. The density of population in 1991 varied from 9 persons/Sqkm in Jaisalmer to 267 persons/Sqkm in Jhunjhunu.

The female literacy in 1991 was as low as 6.12 per cent in Barmer.The low literacy level of the population in general and females in particular is indicative of limited scope to shift workforce from primary agriculture based activities to other sectors.

The work-force pattern show in Table 5 revealed that the relative share of agricultural labourers to total workers increased in 1991 as compared to 1981 in all the 9 districts covered in this region. The increase in the marginal workers with sub-optional work days in a year (less than 183 days in a year) is also quite alarming in all the 9 districts.The relative share of cultivators to total workers was found less in 1991 over 1981 in districts such as Churu, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Nagaur and Sikar.

The high growth rate of population coupled with increase in agricultural labourers and marginal workers in this eco-fragile area is likely to pose severe unemployment problems in the rural areas. The remarkably low literacy level of the population in general and female population in particular limits the scope for any substantial shift of workforce from agriculture to non-agricultural sector. The increased burden on agriculture by the growing population is likely to adversely affect all efforts made to arrest desertification in this belt.

The ratio of rural-urban population (1991) remained at 77.4:22.6 in the Western Dry Region which is very close to the ratio of the same at state level. There were about 20.70 lakh households in this region which is 28.40 per cent of total households at state level. Against the state level density of 129 persons/sq.km at the state level, the density in this region was only 76 persons/sq.km.

5.3 LIVESTOCK POPULATION

The "Thar" desert has animal dominant eco-system, where "eco" has equal relevance for ecology and economy. The small ruminants like sheep and goat dominate the livestock population in almost all the 9 districts. Cattle, buffalo and camel also have sizeable population in these districts. The changes in livestock population over the years in absolute terms and also in terms of density can be seen from Table 6. The animal population has gone up by more than double during the last 40 years in the districts like Barmer, Bikaner, Churu, Jaisalmer and Jodhpur. In fact, these districts are more arid with very high risk in crop farming. In the districts like Jalore, Jhunjhunu, Nagaur and Sikar crop based agriculture is equally dominant. In these districts also the livestock population has increased over the years. The acute drought situation generally brings down the livestock population due to distress sale, migration etc. The 1987 unprecedental drought reduced the number of animal population in almost all the districts, but in varying magnitude.

Table 6. Livestock Population and Density in the Districts Covered Under Western Dry Region over the Years

Year	Barmer		Bikaner		Churu		Jaisalmer		Jalore	
	No. (Lakh)	Density (No. Sq.Km)	No. (Lakh)	Density (No. Sq.Km)	No. (Lakh)	Density (No. Sq.Km)	No. (Lakh)	Density (No. Sq.Km)	No. (Lakh)	Density (No. Sq.Km)
1956	17.30	62	9.49	35	9.93	59	8.50	22	12.03	114
1958	19.48	69	10.54	38	9.83	58	7.68	20	16.22	154
1961	21.05	75	9.04	33	9.73	58	9.88	26	11.85	112
1964	22.80	81	10.45	38	9.73	58	9.87	26	13.67	129
1966	21.21	75	11.19	41	11.42	68	11.99	31	13.97	132
1972	19.74	70	8.99	33	14.26	85	6.16	16	12.35	117
1977	25.32	90	15.35	56	15.75	93	13.00	34	13.22	125
1983	31.84	113	20.75	76	21.29	126	16.31	42	11.15	106
1988	16.20	58	16.93	62	15.55	92	9.57	25	11.78	112
1992	31.57	112	20.07	73	16.88	100	14.18	37	16.90	160
1997	41.77	148	25.31	92	20.99	125	24.77	65	18.14	172

Year	Jhunjhunu		Jodhpur		Nagaur		Sikar	
	No. (Lakh)	Density (No. Sq.Km)	No. (Lakh)	Density (No. Sq.Km)	No. (Lakh)	Density (No. Sq.Km)	No. (Lakh)	Density (No. Sq.Km)
1956	7.84	132	14.39	64	17.25	98	10.69	129
1958	7.28	123	10.61	47	19.54	111	10.19	122
1961	8.06	136	14.40	64	15.48	88	11.92	144
1964	7.37	124	17.17	76	18.74	106	11.32	136
1966	7.86	133	17.55	78	15.10	86	12.95	159
1972	9.78	165	18.93	84	23.04	131	15.84	197
1977	9.68	164	24.42	108	23.72	134	13.61	176
1983	11.76	199	26.66	118	30.56	173	17.59	227
1988	9.99	169	18.30	81	24.65	140	14.23	184
1992	10.65	180	27.78	123	28.03	159	15.21	196
1997	12.48	211	37.89	168	32.28	183	17.98	232

The current livestock density is more than human density in all the districts except Jhunjhunu and Sikar. The large number of human population in the eco-fragile region is a cause for problems related to food security and livestock population which is more than human population poses problems related to fodder security.

The composition of livestock population during 1956 and 1997 can be seen from Table 7. The proportion of buffalo and goat population in most of the districts has gone up. Drastic decline in the proportion of cattle population in all the districts is evident.The fodder problems coupled with lack of economic uses of male cattle could be the cause for such a drastic decline in the cattle population. The proportion of buffalo population has also gone up in all the districts except in Bikaner and Jaisalmer. The proportion of sheep population remained almost static in all the districts. Decline in the proportion of draught animals like camel and horses is also evident in all the districts.

The inclination for more and more mechanization could be the cause behind substitution of drought animals. The increase in the population of buffalo in this belt is going to push up the demand for cultivated fodder and also demand for fodder through crop residues. The steady increase in the net sown area in this region could be attributable to the increasing need for food for people and fodder for animals. The frequent ploughing of more and more land and that too with tractor is in no way going to help the process of sand stabilization in this area. The increased demand for food for

men and fodder for animals has direct bearing on the environmental setting of the desert belt of the state.

Table 7. Composition of Livestock Population (percent to total population) (1956 & 1997) (Per cent)

Animal Type	Barmer		Bikaner		Churu		Jaisalmer		Jalore	
	1956	1997	1956	1997	1956	1997	1956	1997	1956	1997
Cattle	27.44	12.97	26.05	22.11	27.52	15.64	27.46	12.52	26.70	15.85
Buffalo	1.44	2.23	4.27	4.24	9.70	9.88	0.16	0.06	5.99	17.41
Sheep	27.22	36.20	50.56	45.35	34.18	30.59	46.45	48.75	36.29	39.15
Goat	39.75	44.73	15.65	25.38	22.85	39.81	22.19	36.05	29.22	25.74
Donkey	1.07	0.98	0.28	0.45	0.25	0.39	1.25	0.85	0.55	0.40
Camel	2.96	2.73	3.14	2.39	5.43	3.48	2.40	1.73	1.01	0.76
Horse, Ponies & Mules	0.12	0.035	0.05	0.01	0.05	0.017	0.08	0.02	0.24	0.08
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total (Lakh/No.)	17.31	41.77	9.49	25.31	9.93	20.99	8.49	24.77	12.03	18.14

Animal Type	Jhunjhunu		Jodhpur		Nagaur		Sikar	
	1956	1997	1956	1997	1956	1997	1956	1997
Cattle	27.33	9.81	32.43	17.64	34.37	15.08	28.34	11.90
Buffalo	7.79	28.25	3.89	5.53	6.22	13.55	7.64	25.51
Sheep	21.60	17.85	40.15	41.18	38.94	36.29	21.74	17.04
Goat	37.64	40.97	21.29	34.21	19.21	33.73	32.55	43.20
Donkey	0.63	0.24	0.29	0.26	0.31	0.17	0.66	0.17
Camel	4.85	2.42	1.84	1.14	0.79	0.90	2.21	1.53
Horse, Ponies & Mules	0.67	0.04	0.09	0.01	0.09	0.03	0.07	0.05
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total (Lakh/No.)	7.84	12.48	14.39	37.89	17.25	32.27	10.69	17.98

5.4 SOCIO-ECONOMIC DEVELOPMENT INFRASTRUCTURE AND FACILITIES

There are about 8300 villages and 61 cities/towns in this belt of Rajasthan. Majority of the villages are with population above 500 in each village.

Very often famine assumes the form of a calamity in the western dry region of the state. The rural economy often suffers due to famine and droughts. During the years of famine and drought acute shortage of food, fodder and water is experienced. A number of government programmes were launched in the past to solve the problem of famine and draught in this belt. The Drought Prone Area Programme (DPAP) and Desert Development Programme (DDP) of the government were the two major programmes to help in reducing the intensity of famine and drought in this belt. The DPAP programme launched from 1974-75 was a centrally sponsored scheme financed by the centre and state on a 50:50 basis. The main objective of the programme was to ensure optimum utilization of land and water in drought programme areas and to minimize the ill effects of drought and scarcity condition on the economy of these areas. The Desert Development Programme (DDP) was started in 1977-78 as a programme financed by the centre. It's main objective was to arrest the process of desertification and to use the limited resources for drought proofing and also to improve the economy of the area. The programme included activities related to growing of desert trees, ground water development, fodder development, livestock development, water supply, rural electrification etc.

5.4.1 Irrigation

The pattern of average annual irrigated area in the Western Dry Region in relation to that in the state for the 8th five year plan period is given in Table 8.

The major chunk of irrigated area in this region is through ground water sources whose potential depends on the rainfall pattern. In the years of very low rainfall, the water level goes down and most of the wells get dried in the belt. The returns from huge investment made for digging of wells and fitting water pulling devices in such years become quite negligible in such years in this area.

Table 8 Average annual gross irrigated area by source during 8th five year plan (1992-97)

S.No.	Source	Net irrigated area ('000 ha)		Gross irrigated area ('000 ha)	
		Western dry region	State	Western dry region	State
1.	Canal	108	1410	170	1940
2.	Tanks	1	208	1	228
3.	Tubewell	111	540	141	597
4.	Wells	714	2442	861	2822
5.	Other sources	1	43	1	45
	Total	934	4642	1174	5632

5.4.2 Growth of Pump Sets and Electric Motors

The credit policy for developing agricultural infrastructure and the pattern of assistance under Drought Prone Area Progrmme (DPAP) and Desert Development Programme (DDP) launched in this belt made it possible to dig wells/tube wells and mechanize it with pumpsets and electric motors. The growth in pumpsets and electric motors could be seen from Table 9.

It is evident that the number of oil engine and electric motors has been growing at an exorbitant rate in the desert belt. In the absence of any policy restriction on groundwater exploitation, farmers resorted to digging of wells and mechanizing it with the credit availability through institutional and non-institutional sources. the adverse implication of such activities included drying of wells at a faster rate and the large investment made on wells, oil engine and electric motors become on a no return point.

Table 9. Growth in Mechanization of wells in the desert belt

S. No.	District	Year						
		1966	1972	1977	1983	1988	1992	1997
(A)	**Pumpset (Oil Engine)**							
1.	Barmer	310	1102	1434	3256	4619	5282	7987
2.	Bikaner	7	1	3	1	16	7	10
3.	Churu	15	6	1	1	13	6	286
4.	Jaisalmer	11	36	29	4	4	10	106
5.	Jalore	886	4249	9202	17324	25569	26766	32974
6.	Jodhpur	310	1311	1488	4524	4197	4822	5063
7.	Jhunjhunu	50	212	535	2231	3364	3351	3752
8.	Nagaur	88	781	707	3570	4501	4837	4635
9.	Sikar	124	922	1032	2646	6399	6780	4361
	Total	1801	8620	14431	33557	48682	51861	59174
(B)	**Electric Motor**							
1.	Barmer	32	357	718	1587	2048	5445	8341
2.	Bikaner	5	23	31	8	15	160	2430
3.	Churu	41	94	178	68	288	1527	5191
4.	Jaisalmer	3	-	8	18	12	88	541
5.	Jalore	34	421	1384	8068	11786	14531	22948
6.	Jodhpur	145	1184	1822	4441	5990	10342	16871
7.	Jhunjhunu	147	1569	4365	9935	17753	20237	33687
8.	Nagaur	101	1422	2936	6925	9701	17371	33923
9.	Sikar	186	2263	6534	16688	21932	29076	40992
	Total	694	7333	17976	47738	69525	98777	164924

5.4.3 Socio-Economic Infrastructure for Development

The magnitude of various socio-economic and development infrastructure in the desert districts of Rajasthan could be seen from Table 10.

The extent of irrigated area to sown area in the belt is 10.94 which varies from 2.2 per cent in Churu district to 46.94 per cent in Jalore. The level of fertilizer use is only 10 kg/ha for the region as a whole which again varies from 1 kg/ha in Churu to

Table 10. Magnitude of socio-economic and infrastructural facilities in western dry region

S. No.	District	Percent of irrigated to net sown area (1996-97) (%)	Fertilizer consumption (1997-98) (kg/ha)	Commercial bank including RRB, (1997) (Nos.)	Large & medium industries (1995) (Nos.)	Small industries (1995) (Nos.)	No. (1996-97) of schools					Road Length (1996) (km.)	Villages connected by roads (1996)	
							Primary (No.)	Hr.Prm. (No.)	Sec. (No.)	Pr.Sec. (No.)	Total (No.)		Total No.of villages	Connected by road
1.	Barmer	4.55	1.82	75	-	3374	1608	408	80	23	2119	4522	1625	855
2.	Bikaner	10.23	15.97	128	6	5773	833	315	116	29	1303	3155	580	358
3.	Churu	2.20	0.89	116	2	4363	953	420	105	48	1526	2254	926	527
4.	Jaisalmer	5.71	4.37	36	-	1340	446	132	26	9	613	2936	518	302
5.	Jalore	46.84	17.64	66	2	2754	701	272	57	22	1052	2036	665	533
6.	Jodhpur	35.59	7.74	91	4	3954	1053	570	170	84	1827	2057	824	546
7.	Jhunjhunu	8.89	15.82	155	14	11427	1364	554	151	67	2136	4937	860	771
8.	Nagaur	17.76	13.82	131	5	10772	1380	510	156	48	2094	4313	1374	963
9.	Sikar	31.89	12.44	111	3	4864	1182	459	170	47	1858	2152	931	572
	Total	10.94	9.97	909	36	48618	9520	3640	1031	377	14528	28362	8303	5427

17.6 kg/ha in Jalore. For every 9 villages, there is one commercial bank. The total number of primary schools in this belt exceeds the number of villages. However, the number of higher educational institutions does not appear to be on the required norms. About two third of the villages in this belt are connected by road.

There are about 3850 fair price shops in the rural areas and 1377 such shops in urban areas. Despite the great need for warehousing facilities, such facility is available for 39640 tonnes only, out of which more than 60 per cent is used. There are about 3300 post offices, 866 telegraphic offices, 387 telephone exchanges in this area. During mid-nineties there were about 15 central non-credit cooperative societies in this area with membership of 54304. Besides, there were about 1623 agricultural credit cooperative societies and 400 agricultural non-credit societies in this area. There were about 1390 dairy cooperative societies under the dairy sector.

There were about 33 Krishi Upaj Mandi with 63 sub yards to cater the needs of marketing of agricultural produce. In order to take care of the health and family welfare there were about 71 hospitals, 69 dispensaries and 447 primary health centers spread over the region.

5.5 CHANGES IN OPERATIONAL HOLDING

The decadal changes in the number and area covered under the operational holdings in the districts of western dry region could be seen from Table 11.

The total number of operational holdings in the 9 districts was 9.20 lakh in 1970-71 which increased to 14.98 lakh in 1995-96. Similarly the operational area was 103.77 lakh hectares in 1970-71 which increased to 112.64 lakh hectares in 1995-96. In the desert districts like Barmer, Bikaner, Jaisalmer, Jalore, Jhunjhunu, Nagaur and Sikar the number of operational holdings has been increasing on a regular manner. As far as the operational area is concerned, it has been increasing on a regular basis in the districts of Bikaner and Jaisalmer.

The increasing dependence of work force for crop based activities is evident. The very low literacy rate in the rural area limits the scope to divert work force from agriculture to other sector. The increased dependence of workforce on agriculture is likely to pose

environmental problems in this eco-fragile area.

5.6 TEMPORAL DIMENSIONS OF CROP PRODUCTION

Food security for man and fodder security for animals are the major considerations behind the corp production strategy in this area. The failure of crops either partially or fully is not uncommon in this belt. As a remedy to overcome the high risk in crop production, farmers generally resort to the production of such crops for which cost of cultivation is minimum. The major crops generally grown in various combinations of mixed crops are bajra, moth-bean, cluster bean (guar), sesamum (til), and green gram (moong). The mixed cropping pattern of growing all or some of these crops on the same plot has dual purpose. Firstly, it acts as a means for food security as cereals, pulses, oilseeds and commercial crops like guar are included in the crop mix. Secondly, the moisture requirement is though low for all these crops but the survival probability is different at different moisture level. Hence even at low rain fall survival of few crops is made possible.

The cropping pattern in terms of crop commodities like cereals, pulses, oilseeds, guar and other crops during 5th (1974-79) and 8th (1992-97) five year plan is presented in Table 12.

Table 11. Changes in the Number and Area Covered Under Operational Holdings in the Western Dry Region of Rajasthan

District	1970-71		1980-81		1990-91		1995-96	
	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)
Barmer	106090	2091924	151369	2334666	165692	2281342	182799	2273746
Bikaner	47898	1057664	95479	1406610	116954	1409915	145898	1580742
Churu	101698	1497896	96569	1223361	142037	1543052	161929	1548208
Jaisalmer	20920	514532	33585	570631	39376	607871	51268	671421
Jalore	95246	850508	128095	960666	131081	817468	133407	804927
Jhunjhunu	101072	477536	120761	548563	149830	459830	165703	463562
Jodhpur	136921	1756118	135556	1520006	192814	1788656	207277	1808609
Nagaur	177115	1509121	218644	1562897	238944	1483196	251375	1498780
Sikar	133067	622074	140714	513687	181836	612284	198291	611280
Total	920027	10377373	998972	10641087	1358564	11003614	1497947	11261275

Table 12 Cropping Pattern over Plan Periods in the Districts in the Western Dry Region (Area in '000 ha.)

Districts	Cereals		Pulses		Oilseeds		Guar		Other		Gross crop seed area	
	Vth Plan	VIII Plan	Vth Plan	VIII Plan	Vth Plan	VIII Plan	Vth Plan	VIII Plan	Vth Plan	VIII Plan	Vth Plan	VIII Plan
Barmer	8274	894.42	129.6	235.56	22.01	27.32	358.6	383.54	20.39	72.60	1358	1613.44
	(60.93)	(55.44)	(9.54)	(14.60)	(1.62)	(1.69)	(26.41)	(23.77)	(1.50)	(4.50)	(100)	(100)
Bikaner	216.6	300.96	313.8	323.08	18.2	75.86	53.8	117.3	166	380.05	768.4	1197.25
	(28.19)	(25.14)	(40.84)	(26.99)	(2.37)	(6.34)	(7.00)	(9.79)	(21.60)	(31.74)	(100)	(100)
Churu	377.6	442.98	488.4	514.88	3.00	17.26	339.2	419.36	78.4	13.60	1286.6	1408.08
	(29.35)	(31.46)	(37.96)	(36.57)	(0.23)	(1.23)	(26.36)	(29.78)	(6.09)	(0.97)	(100)	(100)
Jaisalmer	127.2	163.46	0	1.22	0.2	10.92	43.8	115.92	1.0	49.66	172.2	341.18
	(73.87)	(47.91)	(0.0)	(0.35)	(0.116)	(3.20)	(25.44)	(33.97)	(0.58)	(14.55)	(100)	(100)
Jalore	303.4	335.58	64.8	66.16	70.42	163.85	154.6	221.0	43.18	15.87	636.4	802.46
	(47.67)	(41.82)	(10.18)	(8.24)	(11.07)	(20.42)	(24.29)	(27.54)	(6.79)	(1.98)	(100)	(100)
Jhunjhunu	211.2	283.58	243.2	121.0	5.0	72.63	47.0	43.98	24.0	54.69	530.4	575.88
	(39.82)	(49.24)	(45.85)	(21.01)	(0.94)	(12.61)	(8.86)	(7.64)	(4.52)	(9.49)	(100)	(100)
Jodhpur	585.6	696.3	199.6	244.8	58.0	123.18	145.8	47.48	138.2	207.19	1127.2	1318.95
	(51.95)	(52.79)	(17.71)	(18.56)	(5.15)	(9.34)	(12.93)	(3.60)	(12.26)	(15.71)	(100)	(100)
Nagaur	585.5	601.71	320.6	310.0	87.8	222.42	181.2	143.48	30.8	74.89	1206.2	1352.51
	(48.57)	(44.49)	(26.58)	(22.92)	(7.28)	(16.44)	(15.02)	(10.61)	(2.55)	(5.54)	(100)	(100)
Sikar	243.8	333.94	184.6	127.88	6.2	46.54	121.8	117.24	12.2	19.66	568.6	645.26
	(42.88)	(51.75)	(32.47)	(19.82)	(1.09)	(7.21)	(21.42)	(18.17)	(2.15)	(3.05)	(100)	(100)

The average gross cropped area has increased in all the nine districts during 8th plan period as compared to 5th plan period. The area under cereal crops in absolute terms has increased in all the nine districts. However, the relative share of area under cereal crops in relation to gross cropped area has come down in the districts of Barmer, Bikaner, Jaisalmer, Jalore and Nagaur. The area under pulses also increased in all districts except Jhunjhunu, Nagaur and Sikar. As far as area under oilseeds are concerned, large increase was observed in Bikaner, Churu, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Nagaur and Sikar. The area under guar which has fodder, food and commercial value was found to decline in Jhunjhunu, Jodhpur, Nagaur and Sikar.

The estimated trend equations and compound growth rate in gross cropped area of districts covered in western dry region are given in Table 13.

Table 13. Estimated Trend Equation and Compound Growth Rate in Gross Cropped Area in the Districts of Western Dry Region

Districts	Period	Trend Equation	Sc(b)	R^2	CGR
Barmer	81-97	Y_t =1511.66-10.131t	20.31	0.0163	-2.27
Bikaner	81-97	Y_t =756.48-22.72t	8.88	0.3034	2.23
Churu	81-97	Y_t =1320.36+3.72t	5.89	0.0258	0.30
Jaisalmer	81-97	Y_t =192.37+6.94t	3.81	0.1808	2.73
Jalore	81-97	Y_t =676.26+6.72t	4.77	0.1170	0.94
Jodhpur	81-97	Y_t =1067.56+12.91t	7.67	0.1589	1.10
Jhunjhunu	81-97	Y_t =578.32+2.971t	1.97	0.1317	0.54
Nagaur	81-97	Y_t =1207.39+8.78t	2.85	0.3865	0.69
Sikar	81-97	Y_t =565.91+4.66t	1.70	0.331	0.77

Though positive trend in gross cropped area was found to exist in almost all the districts, the trend was found statistically significant in Nagaur, Sikar during 1981-1997.

The compound growth rates in area, production and yield of major crops during the temporal phases 1981-1998 are given in Table 14. As far as bajra crop is concerned, spectacular positive growth in production during 1981-98 as evident and the production growth in bajra is largely attributable to growth in the productivity of this crop.During the same period, guar production was also found to have high positive growth rate in

Barmer, Bikaner, Churu, Jalore, Jhunjhunu, Nagaur and Sikar. Except for Bikaner, the production growth for guar is largely attributable to yield growth. Similar trend in moong, moth and sesamum is also evident.

The large growth in the productivity for major kharif crops of the region could be attributable to the technological support as a result of continuous research, effective input delivery system and the favourable rainfall pattern during the past many years. However, the growth in yield alone is not an indicator for the prospects of crop production in this ecologically unfit area for ensured crop production. In order to measure the inter-year instability in the yield, the coefficient of variation of yield was calculated both for the actual yield data and also for the detrended yield for the temporal phases 1981 to 1998. The calculated coefficient of variation for the raw yield and detrended yield area given in Table 15.

Table 14 Compound Growth Rates in Area, Production and Yield of Crops in Western Dry Region (1981-98)

Districts	Bajra			Guar			Moong			Moth			Sesamum		
	A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
Barmer	-0.97	4.37	5.40	-0.35	11.06	11.45	3.82	18.07	13.73	10.99	23.82	11.56	2.33	15.17	12.55
Bikaner	0.09	21.02	20.90	6.41	4.62	-1.68	3.06	7.05	3.86	-0.67	2.81	3.51	4.03	NA	NA
Churu	0.35	5.80	5.42	1.27	8.17	6.81	7.35	14.13	6.31	-1.84	4.46	6.42	5.97	11.77	5.52
Jaisalmer	0.46	NA	NA	2.41	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.32
Jalore	1.08	9.40	8.22	1.85	12.27	10.23	3.11	-	-	11.47	-	-	5.99	19.15	12.41
Jhunjhunu	-0.16	2.59	2.75	3.92	12.23	7.99	7.09	24.91	16.63	-7.80	-2.98	5.23	NA	NA	NA
Jodhpur	0.56	13.98	13.34	NA	NA	NA	6.47	NA	NA	1.67	NA	NA	2.89	NA	NA
Nagaur	-0.49	5.67	6.19	-2.27	6.22	8.68	12.87	21.21	7.41	-0.42	6.11	6.57	0.94	8.38	7.37
Sikar	0.52	5.23	4.68	0.07	17.00	16.22	8.60	26.98	16.93	-5.91	6.11	12.78	13.37	19.57	5.46

Note : A = Area; P = Production; Y = Yield

The high coefficient of variation in the inter-year raw yield of different crops is indicative of large fluctuations in the yield over the years. In most of the cases the coefficient of variation of detrended yield are also very large indicating that the influence of temporal trend component in the total variation has not been very significant.

In fact, the crop production strategy in this area must aim to bring down the very high yield instability which in turn will cause for high risk in crop farming.

5.7 INTER-YEAR YIELD INSTABILITY OF CROPS

The yield instability measures have been worked out using the following three measures :

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Index 3 = $CV^2 (1-R^2)$ where,

CV = Coefficient of variation

R^2 = Coefficient of determination of the trend equation.

In order to work out the set of first index, the raw yield data for the years 1966-67 to 1997-98 for bajra, sesamum, gram and rapeseed and mustard and the same for the period 1974-75 to 1997-98 for moth, moong and guar were used. To work out the second set of index, the trend values were worked out based on the estimated linear trend equation. The tend was eliminated by assuming the multiplicative model of the components of time series data.

i.e. Y_t = T.S.C.I.

Where,

T = trend

S = seasonal variation

C = cyclical variation

I = Irregular fluctuations

Table 15 Coefficient of Variation in Yield of Crop in Western Dry Region (1981-98)

Districts	Bajra		Guar		Moong		Moth		Sesamum	
	RCV	DTCV	RCV	DTCV	RCV	DTCV	RCV	DTCV	RCV	DTCV
Barmer	82.85	89.15	95.11	90.29	73.60	92.81	109.77	103.48	83.61	96.18
Bikaner	114.90	124.68	114.37	90.14	38.21	33.69	56.80	56.65	123.47	98.35
Churu	61.55	52.89	48.18	52.73	61.04	62.11	60.27	57.17	53.00	48.72
Jaisalmer	149.21	152.69	140.28	115.53	110.56	109.20	153.47	170.56	52.70	48.22
Jalore	75.69	75.43	93.84	90.57	105.33	98.21	88.91	82.71	91.39	92.59
Jhunjhunu	51.70	52.22	88.97	105.96	96.11	102.82	109.81	109.41	NA	NA
Jodhpur	82.73	79.05	160.28	152.31	96.95	81.31	75.56	82.51	97.60	82.52
Nagaur	49.43	51.59	70.61	53.38	67.58	59.26	71.71	69.33	65.36	60.28
Sikar	43.44	40.02	111.08	307.2	92.91	122.72	157.29	149.87	52.95	48.66

Note : *RCV = Coefficient of variation of raw yield data*

DTCV = Coefficient of variation of detrended yield data

Detrending was done using the formula

Install Equation Editor and double-click here to view equation. 16

Where,

Y^*_t = detrended yield

Y_t = original yield data

Y_t = estimated yield using linear trend equation.

The set of third indices was worked out using the C.V. values obtained from first indices and the coefficient of determination obtained from the linear trend equations used for working out the second index.

The crop wise and district wise instability indices worked out on the above lines are presented in Table 16, 17 and 18 respectively.

Table 16. Instability Indices (Index 1) of Yield of Crops Across Districts [(SD/AM) x 100]

District	Crops						
	Bajra	Moth bean	Green gram	Sesamum	Cluster bean	Gram	Rapeseed & Mustard
Barmer	92.89	123.35	111.03	88.74	133.43	26.54	33.27
Bikaner	123.92	86.91	36.96	126.21	107.53	46.27	38.91
Churu	69.55	63.49	64.16	86.27	60.46	55.30	32.98
Jaisalmer	144.07	124.90	110.93	59.90	139.82	25.33	42.39
Jalore	86.68	96.71	98.19	98.96	87.50	24.43	34.70
Jhunjhunu	61.73	126.72	111.82	55.83	104.44	55.75	39.18
Jodhpur	83.33	110.19	94.76	91.25	82.27	24.53	40.47
Nagaur	56.92	76.26	68.60	64.27	74.06	32.89	52.48
Sikar	49.61	178.36	107.15	54.66	128.01	41.97	43.91

Table 17. Instability Indices (Index 2) of Yield of Crops Across Districts [(SD^*/AM^*) x 100]

District	Crops						
	Bajra	Moth bean	Green gram	Sesamum	Cluster bean	Gram	Rapeseed & Mustard
Barmer	88.93	120.83	107.30	89.44	104.19	25.96	27.49
Bikaner	111.32	79.75	32.30	360.48	101.62	44.86	38.56
Churu	58.08	62.06	56.49	186.29	60.85	54.98	27.41
Jaisalmer	131.86	125.56	120.08	57.72	139.34	24.49	38.43
Jalore	87.99	92.77	103.57	100.62	87.64	24.26	29.00
Jhunjhunu	58.77	127.99	109.62	48.72	102.06	56.25	33.19
Jodhpur	83.86	109.51	93.86	91.13	82.37	23.76	34.14
Nagaur	47.58	71.32	59.45	58.13	59.72	32.47	44.07
Sikar	48.18	126.98	10118.38	46.34	1604.39	41.82	36.92

** Detrended measures*

Table 18. Instability Indices (Index 3) of Yield of Crops Across Districts [(CV^2x(1-R^2))] x 100]

District	Crops						
	Bajra	Moth bean	Green gram	Sesamum	Cluster bean	Gram	Rapeseed & Mustard
Barmer	8511.12	15145.38	12292.28	7711.94	15901.43	630.54	904.17
Bikaner	13093.59	7335.06	1098.84	12155.71	11260.91	2121.41	1463.39
Churu	3840.26	3646.83	3242.98	4011.07	3385.46	3048.92	434.93
Jaisalmer	19231.83	15425.60	10434.17	3311.12	19337.71	515.21	954.16
Jalore	7496.89	8622.09	9221.30	9184.05	7654.26	513.28	650.22
Jhunjhunu	3466.49	15605.12	9859.55	276.39	9007.59	2885.93	836.89
Jodhpur	6683.49	12140.86	8965.81	8092.50	6516.23	478.21	995.39
Nagaur	2343.73	5389.89	3612.39	3463.54	3874.52	954.11	1589.21
Sikar	2147.11	28964.45	7675.82	2482.79	10441.52	1740.33	885.98

Barring few cases, the order of instability across crop in different districts and across districts for different crops has been found to be consistent irrespective of the different measures of instability. The instability indices of yield of guar, moong and moth were quite high in Barmer district. In Bikaner, the instability indices of sesamum, bajra and guar have been very high. The instability measures of yield of crops in Jaisalmer district indicated that the inter-year yield fluctuations for bajra, moth, moong and guar has been very high. The inter-year yield fluctuations have been high for moth, moong and guar in Jhunjhunu district. The yield instability has been relatively high for moth, moong and sesamum in Jodhpur district. In Sikar district, guar and moong were found to have very high yield instability measures.

The crop wise review of yield instability measures across districts indicated that the yield instability measures for bajra in Bikaner and Jaisalmer, for moth in Barmer, Jaisalmer, Jhunjhunu, Jodhpur and Sikar, for moong in Barmer, Jaisalmer, Jhunjhunu and Sikar, for sesamum in Bikaner, for guar in Barmer, Bikaner, Jaisalmer, Jhunjhunu and Sikar have been very high. Both the rabi crops gram and rapeseed and mustard emerged with relatively low inter-yield instability in all the districts. While the kharif crops are grown under the vagaries of nature, the rabi crops are grown either under limited irrigation facilities or using conserved moisture by keeping the land fallow in kharif in this

region. The large yield instability in kharif crops and relatively low instability in rabi crops would be attributable to the above cultivation practices followed for these crops.

The inter-crop instability analysis of yield shows that there exist scope to minimize yield instability by suitably selecting crops for different districts covered under the Western Dry Region.

5.8 CROP PRODUCTION RISK

The yield risk in crop production was assessed in terms of chances of success/failure of major crops for the period 1981-1998. The thresh-hold yield which offsets the cost of cultivation was assessed using the cost estimates available in the centrally sponsored scheme on cot of cultivation of principal corps in Rajasthan. If the realized yield of a particular year is greater than the thresh-hold yield, it was considered as success, otherwise failure. Based on the frequency of success yield years/failure yield years, the ratio of success yield years to total years for different crops was worked out. The ratio of success was considered at two cost level firstly, at the actually paid/incurred cost level (Cost A according to cost concept) and secondly at the total cost (Cost C level) which includes the imputed cost also.

The ratio of success at Cost A for major crops in different districts is given in Table 19 and the ratio of success at Cost C is given in Table 20. For bajra the ratio of success at Cost A varied from 0.43 in Jaisalmer to 1.00 in Jhunjhunu, for guar it varied from 0.19 in Jaisalmer to 0.86 in Jodhpur. For moong and moth the ratio was relatively more in all the districts. However, for sesamum it varied from 0.44 in Bikaner to 0.89 in Jaisalmer.

At the level of total cost which includes the paid or incurred cost as well as imputed cost, the situation was found quite different. For bajra only Jhunjhunu and Sikar districts work found to have higher changes of success. For guar crop, all the districts have either very low or zero chance of success at total cost. For moong the chance of success was higher over the chance of failure in Churu, Jaisalmer, Jalore, Jodhpur and Nagaur districts. As far as moth and sesamum crops are concerned, for all the nine districts, the chances of failure of these crops was higher over the chances of success at total cost. Thus, crop production in these districts is prone to very high risk which has lot of environmental and economic implications.

Table 19. Probability of success for different crops at paid/incurred cost level (1981-98)

Districts	Bajra	Guar	Moong	Moth	Sesamum
Barmer	0.53	0.22	0.76	0.50	0.50
Bikaner	0.56	0.39	1.00	0.53	0.44
Churu	0.94	0.44	0.94	0.72	0.83
Jaisalmer	0.43	0.19	0.83	1.00	0.89
Jalore	0.72	0.39	0.60	0.73	0.67
Jhunjhunu	1.00	0.56	0.71	0.56	0.83
Jodhpur	0.61	0.86	0.93	0.73	0.63
Nagaur	0.94	0.56	1.00	0.67	0.83
Sikar	0.94	0.56	0.71	0.65	0.83

Table 20. Probability of success for different crops at total cost level (1981-98)

Districts	Bajra	Guar	Moong	Moth	Sesamum
Barmer	0.24	0.00	0.47	0.11	0.17
Bikaner	0.28	0.06	0.24	0.00	0.19
Churu	0.67	0.00	0.83	0.11	0.39
Jaisalmer	0.21	0.00	0.58	0.33	0.39
Jalore	0.50	0.00	0.53	0.13	0.28
Jhunjhunu	0.83	0.17	0.17	0.28	0.33
Jodhpur	0.33	0.14	0.67	0.33	0.38
Nagaur	0.78	0.19	0.76	0.11	0.28
Sikar	0.83	0.17	0.41	0.12	0.39

5.9 FOOD SECURITY

The pattern of food security in terms of availability has been analysed for a normal and a drought year during the current decade. The projected population for the year 1993-94 and 1997-98, the former a drought and the later a normal year during the current decade, was considered. The per capita requirements for the balanced diet as per ICMR norms were used to work out the district level requirements. The total production of cereals, pulses, and oilseed during the respective years was compared with the requirement and the production expressed as per cent of requirement for these years are presented in Table 21.

Table 21. Extent of production over requirement for agricultural commodities in normal (1997-98) and abnormal (1993-94) years

District	Extent of production over requirement (per cent)							
	1993-94				1997-98			
	Cereals	Pulses	Food grain	Oilseeds	Cereals	Pulses	Food grain	Oilseeds
Barmer	17.64	19.51	17.93	13.46	120.37	254.87	140.62	24.93
Bikaner	23.54	140.51	41.16	82.44	107.55	234.70	126.70	202.68
Churu	38.56	190.80	61.48	14.03	153.51	896.59	265.39	95.82
Jaisalmer	24.84	3.94	21.69	25.34	45.57	21.79	41.94	187.84
Jalore	41.08	11.03	36.56	173.41	122.49	98.62	118.89	261.5
Jhunjhunu	69.83	73.28	70.35	60.61	116.37	306.42	144.98	125.08
Jodhpur	23.12	22.53	3.03	66.76	87.58	148.26	96.72	109.39
Nagaur	88.52	101.36	90.45	146.92	116.62	234.73	134.40	242.29
Sikar	79.76	68.31	78.03	42.05	126.12	231.88	142.40	63.29
Rajasthan	91.63	92.45	91.75	144.97	158.67	206.94	165.94	180.65

During the drought year cereal production was short for requirement in all the nine districts. In four districts the production was not sufficient to meet even one fourth of the requirement of cereals. As far as pulse production in the drought year is considered, in three districts it was higher over requirement and in the remaining six districts it was short of requirement. The production of food grain (cereal + pulses) was also short of requirement in all the 9 districts. For oilseed, the production was higher over requirement only in two districts. However, in a normal year production was short of requirement only in Jaisalmer and Jodhpur for cereals, in Jaisalmer and Jalore for pulses and in Barmer, Churu and Sikar for oilseeds.

5.10 COMPOSITION OF FARM ENERGY

The composition and magnitude of farm power/energy for agricultural purposes in terms of its availability is given in Table 22.

Table 22. Composition of farm power availability (1997)

S.No.	District	Share of Farm Power (%)			Total farm power (H.P.)	Energy/ Net sown area (M.J.)
		Machine	Animal	Human		
1.	Barmer	42.59	45.17	12.24	364810	1476
2.	Bikaner	58.83	31.30	9.87	281619	1404
3.	Churu	54.26	32.87	12.87	291663	1260
4.	Jaisalmer	22.01	70.58	7.42	88976	1584
5.	Jalore	86.77	7.45	5.78	601885	5796
6.	Jhunjhunu	81.48	11.09	7.43	367723	5076
7.	Jodhpur	91.00	5.67	3.33	1196057	5724
8.	Nagaur	92.00	3.74	4.27	1303641	6300
9.	Sikar	83.70	9.23	7.08	474835	5364
	State Average	81.40	12.35	6.25	17963558	6466

It is seen that in five out of 9 districts the share of mechanical energy is higher than that at state level. The intensive use of tractor for repeated deep ploughing is a threat for the process of sand stabilization in the desert belt. Remarkably, in the acute desert area the share of animal power is relatively more. However, it is on a decline over the years.

The composition of farm energy in the desert belt has undergone drastic changes. The relative shares of different farm energy components for the year 1972 and 1992 in the acute desert region as under :

Source	**Share of Energy (%)**	
	1972	1993
Human	10.78	8.53
Animal	77.17	38.18
Machine	12.05	53.29
	100.00	100.00

The large increase in mechanization in the desert belt is to be looked upon for possible environmental adverse implications.

5.11 FODDER SECURITY

An assessment of fodder security issues in terms of forage availability through range lands, crops residues and exclusive fodder production was made using the norms developed by Indian Grass and Fodder Research Institute, Jhansi. The emerging situation for the year 1997 is presented in Table 23.

Table 23. Demand supply balance of fodder in the districts covered under Western Dry Region of Rajasthan

District	Total Livestock (ACU) (Lakh)	Grazing Area (Lakh/ha.)	Grazing Pressure ACU/ha	Grazing Intensity (ha/ACU)	Animal/ H.H.	Total forage supply (million tonnes)	Total forage demand (million tonnes)	Balance (million tonnes)
Barmer	13.50	12.60	1.07	0.93	15	8.38	3.45	4.93
Bikaner	9.83	12.58	0.78	1.28	19	9.45	2.51	6.94
Churu	8.34	2.35	3.55	0.28	9	7.11	2.13	4.98
Jaisalmer	7.26	34.03	0.21	4.69	28	9.33	1.85	7.47
Jalore	7.86	3.84	2.05	0.49	9	2.51	2.00	0.51
Jhunjhunu	6.01	1.15	5.22	0.19	6	2.11	1.54	0.57
Jodhpur	13.61	9.21	1.48	0.68	13	5.02	3.48	1.55
Nagaur	12.98	4.28	3.03	0.33	10	3.70	3.32	0.38
Sikar	8.46	1.82	4.66	0.21	7	2.15	2.18	-0.03

The grazing pressure in terms of adult cattle unit (ACU) varies from 0.21 ACU/ha. in Jaisalmer to 5.22 ACU/ha. in Jhunjhunu. The number of actual animals per rural household varies from 6 in Jhunjhunu to 28 in Jaisalmer. Even with the total production potential of forage, most of the districts have supply potential just to meet the forage demand. Further increase in livestock population is likely to aggravate the fodder problem in this belt which is prone to seasonal migration in abnormal years. Time has come to explore the possibilities of "herd planning" to check the unplanned growth of animal in this area. The wild spread and growth of tree species locally known as vilayati babul (*Prospis juliflora*) in most part of this area is likely to adversely effect the fodder supply as grass does not grow under the shade of this tree species. The fast spread of "vilayati babul" is viewed as a major environmental hazard as this tree species has only limited use like natural fencing, and in some cases on fuel for cooking.

5.12 ECONOMICS OF DESERT AGRICULTURE

Despite all odd conditions, agriculture comprising of crop production and animal husbandry is the main stay for the people in the desert belt. The crop and crop mixes which can survive under highly stressed conditions are grown every year with varying chances of its survival. Generally, low input requiring crops are grown in this belt so that if the crop is failed, the losses are minimum. Similarly animal spices and breeds which can survive under very extreme conditions like sheep for wool, goat for milk and meat, camel for draught power purposes and cow and buffalo for milk purposes are kept on the farm.

The economics of agricultural activities like crop production and animal husbandry is of paramount importance as these activities are taken up under very high risk in the desert belt. The evidences emerged out of the analysis of the cross-sectional data of 300 sample farmers covering the following situations are spelt out in the forthcoming sections.

Unirrigated Desertic Situation (UDS)	-	255 sample farmers
Partially Irrigated Desertic Situation (PIDS)	-	15 sample farmers
Irrigated Desertic Situation (IDS)	-	30 sample farmers
Total		300 sample farmers

The results in the forthcoming section are based on the analysis of village level observations and primary farm household level data collected from 300 sample households spread over 10 villages in the region. The name of selected villages with tehsils and districts, are as under:

S.No.	Village	Tehsil	District
1.	Dudua	Pachpadra	Barmer

2.	Pemasar	Bikaner	Bikaner
3.	Himatsar	Nokha	Bikaner
4.	Sandwa	Sujjangarh	Churu
5	Mojas	Jhunjhunu	Jhunjhunu
6.	Thirod	Nagaur	Nagaur
7.	Bay	Data Ramgarh	Sikar
8.	Modra	Bhinmal	Jalore
9.	Chordia	Shergarh	Jodhpur
10.	Roopsi	Jaisalmer	Jaisalmer

5.12.1 Scenario in Selected Villages

The extent of access to various facilities in the selected villages is given in Table 24. Out of 10 selected villages 8 were connected by `Pacca' road and for the other two villages the access to road was available at 5 km distance. However, all the villages were connected by `Kaccha' road. Six out of 10 villages were connected with bus services. Out of the 10 selected villages, only 2 were connected by rail, 8 villages were having post offices, 3 were having telegraphic office. In 4 out of 10 village the bank facilities were available. None for the village was having easy access to Krishi Mandi and on an average

Table 24. Extent of Access to Important Services in Selected Villages

S.No.	Facilities	Number of villages having the facility	Number of villages not having the facility	Average distance from village at which facilities are available
1.	Pacca Road	8	2	5
2.	Kacha Road	10	-	-
3.	Bus Stand	6	4	12.5
4.	Railway Station	2	8	16.37
5.	Post Office	8	2	8.5
6.	Telegraphic Office	3	7	14.85
7.	Banks	4	6	12.00
8.	Mandi	-	10	21.80
9.	Ag.Co-operative Society	6	4	9.25
10.	Seed Store	2	8	17.75
11.	Fertilizer Shop	3	7	15.28
12.	Insecticide Shop	3	7	15.28
13.	Diesel/Petrol pump	2	8	22.00
14.	Tractor Service Station	2	8	16.37
15.	Patwari Office	8	2	13.00
16.	VEW Office	8	2	15.00
17.	Hospital/Dispensary	8	2	14.50
18.	Veterinary Hospital/ Dispensary	5	5	9.00
19.	Provisional Shop	10	-	-
20.	Vegetable Shop	8	2	8.5
21.	Fruit Shop	4	6	10.83
22.	Primary School	10	-	-
23.	Middle School	8	2	5.00
24.	Secondary School	5	5	15.20
25.	Sr.Secondary School	2	8	16.50
26.	College	-	10	34.70
27.	Drinking Water	10	-	-
28.	Milk Collection Centre	1	9	14.88
29.	Wool Selling Point	2	8	21.62
30.	Grazing Land for Animal	9	1	-
31.	Ground Water Tank	9	1	-

such facility was available at 22 km distance from the selected villages. Only 6 villages were having agricultural based primary cooperative societies. Agricultural facilities like selling point/centres for seed were available in 2 villages, fertilizer in 3 villages, insecticides in 3 villages, diesel in one village and tractor service station in 2 villages. The services of village extension worker was available in 8 villages. About 8 villages had access to veterinary hospital/dispensary. Access to primary school existed in all the 10 villages, middle school in 8 villages, secondary school in 5 villages and senior secondary school in 2 villages. Drinking water facility was available in all the 10 villages.

Crops like bajra, mothbean, guar (cluster bean), sesamum and moong (green gram) were grown either as single crop or as mixed crop in the acute desert areas. In moderate desert areas with groundwater resources, in addition to the above crops in kharif, wheat, gram and rapeseed and mustard were grown in rabi season. The major animal species reared on farm included cow, buffalo, goat, sheep and camel. The most dominant tree species grown on farm land and other land are `Khejri and `babool'. Besides tree spices like `neem', `kikar', `rohida', `pipal', `sisam' etc. are also grown at selected location. All the villages were having a good number of tractors. There were about 109 tractors in 10 villages. There were about 125 open wells in the selected villages, out of which 67 were dried. Besides, there were about 119 tube wells, out of which 10 were not-working.

The major problems in these village included shifting sand dunes, recurrent failure of crops, high rate of animal mortality, problem of quality and quantity of drinking water, seasonal unemployment, migration for work, migration for animal grazing etc. The unplanned growth of `vilayti babool' was also reported as a newly emerging problem, as it does not permit growth of grasses and other species under it.

5.12.2 Average Irrigated and Unirrigated Farm Area

The details of irrigated and unirrigated farm area of the selected holdings in the three situation is shown in Table 25.

The average farm size of UDS category was 5.67 ha, the whole of which was deprived of any source of irrigation. The average farm size of PIDS category was 8.99 ha, out of which 2.83 was irrigated and 6.16 ha was unirrigated. The entire area of 30 holdings

under IDS category was irrigated and 26 out of 30 holdings were in the command area of IGNP. The average per farm area of IDS category was 8.38 ha.

Table 25. Extent of Irrigated Farm Area of Selected Holdings

S.No.	Type of Holdings	Irrigated area/ farm (ha)	Unirrigated area/ farm (ha)	Total area/ farm (ha)
1.	UDS	-	5.67	5.67
2.	PIDS	2.83	6.16	8.99
3.	IDS	8.38		8.38

5.12.3 Cropping Intensity

The average cropping intensity (ratio of gross cropped area to cultivated area) for the three categories of the farm is given in Table 26.

Table 26. Cropping Intensity of Selected Holdings

S.No.	Type of Holding	Av. farm size (ha)	Gross cropped area/farm (ha)	Cropping intensity (%)
1.	Unirrigated Desertic Situation (UDS)	5.67	4.13	72.84
2.	Partially Irrigated Desertic Situation (PIDS)	8.99	8.13	90.43
3.	Irrigated Desertic Situation (IDS)	8.38	7.85	93.67

The average cropping intensity was worked to be 72.84 per cent for UDS category, 90.43 per cent for PIDS category and 93.67 per cent for IDS category of farms.

5.12.4 Cropping Pattern

The cropping pattern of selected holdings is given in Table 27.

Table 27. Cropping Pattern of Selected Farms

S. No.	Crop	UDS		PIDS		IDS	
		Area/farm (ha)	Per cent	Area/farm (ha)	Per cent	Area/farm (ha)	Per cent
1.	Bajra	0.89	21.55	0.85	10.46	0.16	2.04
2.	Jowar	0.06	1.45	-	-	-	-
3.	Moong	0.07	1.19	0.49	6.03	0.08	1.02
4.	Cowpea	0.00	-	0.11	1.35	-	-
5.	Moth	0.15	3.63	3.03	37.27	0.75	9.55
6.	Guar	0.88	21.31	1.46	17.96	0.98	12.48
7.	Groundnut	-	-	0.28	3.44	1.16	14.78
8.	Til	0.04	0.97	-	4.1	-	-
9.	Millet	-	-	0.34	4.18	0.20	2.55
10.	Kharif mix	2.03	49.15	0.13	1.60	-	-
11.	Wheat	-	-	0.93	11.44	1.65	21.02
12.	Gram	0.01	0.25	0.26	3.20	0.39	4.97
13.	Mustard	-	-	0.25	3.07	2.48	31.59
	Total	4.13	100.00	8.13	100.00	7.85	100.00

The cropping pattern of unirrigated holdings is dominated by kharif crops. The kharif mix cropping with bajra, guar, moth, moong, sesamum etc. accounts for 49.15 per cent of gross cropped area of unirrigated holdings. Bajra, guar (cluster bean) and moth bean are the major single crops grown in kharif. The cropped area in rabi is quite insignificant in the unirrigated desertic situation. The partially irrigated holdings have more kharif crop and some rabi crops. On the other hand irrigated holdings have more rabi crops and some kharif crops. Thus the extent of water availability is found to be a determining factor for the choice of crop.

The number of growers of different crops in the selected sample is given in Table 28.

Table 28. Number of Growers of Different Crop Enterprises in the Selected

Sample

S.No.	Particulars	Number of growers		
		Unirrigated desertic situation (UDS)	Partially irrigated desertic situation (PIDS)	Irrigated desertic situation (IDS)
1.	Number of selected farmers	255	15	30
2.	Growers of mixed crop	139	2	0
3.	Growers of bajra	113	10	2
4.	Growers of moth	22	5	2
5.	Growers of moong	19	7	1
6.	Growers of guar	117	13	7
7.	Growers of sesamum	6	0	0
8.	Growers of jowar	13	0	1
9.	Growers of gram	6	4	13
10.	Growers of groundnut	0	4	26
11.	Growers of wheat	0	15	27
12.	Growers of barley	0	11	3

In the unirrigated desertic situation the number of growers of mixed crop has been the maximum followed by guar and bajra. In the partially irrigated desertic condition, all sample farms deverted area for wheat. The crops like guar, bajra and barley were grown by large number of sample farmers under partially irrigated desertic situation. In the irrigated desertic situation wheat was grown by 27 farmers groundnut by 26 farmers out of 30 sample farmers in this category. Thus, there is a distinct shift in the cropping pattern as the access to water resources improves in the desert belt.

5.12.5 Composition of Farm Livestock

The per farm number of animals according to the three farm situations is given in Table 29.

On an average more than 9 animals were maintained by unirrigated farm holdings, 13 animals by partially irrigated holdings and 23 animals by irrigated farm holdings. The animal herd is composed of cow, buffalo, camel, sheep and goat and their young stock.

Table 29. Average number of animals per sample household*

S.No.	Type of Animal	UDS	PIDS	IDS
(A)	**Adult Animals**			
1.	Cow	0.86	1.33	4.33
2.	Buffalo	0.39	1.73	1.06
3.	Bull	0.04	0.06	0.13
4.	Camel	0.10	3.46	0.23
5.	Sheep	2.13	0.80	9.76
6.	Goat	2.28	1.46	2.80
7.	Others	-	-	-
	Total	5.8	8.84	18.31
(A)	**Young stock**			
1.	Cow	0.55	0.93	1.96
2.	Buffalo	0.29	1.53	0.86
3.	Camel	0.02	-	-
4.	Sheep	0.90	-	0.16
5.	Goat	1.81	1.8	1.90
6.	Others	-	-	-
	Total	3.57	4.26	4.88
	G.Total (A+B)	**9.37**	**13.1**	**23.19**

* *The figures are absolute averages.*

5.12.6 Farm Asset Structure

The farm asset structure of the selected holdings according to the three situations are

given in Table 30.

Table 30. Farm Asset Structure of Selected Holdings

S.No.	Particulars of asset	Per farm values (Rs.)		
		UDS	PIDS	IDS
(A)	**Per Farm Item**			
1.	Land holding	202649 (71.95)	660613 (69.29)	791746 (59.72)
2.	Animal stock	14855 (5.27)	28746 (3.02)	40198 (3.03)
3.	Farm building	53789 (19.10)	185266 (19.43)	302756 (22.84)
4.	Machines & Irrigated structure	10360 (3.68)	78782 (8.26)	191005 (14.41)
	Total	281653 (100.0)	953407 (100.0)	1325705 (100.0)
(B)	**Per Hectare**			
1.	Land holding	35740	73483	94480
2.	Animal stock	2619	20608	4796
3.	Farm building	2486	20608	36128
4.	Machines & Irrigated structure	1827	8763	22792
	Total	49672	106052	158196

Note : Figures in parenthesis are percentages to total farm asset value.

The per farm asset values for unirrigated, partially irrigated and irrigated farm households was estimated to be Rs. 2.82 lakh, Rs. 9.53 lakh and Rs. 13.25 lakh respectively. The land alone accounted for 71.95 per cent of asset value for unirrigated holdings, 69.29 per cent of asset value for partially irrigated holdings and 59.72 per cent of asset value for irrigated holdings. The relative share of livestock asset was more for unirrigated holdings. The relative share of farm building was 19.11 per cent for unirrigated holdings, 19.43 per cent for partially irrigated holdings and 22.84 per cent for irrigated holdings. Similarly the combined relative share of machines and irrigation structure was 14.41 per cent for irrigated holdings and only 3.68 per cent for unirrigated holdings. The asset value for unit area was found to increase for land, animals, building and machines with improvement in the status of irrigation.

5.12.7 Economics of Crop Farming

The level of cost, return and profitability of crop enterprises which form the major economic activity of the desert area of Rajasthan is of very high relevance. The details regarding cost, return and profitability of crop enterprises in the desert belt under unirrigated desertic condition, partially irrigated desertic condition and irrigated desertic condition are given in Table 31.

Table 31. Economics of Crop Production in the Western Dry Region of Rajasthan

S.No.	Particulars	Per farm			Per hectare of gross cropped area		
		UDS	PIDS	IDS	UDS	PIDS	IDS
(A)	**Cost of Cultivation (Rs.)**						
1.	Hired human labour	791	2555	4190	192 (6.27)	314 (3.11)	534 (3.14)
2.	Bullock labour	167	1588	905	40 (1.31)	195 (1.93)	115 (0.68)
3.	Tractor	1578	5215	15983	382 (12.47)	641 (6.36)	2036 (11.97)
4.	Thresher	221	1428	4215	54 (1.76)	176 (1.75)	537 (3.16)
5.	Oil engine/El. motor/canal charges	-	451	236	-	55 (0.55)	30 (0.18)
6.	Seed	856	4072	7334	207 (6.76)	501 (4.97)	934 (5.49)
7.	Farm yard manure	798	1193	1602	193 (6.30)	147 (1.46)	204 (1.20)
8.	Fertilizer	45	990	4729	11 (0.36)	122 (1.21)	602 (3.54)
9.	Plant protection chemicals	-	330	2715	-	41 (0.41)	346 (2.03)
10.	Interest on working capital	134	535	1257	32 (1.04)	66 (0.65)	160 (0.94)
11.	Depreciation	518	3939	9550	125 (4.08)	485 (4.81)	1217 (7.16)
12.	Imputed interest on fixed capital	2811	13992	29091	681 (22.23)	1721 (17.07)	3706 (21.79)
13.	Rental value of owned land	2696	21451	40521	653 (21.32)	2638 (26.16)	5162 (30.35)
14.	Imputed value of family labour	2037	11596	11177	493 (16.10)	1426 (14.14)	1424 (8.37)
	Cost A [Total(1) to (10)]	4590	18347	43166	1111 (36.27)	2257 (22.38)	5499 (32.33)
	Cost B [Cost A + (11) + (12)+ (13)]	10615	70381	122328	2570 (83.90)	8657 (85.86)	15583 (91.63)
	Cost C [Cost B +(14)]	12652	81977	133505	3063 (100.00)	10083 (100.00)	17007 (100.00)
(B)	**Output (Rs.)**						
1.	Main product	4824	53380	107794	1168	6566	13732

S.No.	Particulars	Per farm			Per hectare of gross cropped area		
		UDS	PIDS	IDS	UDS	PIDS	IDS
2.	By product	3347	11624	14999	810	1430	1911
(C)	**Income Measures (Rs.)**						
1.	Gross income	8171	65004	122793	1978	7996	15642
2.	Farm business income	3581	46657	79627	867	5739	10144
3.	Family labour income	-2444	-5377	465	-592	-661	59
4.	Net income	-4481	-16273	-10712	-1085	-2088	-1365

Note : Figures parenthesis are percentage to total cost in each category

The total cost in crop production has two components (i) actually incurred cost (ii) imputed cost of own farm resources including family labour. The cost A includes all paid or actually incurred cost. To this if the cost of capital resources including land is added, the cost B is obtained. To cost B if imputed value of family labour is added we get cost C which is synonymous to total cost. In fact Cost A and imputed value of family labour together is equivalent to variable/operational cost. The monetary return is possible from grain (main product) and straw (by product). The total value of main product and by product form the gross return. Gross return less of Cost A is called farm business income which is the disposable income generated out of crop enterprises. It is the joint return to capital resources, family labour and management. Similarly gross output less of cost B is called family labour income as it gives the return to family labour. The cost B accounts for all costs except family labour. The net income is the net profit after accounting for all cost items which are actually incurred as well as imputed.

The per household cost A (incurred cost) for all crops comes to Rs. 4590, Rs. 18347 and Rs. 43166, respectively for UDS, PIDS and IDS category of farms. The per household magnitude of Cost B for the reporting year in respect of UDS, PIDS and IDS comes to Rs. 10615, Rs. 70381 and Rs. 1,22,328 respectively. The estimated total cost for the thee situation comes to Rs. 12652, Rs. 81977 and Rs. 1,33,505 respectively. When considered on unit area basis, the total cost of cultivation comes to Rs. 3063/ha for UDS, Rs. 10083/ha for PIDS and Rs. 17007/ha for IDS in the Western Dry Region of the state. As far as farm business income is concerned there exist substantial differences between the situations as the magnitude of farm business is income Rs. 3851/HH for UDS category, Rs. 46657/HH for PIDS category and Rs. 79627/HH for IDS category respectively. The net income which is the residue of gross return over total

cost was found to be negative for all the three categories. Obviously, when the total cost is taken into account the crop production is a loosing enterprise for the western dry region. However, the major chunk of the cost is imputed cost for capital investment, rental value of land and family labour. The crop activities are taken up every year even under high risk as the actually incurred or paid cost is almost one third or less of the total cost.

The distribution of sample households according to profit and loss for the crop enterprises in the three situations viz., UDS, PIDS and IDS is given in Table 32.

Table 32. Distribution of Sample Farmers According to Positive/Negative Farm Business Income From Crop (all crops) Enterprises in the Western Dry Region of Rajasthan

S.No.	Type of holdings	No. of selected holdings	No. of holdings having	
			Positive FBI	Negative FBI
1.	UDS	255	54	201
2.	PIDS	15	15	-
3.	IDS	30	30	-
	Total	300	99	201

Out of 255 sample farmers 201 had to incur loss from crop farming at actually incurred cost level (cost A). However, all the sample holdings in the PIDS and IDS category could realize the actually incurred cost (cost A) out of crop farming, which shows that crop farming is more risky under the unirrigated desertic situation. The economics of major individual crops under the unirrigated desertic situation (UDS) was worked out on per farm and per hectare basis, the details of which are given in Table 33 and Table 34, respectively.

Table 33. Economics of Major Individual Crop Enterprises in the Unirrigated Desertic Situation in the Western Dry Region of Rajasthan

S.No.	Particulars	Per farm values (Rs/farm)			
		Bajra	Guar	Moth	Mixed Crop
(A)	**Number of growers**	113	117	22	139
(B)	**Average grower area (ha)**	1.97	1.92	1.66	3.66
(C)	**Cost of cultivation (Rs.)**				
1.	Hired human labour	145	302	157	848
2.	Bullock labour	170	58	148	70
3.	Tractor	962	743	693	1142
4.	Thresher	210	130	152	66
5.	Seed	101	679	417	637
6.	Farm yard manure	978	245	540	6
7.	Fertilizer				
8.	Interest on working capital	77	65	63	83
9.	Depreciation	112	110	19	255
10.	Imputed interest on fixed capital	606	599	102	1382
11.	Rental value of owned land	1735	1501	1855	913
12.	Imputed value of family labour	1176	788	1091	1480
	Cost A [Total(1) to (8)]	2643	2222	2270	2852
	Cost B [Cost A + (9+) + (10)+ (11)]	5096	4432	4246	5402
	Cost C [Cost B +(12)]	6272	5220	5337	6882
(D)	**Output (Rs.)**				
1.	Main product	2544	3466	4582	1317
2.	By product	2715	1083	1039	1449
(C)	**Income Measures (Rs.)**				
1.	Gross income	5259	4549	5621	2766
2.	Farm business income	2616	2327	3351	-86
3.	Family labour income	163	117	1375	-2636
4.	Net income	-1013	-617	+284	-4116

Table 34. Economics of Major Individual Crop Enterprises in the Unirrigated Desertic Situation in the Western Dry Region of Rajasthan

S.No.	Particulars	Per hectare values (Rs/ha)			
		Bajra	Guar	Moth	Mixed Crop
(A)	**Cost of cultivation (Rs.)**				
1.	Hired human labour	74	157	95	132
2.	Bullock labour	86	30	89	19
3.	Tractor	488	387	417	312
4.	Thresher	107	68	92	18
5.	Seed	54	354	251	174
6.	Farm yard manure	496	128	325	2
7.	Fertilizer				
8.	Interest on working capital	39	34	38	23
9.	Depreciation	57	57	11	70
10.	Imputed interest on fixed capital	308	312	61	378
11.	Rental value of owned land	881	782	1117	249
12.	Imputed value of family labour	597	410	657	404
	Cost A [Total(1) to (8)]	1342	1157	1367	779
	Cost B [Cost A + (9+) + (10)+ (11)]	2587	2308	2558	1476
	Cost C [Cost B +(12)]	3184	2719	3215	1880
(B)	**Output (Rs.)**				
1.	Main product	1291	1805	2760	360
2.	By product	1378	564	626	396
(C)	**Income Measures (Rs.)**				
1.	Gross income	2670	2369	3386	756
2.	Farm business income	1328	1212	2019	-23
3.	Family labour income	83	61	828	-720
4.	Net income	-514	-349	171	-1125

The per farm cost A for bajra come to Rs. 2643, for guar Rs. 2222, for moth Rs. 2270 at for mixed crop Rs. 2852. The total cost of cultivation comes to Rs. 6272 for bajra, Rs. 5220 for guar, Rs. 5337 for moth and Rs. 6882 for mixed crop. When considered on unit area basis the cost of cultivation is the lowest for mixed crop and the highest for moth. The low cost of cultivation is coupled with low gross income for mixed crop and the relatively more cost of cultivation for moth is associated with more gross return. It is remarkable to note that the loosing crop enterprise of mixed crop was taken up by the maximum number of sample farmers and the relatively profitable enterprise of with was taken up by only very few sample farmers. In fact all the major crops which are grown by more number of farmers and taken up in more area are found to ba loosing enterprises in the unirrigated desertic condition. The high risk in crop farming under the desertic situation is evident from the cost return analysis of major crop enterprises taken up in this region.

The number of growers who could realize the actually incurred cost and who had to incur loss for the major crop enterprises in the unirrigated desertic situation is given in Table 35.

Table 35. Distribution of Crop Growers According to Positive and Negative Farm Business Income for Major Crops in the Unirrigated Desertic System

S.No.	Crop	No.of growers	No.of growers having	
			Positive FBI	Negative FBI
1.	Bajra	113	35	78
		(100.00)	(30.9)	(69.1)
2.	Guar	117	31	86
		(100.0)	(26.5)	(73.5)
3.	Moth	22	12	10
		(100.00)	(54.5)	(45.5)
4.	Mixed crop	139	22	117
		(100.00)	(15.8)	(84.2)

It could be seen that 69 per cent of bajra growers, 74 per cent of guar growers 46 per cent of moth growers and 84 per cent of mixed crop growers could not realize the actual cost incurred for these crops during 1999-2000 crop year. The high risk in crop farming

under unirrigated desertic situation is quite evident. The extent of risk is found to be more for mixed crops.

5.12.8 Economic of Livestock Activities

Animal husbandry is adjunct to crop farming in the desert belt of Rajasthan. The details of economics of animal husbandry in terms of variables cost, gross return and the magnitude of farm business income for the three situation under study are given in Table 36.

Table 36. Economics of Livestock Activities in the Western Dry Region of Rajasthan

S. No.	Particulars	Per farm values (Rs.)		
		UDS	PIDS	IDS
(A)	Cost			
1.	Green fodder	928	2139	2557
2.	Dry fodder	7538	15143	20327
3.	Concentrates	2351	6241	7942
4.	Medicines	51	162	281
5.	Upkeep labour (imputed)	4756	6611	11657
	Total Return	15624	30296	42764
(B)	Return			
1.	Milk	8966	23479	39326
2.	Dung	722	2160	4302
3.	Wool	331	433	1440
4.	Sale of kids/animals	609	200	168
5.	Animal power	186	780	482
	Total Cost	10814	27052	45718
	Farm Business Income	-54	3367	14611
	(Return - cost less of imputed family labour)			

The estimated variable cost due to green fodder, dry fodder, concentrates, medicines and upkeep labour come to Rs. 15624/HH for UDS. Rs. 302196/HH for PIDS and Rs. 42764/HH for IDS. The gross return from milk, dung, wool, sale of animals, and own

farm animal power is estimated to be Rs. 10814/HH for UDS, Rs. 27052/HH for PIDS and Rs. 45718/HH for IDS. While the sample households from PIDS and IDS could generate positive farm business income, the same for UDS was found to be negative. In other words, the livestock activities also do not lead to positive farm business income in the unirrigated desertic situation. When the imputed value of family labour is also accounted to the cost, only sample farmers under irrigated condition could get positive net income out of the livestock based activities.

The distribution of holdings according to positive and negative farm business income measures is given in Table 37.

Table 37. Distribution of Sample Holdings According to Profit/Loss Incurring Out of Livestock Activities

Type of holdings	No. of farmers		Number of farmers with livestock having	
	Without livestock	With livestock	Positive profit	Negative profit
UDS	18	237	73	164
PIDS	-	15	9	6
IDS	1	29	17	12
Total	19	281	99	182

It could be seen that 69 per cent of households keeping animal had to incur loss at actually incurred cost in the unirrigated desertic system. However 9 out 15 holdings in PIDS and 17 out of 29 holdings in IDS could generate positive farm business income.

5.12.9 Other Household Income

The average household income from non-agricultural sources for UDS, PIDS and IDS category of households is given in Table 38.

Table 38. Household Income from Other Sources in the Western Dry Region of Rajasthan

S.No.	Source of income	Household income (Rs./HH)		
		UDS	PIDS	IDS
1.	Income from hiring out of family labour	10456	-	-
2.	Income from services of farm family members	5876	22600	7667
3.	Income from business	1539	5067	5330
4.	Income from hiring services, rent etc.	1289	12200	35877
	Total	19160	39867	48874

The hiring out of family labour is the major source of non-agricultural income for the UDS category. The income from services of family members and hiring services of capital goods form a major chunk of other income for PIDS category. The income from hiring out of capital resources like tractor, thresher etc is a major source of household income for IDS category of farmers.

5.12.10 Farmers Perception on Risk Minimization

Out of the 255 sample farmers in the unirrigated desertic situation, 246 were of the view that crop production activities are more risky over animal husbandry. Similar has been the perception of the farmers in the irrigated and partially irrigated desertic situation. In the UDS, about 60 per cent of the farmers stated that mixed cropping is least risky followed by bajra crop. In the irrigated and partially irrigated situation wheat crop has been reported as least risky, large majority of UDS farmers opined that goat rearing is the least risky livestock activity. But all the sample farmers of IDS felt that buffalo rearing is least risky in this belt. Large majority of farmers felt that mixed cropping can be practiced as a risk minimization strategy. When the crop activity fails farmers resort to options like diverting past reserve for current use, hiring out of family labour to earn income, and migrating to other places for work.

5.12.11 Risk Minimization and Diseconomy of Farm Activities

It seems that farmers resort to livestock activity as a strategy for risk minimization. Subsequently the fodder demands goes up and a sort of diseconomy crops into the farm economy of rural household as shown in the chart on the next page.

5.13 DIVERGENCE BETWEEN PRIVATE AND SOCIAL INCENTIVES

The agricultural activities in this area lead to divergence between private and social incentives. The crop and animal husbandry based activities bear evidences in this context.

5.13.1 Crop Based Activities

The share of net sown area is more than two-third of the geographical area for the districts like Churu (81.5%), Jhunjhunu (73.8%), Nagaur (70.6%) and Sikar (68.6%). Besides, the net sown area indicated positive growth rate for the period 1980-97 in all these districts. This is going towards a very unhealthy situation as far as the process of building better environment is concerned. Once the area is put under plough, it will be a difficulty task to divert area under arid forest and other activities which can develop eco-friendly situations in these eco-fragile areas.

5.13.2 Livestock Rearing Activities

The grazing on land and browsing on trees by the animals for fodder requirement are common practice in this belt. The small ruminants like sheep and goat and large animals like cow and camel are taken in flock for grazing purposes. The plant spices struggling for survival under drought condition, when disturbed by animals during the course of grazing, are further weakened and losses its potential to survive under moisture scarce conditions. The small ruminants, particularly sheep and goat which

graze very close to the land, leads to the destruction of large number of plants. Thus, the process of sand stabilization being attempted through the natural growth of grasses and bushes in this belt is adversely affected by the privately owned animals. The animal husbandry in the desert belt has adverse impact on the process of sand stabilization. Even in the normal rainfall year the feed and fodder production in this belt is short of fodder requirement for the animals.

5.13.3 Growth of Vilayati Babul (*Prosopis juliflora*)

The growth in the area coverage of vilayati babul (*Prosopis juliflora*) which are grown as shelter belt trees and also on fences is reported to be helpful for developing vegetative cover in this area. It also blocks the movement of sand from field to roads. The thorny branches and the unpalatable leaves help to protect the species from grazing animals and also from deliberate attempts by the people from cutting it in early stages of its growth. On the contrary, it is reported that it does not allow to grow grasses and other useful plants under it or even in its neighbourhood.

5.13.4 Farmers Perception

Efforts were made to assess the perception of sample farmers on the likely divergence between social and pirate incentive.

The sample farmers were asked the following questions who in turn answered the questions as `yes' or `no'.

(1) Is animal grazing a constraint for arid forest development?

(2) Does tracterisation lead to desertification?

(3) Is present cropping pattern a cause for desertification?

(4) Is present animal husbandry practices a cause for desertification?

(5) Is present land use pattern a cause for desertification?

Out of 255 sample farmers under UDS, 81 answered in conformity for question (1), 148 for question (2), 75 for question (3), 82 for question (4) and 83 for question (5). It shows that majority of the farmers are aware of the adverse implication of tracterisation in the desert belt. For other aspects like implication of animal grazing, present cropping pattern, present animal husbandry practices and present land use practices etc on desertification the majority of the farmers are not aware of such adverse implications.

5.14 EXTERNALITIES OF AGRICULTURAL ACTIVITIES

The agriculture and animal husbandry are the major occupation for the rural masses in the desert belt. Both these activities bring in distortion to natural resources base and dis-economies to the farm households through adoption of practices and activities made available to the people as policies and programmes for agricultural development. The liberalized farm loans for agricultural purposes prompted many farmers to go for large scale mechanization through tractor. Besides, the number of wells in the area are also going up drastically.

5.14.1 Groundwater Exploitation

Despite desertic condition in the area, the number of wells in all the districts in the region is increasing and so also the wells going out of use. The information of wells in 1991-92 and 1997-98 in the region is given in Table 39. In the year 1991-92, there were 1.88 lakh wells in this region out of which 1.39 lakh wells were in use and 0.49 lakh wells were out of use. In the year 1997-98 the total number of wells has increased to 2.31, lakh out of which 1.77 lakh wells were in use and 0.54 lakh wells were out of use. On one side the number of wells in this water scarce region is increasing tremendously and on the other side the number of wells going out of use is also increasing.

Table 39. Status of Wells in the Western Dry Region of Rajasthan

S. No.	District	1997-98			1991-92		
		In use (No.)	Out of use (No.)	Total (No.)	In use (No.)	Out of use (No.)	Total (No.)
1.	Barmer	13897	1652	15549	7962	2144	10106
2.	Bikaner	680	9	689	114	-	114
3.	Churu	5253	-	5253	2144	-	2144
4.	Jaisalmer	328	-	328	113	-	113
5.	Jalore	43765	10676	54441	33132	10711	43843
6.	Jhunjhunu	34912	3829	38741	25831	4607	30438
7.	Jodhpur	14095	4842	18937	13912	3561	17473
8.	Nagaur	22701	21972	44673	20505	18116	38621
9.	Sikar	41364	10609	51973	35495	9981	45476
	All 9 districts	176995	53589	230584	139208	49120	188328

The digging of wells in the belt is a very costly affair.The average cost of wells with electric fitting etc. go upto 3-4 lakh rupees for each well. The large number of wells going out of use brings in dis-economy to household by way of repayment of loans under no return situation. Besides it creates environmental problems like depletion of ground water.

5.14.2 Tracterisation

The mechanization of agriculture for various farm operations, for lifting of water from wells and also for transportation purposes is a follow up of green revolution in the country. The government credit policies in agriculture sector also prompted the farmers to go for purchase of tractor and other farm machines and implements on a large scale. The eco-fragile western dry region comprising the desert belt of Rajasthan is no exception to this phenomenon. The temporal growth in the number of tractors can be seen from Table 40. There were only 955 tractors in this belt in 1966. Its number has gone upto 82409 in the year 1997. The rate of growth in the number of tractors during the period of last 30 years in the western dry region is much higher to that at state level.

Table 40. Status of Tracterisation in the Western Dry Region of Rajasthan

S. No.	District	Year						
		1966	1972	1977	1983	1988	1992	1997
1.	Barmer	39	188	429	1066	1505	3183	2107
2.	Bikaner	7	14	108	722	1567	2651	4385
3.	Churu	18	52	104	525	1039	1521	3729
4.	Jaisalmer	16	19	41	219	277	183	467
5.	Jalore	60	180	798	1991	3285	6445	6933
6.	Jhunjhunu	380	1513	2120	4293	5052	9843	27963
7.	Jodhpur	33	65	161	364	748	1456	3191
8.	Nagaur	280	812	1498	3800	4947	8459	28758
9.	Sikar	122	246	401	1020	1658	3100	4876
	Total	955	3089	5660	14000	20078	36841	82409

The tractor enhances the efficiency of farm operations particularly when sowing of crops is to be done by making use of the moisture available for short period with the on set of rains. As the frequency of rains is not vary regular in this belt, the general tendency is to make use of the first seasonal rain for sowing purposes. As a result of access to tractor and other farm machines the sown area has gone up tremendously in this belt. However, there are economic and environmental problems associated with large scale tracterisation in this eco-fragile area.

The under-utilization of heavily invested tractor is a reality in this belt as the crop production is generally confined to kharif season and the operations seeking the use of tractor are also limited and hence the tractors remain idle for most of the period. This definitely causes diseconomy to the households possessing tractors. Besides, the deep ploughing of land with tractor prevents the process of sand stabilization through growth of natural vegetation. This fact was evident in such areas where tracterisation is in vogue in this belt.

5.15 COMMUNITY BASED ECONOMIC INSTUTITIONS AND RESOURCE CONSERVATION PRACTICES

The people living in the desert belt have extra ordinary love for trees and animals. The free moments of wild animals like deer and birds like peacock in the area is ensured by the local inhabitants. Anybody making attempt to disturb the free movement of these animals are dealt with severely. The growing of `Khejri' trees on farm land is a common

practice. Every part of khejri tree has some or the other utility. The leaves of khejri are good fodder for animals the fruits are used as vegetable, the timber has lot of uses for farm and household purposes.

A number of bushes and grass spices are allowed to grow freely in this belt. Some of these have commercial uses while others help to keep the sand stabilized. The inhabitants of the area make natural fencing on the roadside with cactus, grasses, bushes and tree spices which prevent the movement of sand on the road from the farm fields.

The community based water storage system at the village level is very common in the area. A number of cemented underground tanks even on the farm of individual farmers to store run off water can be seen at places. The PHED Department also construct bigger covered tanks to store the run off water for drinking purpose round the year.

5.16 SUSTAINABILITY OF DESERT AGRICULTURE

The issues like uncompensated anthropogenic environmental risk to the life support systems of the earth, the impact of avoiding such risks on the nature and scale of economic activity and also ways and means to evolve societal and individual behaviour which enable the above facts to be taken into account in the decision making of individuals, communities and governments to avoid the distortions in the capacity of nature to sustain better modes of life are being raised at national and international forums. It is a naked reality that economic activities including agriculture use natural resources, sometimes beyond the replinishable rates. The economy - environment interactions in the desert belt poses two types of problems. Firstly the economic activities adds to the severity of basic fragile nature of the eco-system. Secondly, the developmental efforts to improve the adverse situations are not allowed to bear results. Therefore, the question of sustainability of desert agriculture is of paramount relevance. In the academic and intellectual field, thinking for modelling for sustainable and ecological economic development by interdisciplinary collaboration across the biological and economic sciences has been initiated. The population biology in models of natural resources utilization and the development based on insights from community and

system ecology are being advocated. Over exploitation of natural resources beyond their regeneration capacity has led to the global disease of environmental degradation, stretching the life sustaining mechanisms well beyond their recuperative limits. Environmentally sound sustainable development is now widely accepted as desirable objective. The natural resource accounting and monitoring is being advocated for the preservation of environmental quality while achieving economic development.

It is possible to conceive of practices for managing resources which enhance the capacity of the present as well as future generation to meet their needs. In the context of agriculture, the sustainability aspect entails strategies and policies that augment existing land and water resources through investment, technologies for increasing productivity of these resources and pricing policies as well as management practices that economise on the use of such inputs.

Desertification results from the human pressure of population increase in dry regions combined with a consequential growth in demand for natural resources for food, water, fuel etc. that exceeds the carrying capacity of the land. Sustainable agricultural development of such a region is important due to (i) the need to produce more to meet the enhanced requirement of agricultural commodities for the rising population (ii) over exploitation of natural resources to meet the current needs of agricultural commodities. The magnitude of problems arising out of increased requirement of commodities and over exploitation of natural resources is more in desert region. The high growth rates of human and livestock population, problem of high risk involved in desert agriculture and consequent activities to get over this problem pose challenges to achieve sustainability in the desert belt of Rajasthan.

On the lines of composite indices evolved to study the levels of development (Narian Prem 1991), efforts were made to develop composite indices for each of the 9 districts covered under the desert belt. The details of methodology are given in section 4.4.

The indicators of sustainable agricultural development considered to develop the composite index in this study include indicators representing land resource, human population livestock population and agricultural infrastructure. These indicators are as follows :

(1) **Forest Area :** The share of area under forest to the total geographical area of the district is considered as indicator representing the land component. More and more area ear marked under forest in the region is likely to help in developing arid forestry in the region. Such forests can have positive contribution in bringing sustainability in the desert agricultural system. Hence maximum standardized value of the indicator is desirable.

(2) **Net Sown Area (Per person):** The net sown area per person was worked out for each of the districts. It was expected to have more net sown area per person as a positive indicator for sustainability. Hence maximum standardized value of this land indicator was assumed as desirable.

(3) **Land-Man Ratio :** The density of population is already very high in the Thar desert as compared to other desert regions in the world. The high density of population leads to over exploitation of natural resources including the regeneration process. The high pressure of population in this eco-fragile region is undesirable. The land-man ratio of (geographical area minus non-agricultural use and culturable waste land) was worked out. For ensuring sustainability, this ratio of land to man was expected to be high. Hence maximum standardized value of this indicator was assumed.

(4) **Growth Rate of Population :** The growth rate is another demographic indicator to cause lack of sustainability to the agricultural system in the eco-fragile desert areas of Rajasthan. Hence minimum standardized value of this indicator was preferred.

(5) **Literacy Rate :** High literacy rate is warranted for the socio-economic development of any region. Remarkably, high literacy rate can help to divert part of work force from land based livelihood to other areas of livelihood. The high literacy rate of population can lead to minimize burden on land. Hence maximum standardized values of literacy was preferred.

(6) **Share of Workforce in Primary Sector :** The large chunk of workforce in most of the district is on primary sector activities either as cultivators or as agricultural labourers. Despite high risk in agriculture, due to lack of alternative occupation, a

large share of workforce depends on agriculture based activities causing pressure on already weak natural resource base of the area. Therefore, minimum of standardized value of this indictor was preferred in developing the composite index for sustainability level.

(7) **Density of Animal :** More the animals, more is the demand for fodder which is produced using land and other natural resources. Besides, grazing is a common practice to meet the fodder requirement for animals.There is already speculation that small ruminants like sheep and goat are `desert makers'. The cattle, sheep and goat are the major species of animals which intensively graze in the area. Therefore, the minimum of standardized value of animal density was preferred.

(8) **Animal Growth Rate :** The size and direction of animal growth rate is another factor which increase the burden on natural resources causing problems for sustainability. Hence the minimum of standardized value of animal growth rate (1992 to 1997) was preferred.

(9) **Share of Grazing Land :** The share of grazing land to the geographical area is expected to increase with increase in livestock population. Hence maximum of standardized value of share of grazing land is desirable.

(10) **Number of Tractors/Thousand Hectare of Sown Area :** Tractarisation may help to cover more area under crop by using the limited moisture on the onset of rains. But deep ploughing of the filed may uproot the limited vegetation particularly, the tree species of the area naturally grown on the onset of rains. Besides, putting more and more area under plough may limit the scope to develop arid forestry practices which has scope to enhance sustainability in the area. Therefore, minimum tractarisation is assumed to help sustainability in the area.

(11) **Number of Wells/Thousand Hectare of Net Sown Area :** The number of new wells and also the number of wells going out of use are already on higher side in this belt. The rainfall is scanty and erratic. Inspite of the limited scope to replenish the ground water resources, more and more wells are being added every year. Despite high inter-district variation in this indicator it was retained in

view of its high relevance in making the desert area sustainable. Minimum of standardized value of the number of well, as indicator for sustainability is preferred.

The district-wise values of these indicators are given in table 41 and the ranks on the basis of magnitude of the sustainability indicators of the districts on the lines explained in section 4.4 are given in table 42.

Table 41. The Sustainability Indicators of Districts Covered Under Desert Belt of Rajasthan

Name of district	Population decennial growth rate (1991-2001) (%)	Agricultural and allied land per person (ha)	Share of primary sector workers (%)	Literacy rate (%) (2001)	Livestock density (1997) (No./sq km)	Livestock growth (%) (1992-97)	Share of forest (%)	Net sown area per person (%)	Share of grazing land (%)	No.of tractors/ (000 ha) net sown area	No.of wells / (000 ha) net sown area	Estimated values of sustainability indices	
												Including no. of wells	Excluding no. of wells
Barmer	36.83	1.34	84.30	59.65	148	32.29	0.99	0.75	7.26	2.65	16.59	5.33	5.31
Bikaner	38.18	1.13	61.90	57.54	93	23.76	2.87	0.73	1.70	6.16	2.73	5.12	5.12
Churu	24.60	0.85	77.10	66.97	127	24.39	0.48	0.65	2.66	4.37	7.95	5.34	5.33
Jaisalmer	47.45	1.80	64.40	51.40	64	74.67	0.58	0.85	2.71	3.78	8.32	6.93	6.93
Jalore	26.78	0.65	84.80	46.51	172	7.37	1.79	0.38	4.32	16.61	107.36	7.22	6.74
Jhunjhunu	20.90	0.29	67.20	73.61	211	17.29	6.70	0.22	6.83	11.66	98.62	6.88	6.25
Jodhpur	33.77	0.76	63.10	57.38	174	36.42	0.31	0.41	5.57	30.30	28.23	6.71	6.68
Naguar	29.33	0.61	78.50	58.26	184	15.13	0.96	0.46	4.06	7.70	42.64	6.11	6.03
Sikar	24.11	0.32	65.50	71.19	232	18.26	7.76	0.23	5.33	13.98	107.70	6.28	5.71
Mean	29.63	0.74	72.05	60.28	133	29.61	1.59	0.47	4.14	10.31	35.56	-	-
S.D.	7.99	0.46	8.74	8.37	51.10	18.55	2.23	0.22	1.81	8.33	42.52	-	-
Desirable (Max./Min.)	Min.	Max.	Min.	Max.	Min.	Min.	Max.	Max.	Max.	Min.	Min.	-	-

Table 42. The sustainability districtwise ranks of indices in the desert belt of Rajasthan

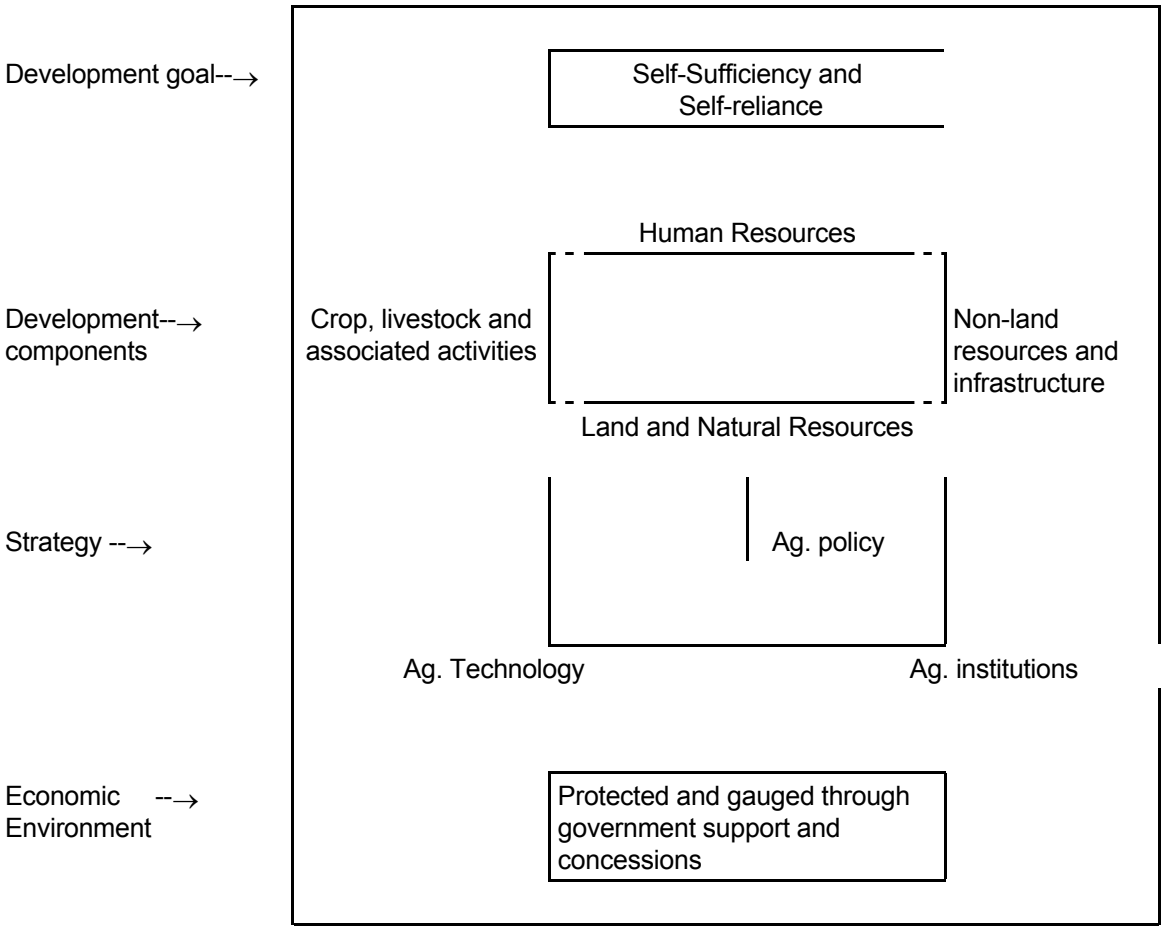
	Ranks of sustainability indices	
District	Including wells	Excluding wells
Barmer	2	2
Bikaner	1	1
Churu	3	3
Jaisalmer	8	8
Jalore	9	9
Jhunjhunu	6	6
Jodhpur	7	7
Naguar	4	5
Siker	5	4

On the basis of eleven indicators representing land resources, human and livestock population and created infrastructure for agricultural development the process of development in the districts of Barmer, Bikaner and Churu emerged as relatively more sustainable. In these districts the literacy rates are high, livestock density is less, livestock growth is less, net sown area per person is high, number of tractors and wells per unit of area is less. On the contrary, the development processes in districts like Jalore, Jaisalmer and Jodhpur are least sustainable. In these districts the population growth is high, literacy rate is low, livestock density and growth are high, share of forest area is the least, share of grazing land is low, number of tractors and wells per unit area is high. In short, in the western dry region where there is either accute desertic situation or where agricultural activities are intensively taken up, there exists lack of sustainability. On the other hand, in those districts where agricultural activities are relatively less intensive, the process of development is more sustainable. In any case traditional agriculture activities are going to continue in these districts until alternative livelihood means are generated. In such a situation two options emerge. Firstly, initiate and promote development programmes particularly social development activities like education so that part of workforce is shifted from agriculture to non-agriculture based activities. Secondly, a paradigm shift is needed in the approach for development. The development approach may be shifted from `**component based**' to `**system based**' on

the lines explained below.

The aspect of sustainability, though a hard task, will have to be an uncompromising goal of development strategy for the desert eco-system. The man, animals and other components in the desert eco-system will have to exist in harmony with the nature and natural resource. The set goal of self-sufficiency/self-reliance in agriculture in the past was achieved through the multi-pronged strategy by evolving technologies, developing a host of agricultural institutions and supporting the system through policy intervention by the government. The whole system has been operating under protected economic environment and was guaged through the government support. The development strategy continued to operate without making required assessment on the implications of any one particular component on the rest of the components of the system. The past development goal, strategy, component and the economic environment are summarised in chart-2.

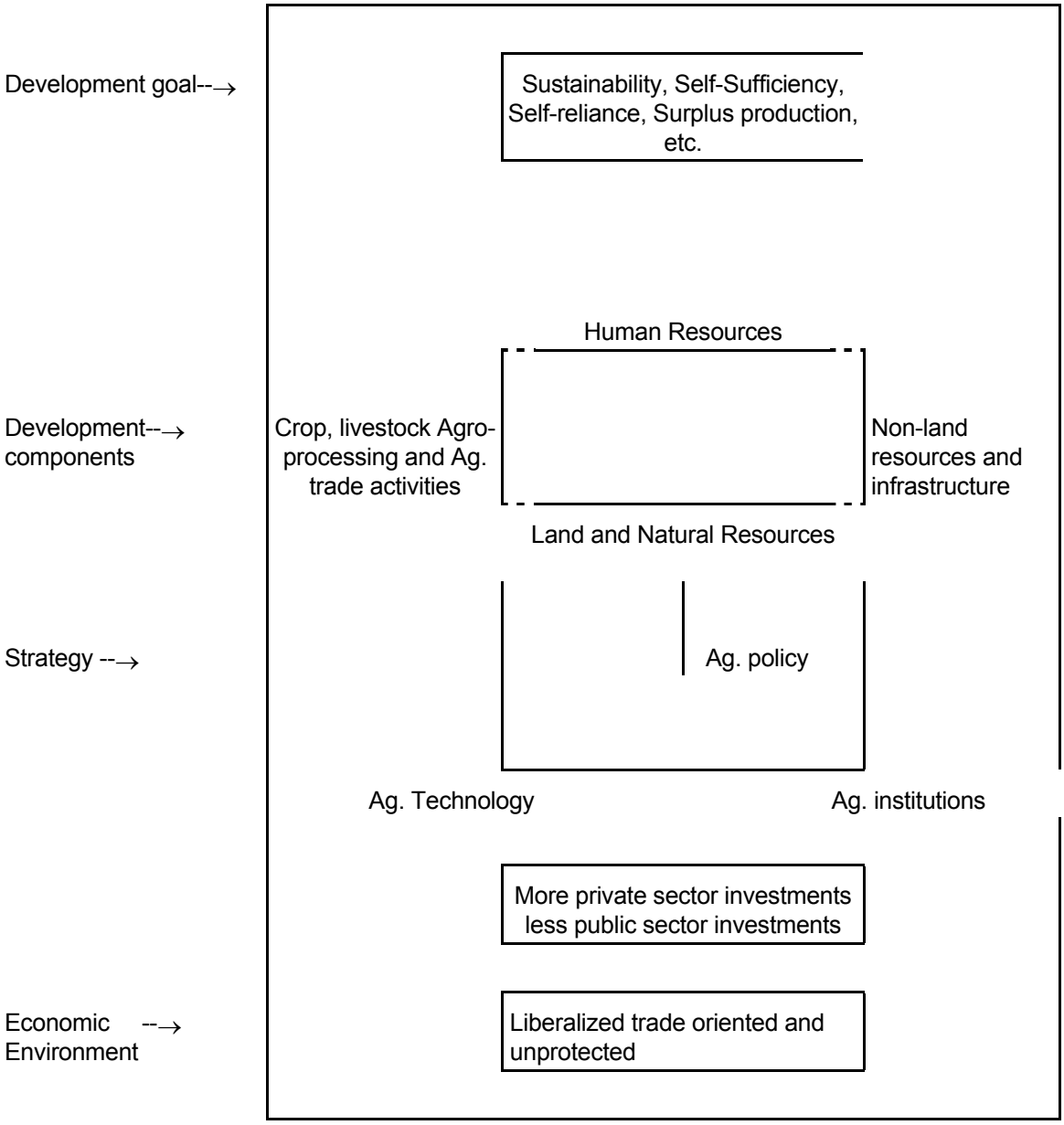
Chart 2. Past Agricultural Development Scenario in Rajasthan Desert Belt



With the opening up of the Indian economy through the process of globalization and liberalization, the desert. agriculture has to attain strength to withstand the new shocks emerging from the new trade regime

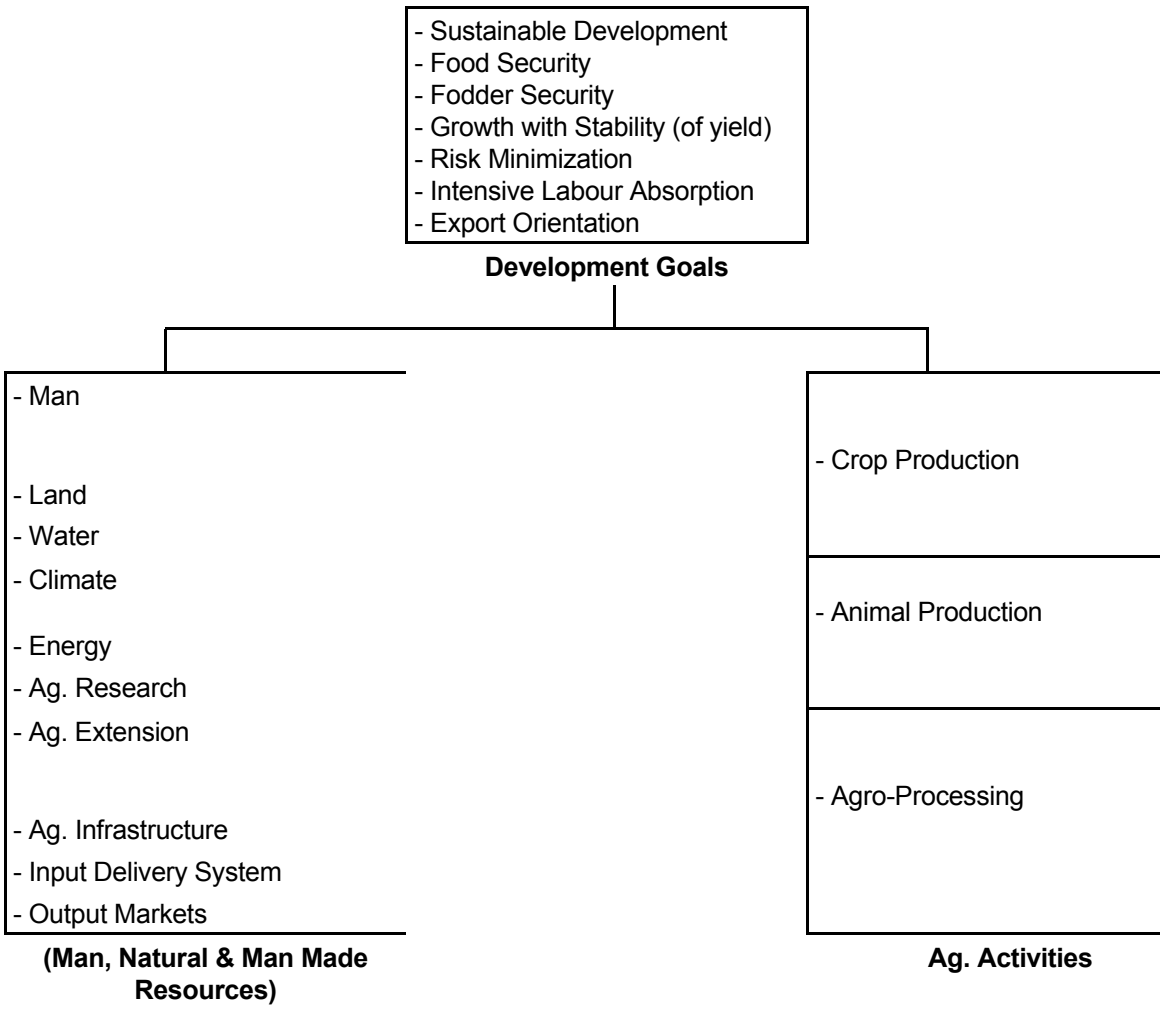
The sustainability is required to be given prime consideration in the changing agricultural development scenario. The proposed agricultural development strategy, so as to ensure sustainability, must include the same as a development goal. The development strategy for various components like human resources land and natural resources, crop livestock and other activities and also non-land resources must be integrated in such a way that the implications of one component should not lead to distortion in other components. The proposed strategy in terms of development goals, components, strategy and the broad economic environment are summarised in chart-3.

Chart 3. Proposed Agricultural Development Strategy for Sustainability in Rajasthan Desert Belt



The development strategy (as summarised in chart-4), keeping sustainability at the top among development goal and integrating the development goals with the resource base including natural resources and resetting of agricultural activities to meet the set goals may help to prevent further distortions in the system and may help to build up a better eco-system to ensure sustainability.

Chart 4. Sustainable Agricultural Development Strategy for Rajasthan



The agricultural activities in the desert belt should not go beyond the capacity of the natural resources. The social development, particularly primary education for all may help to control the ever increasing population rate. Besides, there is a great need to divert major part of work force from land based activities to other areas including abundant source of solar energy based activities. The development strategy for the area must not be one which makes life harder for the already hard life of the people. The strategies involving people may yield rich divident in this direction.

5.17 POLICY IMPLICATIONS

The imbalances in land use pattern, particularly the insignificant share of forest area despite enormous scope to develop arid forestry in the desert belt and also the abnormally large area going under plough every year are in no way indicative of the process of development aiming at sustainability of natural resource base in the ego-fragile desert belt of Rajasthan. The diversion of fallow land, culturable waste land and even pasture and grazing land for cultivation purposes is evident from the temporal trend in the land use pattern of districts covered under western dry region of the state. While the land use pattern in this belt is desired to promote the process of sand stabilization, the present land use pattern is one leading to aggravate the problem of decertification. The continued ploughing of more and more land every year using tractor on the on set of rains will have adverse impact on the increased survival of trees and shrubs which are important to build a better eco-system in this area. A strong location specific land use planning strategy which promotes sand stabilization process and which prevents further aggravation of decertification needs to be devised.

The rapidly increasing size of human population in almost all the arid districts add to the pressure on fragile land as livelihood system is more dependent on land resources in this belt. The dominance of small villages and very large inter-village distances stand in the way of developing adequate infrastructure for social development including education. Hence no substantial shifting of work force from agricultural based activities could be achieved. The female literacy is the lowest in the western dry region of the state. The usual mode of social development programmes may not be feasible in the desert belt. The social development programmes, particularly education and training programmes in this region must aim for diversification of occupational opportunities which are less land based implying creation of more non-land based employment opportunities.

The fast growth in the number of livestock in the districts covered under desert belt adds to the pressure on land. The increased fodder requirement is yet another factor to put more and more area under plough. The animal density is more than human density of population in all the districts covered under western dry region. In fact no `herd planning' strategy is prevalent in this area. While the share of cattle and other draught

animal population is on a decline, the share of buffalo population has gone up in most of the districts, which in turn adds to the demand for feed-fodder. An effective herd-planning strategy which helps in building up a friendly eco-system without adversely effecting the rural household economy is required to be devised.

The growth of oil engine, electric motor and tractors in the desert belt is really alarming. The increase in oil engine in this region is about 33 times over the period 1966 to 1997. Similarly the increase in electric motor is about 240 times during this period. The number of tractors has gone up by 86 times. The over-exploitation of ground water resources is quite evident. The ground water exploitation is required to be restricted to the replinishable level by enforcing stringent laws in this belt. Similarly, there is a great need to restrict the indiscriminate use of tractors and other farm machines to minimize the problems due to shifting sand dunes in this area.

The crop production strategy followed in this region is one aimed at food security of the people and fodder requirement for animals. The cropping pattern is mostly kharif monocropped with dominance in mixed crops having cereals, pulses, oilseeds etc. The high inter-year instability in the yield of these crops is quite natural. It causes heavy losses to the regular investments made by the growers of the crops. The crop production activities are taken up under very high risk. Therefore, the agricultural technological intervention must aim to minimize the risk by stabilizing the yield level of major crops through varieties and cultural practices befitting to the area. The farmer's practice of growing mixed crops on same plots needs appropriate technological support to minimize the risk.

The production environment of agricultural farms in the desert belt consists of (i) unirrigated, (ii) partially irrigated (less than 50% area irrigated) and (iii) irrigated desertic situation, the category (i) being the most predominant one. On unirrigated farms, crops are taken up only in kharif season. On irrigated and partially irrigated farms both kharif and rabi crops are taken up. The herd size of livestock per household revealed positive association with extent of irrigation. The cost of cultivation, the gross income and farm business income on unit area also revealed positive association with extent of irrigation. Large majority of the farmers in unirrigated farm situation could not realize the paid out cost from crop farming. Despite negative profit from mixed crops, farmers still take up

mixed crop which indicate that the food fodder security overweighs the profit motive from crop farming on unirrigated farms. The pulse crop moth bean was found to have minimum risk under unirrigated desertic condition. The animal based economic activities were also found to have net loss on unirrigated farms. In short, both crop and livestock activities are taken up under virtual economic loss and causing damage to the environment in the desert belt, particularly under unirrigated condition. In fact there is close nexus between crop and livestock based economic activities and together those two activities poses problem in sustainable agricultural development. Apart from the direct implications of agricultural activities in building up a better environment in the desert belt, there are divergence between the private and social incentives due to crop and animal based agricultural activities. More and more area under plough limits the scope for arid afforestation. The loss to plant kingdom due to intensive grazing by animals and the subsequent problems in sand stabilization in the desert belt is a reality. The extensive growth of vilayati babul (*Prosopis juliflora*) helps in developing vegetative cover and blocks fast movement of sand from field to roads etc. The adverse implication of this plant species is that it does not allow other plants to grow under it or even in its neighborhood. A large section of sample respondents realized that animal grazing, tracterisation, present cropping pattern, present animal husbandry practices and present land use pattern lead to desertification. The unreplinishable groundwater exploitation and indiscriminate tracterisation are the externalities emerging out of agricultural practices in the desert region.

The economy - environment interactions in the desert belt poses two types of problems. Firstly the economic activities adds to the severity of basic fragile nature of the eco-system. Secondly, the developmental efforts to improve the adverse situations are not allowed to bear results. Therefore, the question of sustainability of desert agriculture is of paramount relevance.

The community based resource conservation practices include growing of Khejri (*Prosopis cinerasia*) trees which are multipurpose ecofriendly type, the indigenous water storage system including wells, baories, jhalaras for ground water and tanks, talab, tankas, khadins etc. for harnessing surface runoff are also community based resource conservation practices.

The sustainability indices were worked out for each of the districts covered under the western dry region. The composite indices were worked out using selected indicators on land resource, human population, livestock population and agricultural infrastructure. More specifically the parameters used for ascertaining sustainability included share of forest area, the size of net sown area per person, land-man ratio, decadal growth rate of population, literacy rate, share of workforce on primary sector, density of livestock, animal growth rate, extent of tracterisation, share of grazing land and extent of groundwater exploitation. On the basis of joint effect of all these factors the districts in the order of sustainability level are Bikaner, Barmer, Churu, Sikar, Nagaur, Jhunjhunu, Jodhpur, Jalore and Jaisalmer. On the basis of eleven indicators representing land resources, human and livestock population and created infrastructure for agricultural development the process of development in the districts of Barmer, Bikaner and Churu emerged as relatively more sustainable. In these districts the literacy rates are high, livestock density is less, livestock growth is less, net sown area per person is high, number of tractors and wells per unit of area is less. On the contrary, the development processes in districts like Jalore, Jaisalmer and Jodhpur are least sustainable. In these districts the population growth is high, literacy rate is low, livestock density and growth are high, share of forest area is the least, share of grazing land is low, number of tractors and wells per unit area is high. In short, in the western dry region where there is either accute desertic situation or where agricultural activities are intensively taken up, there exists lack of sustainability. On the other hand, in those districts where agricultural activities are relatively less intensive, the process of development is more sustainable. In any case traditional agriculture activities are going to continue in these districts until alternative livelihood means are generated. In such a situation two options emerge. Firstly, initiate and promote development programmes particularly social development activities like education so that part of workforce is shifted from agriculture to non-agriculture based activities. Secondly, a paradigm shift is needed in the approach for development. The development approach may be shifted from `**component based**' to `**system based**'.

The specific policy recommendations are as under:

(1) Effective land use planning keeping in view the strength and weakness of the land resources is advocated so as to keep proper balance between the area put

under various land uses to avoid distortions and imbalances.

(2) Herd planning at household level is warranted in the desert belt to block the ever increasing growth of livestock population which in turn increases the demand for fodder and asserts pressure on land for fodder oriented crop production.

(3) Stress on social development programme including that on higher education to divert workforce from land based activities to other sector and also to check the exorbitant growth rate of population are very much required in this area.

(4) Stress on agricultural technologies to reduce the yield instability rather than that of yield increasing technology is the need of the area, as crop production is taken up under very high risk. Risk minimizing management strategies form the crucial aspect of agricultural production in this belt.

(5) The farm credit strategies will have to be given a new orientation keeping in view the exorbitant growth of tractors which may adversely effect the vegetative growth and sand stabilization process in this eco-fragile area. The large increase in the number of wells and tube-wells and also in the number of wells going out of use also stress the need to review the agricultural credit policy for this area.

(6) The growth of livestock population including draught animals on one side and the large stress on farm mechanization caused for diseconomics at the household level. Corrective measures are needed for the farm energy supply in this region.

(7) The large economic losses leading to high risk in crop and livestock based activities supports the need to evolve farm activities by integrating the capability of land resources and also the erratic nature of climatic factors, particularly the quantum and distribution of rainfall.

(8) The pressure of livestock and human population on land is to be kept in accordance to the land productivity to avoid indiscriminate use of land and natural resources.

(9) A shift in the development paradigm by devising strategies so as to have proper interface of agricultural activities with capabilities of resource base, particularly

natural resources is very much warranted.

(10) The community based resource conservation practices like growing of multipurpose, ecofriendly tree species like `Khejri' and indigenous water storage system including wells, baories, jhalaras for ground water and tanks, talab, tankas, khadins etc. for harnessing surface runoff are to be promoted.

(11) The development strategies should follow a system approach rather than a `component approach' so that the ill-effects of one component on the development of other component is minimized.

6. SUMMARY AND CONCLUSION

6.1 SUMMARY AND CONCLUSIONS

The study entitled "Environmental Economics of Desert Agriculture in Relation to Natural Resource Management in Rajasthan" was taken up as a part of world Bank aided India : Environmental Management Capacity Building Technical Assistance Project' which was coordinated by the Indira Gandhi Institute of Development Research, Mumbai. The reference area of the study included nine western districts of Rajasthan which cover the Western Dry Region, of the 15 national level regions delineated for the Agro-chemotic Regional Planning, launched in 1988 by the Planning Commission, Govt. of India, New Delhi. This study basically aims to analyse the phase of growth of agricultural activities and its compatibility with the agricultural resources including land in the eco-fragile region covering the desert belt of Rajasthan. The management of environment in this belt calls for attempts towards developing a better eco-system on one hand and the other hand efforts to blocking any attempt to deteriorate the situation from bad to worse. The specific objectives of the study are as follows :

(i) to asses the pattern of temporal trend in different land use classes in the districts covered under the region.

(ii) to examine the extent of growing pressure of human and livestock population on the eco-fragile land base,

(iii) to study the nature and extent of changes taking place in the cropping pattern,

(iv) to measure the yield instability in various crop enterprises in the region,

(v) to examine the economics of desert agricultural practices/agricultural system in the context of environmental sustainability,

(vi) to work out the nature and extent of risk in various agricultural enterprises,

(vii) to identify the risk minimization strategies being adopted by the farmers,

(viii) to assess the divergence between private and social incentives and also the externalities of risk minimizing strategies of farmers on environmental settings,

(ix) to trace the changes in property rights and status of land ownership due to government policies and development interventions,

(x) to document community based economic institutions and resource conservation practices in desert agriculture.

The analytical approach included the analysis of secondary data available on various aspects related to agriculture as well as collection and analysis of primary data related to farm based activities.

The districtwise analysis of land use pattern revealed very meager coverage of forest in all the districts and very large coverage of sown area in the districts of Churu, Jhunjhunu, Nagaur and Sikar limiting the scope for diverting land for eco-friendly practices like arid forestry which is a prime need for this area. Besides, the declining growth in fallow land, culturable waste land pasture land etc. in most of the districts is indicative of diverting all possible area towards crop production in this sensitive area. There is a great need to have a strong land use planning strategy for this area so that proper eco-balance is established between various classes of land use.

Over the years, the animal population has been growing at a very faster rate in all the districts. Without improving the carrying capacity of land, the indiscriminate growth of all animals, particularly the exorbitant growth of large animals like buffalo and grazing animals like sheep and goat may lead to deterioration of the eco-system. The large risk in crop production prompts the farmers to resort on livestock based activities. The growth and shifting composition of livestock population indicate the absence of herd planning in relation to carrying capacity of land.

The large growth rate in the human population in almost all the districts covered under this region is yet another factor causing imbalance in the eco-system. The ever increasing need for generating income and employment opportunities is largely dependent on land based activities as the literacy rate of the rural population is remarkably low in this region. The workforce pattern over the years revealed that the

extent of marginal workers with sub-optional workdays is also on increase in this area. The increased burden on land arising from agriculture based activities is likely to adversely affect the efforts to arrest desertification in the belt. The large dependence of workforce on agriculture is likely to pose environmental problems in the eco-fragile area.

The crop yield of all the crops in all the districts is prone to high inter-year instability and the cropping pattern has undergone changes over the years. Even the crop production strategy seems to be guided by the traditional sequence determined by food and fodder requirement on the farm households. There is a great need to devise appropriate crop mix strategy in this area, keeping in view the extent of risk in the production of various crops.

There exists a wide gap between production and requirement of major commodities like cereals, pulses oilseeds in most of the districts in drought years. Even in normal sort of years in this area, the production level of these commodities was short of actual requirement.

The farm energy supply was found shifted over the years in favour of mechanical sources like tractor, oil engine and electric motor, though the camel and cattle population ensures on farm supply of energy with the committed burden of maintaining these animals on the farm irrespective of the extent of its use.

The micro level farm data revealed that the cropping pattern in the unirrigated desertic belt is dominated by kharif season crops like bajra, guar, moth as single crop and mixed crop cultivation of different combinations of bajra, guar, moth, moong, sesamum etc. As the extent of moisture availability increased, the cropping pattern gets diversified with more crops in both the kharif and rabi season. The on-farm herd size was found to increase with improvement in the access of water resources. The share of land value dominated the total farm asset value in unirrigated, partially irrigated and irrigated situations in the western dry region of the state. The absolute and relative share of machines and irrigation structures was found to be more on partially irrigated and irrigated situation in the region.

The analysis of crop production economics revealed realization of positive farm business income (return over all paid/actually incurred cost) in all the three situations

(unirrigated, partially irrigated and irrigated) under study. However, when imputed cost for land and other capital resources and family labour is added to the paid cost items, the crops production activity is on a virtual loss in all the three situations. In the typical unirrigated desert belt, about 78 percent of the crop growers could not realize even the paid cost during the study year (1999-2000). The analysis of micro level farm data also confirmed the high risk involved in the corp production activities. The economic analysis of individual crop enterprises revealed that production of moth crop is relatively advantageous in the unirrigated desertic situation. The mixed crop cultivation was found to be a loosing enterprise even at the paid cost level.

The economic analysis of livestock production also revealed that the gross return from the combined livestock based activities has not been sufficient to meet the incurred paid cost for this activity in the unirrigated desert belt. About 69 percent of farm household failed to recover the paid cost out of gross returns from livestock based activities.

The fate of farmers living under the unirrigated desertic condition is quite deplorable as the size of household income from all sources is only Rs. 22687/household for the whole, year.

Both crop and livestock based activities have divergence between private and social incentives in the desert belt. The positive growth in the sown area over the years coupled with high share of sown area to total geographical area blocks the prospects for diverting land for environmental friendly activities like development of arid forestry. Besides, frequent ploughing of soil with machines like tractor uproot the bushes and grasses and does not allow the natural sand stabilization process to play its role. The feeding practices for animals in this belt is largely based on indiscriminate grazing of animals on land which in turn adversely affects the survival of struggling plant species under moisture stress condition. The government policies for easy access to farm loans have prompted the farmers to go for more and more groundwater exploitation by digging wells and farm mechanization by purchasing heavy mechanics like tractors. While promoting agriculture through irrigation based on groundwater exploitation followed by mechanization,the likely adverse impact on environmental aspects were probably not taken into account.As a result a large number of wells have dried and are out of use in this belt. Since the crop production is mostly confined to one season

immediately after monsoon, the use of tractor is also seasonal and hence remains idle for the major part of the year. Apart form environmental problems, such activities lead to diseconomics at the farm household level, as involves high investment with limited scope for adequate use of its potential.

Though the practice of growing and protecting tree species like `khejri', `babool' etc. on the farm is on age old tradition in this belt, the required technological support is a mislink. These tree species have lot of feed, fuel and other values. There is virtually no institutional support to develop the tree species which have proved its survival under extreme condition.

The values of composite indices based on indicators representing land, people, animal and agricultural infrastructure indicated lack of sustainability in all the districts of the desert belt. On the basis of eleven indicators representing land resources, human and livestock population and created infrastructure for agricultural development the process of development in the districts of Barmer, Bikaner and Churu emerged as relatively more sustainable. In these districts the literacy rates are high, livestock density is less, livestock growth is less, net sown area per person is high, number of tractors and wells per unit of area is less. On the contrary, the development processes in districts like Jalore, Jaisalmer and Jodhpur are least sustainable. In these districts the population growth is high, literacy rate is low, livestock density and growth are high, share of forest area is the least, share of grazing land is low, number of tractors and wells per unit area is high. In short, in the western dry region where there is either accute desertic situation or where agricultural activities are intensively taken up, there exists lack of sustainability. On the other hand, in those districts where agricultural activities are relatively less intensive, the process of development is more sustainable. In any case traditional agriculture activities are going to continue in these districts until alternative livelihood means are generated. In such a situation two options emerge. Firstly, initiate and promote development programmes particularly social development activities like education so that part of workforce is shifted from agriculture to non-agriculture based activities. Secondly, a paradigm shift is needed in the approach for development. The development approach may be shifted from `**component based**' to `**system based**'. The developmental activities taken up in this belt were more component based rather than system based. Efforts were made in the past to develop natural resources like land

and water, infrastructural facilities like road and rail, communication facilities, social development institutions, agricultural activities based on crop and livestock and also the human resources. However, the implications of the development of one on the other were not adequately looked into and as a result a lot of distortions have crept into the system components. Corrective steps are warranted to make the process of development more sustainable in the eco-fragile desert belt of Rajasthan.

6.2 RECOMMENDATIONS

(1) Effective land use planning keeping in view the strength and weakness of the land resources is advocated so as to keep proper balance between the area put under various land uses to avoid distortions and imbalances.

(2) Herd planning at household level is warranted in the desert belt to block the ever increasing growth of livestock population which in turn increases the demand for fodder and asserts pressure on land for fodder oriented crop production.

(3) Stress on social development programme including that on higher education to divert workforce from land based activities to other sector and also to check the exorbitant growth rate of population are very much required in this area.

(4) Stress on agricultural technologies to reduce the yield instability rather than that of yield increasing technology is the need of the area, as crop production is taken up under very high risk. Risk minimizing management strategies form the crucial aspect of agricultural production in this belt.

(5) The farm credit strategies will have to be given a new orientation keeping in view the exorbitant growth of tractors which may adversely effect the vegetative growth and sand stabilization process in this eco-fragile area. The large increase in the number of wells and tube-wells and also in the number of wells going out of use also stress the need to review the agricultural credit policy for this area.

(6) The growth of livestock population including draught animals on one side and the large stress on farm mechanization caused for diseconomics at the household

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(7) The large economic losses leading to high risk in crop and livestock based activities supports the need to evolve farm activities by integrating the capability of land resources and also the erratic nature of climatic factors, particularly the quantum and distribution of rainfall.

(8) The pressure of livestock and human population on land is to be kept in accordance to the land productivity to avoid indiscriminate use of land and natural resources.

(9) A shift in the development paradigm by devising strategies so as to have proper interface of agricultural activities with capabilities of resource base, particularly natural resources is very much warranted.

(10) The community based resource conservation practices like growing of multipurpose, ecofriendly tree species like `Khejri' and indigenous water storage system including wells, baories, jhalaras for ground water and tanks, talab, tankas, khadins etc. for harnessing surface runoff are to be promoted.

(11) The development strategies should follow a system approach rather than a `component approach' so that the ill-effects of one component on the development of other component is minimized.

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