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Towards solving the global desertification problem (2)

—Research on the evaluation of interaction between desertification and human activities—

砂漠化問題の解決にむけて（2）

—砂漠化と人間活動の相互影響評価に関する研究—

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Preface

Japan Environment Agency has established Global Environment Research Programs in 1990. The Desertification Research Project was started in 1990 as "Feasibility study on the environmental assessment of desertification in arid and semi-arid areas", for which the National Institute for Environmental Studies (NIES) played the role of a leading organization. The feasibility study continued for two years till March 1992.

Following the feasibility study, "Research on the evaluation of interaction between desertification and human activities" has been proceeded as a three year program from 1992 up to March 1995. It consists of three sub-themes; (1) "Evaluation of human activities on desertification in arid and semi-arid areas", being conducted by the National Institute for Environmental Studies (NIES), in Indian Desert, (2) "Evaluation of human activities on desertification in semi-arid and sub-humid areas", being carried out by the National Institute of Agro-Environmental Sciences (NIAES), in Chinese Desert, and (3) "Comparative study of human activities on desertification in arid and semi-arid areas of different countries", being coordinated by the NIES.

For the desertification study in India, "Memorandum of Understanding between Indian Council of Agricultural Research and National Institute for Environmental Studies for Collaborative Research on Desertification" was signed in August 1993, and the field studies commenced with the Central Arid Zone Research Institute (CAZRI), Jodhpur.

The first volume of monograph, "Towards solving the global desertification problem (1) - Feasibility study on the environmental assessment of desertification in arid and semi-arid areas -" was published in Japanese in March 1992.

This monograph is summarizing mainly sub-theme (1), Indian study, and contains the summary of the present status of the desertification and reviews of the vegetation studies and methodologies for desertification monitoring using remote sensing techniques. In addition, the records of the processes to initiate the Project and the information on the Chinese institutes related to desertification studies in a context of sub-theme (2) were included.

This monograph would be useful for understanding the desertification phenomena and also helpful when a similar International Program is to be established.

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Part 1 Status of Indian Desertification

I. Desert Region in India: Resource Management Issues and Research Strategy

R. B. Singh

1. Introduction

About 36 percent of the land surface and half of the countries of the world face problem of desertification. The major deserts are located in tropical parts over western margins of continents. But other lands are also affected by desertification through their extreme temperature, low rainfall and aridity and these areas contribute towards low productivity and ecological degradation. The desert regions which represent the complex, and interrelated ecosystem of our planet are rapidly changing. The human and livestock population are increasing at a rapid rate. They are susceptible to accelerated hazards and desertification. There is widespread poverty among inhabitants. Thus, the proper resource management and socio-economic development of the people deserves immediate action. Recognizing the interplay of ecological and developmental factors, there is an urgent need to generate and strength knowledge about the ecology and sustainable development of the arid land ecosystem on the one hand and promoting integrated development and alternative livelihood opportunities.

Ecological degradation is the major critical issue in any desert land because it causes human disaster. Desertification is considered as a human problem (Eckholm and Brown, 1977). Man is both the main cause and the victim of such ecological degradation. Despite frequent droughts and impossible living conditions, the human and livestock population in the Indian desert area is increasing at an alarming rate. This has considerably increased the biotic interference in the natural environment, resulting expansion of the desert. There is urgent need to streamline all human activities in the region, strictly in consonance with its ecosystems. In this context, consistent and accurate environmental data are prerequisite to protect natural resources and environmental quality. Ecological studies have been useful interest of geographers since long, Therefore, geographical monitoring should be considered as an integral part of such

studies. This approach is conceived by geographers as geosystem monitoring, describing natural-economic monitoring. The concept of ecological monitoring (i.e. a system of observation of anthropogenic changes in the environment) is now very popular (Gerasimov, 1983). An effective monitoring system of natural and man-made changes should enable to observe complex process of desertification at an early stage. This will further help to forecast such changes and will also provide sound base for resource management strategy.

In present paper, an attempt has been made to assess landscape degradation for future potential risk of such degradation in desert region. Priority has been given to monitoring renewable reissues. It is anticipated that such assessment will form the base against which future changes can be measured. It shows that there are two groups of indicators to be monitored: the physical set of indicators and the socio-economic (human) ones.

2. Indian Semiarid Areas and the Study Region

Broadly Indian semi-arid land lies in the states of Rajasthan, Gujarat and Haryana besides small areas in Andhra Pradesh and Karnataka (32 lakh sq. km.). About 70 percent of the cultivated area in India is rainfed of unirrigated, covering 100 million ha., mostly it coincides with the semi-arid regions, having an annual rainfall of 500 to 1100 m.m. The hot arid regions of Rajasthan comprises 11 districts of western Rajasthan. About 96 percent of the area is being degraded by various processes and 4 percent is in desert situation.

The Indian desert region extends approximately between 21 and 31 north latitudes and between 69 and 76 east longitudes. It comprises about 295,000 sq. km. area of western Rajasthan incorporating 11 arid districts and 60 sub-units (Tehsils) west of Aravalli. The region with population of 10.9 mill. (1981) is one of the highest densely populated arid regions of the world. It supports large human population (64 persons per sq. km. in comparison to 3 in other arid regions). It shares 61 per cent area and 39 per cent population of Rajasthan state. The concentration of population, settlement and resources in Indian context are low due to lack of rainfall, high temperature, poor and unproductive sandy soil surface, problem of drinking water as well as lack of transport and communication facilities and economic opportunities (Singh, 1984).

The Thar desert (west Jaisalmer district) in western Rajasthan of India is a large desolate sandy tract, devoid of surface water, receiving capricious rain-fall, often varying in quantity from year to year. A lower rainfall bring periodic drought and famine conditions causing large scale migration of people, with their herds of cattle to neighboring lands causing great hardships. It was early realized that irrigation water is the principle means in this region which could change the scenario of scarcity to prosperous agriculture.

The empirical study also covers three tehsils of Ganganagar district which have come in the command area of the India canal, namely Hanumangarh, Suratgarha and Anupgarh. This district has a unique situation of receiving canal irrigation through several irrigation networks in the last four decades. It, thus, provides a rare combination for eco-geographical studies due to existence of original desert ecology, having rainfed agriculture besides the changed landmass which has come under assured irrigation supply, in varying stages of environmental transformation through successive laying out of irrigation networks.

3. Geographic Dimensions of Natural and Human Resources

Almost all physical and economic resource characteristics of the region depend upon the prevailing climatic conditions. The annual rainfall is below 10 cm. in eastern sides. It is characterized by extremely high range of temperature and aridity. The sand dunes are found in most part of the area, while sandstone is also found in limited area. Sri Ganganagar has plain area formed by older alluvium. Mainly two types of soil exist: i) Yellow brown (desert) soil - It is found in western and northern part of the region. It contains about 90-95 per cent sand and about 5.7 per cent clay, high pH value, much soluble salt and some amount of calcium carbonate with poor organic matter, and ii) Grey brown (desert) soil - It is found in the eastern part of the study area, containing rich organic matter and more nitrogenous elements than previous. Ground water table is very deep (91-120 metre). The north-eastern areas i.e. Jhunjhunu (201) and Sikar (31) are the areas of high density. 21.31 per cent of population is characterized as urban which is higher than that of the state, varying from 8.06 per cent in Jalor to 39.01 per cent in Bikaner district. Rapid urban growth has been observed in Sri Ganganagar district due to agro-industrial development. About 22.25 per cent population is literate which is lower

than that of India (36.12). Literacy rate of males is 33.60 per cent as against 10.80 per cent of females in 1981. Poverty, lack of educational institutions, poor transport connections to the growing population have caused low literacy in the region.

The arid region of India is less fertile and it suffers from lack of moisture and poor irrigation. Therefore, slight increase in net sown area has been found but over all agricultural output has not been much affected. Agricultural efficiency indices have positive relationship with the rainfall and per cent arid area. The indices vary from 45.5 in Jaisalmer to 139.5 in Sri Ganganagar. 29.44 per cent population is working which is below the national average (33.44%). In the western Rajasthan, 71.81 per cent of workers are engaged in agricultural activities and the rest in non-agricultural activities (28.19%) having maximum (42.81%) and minimum (17.22%) in Bikaner and Barmer respectively. Only 3.99 per cent of workers are recorded in household industry. Sri Ganganagar records the highest proportion of immigration due to the new agricultural economy based on irrigation facilities. Here about half of the population that lives at present belongs to outside the place of birth category. The rural-urban migration varies from 2.8% in Jalor to 9.2% in Bikaner district (Singh, 1984).

4. Desert Recroachment

Desert encroachment is a serious problem in Indian arid zone. There have been fears expressed that Thar is spreading across parts of Rajasthan, Gujarat, Punjab and Haryana where there was some vegetation. According to studies conducted by (AZR) in Jodhpur, 9,290 sq. km. or 4.36 per cent area of western Rajasthan has already been desertified in the last yeas and a further 162,900 sq. km. is vulnerable to desertification. Recent topographical surveys show the spreading desert outwards towards Ferozepur, Patiala, Delhi and Agra at the rate of about half a km. per year for the last few decades and it is encroaching fast upon the fertile land. But the meteorological record over previous 70 years showed no significant change in rainfall, temperature and humidity over the desert areas. So that the cause of this process is not only climatic change but human actions. Increase in population and lack of alternative employment opportunities have left the people living in the arid region with no choice but to continue grazing of cattle.

5. Increasing Overgrazing

The desert has faced an unprecedental growth in its population in the last 30 years from 5.53 mill. in 1951 to 10.9 mill. in 1981. The increase of cattle population (51 per sq. km. in 1983) has put unbearable pressure on the restricted grazing area that exists in the desert. In 20 years, the cattle population increased from 10.27 mill. in 1951 to 16.44 mill. in 1971.

Livestock is an important asset of Rajasthan arid zone nest only to agriculture and in certain pickets of western Rajasthan, where drought is a regular phenomenon, livestock rearing is the main occupation. With more than 40 mill. heads of livestock, Rajasthan ranks third in India in animal wealth, The state's sheep population is about 16 per cent of the country's total population. The livestock population has steadily increased in the last 30 years. The number of cattle, buffaloes and sheep increased by 25 per cent, 72 per cent and 100 per cent respectively, while the number of goats increased by 338 per cent between 1951 -83 (CSE, 1985). The rapid rise in goat population has alarmed many ecologists. They are considered more harmful for soil conservation because they consume all ground vegetation. In this way, increase in livestock pressure caused serious overgrazing.

6. Declining Grazing Lands

In all the 11 districts of the arid zone, grazing areas have declined consistently since 1951-52. In 1983, grazing land has gone down to 7.6 m ha. Between 1961-71, while the area used for grazing declined by 15.6 per cent, the population of grazing animals increased by 63.2 per cent, creating imbalance between animal population and grazing lands. Local data from Luni block indicates that the grazing capacity of the land is approaching its limit and that the sand cover expanded from 25 to 33 per cent within the last 20 years (USAID). Land reform also affected such common lands due to large scale conversion of public land to private use. The slow destruction of region's grazing lands has created serious problems for management of vast animal population and particularly the affected are the nomadic population. Stall feeding has been repeatedly recommended by experts to stop ecological destruction but this is clearly impossible

unless there is a massive fodder production program (CSE, 1985)

In this way, land available for grazing is reduced, and the number of grazing animals increased which make it a sure case for overgrazing, soil erosion and desertification.

7. Impact of Droughts on Process of Desertification

Over 70 million people and 18 million ha. of cropped area spread over seven states i.e. Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Rajasthan and west Bengal are gripped by drought in 1992. The estimated loss in terms of kharif food-grains is placed at over Rs. 3,000 crore and for cash crop like cotton and oil seeds is estimated at about Rs. 5,000 crore.

According to an estimate, western Rajasthan is expected to face drought every 2.5 years. Such frequent occurrence of droughts creates environment of desertification. During 1971-72, there was an increasing trends of dust storms. Whenever rainfall falls steeply, there is a sharp rise in the occurrence of dust storms. It has a considerable significance in the soil erosion and desertification process. It also speeds up the process of their formation. The process of desertification is further accelerated by overgrazing on the pasture lands due to lack of fodder during droughts. An erratic climate and frequent failure of crops make the farmers all the more dependent on the livestock. For this purpose, a knowledge of the drought climatology of the region i.e. the frequency of occurrence of droughts, its duration and also the intensity would be of immense help (Singh, 1990).

8. Recent Dunes Formation

Recent dune formation provides a sure evidence of desertification. But it is not easy to convince that this phenomenon is not simply a naturally controlled one, but is a consequence of human impact of that is process which is enhanced by land misuse of catchment areas of these sands. Information collected from the old and new topographical sheets reveals that most of the stabilized dunes in eastern part of Jodhpur district, south-eastern part of Bikaner district and in Negaura and Jalor districts have been reduced in height by at least 3 to 5 metres which show the increase and decrease of sands within the desert in the recent years.

9. Impact of Mining

In Indian arid region, mining adds significantly to other desertification process. The region accounts for most production of lead, zinc, tungsten, phospherite, gypsum and steatite. Other major minerals are copper ore and lime-stone. Between 1979 and 1976, there was 86 per cent increase in area under mining for almost 50 different mineral. According to Mann (Director, CAZRI) and Chatterji. The existing mining regulations have taken into account only the systematic and complete exploration of mineral deposit without any consideration of the after effects of the mining operations on land productivity. Removal of vegetation and waste disposal of mining in arid increases erosion process (CSE, 1985). Desertification processes originates from such area. Development of soil salinity due to mining has degraded land around quarries in Jodhpur and near the gypsum quarries in Barmer district. The hydrology has been also disturbed effecting existing potential area for waters harvesting through traditional methods like Nadis and Khadins (Venkateswarlu,1991).

10. Impact of Indira Canal Project

Ganganagar district is benefited by a major irrigation network called Indira Gandhi Nahar Pariyojana which bring surplus water of river Ravi and Beas to the thirsty lands of Ganganagar, Bikaner and Jaisalmer districts of western Rajasthan. The canal water reached Ganganagar through Nasitawali Feeder in the year 1970. The Ganganagar district is the first beneficiary and its three tehsil have come under the command area of this canal system. The canal draws 7.59 MAF water in 204 km long feeder, 445 km long main canal and 16 branch canals, which makes up a total length of 6,500 km and irrigates 0.54 mha. land. It takes 60 days for the water to flow from Harike barrage to the end of the main canal. It is thus one of the largest canal system of the world, which has transformed the rainfed subsistence agriculture into commercial and highly profitable farming system in India. The canal has made Ganganagar district a cultivator's paradise.

11. Changing Land Use Pattern

The canal has increased total irrigation area from 353,993 ha (1961) to 902,849 in 1981, and cropping intensity to 110 per cent in Ganganagar district. This has introduced new commercial crops like cotton and groundnut in Kharif and sugar beet and Berseem in Rabi season. This has transformed the agriculture scenario into a dynamic and prosperous farming system. There is a small increase in the land under forest i.e, 2,988 ha in 1971 to 28,832 ha in 1981, but emphasis is increasing rapidly on afforestation work in the district as it is considered as key to improving ecological balance. In agriculture sector, therefore, there is no more land available for addition; the increase in production is possible due to better utilization of land resources and inputs like irrigation, fertilizer, mechanization in operation, adoption of new crop sequences and selection of new high yielding varieties. The change in cropping pattern is perceptible in the district. We note that area under cereal and pulse crops has gone down from 1976 to 1981 year whereas that under oil seed, cotton and other cash crops has increased illustrating the trend towards better utilization of land for more profitable agriculture. Even amongst the cereals and coarse grain, there is more land under high yielding varieties (HYV). For example HYV is wheat has risen from 80,100 ha in 1981 to 155,000 ha in 1977-88. Consumption of inorganic fertilizers have gone up from 13,093 tones (1970-71) to 38,097 tones (1981). The farmers, during field survey were found to adopt new and specific package of cultivation practices, recommended by state agriculture department. The yield of cotton and groundnut in the district is found at par with maximum reported in the country. This change in attitude of farming community for adoption of better technology promises not only for increasing crop yield but also improvement in ecological balance and call a halt to all those forces which cause land degradation and environmental deterioration.

12. Environmental Effects of Irrigation

The increase in human activity in form of multi-facet development in the arid tract, such as taking place in the district of Ganganagar has resulted in greater use of land and water, impeding hydrological and environmental changes. The soil in the district has high sodium and

calcium salts. It is found that the copious source of irrigation has supported movement of salt in upward direction due to impeded drainage and high rate of evaporation. This salt accumulates at the soil surface, making the land unsuitable for cultivation except for a possibly few salt tolerant species. During the survey of chalks along the Mundawali Minor in Hanumangarh tehsil, the study recorded a large part of land which bears white irregular patches showing salt accumulation. The natives call such land as "Sem". The "Sem" is of recent occurrence, its pH though was 7.9, but EC was 15.0 mmhos/cc with high calcium carbonate content. The cause of salt deposition was found due to faulty irrigation.

12.1. Soil degradation

The ordinary people in the desert recognize soil degradation only when land productivity decreases. For monitoring purpose, it is essential to make assessment of indicators i.e. lose of top-soil, salinity, alkalinisation, water-logging, decrease of soil moisture and water seepage etc. Canal irrigation is necessary because raising the crops without irrigation is either not possible or uneconomical. Moreover, the groundnut is saline in many areas and hence the potential for tube-well irrigation is limited. The introduction of Indira canal project has resulted in a significant increase in yield of various crops like cotton, sugar cane etc. But in all these areas water logging and soil salinisation have emerged as serious problem. The problem of water logging in the west of canal is more because there is no exit of excess water due to border. The canal irrigation also raised water table and as a result, water logging in certain low lying area is increased, resulting salinity problem. Soil survey revealed that 0.17 M ha, mostly in Anupgarh branch have moderate to severe problems of salinity and alkalinity. Due to high temperature, there exists problem of high evaporation and high parcelation. Salinity is also result of excessive evaporation. About 76 per cent of the area shows high to medium vulnerability to land degradation process while the rest shows medium to light vulnerability. The degraded land constitutes about 33 per cent of the area (Venkateswarlu, 1991).

12.2 Transportation of soil to water reservoirs

Due to soil erosion the silting up to water reservoirs is enhanced. Canal system in desert area are in constant danger of being buried under shifting sand transport. This has become one of the most serious processes

threatening the supply of water in many areas of Indian desert region. Desilting is a relatively difficult technical enterprise.

12.3. Loss of water from canals

A study conducted by the Central Water and Power Commission in 1967 revealed that about 71 per cent of water is lost in transit from the reservoir to the field as far as the unlined canals and distributaries are concerned.

12.4. Increase in water table

There is gradual rise in water table all over the irrigated lands in Ganganagar district. Water logging is another menace introducing by canal network in the district. This is due to a hard layer of gypsum present at a shallow depth in this tract. The Canal Authority has estimated that 8 per cent of the total 7,000 sq.km. land in the command area of Indira Gandhi Nahar Pariyojana has possibility of gypsum present in the substratum. It is estimated that out of this total area, about 500 sq.km. area is already water logged. The present rate in the rise of water table is by 60 cm. a year. If the trend persists, expert belief that a quarter of the total command area will ultimately be affected by water logged conditions.

The seepage losses is another serious menace of the massive canal irrigation in the district. The Govt. has lined the main distributary but the minor along the chalks in the remote fields possesses seed for creating marshes along the water ways. It reflects a serious lacuna of planning the huge network whereas the canal is laid out to reclaim barren land, it has induced more serious condition of water logged lands due to short sighted planning, The water logging, by all account is a bigger menace to crop productivity, compared to paucity of irrigation in drier conditions. The arid condition allows growing of short duration rainfall crops which the water logging will present.

13. Impact of Canal Irrigation on Natural Vegetation

The complex ecology of this arid region has supported evolution of xerophytic plant life, which over years of evolution have adopted morphological, anatomical and chemical devices to draw its sustenance from scarce moisture of the substratum and use it sparingly and thus complete their life cycle in harmony with the surrounding environment.

It is interesting and very remarkable that the desert of western Rajasthan has a unique vegetation and floristic wealth; many species found here are endemic in nature.

The desert vegetation in Western Rajasthan is largely devoid of tree life both in diversity and number as compared to the other part of state located over south-east of as the soil gets dry to high temperature and continuing heavy evapo-transpiration (Gupta, 1989)/

13.1. Need for afforestation

The canal is very promising source of irrigation but is in constant danger of being buried under shifting sand for which various protective steps are taken by the Government. The canal water provide a valuable source for afforestation in the desert tracts of Rajasthan to mitigate the harsh environment and also assist in reducing the cost of maintenance of canal and roads. The tree cover is expected to provide timber, fuel-wood and fodder to the men and his cattle wealth. It will reduce wind velocity, check occurrence of dust storms and drifting sand. Afforestation shall check the silting of Canal from the ever shifting sand dunes. Apart from improving the micro-climatic condition in the ecosystem, it will meet the demand of fire-wood, timber and fodder. A scheme of economic plantation was formulated by the Government. Thus experimental afforestation in the study area was carried during the year 1962-66 to identify suitable species and workout methodology for their nurture under the local surrounding. Later in 1965, a regular afforestation program was launched under the over all Development of the Indira Gandhi Canal Project Area. This program later received financial support of the World Bank Under "The World Food Programme" during 1971-75 years. This work set a trend in raising of new tree vegetation and its benefits were better realize amongst the people. Gradually, the afforestation became part of other plan programmers in this region such as Desert Development program and the Tree Plantation program.

13.2. Shelter-belt plantation

Tall trees of suitable species such as *Dalbergia sissoo* (Shisham), *Acacia nilotica* (Bobool), *Eucalytus camaldulensis* (Safeda) and *Tamarix articulata*(Farash) are planted along the canal in rows. The rows are kept five metres apart and the distance between the trees in the row is kept at three metres. Thus, 660 plants are planted per hectare.

The *Dalbergia sissoo* and *Acacia nilotica* trees are expected to attain a height of about 20 mts. and a diameter of 50 cm. at the end of 10 years. The newly planted trees are provided irrigation facilities to help them through crucial period of establishment until they have developed their root system when these could rely up on moisture resource of the soil. The internal rate of return on investment is expected to be 12 per cent. Tall trees of Shesham, Safeda, babool etc. are also planted over the culturable waste land along the roads. Sowing of castor seeds (*Riccinus Communis*) and munja (*Saccharum munja*) tufts is done along water courses to accord protection to the tree species from occasional frost and also to act as a middle canopy in the shelter belt.

Whenever the road passes through un-stabilized sand dunes, planting is done only on the wind-ward side of the roads. These are planted with *Tarmanx glauca* and *Acacia tortilis*. In such stretches the lee sand. lee ward side remains un-planted because of continuos dumping of blowing sand. These tree-belts are irrigated either by direct flow from the canal or by carrying water in rail tankers. The internal rate of return on investment in this scheme is estimated around 9 per cent. It has been found that the trees have reduces flow of sand on the road; it has also reduced the loss due to wind erosion along the canal, and provide shade for the population.

13.3. Fuelwood plantation in villages

In the canal command area, the fuel need of people are met from the naturally growing *Prosopis cineraria* (Khejri) trees and the *Cellingonum polygonides* (Phog) bushes. With the advance of irrigation and colonization of the area, the population has increased rapidly. As such this natural source of fuel-wood has got largely depleted. In absence of a natural source of fuel-wood, the rural population burn cow-dung and agriculture wastes for meeting their domestic needs. In order to divert cow-dung from use as a farm manure and to conserve natural vegetation cover, adequate supplies of fuel-wood at reasonable prices has to be ensured. As a result the canal Command Authority has reserved a piece of 12.5 hectares of irrigated land in each village for raising the fuel-wood plantation for the benefit of local people.

The fuel-wood plantation comprises of *Dalbergia sissoo*, *Acacia tortillis*, *A. nilotica* and various *Eucalyptus* species. These trees are spaced at 5 by 3 meters, providing 665 trees per hectare. The internal rate of

return of this investment in the scheme is expected to be 11 percent. This plantation will provide recreational facilities and will protect the land from wind erosion besides augmenting fodder supply in the region.

13.4. Stabilization of sand dunes

The Western Rajasthan is estimated to possess 58.5 percent land under dune infested area. The intensity of Sand-dune affecting lands is paced in five categories. Thus, out of this total, about 11.5 percent land is very severely (80-100%), 4.8 percent severely (60-80%), 14.7 percent strongly (40-60%), 18.6 percent moderately (20-40%) and 8.9 percent slightly (10-20%) infested by sand dunes. The methodology for stabilization of these shifting dunes consist of (a) protection of shifting dunes against all biotic interferences, (b) laying of effective micro-wind breaks on the wind-ward side of dunes (c) sowing of grass or transplanting of drought resistant trees on the lee-ward side.

The village survey data by NCAER indicates that out of the total surveyed villages, 81 percent of them have reported decreasing trend in the occurrence of sand storms after 1970, the year of the commencement of canal irrigation. The empirical studies confirm this observation. Interviews with old skilled farmers said that both the frequency as well as intensity of the sand storms have reduced in the last 18 years in Ganganagar. In particular, sand dune infested land was recorded to have covered by vegetation and it now showed reduced loss of soil by wind erosion. The plantation along metaled road also helped in showing dunes as there is less obstruction on roads which was stated to be more frequent in the past.

14. Programme Combating Desertification

The combating of desertification in western Rajasthan calls for several social aspects. These measures could be effective only when there is a combined effort of individuals, voluntary organizations, government departments and other allied agencies. The approach should be 'Peoples development through peoples participation'. Recognizing the need for a sound management of the region, the state and union governments have added a new dimension to the spatial transformation of Indian desert. Thus, various program operating at different level in the region of western Rajasthan for the economic and infrastructural development are outlined

below:

(A) The Drought Prone Area Programme (DPAP).
(B) Desert Development Programme (DDP).
(C) The Desert National Park (DNP).
(D) Integrated Rural Development Programme (IRDP).
(E) Indira Canal Project
(F) Colonizing Organization.
(G) Command Area Development (CAD).
(H) Central Arid Zone Research Institute (CAZRI).

These programmer acting at various level have adopted the following salient strategy on specific issues:

(i) Development and management of water resources.
(ii) Soil and water conservation measures.
(iii) Afforestation with special emphases on social and farm forestry.
(iv) Development of pasture and range lands.
(v) Livestock development and Dairy development.
(vi) Development of subsidiary occupation.
(vii) Development of infra-structure like drinking water, electrification and network of roads.

15. The Desert National Park (DNP): Conservation of Biodiversity

A national commission of agriculture was constituted by the Government of India in early seventies to develop agriculture by the close of this century in India. This commission has recommended by providing preservation of ecological balance of desert areas by providing establishment of a desert National Park in this region. Apart from a purely tourist attraction, the desert national park will help in the understanding and study of plant and animal life which has evolved in this critical ecosystem of Indian desert.

The scheme consisted establishment of the park in three stages involving a total expenditure of about Rs.35 million over a period of five years. Firstly, the area of the National Park has been classified as a core zone, free from intervention of all human activities. It is surrounded by a peripheral belt of controlled grazing and restricted farming. Secondly, a research centre is being developed with in the park to conduct special studies on the desert flora and fauna which is endemic to this region. And

lastly, a network of tourist observation posts are established. Thus the entire project is aimed to preserve natural habitats as well as to protect the unique plant and animal life found there from human interference. It will allow the process of evolution taking place in the plant and animal life and forestal ecological imbalance due to interference in the name of development.

Management in various part of the western Rajasthan to optimise the returns from the scarce water resources. There is a need to improve existing irrigation potential by lining the canals, rational utilization of water in farming. This will make available more water for agricultural reducing seepage and evaporation losses. Improved technology (using sprinkler & drip farming) of irrigation should be introduced to increase the benefit from the land.

16. Need for Effective Resource Management Strategy

As canal irrigation has opened new avenues for intensive agriculture, forestry and horticulture, it is impossible to halt the progress of new settlements, colonization and industrialization. It is, therefore, necessary to introduce advance technology in these fields to protect the habitat from ill-effects. It may be seen that the benefits of the technology are not corned by a small class of neo-rich settlers in the district, which may fuel, inter-class disparities and rivalries. The government itself has brought out several new programmer to make judicious management, better soil and water conservation, develop social and farm forestry, pasture and range lands and provide avenues for subsidiary occupation to release pressure on land. However, it will be better for the state to integrate the planning at district level and remove the multi-facet funding and sectoral operation of different schemes with overlapping mandate. There should be emphasis on introduction of drought prone varieties of crops which can do away to some extent the demand for frequent irrigation. New devices to optimum use of water like drip and sprinkler irrigation be supported. Large scale development of forest plantation, shelter belts against soil erosion pasture development be carried to an integrated area development planning which may include soil conservation, social forestry, and introduction of fodder crops in cultivation. Seepage loss be plugged on priority. More emphasis may be granted to silvi-pastoral colonization in the region with emphasis on sheep

breeding. The local skill be developed and utilized for the entire plan development with peoples participation both in planning as well as execution of the development programmer in the district. The extensive participation of local people is likely to imbibe a feeling of ownership of the resources to prevent mis-use and protect the ecological balance and combat further desertification and land degradation. The mobilization of the society in the development planning of the district will strengthen local institution and build-up better infrastructure facilities for all developmental works envisaged for improving agriculture, forestry, horticulture, animal husbandry and establishing new agro-industries and ancillaries without affecting the land and its scarce physical resources in this fragile environment (Singh, 1990).

The following research strategies are tentatively suggested for sustainable development of the region:

1. Micro-level assessment of desertification problems at district or block level.
2. Establishing local priorities for actions against implementation of actions in accordance with national plans.
3. preparation of land use plans based on land capability, classifications and the dominant socio-economic conditions.
4. Effective use of the development of rain-fed/dryland farming techniques.
5. Improvement of range lands through regeneration of natural vegetation.

The highly overgrazed culturable of unculturable land should be utilized for agri-Silvi-Pastoral-System.

6. The integrated approach to management of forest lands, grazing lands and crop lands.
7. Afforestation and development of pasture lands to create fodder and bank in each village.
8. Sand dune stabilization through planting grasses, fodder trees and controlled pasture lands.
9. Selection of suitable species for plantation
10. Improving livestock development programmer so that villagers are induced to keep fewer but productive cattle. Number of animals should confirm to the carrying capacity of the area.
11. Shelter belt plantations along canals and roads.
12. Development of relevant indigenous technologies to improve and rehabilitate soils and vegetation through soil moisture conservation.

13. Effective integrated schemes for rainfall, proper use, drinking and irrigation purposes.
14. Development of such non-conventional energy sources such as solar energy, gobar gas and wind mills.
15. Development of labor intensive occupations with the purpose of absorbing labor surplus from agricultural areas.
16. Establishing research and training centres in the affected areas in order to investigate specific local problems and to train local people in their native environments.
17. Social measures to encourage people's participation in the anti-desertification programmer.
18. Appropriate use of environmental technology in above fields CAT has developed few such technologies.
19. Research collaboration between national and international agencies like universities, research institutes and governmental institutions.

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