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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.

References

Centre for Science and Environment (1985): the State of India's Environment - 1984-85, The Second Citizen's Report, New Delhi, 2-9.

Eckholm, E. and Brown, L. R. (1977): Spreading Deserts - The Hand of Man, World Watch Paper 13, Washington, 5-27.

Gerasimov, I. P. (1983): Geography and Ecology, Progress Pub., Moscow, 8.

Gupta, Seema (1989): Environmental Transformation of Ganganagar: Impact of Indira Gandhi Canal, Unpublished M.Phil. Thesis, Delhi University.

Ibrahim, F. N. (1982): Monitoring and controlling Ecological Degradation in the Semiarid Zone of the Sudan, Scientific Reviews on Arid Zone Research, Vol. 1, 53-85.

Meckelein, W. and Mensching, H. G. (eds.) (1985): Resource Management in Drylands, Results of the Pre-Congress Symp. at Stuttgart, Aug. 23-25, 1984, Stuttgarter Geographische Studies, Stuttgart.

Mensching, H .G. (ed.) (1982): Problem of the Management of Irrigated Land in Areas of Traditional and Modern Cultivation, Report Management in Drylands, 22-31 March, Univ. of Homburg.

Singh, R. B. (1984): Spatial Perspective on Population and Resource in Arid Environment: A Case Study of Western Rajasthan, Resource Management in Drylands, eds. H.G. Mensching and R.C. Sharma, Rajesh Pub., New Delhi, 206-14.

Singh, R. B. (1990): Environment and Resource Management in the Drylands of North India, In Environmental Geography, ed. R.B. Singh, Heritage Pub. New Delhi, 338-48.

Singh, R. B. (1990): Drought-Prone Areas in India: Regional Planning Issues and Resource Management Strategy in Planning Development and Disparities in Rural India, ed. Ashok Kumar, Commonwealth Pub., New Delhi.

U. S. Agency for International Development Environmental and Natural Resource Management in the Developing Counties, vol. 1, Washington.

Venkateswarlu, J. (1991): Taming the Arids, The Hindu Survey of the Environment, 1991, Madras, 162-63.

II. Current Status of Desertification in India and Future Research Priorities from Ecological Viewpoint

Suresh Kumar

1. Introduction

Desertification has been defined by UNEP in 1990 as land degradation in arid, semiarid and dry sub humid areas resulting from adverse human impacts. It differs from the earlier definition of desertification i.e. diminution or destruction of the biological potential of the land and can lead ultimately to desert like conditions. This definition adopted at United Nations Conference on Desertification in 1977 in Nairobi, does not restrict to any climatic zone, whereas 1990 definition clearly delimits Desertification processes being operative in arid, semiarid and sub-humid areas. Droughts and human actions were identified as direct causative agents of desertification in 1977 definition. The recent definition clearly states mankind to be responsible for desertification. Therefore, hyper arid regions are excluded from the purview of this latest definition as these are practically zero-population zone except in case of oasis or when irrigated.

A climatic delimitation of the area within the purview of this definition is therefore desirable. Thus, a total of 41% area in India is under arid and semi arid conditions. An attempt has been made in the present paper to understand various desertification processes, their causes and finally the research needs.

2. The Theoretical Framework

Development of each ecosystem results from autogenic and allogenic forces. Two major allogenic forces are climate and geological activities (e.g. volcanic eruptions). Considering geological forces as very slow, often imperceptible and the geology of an area remaining fairly same over centuries, it is the climatic conditions that exert major influence in an ecosystem's development and maintenance. Thus it is logical to consider that any change in climate over space and time shall result in such ecosystems that are spatially separable. Such a separability is more distinct if viewed in the context of evapotranspiration-precipitation relations. Consequently, arid-semiarid dry sub-humid ecosystem (ASD) (Fig. 2.1) provides a suitable conceptual ecosystem to begin with. The six major characteristics of this, or for that matter any, ecosystem are energy circuits, food chains, diversity patterns in time and space, biogeochemical cycles, development and evolution and finally control or cybernetics. It will be pertinent to first examine these characteristics of the ASD ecosystem and then see how these six major characteristics are altered by degradation and desertification processes.

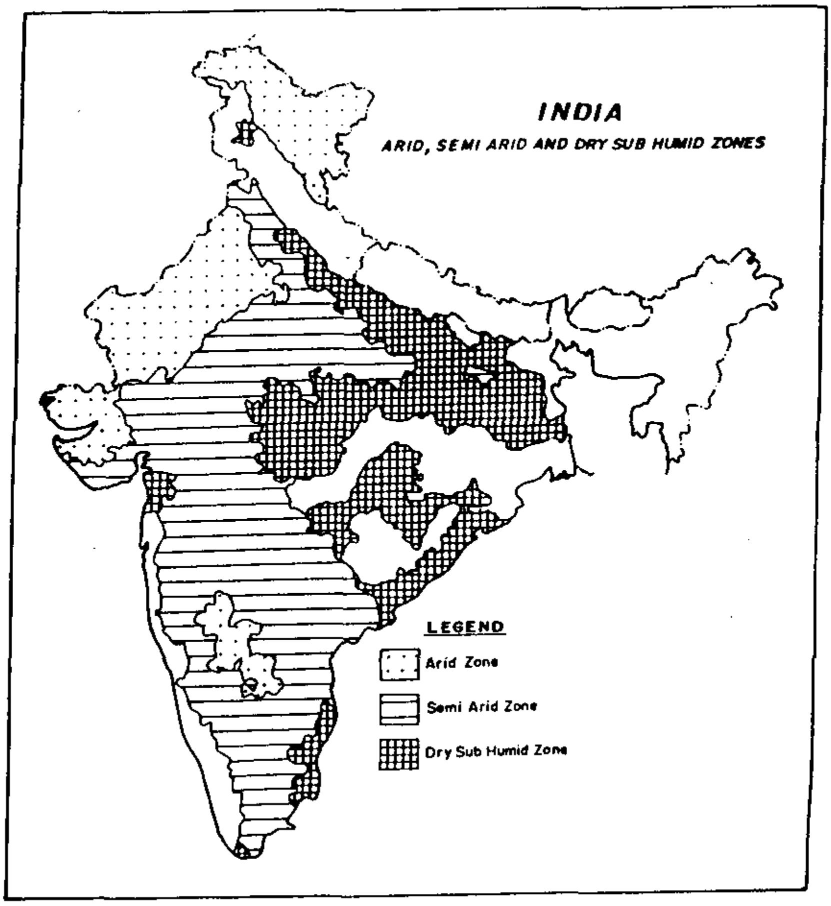

Fig. 2.1 India - arid, semi arid and dry sub humid zones

3. Main Features of ASD Ecosystems

Since ASD ecosystem cover vast geographical area, it will be convenient to describe it in two major land uses: cropped and non-cropped. In the cropped category, it could be either irrigated or rainfed. The non cropped category can have many subunits, but two, forests and grazing lands are the most important ones. Besides biotic and abiotic conditions, socio-cultural conditions also play important role in functioning of ASD ecosystems.

From functional viewpoint, each subsystem needs to be examined for a variety of parameters in a given set of normal conditions as well as those that initiate or engender processes leading to desertification. Since these processes are triggered and accelerated by system's own component, i.e. human and his livestock who are tertiary and secondary consumer in the food chain, these can conveniently be classified as autogenic. Desertification is thus an autogenic process within the ASD ecosystem and allogenic forces may or may not accentuate it. Such an understanding is important as it opens new vistas in the management of desertification. Now, what are those autogenic processes as well as their trends over space and time in ASD ecosystem. Since producer-consumer model is basic to the functioning and operation of these characterizing parameters, the changes in consumer compartment are described first so that these are viewed as causes for inducing changes in producer compartment and finally desertification. The trends in human-livestock-fauna of Indian arid zone are as follows:

4. The Trends in Human Population

4.1 Increase in population

Human population growth was extremely slow in the late Medieval period to the early part of the present century. In fact, historical records of the Marwar state in the Indian Thar Desert reveal that from 1658-1662 to 1901, the population increased by just two times. The rate of growth up to the year 1921 was very slow and consequently the resource depletion was at much less pace. The phenomenal increase occurred between 1921 to 1961 by doubling its number. In the two decades, thereafter, it further increased by another 75 percent. As of 1981 census, an all time high 13.40m population was supported by Indian desert, with average density of 64 persons per sq. km. The growth rate of population between 1901 to 1981 has been 249% which is higher than the Rajasthan state (231%) and the country as a whole. Within the arid zone of Rajasthan, highest population growth (279%) was in the lowest rainfall zone (less than 12") followed by 262% in areas receiving 12-16" rainfall and 219% in areas of receiving over 16" rainfall. Thus the most arid areas with severe paucity of primary produce exhibited the higher growth rate and also largest population.

4.2. Future trends in human population

Since 75 percent of total population of Indian desert is in 0-34 years age group, substantial increase in the population in near future is inevitable even if measures of population control are taken. In fact 47.12% of population is in productive age (15-54 yrs) group (Malhotra, 1978). It has been predicted that with same growth rate as of 1961-71 the population of the region in 2000 A.D. will touch 21.54 million, an increase of nearly six times over 1901 population level.

4.3. Causes of higher growth rates

Socio-cultural ethos of desert community are responsible for such high growth. Some of these are: Early marriage, positive sanction for more children, financial premium on sons at their marriage, improved medical care increasing survival and less child mortality and illiteracy (Malhotra, 1978). In fact under uncertain economic situation due to erratic rains, when a person need fresh capital to be able to produce or earn, an extra child is viewed as a very good risk capital as he would start earning at an age of 9-10 yrs.

5. Impacts of Increased Human Population

5.1. Fragmentation of land holdings

Increase in population causes fragmentation of land holding. The average land holding of 17.77 ha per household in 1951 has declined to 14.69 ha in 1961, 12.40 ha in 1971 and is estimated to be nearly half, 7.15 ha by 2000 A.D. Thus the crop fields have become increasingly smaller in size, quite often scattered also. Since sediments of the fields itself keep piling on its fences (Dhir, 1977 b), due to wind action, occurrences and formation of these fence line hummocks (Fig. 2.2) have increased due to more number of fences erected because of fragmentation of erstwhile bigger plot of land.

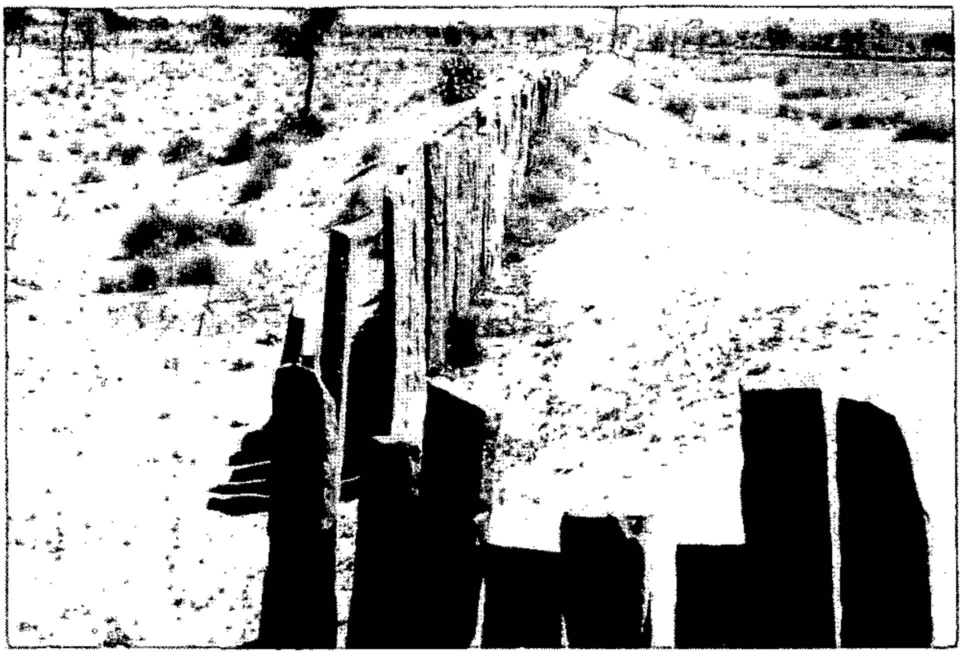

Fig. 2.2 Active wind erosion in the cropland resulting in the formation of fence line hummocks near Osian, Jodhpur, India.

Fig. 2.3 Pearl millet crop on dune slope in Osian, Jodhpur, India.

5.2. Cultivation of marginal and pasture land

The increasing population also need more land and in this process encroach upon marginal land (Fig. 2.3). Cultivation on marginal land increased by 44.6% during 1951-61 and by an additional 9.47% during 1961-71; while pasture areas declined by 16.8% and 6.95%. Landsat Thematic Mapper false color composites and ground surveys of Jodhpur district in Rajasthan state of India revealed that natural grazing land areas have declined as much as 9 to 30% on different land forms from 1958 to 1986. Both these factors, cultivation of marginal lands and decline in grazing land have negative impacts. While marginal lands when cultivated are highly susceptible to erosion (i.e. allogenic forces) and consequent degradation, the decline in grazing land area results in lesser availability of grazable material and that too when the livestock has been registering a continuing increase.

5.3. Equity in land holding ownership

Though average land holding (9.9 ha) in arid Rajasthan is nearly double than that of Rajasthan state, its sizewise distribution is uneven. Over 50% area is owned by only 11.2% farmers and only 10% land area is with the 47.3% farmers. This indicates that large majority of farmers (47.3%) having very small holdings eventually overexploit these lands for their subsistence.

5.4. Impact on land fallowing

Land is rested from cultivation (fallowing) to regain its fertility in this region (Fig. 2.4). This practice of fallowing is now disturbed in the quest for more food production so as to feed increasing populations. The land is being constantly ploughed. Consequently net sown area has increased in 1951 as 28.61 to 41.01 in 1961 and 45.05 in 1971. The net irrigated area remained a meagre 0.41 to 1.45%. This sort of overcropping (Fig. 2.5) has resulted in decline in productivity to varying degrees in different crops (Table 2.1).

5.5. Farming practices

Subsistence farming has come to stay because of low capital investment, labor intensive agriculture operation (Fig. 2.6), poor communication, and inadequate marketing facilities.

Fig. 2.4 Two years old fallow supporting good cover of *Crotalaria burhia* and *Prosopis cineraria* along with adjoining cropland in Sanchore, Rajasthan, India.

Fig. 2.5 Sandy undulating plains freshly cleared of natural vegetation for cropping in Sanchore, Rajasthan, India.

Fig. 2.6 Weeding in pearl millet cropland by bullock drawn primitive weeder at Sanchore, Rajasthan, India.

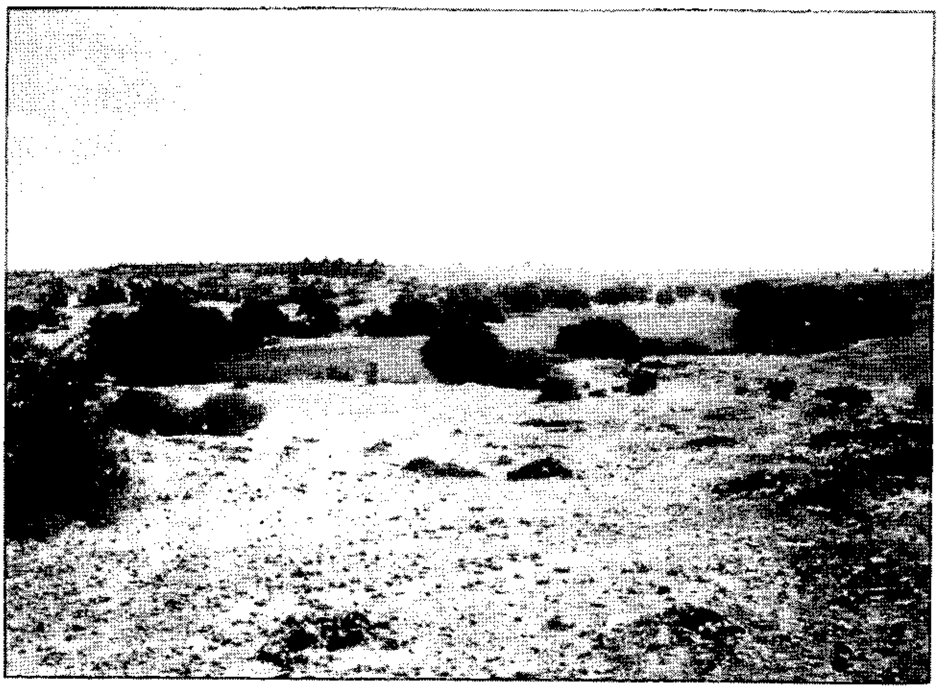

Fig. 2.7 'Khadeen' (run-off farming) crop of wheat in Jaisalmer, Rajasthan, India.

Table 2.1. The annual linear growth rate of the area, production and productivity in respect of various crops (1954-70).

Crop	Area	Production	Productivity
Bajra	+2.41	+1.34	-0.66
Jowar	-3.41	-5.42	-4.88
Wheat	-0.82	-0.24	+0.60
Barley	-1.16	-0.05	+0.68
Gram	-6.31	-1.67	-1.59
Sesamum	+3.24	-3.57	-4.23
Other pulses	+1.91	-1.08	-2.70

Source: Malhotra(1988)

To increase yields farmer choose to stay in scattered type of dwelling (Dhani system) for better care of fields, and adopt run off farming (Khadeen cultivation) (Fig. 2.7) and finally use of tractors. But when dwelling are dispersed in far-flung fields areas; as Dhani, the human and their livestock tend to exploit the abundance of vegetation in the surrounding environs, thus becoming the foci of degradation and desertification. Increasing popularity of tractors as evidenced by their number in 1956 as 698, increasing to 14535 in 1977 clearly shows its utility in sowing large areas in shorter duration of moisture availability in the top soil during monsoon. But in its wake, tractor discs cut the roots of important top feed *e.g. Ziziphus nummularia, Calligonum polygonoides* and perennial grasses like *Lasiurus sindicus*, thus preventing their regeneration and eventual reduction in their number and hence scarcity of this resource.

6. Irrigated Farming

Irrigated farming through water imported from outside the deserts has increased production in the deserts. Incoming of canal in the Indira Gandhi Nahar Pariyojna (IGNP), has increased the commanded irrigation (Fig. 2.8) from 1445 ha in 1962 to 2,88,000 ha in 1976 in the Rajasthan desert (Kapoor & Rajvanshi, 1977). While water is undoubtedly an agent for greening the desert, its overuse has shown adverse effects in all types of deserts. In fact it has converted 'dry desert' into 'wet desert' with the problems of water logging, salinity and community health.

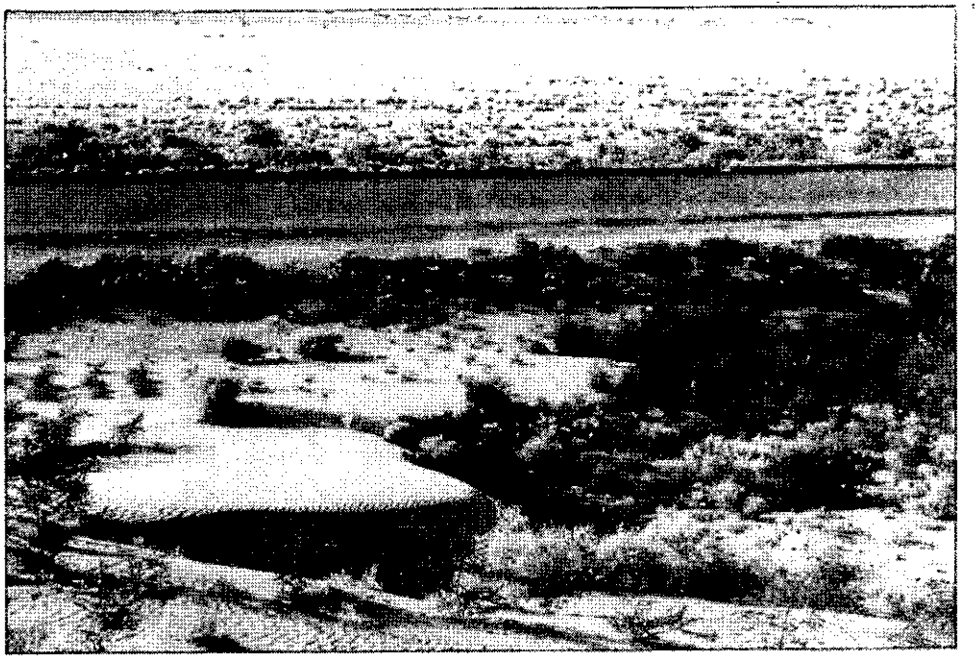

Fig. 2.8 A view of India Gandhi Canal for irrigated cropping near Nachna, Jaisalmer, India.

Fig. 2.9 *Euphorbia caducifolia*, the last remaining plants on hillocks are removed as source of fuelwood near Jodhpur, Rajasthan, India.

6.1. Water logging

Due to seepage and flood irrigation, water keeps in being stored in soil and water table rises. In the Indian desert, different claims have been made as to the rate of water table rise in Gang canal command area irrigated by IGNP phase I. The rate of water table rise has been estimated as 0.305m to 3.04m per year in different command areas of IGNP. In a study by CAZRI, it was estimated that water table is rising at 0.03 m per year in IGNP area, 0.15 m per year in Bhakra Canal Zone, 0.29 m per year in south phase I of IGNP and eastern block of Bhakra area. The rise varies between 0.62 to 0.71 m per year (Mann and Chatterji, 1978). Based on depth to water and depth to first barrier, Bithu (1984) predicted that 34% of the IGNP-I command area will have water logging within six years of irrigation. Similar situations have been reported in Pakistan too. Thus, these are serious warnings. Water table coming closer to the surface endangers the establishments and many villages have to be shifted to elevated grounds in Gang Canal area.

6.2. Salinity

While there has been initial decline in the in situ salinity at various places in Anoopgarh and Ghaggar basin commanded by IGNP, the conditions are likely to worsen due to marshyness which later develops, as has happened in Pakistan (DESCONAP, 1988). Construction of Tanks and consequent inflow of water brings with it the silt load and causes salinity problems in the command area. It has been estimated that nearly 9,600 ha of cultural command area has turned saline in Sardarsamand Tank near Jodhpur in the last 85 years. Chatterji and Vangani (1985) reported occurrence of similar conditions in large number of Dams in Luni Basin in the Rajasthan desert. In fact 15.6 sq. km area of this block is now affected by salinity and its spread to 40 sq. km area was predicted in 1977 (Dhir, 1977 a).

6.3. Introduction of new weeds

Imported water in the desert causes phenomenal outburst of seeds in the irrigated area. The desert scrub vegetation changes to mesophytic vegetation. *Typha anqustata, Arundo donax, Inperata cylindrica, Saccharum spontaneum* and *Eichhornia crassiipes* have already assumed alarming proportions in the waterways. Chatterji and Saxena (1990) have also listed annual floral components that undergo a change. Majority of new species are not useful as fodder of fuel and thus, irrigation has caused "green desertification".

6.4. Introduction of new pests

Nematodes, snails, insects and rodents (*Bandicota bengalensis*) make their appearance, multiply fast and not only feed upon natural and cultivated vegetation but also become carrier of many diseases. Increase in the incidence of malaria and schistosomiasis have been common knowledge wherever irrigation has been introduced in the deserts.

7. Increased Vegetation Removal for Human Needs

7.1. Rural dwellings

Rural peasantry depend on natural vegetation to meet a variety of their needs. The rural dwellings have mud walls with roof thatching of stalks of *Crotalaria burhia*, *Leptadenia pyrotechnica*, and *Calotropis procera* besides pearl millet stalks. Stumps of Indian mesquite *Prosopis cineraria* or *Tecomella undulata* constitute the central pole supporting roof apex. Twigs of bordi (*Ziziphus nummularia*) are used for fencing, field and dwellings. The demand for these is always increasing as rural dwellings are renovated every 2 or 3 years. Hence these also face consequential degradation. There is no quantitative estimate of their uses resulting in how much of degradation.

7.2. Seeds as food

Seeds of large number of plants are either used in preparation of curry or eaten raw. In fact, rural folks collect these seeds to sell in local market. Seeds of *Acacia senegal*, pods of *Prosopis cineraria* and fruits of *Capparis decidua* and *Ziziphus nummularia* are consumed by local populace. Likewise, seeds of grasses like *Panicum turgidum*, *P. antidotale*, *Cenchrus biflorus*, *Echinochloa colonum* are mixed with millet and eaten as flour. It is of course true that these plants are prolific seeders but studies have shown that in desert, plants are endowed with this capability to produce more seeds so that finally some culminate into mature plants. Kumar (1990) demonstrated that in the natural populations of *Haloxylon salicornicum*, 40,000 seeds are required to have finally one additional mature plant in the community. And if the system is deprived of these propagules, by collecting them for human consumption, it is easy to imagine the hugeness of loss of seed source and consequently less or no regeneration. Thus, not only are there limitations of soil and climate, there is serious set back to natural regeneration resulting in poor cover, inadequate to meet the future demand.

7.3. Fuel wood

Added to this loss of propagules is the removal of woody material and twigs, depriving regeneration of new shoots in the existing plants as growing main stems are lost in such removal. This woody material, besides being used in other activities as mentioned earlier, is the chief source of fuel and energy for rural population (Fig. 2.9). With annual energy requirement of 1,512 K Cal per person as recommended by National Council of Applied Economic Research, arid zone of Rajasthan is estimated to have fuel wood requirement of 2.06 m tons in 1951 which increased to 2.76 tons in 1961 and 3.50 m tons in 1971. For other purposes, wood requirement comes to 0.24 m tons is 1951, 0.31 m tons is 1961 and 0.31 m tons in 1971 (Malhotra, 1978). Although wood availability has been estimated pretty high, as 25.04 m tons in 1951, 23.48 m tons in 1961 and 20.76 m tons (Malhotra, 1978; Mann & Prakash, 1983), it is yet not known as to what are the safe levels of wood extraction from these woodlands. Further, these estimates are misleading in the sense that they include total woody biomass of all the species, whereas wood extraction is by and large, of a few preferred species. This preferential extraction of wood has not only made an important species Tecomella undulata (Marwar Teak) as threatened with extinction but also cause loosening of sand for example, by digging of Calligonum roots in Bikaner to make land prone to soil erosion.

8. The Trends in Livestock Population

8.1. Increase in population

Cattle, sheep. goat, buffalo and camel constitute the livestock that consume all type of vegetation (Fig. 2.10). Rajasthan arid zone supported 23.2 million heads of livestock in 1983, representing an increase of 4.2 million over that of 1977. The region thus had 73 percent more livestock in 1983 than in 1956.

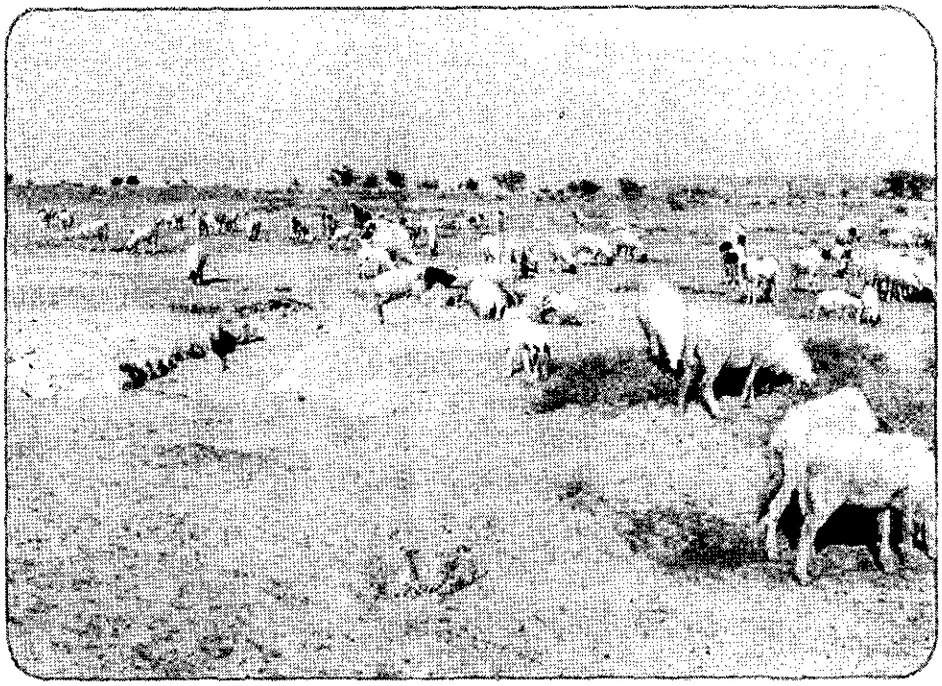

Fig. 2.10 Sheep and goat grazing on Ziziphus nummularia in a degraded grazing land in Tonk, Rajasthan, India.

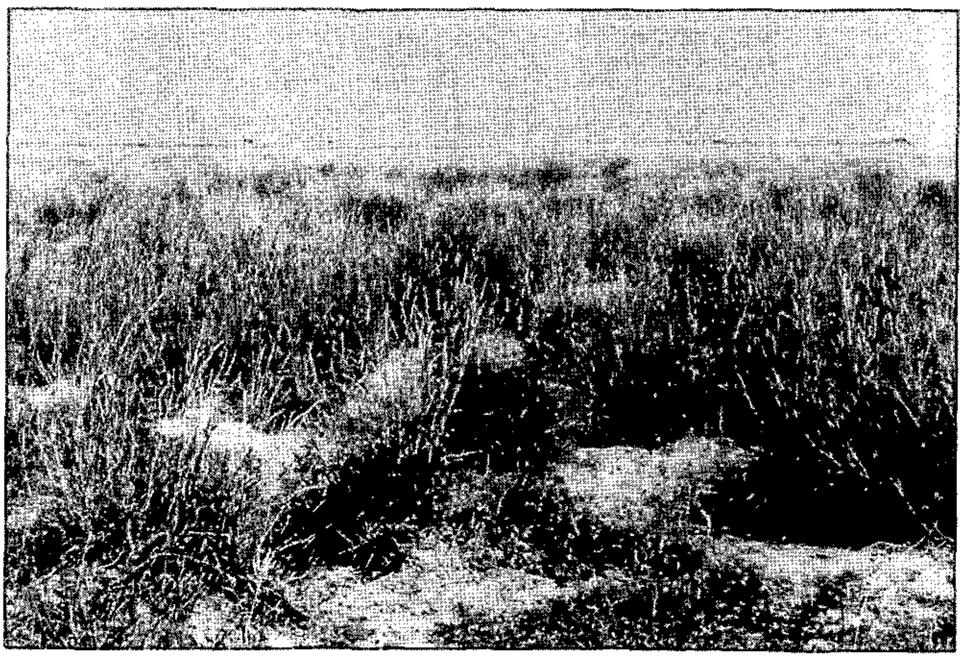

Fig. 2.11 An excellent stand of *Lasiurus sindicus* near Asutar in Jaisalmer, Rajasthan, India.

8.2. Causes of livestock increase

The social ethos encourage farmers to have larger herds. Culling is not permitted. Upper castes consider it irreligious to get their bulls castrated and often wait till the opportunity for exchanging the same is available, killing as a means for reducing herd size is never accepted by the people. It is in fact a religious taboo to revere cow as sacred. Quantity of livestock over rules quality because of rink insurance.

9. Impacts of Livestock Increase

9.1. Increase in grazing pressure

With increase in livestock number, the effective area of grazing land available for each livestock has declined. Shankarnarayan (1985) estimated that from 1972 to 1977 in 12 districts of western Rajasthan, Grazing land per livestock has declined (Table 2.2) to the tune of 7 to 97 percent. The per capita grazing area available was 1.90 ha in 1956, 1.7 ha in 1961, 1.39 ha in 1966, 1.35 ha in 1972 and 1.11 ha in 1977. Thus decline in area and fall in productivity result in poor availability of forage which becomes scarcer in the wake of increasing livestock.

Table 2.2 Extent and availability of grazing land per unit of livestock in 12 districts of western Rajasthan (After Shankarnarayan, 1985).

District	Land area (ha)	Grazinglands (% of the land area)	Grazing lands/ livestock (ha)		Decline %
			1972	1977	
Bikaner	2885072	60.2	1.93	1.13	41.45
Barmer	2617294	26.1	0.37	0.29	21.62
Churu	1685114	12.4	0.14	0.13	.7.14
Jodhpur	2217800	49.1	0.57	0.44	22.80
Jaisalmer	-	-	6.14	2.91	52.60
Ganganagar	2041446	19.0	0.25	0.23	8.00
Sikar	774925	15.6	0.98	0.08	91.83
Jhunjhunu	542730	12.3	0.07	0.07	0.00
Nagaur	-	-	0.08	0.07	12.50
Jalore	1056357	14.1	0.12	0.11	8.33
Pali	1229762	23.6	0.15	0.14	97.72

9.2. Deficit in forage supply

In an exercise on demand-supply situation of grazing resources of different districts (Shankarnarayan and Kalla, 1985) it has been clearly shown that from 1961 to 1981 demand for grazing resources have registered a continuous increase (Table 2.3) in the arid western Rajasthan, a decline in Gujarat and an increase in 1971 with decline in 1981 in Haryana to attain almost an equal level of 1961 demand. It was further stated that even if estimates for crop residues were added to supply of herbage from grazing lands, all 5 districts of Haryana, 10 districts of Rajasthan (except Churu) and three districts of Gujarat were deficit in forage supply in 1981 (Table 2.4). This deficit was larger, 1.26 to 13.48 lakh tones for Rajasthan and 4.25 to 9.66 lakh tones for Haryana and lesser, 0.58 to 1.07 lakh tones for Gujarat. In 1981, a total deficit of 61.06 and 35.75 lakh tones was experienced in Rajasthan and Haryana arid region respectively (Table 2.4). It was also concluded that if crop residue component is excluded from these estimates, almost all arid districts in all the years experience continuous deficit (Table 2.4). Although, top feed component has not been added to this exercise, it is likely to change the situation only slightly.

9.3. Unbalanced nutritive content

It is known that animals first graze the most palatable, and quite often most nutritive too. Selective removal of preferred species, continuously, that too by large herds, impoverishes the grazing lands of palatable species. It has been shown that barring a few species, top feeds have over 10 percent crude protein and over 15 percent crude fibre (Shankar *et al.*, 1987). The situation is opposite in respect of grasses which have less protein but more fibre. Similarly in respect of macro and micro elements also, they exhibit complementarity, for example in zinc, copper, calcium, magnesium and potassium. Thus selective removal of a few species would result in imbalance of animal feed and lop sided development of livestock.

9.4. Increased nomadism

Since in low rainfall years, less biomass produced is exhausted early, livestock move in herds to some other greener areas. Livestock migration could be for a short period (1 month) in summer and/or long period (3-4 months) as in winter. Routes of migration are decided on the availability

Table 2.3 Demand-supply of grazing resources in north-western Indian arid zone (lakh tonnes) in 1981 (After Shankarnarayan and Kalla, 1985).

State/District		Demand	Supply	
			Without crop residue	With crop residue
Gujarat				
Kutch		9.75	12.23	26.83
Jamnagar		9.23	0.94	11.52
Rajkot		11.99	2.86	19.78
Surendranagar		7.15	1.68	15.60
Junagarh		15.69	2.29	15.10
Banaskanta		18.03	1.91	18.87
Mehsana		18.14	1.54	17.06
Ahmedabad		10.65	1.55	15.14
	Total	100.63	25.00	139.90
Haryana				
Hissar		14.83	0.40	6.17
Jind		11.88	0.16	4.25
Mahendragarh		8.39	0.20	4.14
Ambala		11.96	0.94	4.07
Rohtak		12.27	0.20	4.95
	Total	59.33	1.30	23.58
Rajasthan				
Barmer		32.46	2.49	24.87
Bikaner		23.83	3.40	16.34
Churu		17.86	0.60	19.97
Ganganagar		29.86	0.87	23.19
Jaisalmer		12.28	6.90	10.96
Jalore		14.87	0.88	9.65
Jhunjhunu		11.82	0.28	6.74
Jodhpur		21.84	2.05	20.57
Nagaur		25.80	2.06	19.81
Pali		19.75	3.80	11.81
Sikar		16.66	0.50	8.04
	Total	233.03	23.83	172.00

of forage and water enroute. Different households, with their large herds move together with a view to help each other. Thus, these livestock cause devastating damage to vegetation resource en route.

Table 2.4 A demand-supply imbalance for forage with crop residues in north-western Indian arid zone (in lakh tonnes) (After Shankarnarayan and Kalla, 1985).

State/District		1961	1971	1981
Gujarat				
Kutch		+2.54	+6.47	+17.08
Jamnagar		-1.18	-1.15	+2.29
Rajkot		+0.17	-1.51	+7.78
Surendranagar		+3.38	+3.53	+8.44
Junagarh		-3.84	-5.83	-0.58
Banaskanta		-7.69	-3.39	-0.83
Mehsana		-6.26	-7.02	-1.07
Ahmedabad		+0.22	-1.19	+4.48
	Total	-12.66	-10.09	+39.27
Haryana				
Hissar		-1.58	-8.93	-8.66
Jind		-3.40	-4.32	-7.63
Mahendragarh		-1.76	-4.01	-4.25
Ambala		-5.32	-7.08	-7.89
Rohtak		-8.71	-11.72	-7.32
	Total	-20.77	-36.60	-35.75
Rajasthan				
Barmer		-1.02	-4.03	-7.58
Bikaner		+2.42	+1.63	-13.48
Churu		-7.70	+3.98	+2.10
Ganganagar		-5.00	-0.51	-6.67
Jaisalmer		-1.99	+4.18	-1.31
Jalore		+2.08	-3.57	-5.21
Jhunjhunu		-0.86	-4.23	-5.07
Jodhpur		+12.29	-3.15	-1.26
Nagaur		-6.41	-3.71	-5.99
Pali		+4.85	-8.72	-7.93
Sikar		+2.12	-6.19	-8.61
	Total	-22.08	-16.28	-61.06

10. Increase in Faunal Resources

Faunal resources exhibit richness in diversity and abundance in occurrence. The fifty mammalian species, in addition to locusts, birds and reptiles depend on vegetation and crop residue for their survival. While many species, such as Cheetah (*Cinonyx jubatus*) and Caracal (*Felis caracal*) are now extinct due to disturbance of their native habitats, the Great

Indian bastard (*Adreotis nigriceps*) and the Panthers (*Panthera pardus*) are threatened. But there are desert communities like Bishnoi which consider black buck sacred and protect them. So is the case with rodents. Consequently, these pests have assumed alarming proportions. Locust, a tiny herbivore, in swarms of 1 sq. km (about 200 million individuals) can devour 200-300 tones of biomass daily. Widespread locust plagues have been recorded during 1900-07, 1912-20, 1926-31, 1940-46, 1949-55, and 1959-63. Such huge removal of vegetation not only adversely affects its own regeneration but also cannot support and sustain the wildlife. With removal or extinction of any species, hitherto unknown impact are felt due to dislocation of food chains and food webs.

11. Impacts of Over Utilization on Vegetation

The above trends in the primary and secondary consumers adversely influence the structure-functioning of primary producers. Some of the impacts studied are as follows:

11.1. Change in ecological status

Removal beyond regeneration thresholds ultimately kills the plant (Fig. 2.11, 2.12). Thus these communities get arrested at disclimax states (Gupta and Saxena, 1972) ranging from *Cenchrus-Lasiurus* to *Cynodon-Eleusine* to *Cenchrus biflorus* to *Aristida-Oropetium thomaeum* type. Species of lower successional status only thrive. Majority of these are therophytes and hemicryptophytes (Shankar and Kumar, 1987). Removal of palatable annual and perennials also cause a decline in the basal cover and density of plants (Shankar, 1983). Consequently their yield declines manifolds (Shankar & Kumar, 1987; Kumar & Shankar, 1986).

11.2. Decline in vegetation health

Vegetation becomes sparser, stunted, and poor in health. Over 70 percent of grazing lands in Jaisalmer, Jalore and the Luni Basin in Indian desert have poor condition, 13 percent have good and 14 percent fair and 2-3 percent are in excellent condition (Shankar *et al.*, 1988). Woody perennials also deteriorate as they are badly cut and browsed (Fig. 2.13, 2.14). Existing tree-shrub cover in Jaisalmer for example, has been estimated to be much less (1.5-9.5 percent) than the desired level (Shankar & Kumar, 1988).

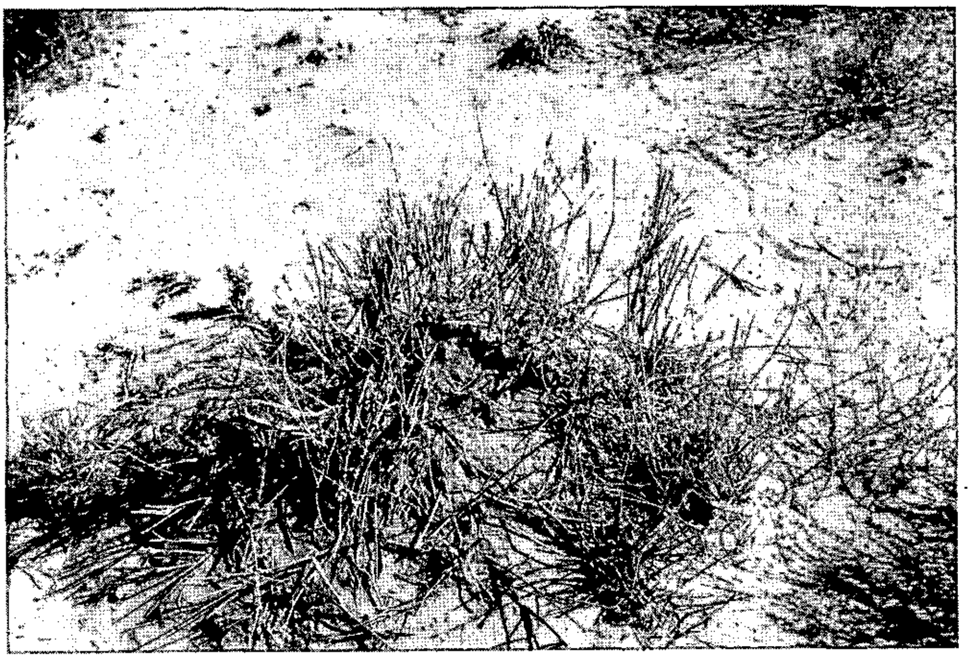

Fig. 2.12 Close up of dead tussocks of *Lasiurus sindicus* so commonly seen upon degradation at Bijju in Bikaner, Rajasthan, India.

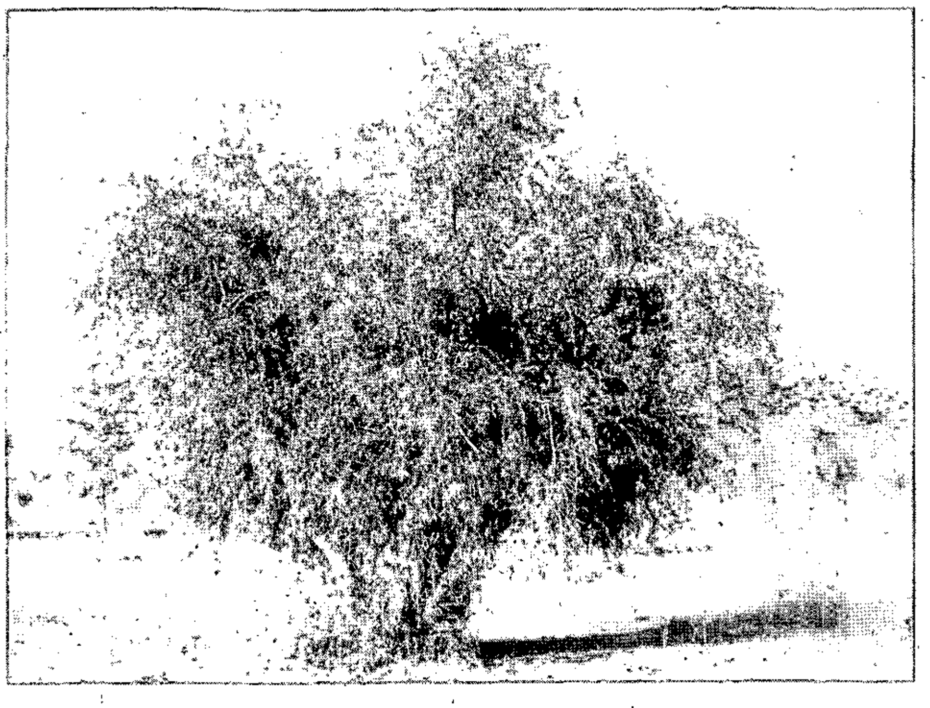

Fig. 2.13 *Salvadora oleoides - Prosopis cineraria* grazing land in Sanchore, Rajasthan, India.

11.3. *Changed dominance-diversity relations*

Dominance-diversity relations undergo change upon degradation. Woody perennials in older alluvial plains in the Luni basin had low diversity and low equitability on sites having degraded grass-covers such as *Oropetium-Eragrostis* or *Dactyloctenium-Eleusine* type (Kumar and Shankar, 1986). Intermediate to high diversity and equitability characterized the sites having optimum cover of *Dichanthium-Desmostachya.* Dominance diversity curves of woody perennials approach geometric progression on degraded sites from lognormal ones on non degraded sites as has been observed in Luni basin and Jaisalmer (Kumar, 1987).

11.4. *Increased wind erosion*

Degradation of vegetation loosens the soil. It becomes prone to the allogenic forces of wind erosion (Fig. 2.15). In the Rajasthan desert, deep ploughed fields in June-July 1985 lost 2630 to 3160 tones sand per ha when wind velocity was 24-35 kmph. Lands with vegetation such as fallows, lost ten times less, i.e. 207 to 283 tones per ha. The pristine pasture with natural cover of 8-12 percent remained unaffected. With loss of soil, nutrients are also lost. Organic carbon available potassium and phosphorus are much less in degraded condition (Raina & Sen, 1991).

11.5. *Increased water erosion*

Since more vegetation is removed, water erodes and carries with it larger amount of soil (Fig. 2.16). Run off in overgrazed grassland was 27 percent with maximum soil loss (1050 kg/acre) and 22 percent with 1015 kg/acre soil loss in overgrazed follows (Chatterji and Maiti, 1974). Heavy grazing in arid watersheds caused 41 times more sediment yield, three times more sediment concentration, eight times more runoff compared to that in the undisturbed and ungrazed areas (Shankarnarayan *et al.*, 1987). Stem flow and recharge are adversely affected. This has resulted in decline in the static levels of the wells in many desertic areas (Fig. 2.17). Monitoring of Luni block in the Indian desert revealed, that over exploitation of ground water has increased from 6.2 percent area in 1966 to 76.8 percent in 1976 with fall in discharge potential, and consequent loss in productivity (CAZRI, 1977).

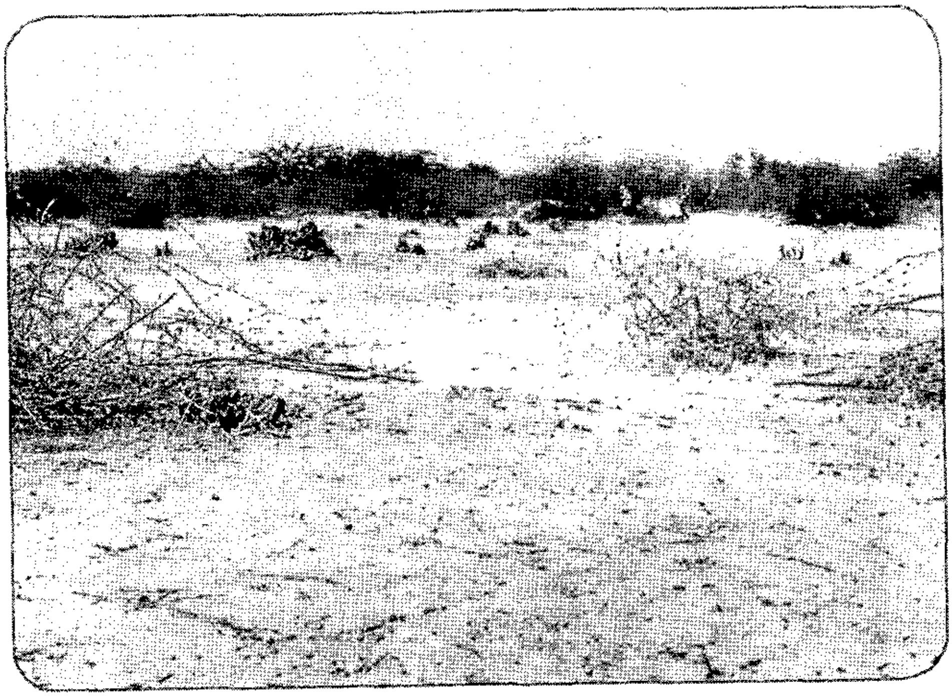

Fig. 2.14 A degraded grazing land where *S. oleoides* and *P. cineraria* have all been removed, leaving only *Prosopis juliflora.*

Fig. 2.15 Sand pile on Tinwari Osian Road (Jodhpur, India) becoming muddy during rain and disrupting vehicle movement.

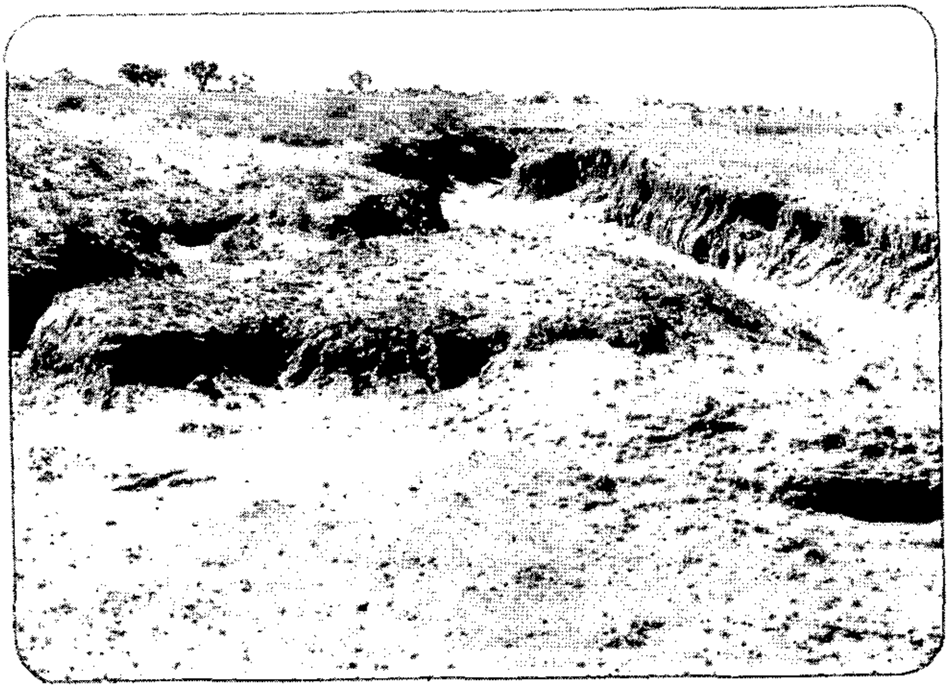

Fig. 2.16 Increased vegetation removal resulting in accelated water erosion and gulley formation in tonk, Rajasthan, India.

Fig. 2.17 Declining water level in wells forces people to go long distances for fetching water in Jalore district, Rajasthan, India.

12. Future Research Needs

Thus trends in the consumer subsystem their impacts on producer subsystem are fairly well understood. But trends of various attributes from producers to consumers in their totality are poorly understood, in order to reach a conclusion about the status of Desertification. Odum (1969) listed as many as 24 attributes to characterize evolution of an ecosystem from 'young' to 'mature' state. Considering desertification as disruption or change in the evolutionary status of the whole ecosystem, the expected trend in various parameters upon desertification could be as follows: Gross production to community respiration ratio (P/R) would be less than 1, instead of 1 in stable mature system. Gross production to standard crop biomass is high. Biomass supported per unit energy flow (B/F) is low. Net community production (yield) is high. Food chains are linear. Experimental evidences indicate that in non-desertified system P/R ratio is over one. For example, the total incident solar radiation was 178.74 :104 k cal/m^2 in a *Cenchrus ciliaris* sown pasture. Of this, 802.08:103 k cal/m^2 constituted photosynthetically active radiation (Ph AR), and 801.59:103 k cal/m^2 of Ph AR was used for gross primary production (Shankar *et al.*, 1977). 111.99 k cal/m^2 constituted respiratory losses and remaining 373.3 k cal/m^2 actually constituted the harvestable energy production. Average efficiency of energy conversion over years was 0.05 percent. In contrast, it was 0.41% in *Lasiurus sindicus* natural climax pasture, But high deficiency of energy conversion in tropical grasslands is hampered by high flux density, water deficit and accumulation of silica in the plants (Shankar *et al.*, 1977). Energy use efficiency of pearl millet was 0.21, 0.96, 1.55, 2.09, 0.62 and 0.15 respectively on 30th day, 30-40 days, 41-48 days, 49-57 days, 58-68 days and on 69 days after sowing. Shankar and Kachwaha (1978) reported that the semi-arid grasslands have the highest efficiency (0.24 to 4%) followed by dry sub-humid grasslands (0.34 to 1.66%) and the arid grasslands (0.05 to 0.85%). Interestingly, the energy storage in above-ground parts is always more than that in the below-ground parts, in natural climax situations. But as these arid grazing lands degrade, energy storage was more in below-ground parts than that in the above-ground parts (Fig. 2.18). The trends in respect of secondary producers is poorly understood except for some estimates from a California range where 0.004% of primary production is used up for secondary production

(Williams, 1966).

Much of the trends in respect of community structure of plants upon desertification are now well understood. Total organic matter is always low. Inorganic nutrients are extra biotic, Diversity declines ultimately after first increasing in the form of invaders Sensu Dyksterhuis (1949). Equitability has been shown to be low in degraded systems (Kumar & Shankar, 1987). It is hypothesized that biochemical diversity will be low increasing desertification but yet not documented. Stratification and spatial heterogeneity is of course poorly organized. Similar trends are expected also in respect of primary consumer, and others. There is still no documentation as how changes in these attributes in producers affect consumers and vice-versa. Of course, there are circumstantial evidences that with decline in vegetation, a particular animal species has either declined or threatened with extinction.

Impact on life history trends of organisms like niche specialization, size of organism and life cycles are not known. Niche specialization is expected to be broad, organism tend to be smaller and life cycles short and simple, upon desertification stress.

There are very few works on nutrient cycling, selection pressure strategies and overall homeostasis, which are all important functional attributes of an ecosystem.

While much of the information at ecosystem level is lacking, the overall impacts of desertification have been assessed in terms of land degradation due to wind and water erosion, salinisation and vegetation removal (Dregne, 1991; Singh *et al*., 1992). These impacts have been quantified by Dregne (1991), Kharin *et al.* (1988) and Singh *et al.* (1992) for global level, Karakum desert and Thar desert respectively. An assessment of Indian desert using all the above four parameters revealed that nearly 21 per cent area of western Rajasthan is severely affected, 40 per cent, moderately and 32 per cent, slightly affected by the desertification processes (Fig. 2.19). Thus these studies provide an excellent baseline information to start analysis of desertification processes in systems approach, as outlined above, for wholesome management of sub-humid, semiarid and arid areas.

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References

Bithu, B. D. (1984): Present status of ground water development in Rajasthan Canal stage II area. National Seminar on 'Present and future status of ground water development in 2000 AD'.

CAZRI (Central Arid Zone Research Institute) (1977): Case study on Desertification. Luni development Block, India. Nairobi, UNCOD.

Chatterji, B. N. and Maiti, S. (1974): Role of grasses in soil conservation in eastern India. Soil Cons. Digest, 15-23.

Chatterji, P. C. and Vangani, N. S. (1985): Effects of human activities on water resources of arid zone of Rajasthan. Proc.Int. Symp. on Environmental Impact Assessment of Water Resources. Univ. of Roorkee, Vol. 3, 182-189.

Chatterji, P. C. and Saxena, S. K. (1990): Canal irrigation in arid zone of Rajasthan and its ecological implications. pp. 223-258. In Prakash, I. (Ed.) Desert Ecology. Scientific Publishers, Jodhpur.

DESCONAP (1988): An introduction to the regional network of research and training centres on desertification control in Asia and the Pacific.

Dhir, R. P. (1977a): Soil degradation due to overexploitative human effort. Ann.Arid Zone 16, 321-30.

Dhir, R. P. (1977b): Saline Waters - their potentiality as a source of irrigation. In 'Desertification and its control', ICAR, New Delhi, 130-148.

Dhir, R. P. (1986): Desertification and development in the arid Rajasthan. In Proc. of Appreciation Workshop on Desert Meteorology. Defense Laboratory, Jodhpur, India.

Dhir, R. P. (1989): Wind erosion in relation to landuse and management in Indian arid zone. Int.Symp.Managing Sandy Soils Abst. Pt. ii: 572-575.

Dregne. H. E. (1991). Global Status of desertification. Annals of Arid Zone 30(3), 179-185.

Dyksterhuis, E. J. (1949): Condition and management of range lands based on quantitative ecology. J. Range Management 2, 104-115.

Gupta, R. K. and Saxena, S. K. (1972): Potential grassland types and their ecological succession in Rajasthan desert. Ann.Arid Zone 11(384), 198-218.

Kapoor, A. S. and Rajvanshi, B. S. (1977): The Rajasthan Canal Project. In "Desertification and its control", New Delhi, ICAR, 121-129.

Kharin, N. G., Nechaeva, N. T., Nikolaev, V. N., Babaeva, T., Dobrin, L. C., Babaev, A., Orlovsky, N. S., Redzhepbaev, K., Kirsta, B. T., Nargeldyev, O. N., Batyrov, A. and Svintsov, I. P. (1985): Methodological principles of desertification processes assessment and mapping (Arid lands of Turkmenistan taken as example) Edited by A. G. Babaev, Desert Institute, Turkmen SSR Academy of Sciences, Ashkhabad, pp. 116.

Kumar, S. (1987): Classification and ordination of the vegetation of Jaisalmer. Ph.D. Thesis, University of Jodhpur, Jodhpur.

Kumar, S. and Shankar, V. (1986): Grass covers of the Guhiya catchment of the upper Luni basin I. Present and potential herbage production and carrying capacity. Ind. Journ. Forestry 9(2), 126-31.

Kumar, S. and Shankar, V. (1987): Vegetation ecology of the Bandi catchment in the Upper Luni Basin, Western Rajasthan. Tropical Ecology 28, 246-258.

Kumar, S. (1990): Seed source stand density dynamics in natural and aerially seeded populations in the Indian desert. In Proc. of Int.Seed Symp., University of Jodhpur, Rajasthan, India. pp. 93-98.

Malhotra, S. P. (1978): Socio economic structure of populations in arid Rajasthan. CAZRI Tech.Bull. 3, pp. 51.

Mann, H. S. and Chatterji, P. C. (1978): Effect of land use changes in the ground water conditions in canal irrigated areas of western Rajasthan and their management. Proc.Symp.Land and Water Management in the Indus Basin (India) 1, 252-268.

Mann, H. S. and Prakash, I. (1983): Halting the March-ecodevelopment in the Thar. Environmental Services Group Publication, New Delhi.pp. 36.

Odum, E. P. 1969. The strategy of ecosystem development. Science 164, 262-270.

Raina, P. and Sen, A.K. (1991): Soil degradation studies under different landuse system in an arid environment. Annals Arid Zone 30(1), 11- 15.

Shankar, V. and Kachhwaha, T. S. (1978): Efficiency of solar energy capture by dry sub-humid, semiarid and arid grasslands of India-A review. Forage Research 4(1), 43-52.

Shankar, V., Kachhwaha, T. S. and Saxena, S. K. (1977): Factors affecting efficiency of solar energy capture by Anjan (*Cenchrus ciliaris*) pasture. Forage Research 3(2), 107-120.

Shankar, V. and Kumar, S. (1987): Grazing resources of Jaisalmer Ecology and developmental planning with special reference to Sewan grasslands. Pub.No.28, CAZRI, Jodhpur.

Shankar, V. and Kumar. S. (1988): Vegetation ecology of the Indian Thar desert. Intern.

Jour.Ecol.Environ. 14, 131-155.

Shankar, V., Kumar, S. and Tyagi, A. K. (1988): Grazing resources of arid and semi-arid regions, In Pasture and Forage Crop Research - A state of knowledge report. 3rd International Rangeland Congress, New Delhi. 63-85.

Shankar, V. (1983): Depleted vegetation of the desertic habitats: studies on natural regeneration. Pub.No.21. CAZRI, Jodhpur.

Shankarnarayan, K. A. and Kalla, J. C. 1985. Management systems for natural vegetation in arid and semi-arid areas - A case study. CAZRI, Jodhpur, pp. 132 (mimeo.).

Shankarnarayan, K. A. (1985): Arid land irrigation and combating desertification. In Singh, S. D. (Ed.) Development and Management Training Course on Irrigated Agriculture in Arid Areas. WAPCOS, New Delhi. 180-189.

Shankarnarayan, K. A., Sharma, K. D., and Kalla, A. K. (1987): Effects of grazing on run off and soil loss in arid rhyolite basins. Annals of Arid zone. Vol. 26(1&2): 111-113.

Singh, S., Kar, A., Joshi, D. C., Ram, B., Kumar, S., Vats, P. C. Singh, N., Raina, P., Kolarkar, A. S., Dhir, R. P. (1992): Desertification mapping in western Rajasthan. Annals Arid Zone 31(3).

Williams, A. W. (1966): Range improvement as related to net productivity, energy flow, and foliage configuration. J.Range Management 19: 29 - 34.

III. Vegetation Mapping and Change Analysis in Thar Desert of Western India from NOAA AVHRR LAC Imageries

Tadakuni Miyazaki and Yoshifumi Yasuoka

Abstract

An outline of the vegetation change monitoring program at Thar desert in western India is introduced. A vegetation Index map of Thar desert in western India is produced from NOAA AVHRR LAC imageries with 1km spatial resolution to assess vegetation distribution in the region. Also land-cover change detection with multi-temporal AVHRR images was examined for monitoring changes in vegetation at continental scale.

1. Introduction

In South-East Asian countries there have been observed serious natural disasters such as droughts, landslides or floods in recent years. As one of the causes for these phenomena, regional scale or meso-scale climatic changes due to deforestation are pointed out. Monitoring earth surface conditions and their changes is essential to the management of the environmental problems in both of the regional and the global scale.

National Institute for Environmental Studies, Tsukuba, Japan has started a program for monitoring vegetation distribution and its change in South-East Asian region using NOAA AVHRR LAC imageries. In this program the AVHRR image mosaic map and the Vegetation Index maps with 1km spatial resolution are being produced regularly, and also the changes in vegetation are being analyzed to assess environmental changes. In this paper, the NDVI mapping and the preliminary study for the land-cover change analysis are introduced.

2. NOAA AVHRR LAC Image Mosaicing and NDVI Mapping

Eleven NOAA AVHRR LAC imageries with low cloud-cover were selected in South-East Asian region (Latitude 0 - 35N, Longitude 66 - 110E) from December 1989 to March 1990.

2.1. Albedo conversion and tangent correction

First the raw in the visible and the near infrared bands were converted to albedo and the data in the thermal band to temperature. Also in each scan line the tangent correction was performed by resampling each pixel from the original scan-angle coordinate to the distance coordinate on the earth surface by taking the earth surface curvature into account.

2.2. Path radiance correction

The scan-angle effect in brightness due to the path length difference was removed by subtraction the path radiance component for each scan-angle (column) from the original density. The path radiance component was estimated by fitting the third order polynomial along the scan line direction to a set of column densities composed of the minimum value searched in each column.

2.3. Geometric correction

Each image was overlaid onto the longitude/latitude coordinate through geometric correction. The third order polynomial decided by the tick mark information was used for converting the image coordinate to the longitude/latitude coordinate. The pixel size of the corrected image was 0.01 degree both in longitude and latitude. The image density of the resampled pixel was linearly interpolated from four surrounding points.

2.4. Mosaicing

A cloud-free mosaic map was produced by composing the images. The secondary geometric correction and the density normalization were performed to compensate the location error and to adjust the spectral difference between combined images. Also the cloud pixel was eliminated by selecting the pixel with highest NDVI value from multiple overlaid images for the same area. In the case that the NDVI of the selected pixel was lower than the specified threshold, the pixel with the highest temperature was selected as cloud-free.

Figure 3.1 shows a mosaicmap of South Asia produced from NOAA AVHRR LAC images.

2.5. NDVI mapping

The vegetation index was calculated using band 1 and 2 of the mosaiced image. Here, the Calibrated Vegetation Index,

$$CVI = 260 \times (A2-A1)/(A2+A1)+15$$

where A1 and A2 denote the albedo in band 1 and 2, was adopted as the Normalized Difference Vegetation Index. The produced NDVI map of South Asia is shown in Fig. 3.2.

3. Land-cover Change Detection

Land-cover change detection with multi-temporal AVHRR images was examined. Two methods including principal component analysis and spectral signature similarity were applied to the AVHRR LAC images from two different years to enhance the differences in the spectral signatures and to detect the land-cover changes. Three bands of band 1, 2 and 3... from NVHRR images were used for the comparison of images.

3.1. Principal component analysis

Let $\mathbf{L} = \{L_1(\lambda_k), L_2(\lambda_k)\}$ be a combined set of the six $(2\times3 = 6)$ bands image from two dates and C_L be the covariance matrix of **L**. The difference in land-cover between two dates is evaluated by the principal component

$$D = \sum_{k=1}^{3} \alpha_k L_1(\lambda_k) + \sum_{k=1}^{3} \beta_k L_2(\lambda_k) \tag{1}$$

where $\{\alpha_k, \beta_k\}$ is the normalized eigen vectors of C_L which statistics $\alpha_k>0$, $\beta_k<0$ for all k. In this case D shows the subtraction between two dates images and may indicate the change between two dates.

3.2. Spectral signature similarity

The spectral signature similarity is defined by the correlation coefficient between $\{L_1(\lambda_k)\}$ and $\{L_2(\lambda_k)\}$ and expressed by

$$r = \frac{\sum_{k=1}^{3} (L_1(\lambda_k)\overline{L_1})(L_2(\lambda_k)\overline{L_2})}{\sqrt{\sum_{k=1}^{3} (L_1(\lambda_k)\overline{L_1})^2 \sum_{k=1}^{3} (L_2(\lambda_k)\overline{L_2})^2}} \quad (2)$$

The spectral signature similarity r takes the value $-1.0 < r < 1.0$, and $r = +1.0$ only when $\{L_1(\lambda_k)\}$ and $\{L_2(\lambda_k)\}$ have a linear relation. If r takes a higher value it means that two spectral signatures are similar and the point is judged as not changed. On the other hand if it takes a lower value it means they differ nonlinearly and the point is detected as changed. Figure 3.3 and 3.4 show the AVHRR images of January 7, 1986 and February 4, 1992 around west India (Red, Green, Blue = Ch3, Ch2, Ch1) and two examples of the land-cover change detection from AVHRR images using the principal component analysis and the spectral signature similarity are presented in Fig. 3.5.and 3.6, respectively. In Fig. 3.5 and 3.6, detected areas as changed during the period from 1086 to 1990 are marked white on the images.

4. Conclusions

Application of the NOAA AVHRR LAC images to the monitoring of the vegetation change was introduced.

The total area of the image showed in Fig. 3.5 or Fig. 3.6 is about 922,292km^2 and the detected changed areas calculated from the principal component analysis and the spectral signature similarity are summarized in Table 3.1.

Table 3.1 Summary of the detection of the changed area.

	Principal component analysis	Spectral signature similarity analysis
Total area (km^2)	922,291.92	922,291.92
Detected changed area (km^2)	376,940.71	188,700.93
Rate of the changed area (%)	40.87	20.46

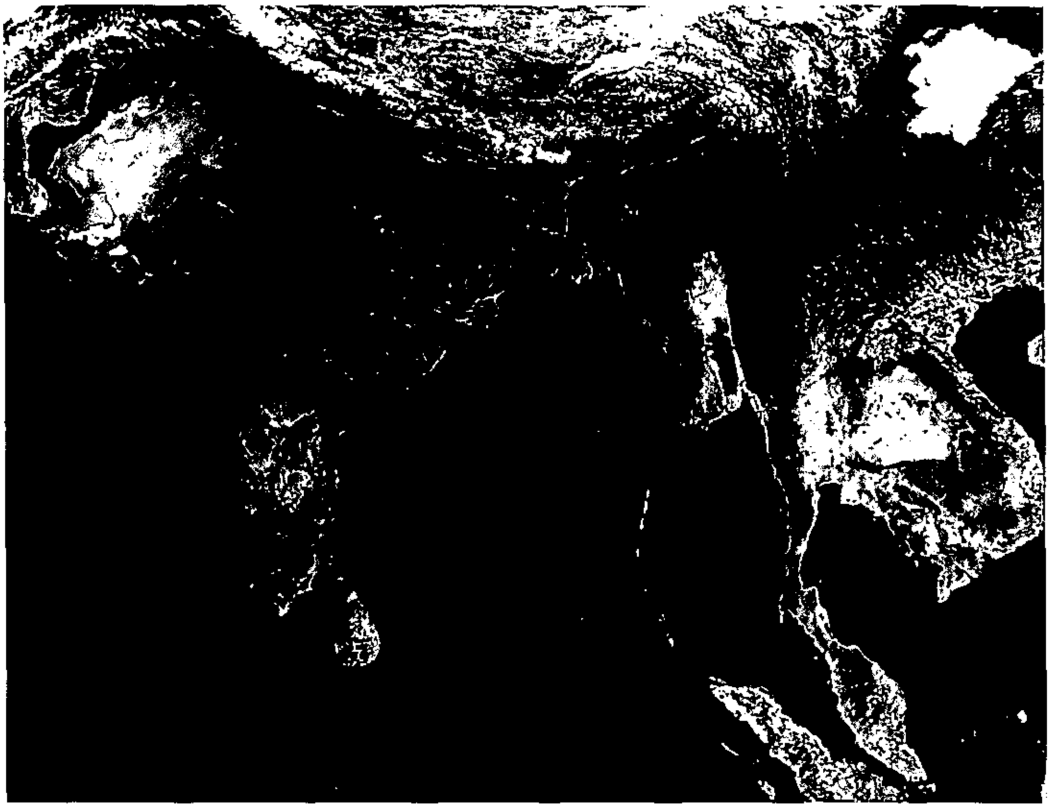

Fig. 3.1 Mosaic map of South Asia produced from NOAA AVHRR LAC images.

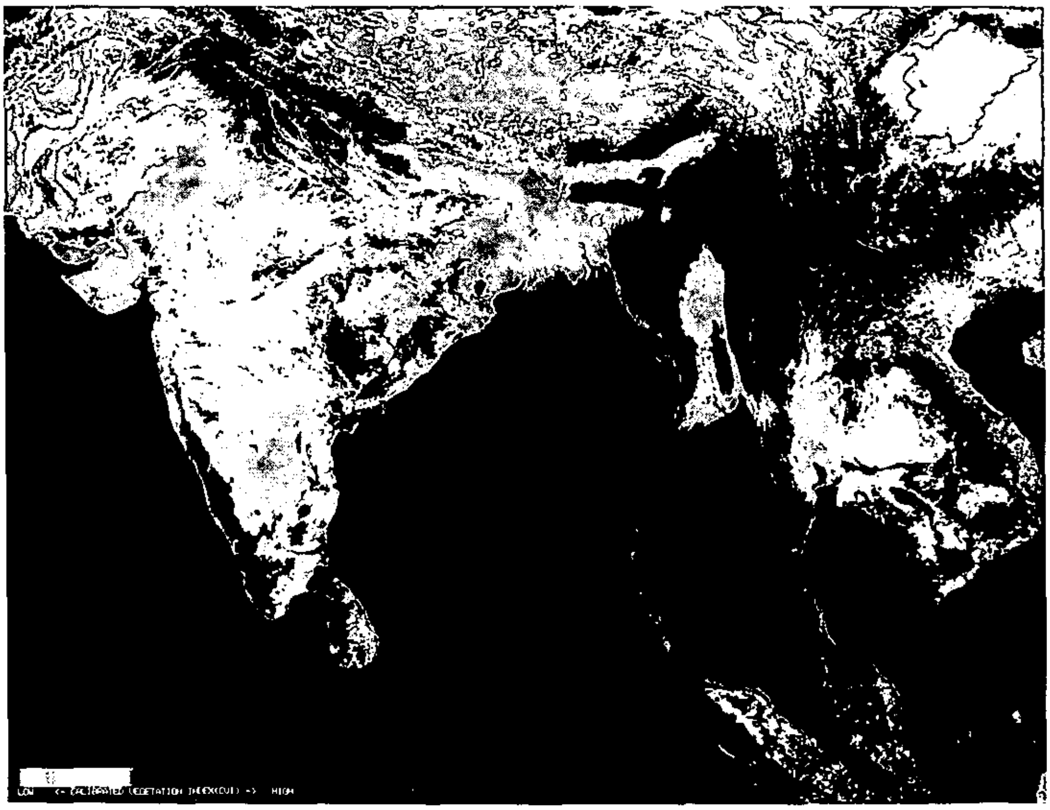

Fig. 3.2 The NDVI map in South Asia produced from NOAA AVHRR LAC image mosaic map.

Fig. 3.3　　NOAA AVHRR original image of January 7, 1986.

Fig. 3.4　　NOAA AVHRR original image of February 4, 1992.

From the Table 3.1, the calculated changed areas during the period from 1986 to 1990 are 376,941km^2 (41%) from the principal component analysis and 188,701km^2 (20%) from the spectral signature similarity analysis. The actual area of landuse change in the region is much less than 50%, so the the spectral signature similarity analysis seems to be more practical than the principal component analysis for arid and semi-arid area in West India.

The mapping of vegetation distribution and its change in appropriate spatial resolution and temporal interval provides the basis for the effective management in deforestation of desertification. This preliminary study indicated the usefulness of the NOAA AVHRR LAC data for the continental scale vegetation monitoring. However, it was also shown that the combination of the high spatial resolution data with the frequent AVHRR data would be required for more practical monitoring.

Fig. 3.5 Land-cover change detection from AVHRR images around west India by principal component analysis. Changed areas are marked white.

Fig. 3.6 Land-cover change detection from AVHRR images around west India by spectral signature similarity. Changed areas are marked white.

References

NOAA/NESDID: NOAA Polar Orbiter Data Users Guide.

Yasuoka, Y., Yamagata, Y., Otoma, S., Miyazaki, T. and Takeuchi, S. (1990): Detection of vegetation change from remotely sensed images using spectral signature similarity. Proc. of IGARSS'90.

Part 2 Review of Desertification Studies

IV. Review of Ecological Study on Desertification in Indian Desert

Kenji Narita

1. Introduction

The desertification process is generally defined as a package of processes which bring about certain changes in a particular ecosystem, converting the relatively non-desertic terrain to a desertic one. One of the most distinct process is the complex combination of climatic, edaphic and biotic factors that cause a climatic opportunity which leads to the formation of a desert or increase of arid conditions, or cause creeping of desertic conditions in a desert tract towards adjoining areas. Although opinions vary whether the effect of human activities are a major or minor factor, it is also a cause of desertification that cannot be denied.

In India, 12 percent of the total geographical area is in arid zones (28,600 km^2) and the majority are situated in the north-western states. The deterioration of the climate, rise of the Himalayas, lowering of the Aravalis, changing of river systems and lowering of underground water-tables are causes of the occurrence of the Indian Desert (Wadia, 1960).

Based on features of landscape, soil types, availability of water and the distribution of natural vegetation, the land-forms in this region are classified into six groups; desert peneplains, sand dunes, sandy plains, floodplains, marsh lands and salt playas (Gupta and Prakash, 1975).

The Indian desert is one of the most densely populated deserts of the world; 19 million people with an average density of 61 people/km^2 against the average of 3 people/km^2 in other deserts (1971, census)

The increase of the human population in Indian arid region between 1900-1971 was 157.35 %, and was especially 126.04 % from 1961 to 1971. Following human activities such as cropping, grazing, removal of trees and shrubs for fuel or other purposes and construction of irrigation systems on vulnerable land have affected the desert making it more and more uninhabitable (Sen, 1986).

The land use in this region is divided into five categories: forest (1.88%), not available for cultivation (23.85%), other uncultivated land excluding fallow lands (19.30%), fallow land (11.72%), and net area sown (43.25%). Most of the present land is not adequately used judging from soil characteristics (Mann *et al.*, 1977).

The definition for desertification is diminution or destruction of the biological potential of the land that can ultimately lead to desert-like conditions; grazing land ceases to produce grass, dryland agriculture fails, irrigation fields are abandoned owing to salinization, waterlogging or some other form of soil deterioration (United Nations' definition, 1977; Biwas, 1980). Among these, overgrazing of livestock has most severely and widely destroyed the vegetation, changing its composition and decreasing the coverage, finally leading to bare land.

Yet, ecologically and economically, animal husbandry is the most suitable form of land use in arid and semi arid regions. In the Indian arid regions, the livestock sector is the most important. The livestock population increased from 10.27 million in 1951 to 16.44 million in 1972, and 23.2 million in 1983 in the Rajasthan region.

Though the number differs in habitats, the present grassland productivity can sustain 13-30 Adult Cattle Unit (ACU)/100 ha, although there are actually 30 ACU/100 ha on an average (1971 census). Therefore, 80-90% of the grassland in this region is categorized as in poor or very poor condition (Raheja, 1962).

2. Vegetation

Vegetation is the principle of the ecological and economical system, and its management is one of the most important keys to fight desertification. Therefore, studies on the vegetation cover, its quality, quantity, and vigor are important to understand the present fundamental natural condition, preserve the ecological conditions and utilize the natural resources rationally. Such attempts begin with basic understanding of the existing vegetation community and their spatial, temporal dynamics and stability. The first studies began in the Indian arid region by King (1879), Macadam (1917), and Blatter and Hallberg (1921). Shown below are following classification studies:

(1) Based on Clements's climax concept (Champion, 1936; Champion and Seth, 1968).

(2) Based on Braun Blanquet's approach (Sen, 1966; Bharucha, 1975).

(3) Floristic investigation (Sarup, 1952, 1953; Joshi, 1956, 1958; Nair and

Joshi, 1962; Martia and Bhandari, 1980).

(4) Physiognomic and life form study (Gupta, 1975), (Das and Sarup, 1951; Meher-Honji, 1962; Martia and Bhandari, 1980).

(5) Classification based on dominance indices (Satyanarayan, 1963; Shankarnarayan, *et al*., 1966; Gaur and Satyanarayan, 1967; Gupta and Saxena, 1971; Abichandani *et al*., 1975; Gupta, 1975; Saxena and Singh, 1976; Anonymous, 1966, 1967, 1970; Shankar and Saxena, 1975; Shankar and Bhati, 1977; Shankar and Kumar, 1980, 1981, 1982; Kumar and Shankar, 1985, 1986).

(6) Multivariate methods (Kumar *et al*., 1980; Kumar and Tewari, 1982; Shankar, 1982).

Blatter and Hallberg (1921) recognized five main formations in the Indian desert. Four main vegetation types were described by Champion in 1936, and later classified as eight (Champion and Seth, 1968). Sen (1966) described 44 associations in 15 alliances and eight orders for the vegetation in Jodhpur.

Mathur (1960) classified six forest types. Bharadwaj(1961) distinguished three primary and six secondary land form regions, and based on this study, Satyanarayan (1963) classified the plant communities of Central Luni Basin into five groups. Gaussen *et al.* classified the vegetation of Rajasthan which constitutes three formations into twelve types. Based on five formations enlisted by Satyanarayan (1963), Saxena (1972) recognized seven ecosystems in Western Rajasthan.

Gupta and Saxena (1971) and Gupta (1975) also adopted and enlarged the classification by Satyanarayan (1963) to six formations. Mertia and Bhandari (1980) identified four major forms in Jaisalmer following Du Reitz's classification. One of the vegetation classifications (Gupta, 1975) is shown as follows:

(A) mixed xeromorphic thorn forest
(B) mixed xeromorphic woodland
(C) mixed xeromorphic riverine thorn forest
(D) lithophytic scrub desert
(E) psammorphytic
(F) halophytic scrub desert

In 1975, Shankar and Saxena used IVI (Important Value Index) to determine dominance index for studying ground vegetation under different tree canopies and in comparing vegetation changes on protected rocky habitats. Since then, the IVI has been extensively used in studies on desert vegetation and its phytosociology. Shankar and Kumar (1980, 1981, 1982) determined dominance and co-dominance on grasslands of the Guhiya and Bandi cathments based on RIV and classified seven grassland types.

So far, multi-variate methods have been used in only three attempts. Kumar *et al.* (1980) used monothetic classificatory technique in studies of the Sal forest. Tewari (1982) used polar ordination in studies of pine-oak communities in the western Himalayas. Shankar (1982) used standardized computer programs for the first time in the Indian desert to classify desert shrub land communities. In an attempt to reveal relationship between sites, species, and between sites and species, some studies were carried out using soil characteristics as site quality indices. These studies were aimed to identify community types by investigating spatial arrangement of species, and, through direct or gradient ordination, to determine changes in species population and community characteristics influenced by changes in environmental factors, finally revealing directions to follow in establishing site management.

3. Succession

Usually, the succession progresses slowly in arid regions due to the extremely severe desert environment. The present natural vegetation in the Indian Desert consists of sparse thorny shrubs with grasses, widely varying between sites. The vegetation comes into existence in equilibrium with many environmental factors. One small change of a single environmental factor causes dynamic change in plant life.

The desertification is accelerated by degradation of vegetation, therefore, it is important to study the processes of succession and degradation to understand the desertification process and discover measures for the recovery of vegetation. The ecological studies of potential successional stages were extensively carried out on various habitats and some rainfall zones under protected conditions in western Rajasthan. Saxena (1977) summarized the woodland and grassland succession in six different geological habitats under undisturbed conditions: hills, older alluvial plains, undulating hummocky plains, younger alluvial plains, sand dunes and saline depressions.

The grasslands are stable as pre-climax when grazing is in the carrying capacity. Yet, when the grazing pressure exceeds the carrying capacity, the vegetation slowly degrades starting the succession and degeneration stage. The way degradation caused by overgrazing differs by site quality, habitat, type of grass cover, its palatability, grazing habit of herbivores and the quantitative relation between forage yield and grazing pressure. Gupta and Saxena (1972) studied the succession affected by grazing intensity (severe, medium and protected) in two types of grasslands.

The most palatable species are damaged by overgrazing first, then reduction of the less palatable species follows. Dabadghao and Marwaha (1962) investigated palatability and growth stages of grasses and reported that the palatability of the plants differed in growth stages, except for *Dichanthium annulatum* and *Cenchrus cilialis* which showed high palatability throughout all growth stages. These studies show that the degradation of grasslands chiefly occurs by the selective grazing habits of herbivores. This selective grazing results in changes in the succession process.

In addition to qualitative studies, quantitative relation between the herbage yield and demand of livestock was studied to determine methods in management to preserve grasslands for sustainable use. The carrying capacity of grasslands under different conditions during a normal rainfall year was investigated by Ahuja (1975).

The effect of grazing intensity on the herbage productivity in grasslands was investigated by changing the cutting height of grasses (Shankarnarayan *et al.*, 1976). Results showed that dry matter yield increased with decrease in grazing intensity. By fencing the grassland, the potential herbage productivity was calculated. Bhimaya *et al.* (1967) observed forage yields from protected range lands under different conditions classified as poor, fair and good for six years. Mann and Ahuja (1975) studied the forage yield on twelve managed paddocks under different rainfall and soil conditions for 14 years. Their study revealed that the forage yield increases with rainfall increase, although this depends on the soil condition. Shankar (1983) examined the period necessary to protect range land for the purpose of generating an intended stage of succession for grazing land and farm forestry in nine habitats.

Shankar and Kumar (1987) estimated the potential herbage production of different grass cover types (*Lasiurus*, *Dactyloctenium-Eleusine*, *Aristida- Oropetium*, *Sporobolus-Eleusine*) in the Jaisalmer district. The potential herbage yields of each grass type increased up to nearly four times of the actual vegetation. Kumar (1991) set up a protected area for two years and compared the herbage yield of both browsing and herbaceous species with that of unprotected areas. He showed that overgrazed grassland had only a half of the herbage yield of the protected area (Kumar, 1991). Through grazing and browsing, palatability of plants influence the vegetation succession.

4. Soil Erosion and Salinization

Wind regime is very high in the arid region, and thus, a serious problem that causes wind erosion and sand movement which affect agriculture, houses, roads, railways and canals. Serious erosion occurs when vegetation is destroyed by overgrazing or removal of trees and shrubs for fuel or other resources.

Dhir (1977) did research on soil fertility and the distribution of soil textures in areas under different land use in the Rajasthan district. His study showed that irrational land use causes the quality of the surface soil to change to a sandier texture that lacks silt and clay. He described the continuous existence of vegetation covering soil is very important for combating soil erosion by winds.

Gupta (1981) investigated the relation between wind velocity and soil erosion in different regions in Western Rajasthan. He reported that the soil eroded more severely in sites having less vegetation. Soil fractions ranging from 0.10-0.25 mm were highly eroded compared to the 0.05-0.07 and 0.07-0.10 mm ones, and the fractions less than 0.05 mm were least eroded. Soil nutrients such as organic, nitrogen and minerals were concentrated mainly in the grain size less than 0.05 mm, but highest nutrient loss occurred in the fractions ranging from 0.10-0.25 mm. This resulted from the maximum erosion of this fraction. In arid regions, organic and nitrogen are inherently low in soils, meaning the loss of these will lead to critical decrease of land fertility and vegetation.

The trampling by livestock also leads to disintegration of humus and organic matters and alters the physical condition of soils (Shankarnarayan, 1977). The compacting of soil surface decreases infiltration and increases runoff, and owing to the low vegetative coverage, soil erosion occurs, ultimately making arid land unproductive.

There are two types of saline soils: naturally saline soils formed by the capillary rise of underground saline waters gathered from surrounding areas, and secondary saline soils owing to irrigation with saline underground water and construction of canals on vulnerable land-forms. These areas have only a few halophitic shrubs and grasses, which are usually utilized for grazing (Saxena, 1977). Ghose *et al.* (1976) investigated soil salinization in the Jodhpur-Nagaur region. This research showed that 1,568 ha of land suffered salinization due to construction of tanks along channels of Agana nara and constant irrigation with saline water. Sen *et al.* (1976) reported that construction of a dam across the Luni basin spread the saline land to surrounding areas. The over-use and bad management of water resources caused rise of the water table in the soil. Also, concentration of minerals in soil surfaces occurred owing to high evaporation ratio and absence of drainage systems in the arid region.

5. Combating Desertification

Sen reported some of the main human and biotic interferences as follows;

(1) Uncontrolled grazing and indiscriminate cutting of trees leading to soil erosion and the increase of desertification hazards.

(2) Uneconomic land use: cultivation on the sand dunes and marginal lands which affect adjoining fertile lands become a menace causing soil erosion.

(3) The intensive and uneconomic use of canal irrigation, over exploitation of water resources leading to the rise of water table, causing seepage problems and increasing salinity.

The main problems of desertification in the Indian desert are deterioration of vegetation, soil erosion and salinization. Many attempts have been extensively carried out aiming to combat these hazards.

5.1. The Recovery of Vegetation

To assess site conditions and influences of desertification, extensive studies have been done. Based on quantitative and qualitative vegetation parameters which consist of the ecological status, developmental stage of the vegetation, analytical attributes of perennial grasses, dominance on the production basis, vigor of perennial grasses, weeds, shrubs, and grazing or browsing intensity, Shankar (1977) measured the changes in the ecological status of the plants caused by abiotic factors, especially herbivores by the score card method.

Besides plant indicators, Shankar and Kumar (1983, 1986) used soil parameters such as fragility, quantity of deposits, erosional status, drainage, and bare area and litter quality to classify the site quality of ten different habitats into four categories in the Guhiya Catchment to measure the desertification.

Aiming to rehabilitate the vegetation, many extensive studies have been accomplished, which include conservation of soils, limitation of herbivores, and planting or reseeding measures. The fencing methods are most effective to rehabilitate the productivity, coverage and vigor of grassland and tree shrubs by decreasing grazing pressures of herbivores and following increase of re-seedings. Ahuja *et al.* (1973) carried out a ten year research on forage yields of highly eroded, medium loam soils undergoing different soil conservation treatments. Shankar (1983) carried out surveys in eight habitats (hills, rocky, gravelly pediments, flat buried pediments, sandy undulating buried pediments, flat aggraded older alluvial plains, sandy undulating aggraded older alluvial plains, sand dunes and shallow saline depressions) in protected and unprotected areas for ten to 15 years. His experiments showed that the herbage yields in protected areas were 3.3 times (at hills) to 10.9 times (at sand dunes) higher than in the unprotected areas.

In the arid region, progress of the natural regeneration by self-seeding in grassland to the level of proper utilization is slow. Therefore, rational reseeding measures with suitable perennial grass species for livestock grazing would be fruitful. Ahuja and Bhimaya (1967) have worked on the effect of reseeding under different range land conditions and soil treatment, their results showed that the increase in forage yield by reseeding was 30-122%, and 29-107% in poor and fair range lands respectively.

5.2. Soil stabilization and Desalinization

Sand dune movement and soil erosion by wind are serious problems in the arid regions. Reducing of vegetation by overgrazing and removal of trees for fuel or other materials, started in sand dune movement and soil erosion. Therefore, to prevent these hazards, covering soil surface by vegetation is very important.

The sand dune stabilization consists of four progresses:

(1) protection from biotic influences

(2) treatment of shifting sand dunes by fixing barriers across the wind direction
(3) afforestation by direct sowing and/or planting suitable trees
(4) planting seedlings or root slips of drought prone perennial tussocky grass (Muthana and Ahuja, 1973).

Aerial seeding has been employed to cover the vast and inaccessible seeding area in the Indian arid regions since 1950, and minute studies about its germination and seedling features and favorable species were conducted (Bhimaya, 1977; Sharma, 1985; Shakarnarayan and Kumar, 1986; Kumar and Shankarnayan, 1988). Planting trees in moving sand dunes not only effectively stabilize the sand dunes, but also improve soil fertility by building up organic matters and supply fodder and shade zone for livestock.

Intensive and irrational use of canal irrigation, and over exploitation of water resources lead to rise of the underground water table, salinizing the land and making it useless. To improve saline range lands, draining away excessive salts by digging trenches is very effective. After this measure, the trenches can be effectively stabilized by sowing or seeding salt resistant tree species such as *Acacia tortilis*, *Prosopis juliflora* and *Salvadora persica* along the mound of trenches. Using such measures, grassland production increase due to occurrence of *Sporobolus helvolus* and *Dichanthium annulatum* has been reported as improvement of salinization.(Ahuja and Bhimaya, 1966).

6. Discussion

Desertification is nothing but ecological succession where there is not only change in the construction of biotic factors but also in the interaction-system of biotic and abiotic factors. The main factors of desertification are decrease of plant production, sand dune movement and salinization. Especially, the affecting relation of vegetation degeneration and soil degradation play the most important parts. The reason why such deterioration occurs is human activities that disregard the complex and fragile ecosystems which keep equilibrium with the severe and unstable environments.

The Indian Desert is the most densely populated desert in the world, high in human activities which bring about the desertification. Economically and ecologically, animal husbandry is the most popular industry in the arid or semi-arid regions of the world. This is also true for the Indian Desert, having the Rajasthan district in its center. Though animal husbandry is suitable for arid regions, the pressure caused by abrupt increase of livestock that exceeds the production of the inherently scarce desert vegetation results in degrading the vegetation to unproductive, low coverage and finally bare land. Adding to this, removal of trees and shrubs for fuel and other purposes influence the degeneration of vegetation. This destroy of the vegetation affects topographic and edaphic conditions, and makes land more and more desertic.

Many researches have been performed to investigate this problem. Some researchers studied the recovery of vegetation by excluding herbivores under protected areas, and were able to reveal detailed processes of succession which consisted from qualitative and quantitative changes (vegetative production and coverages).

Although succession is a synthesis of temporal and spatial dynamics of plant populations, past studies do not put much emphasis in population ecology controlled by each stage of plant life cycles. Especially, dynamics and roles of seed banks of annual or perennial grasses in the soil have not been studied. Basically, the seed is a component of reproduction, dispersal and survival. In the deserts, germination and seedling survival are among the most important elements in understanding the vegetation and describing the ecosystem (Went, 1981), and as expressed by Batanouny (1965), 'the final floristic composition of the desert vegetation is controlled by seed germination'. The seeds dispersal and germination are affected by many biotic and abiotic factors such as vertebrates and insects, temperature, wind and soil moisture.

In the Indian desert, there are not many studies focusing on this point. For example, the rodents and harvester ants are individually studied, but the role they play concerning seed and seedling dynamics needs to be investigated further (Chew and Butterworth, 1964; Mauer, 1967; Tevis, 1958; Whitfold, 1973 and Went, Wheeler and Wheeler, 1972). To reveal how vegetation occurs or will progress, the study on relation between behaviors of seeds and its consumers will give important information. In different habitats under control of not only herbivores but also seeds consumers, succession should be studied through comparison of the present (adult) vegetation and spatial and temporal dynamics of seeds and seedlings.

Though there are many approaches to combat desertification, economically and ecologically speaking, it is necessary to recover the vegetation in the most natural way possible. After all, the vegetation is the foundation and rivet of the ecosystem.

References

Abichandani, C. T., Singh, S., Saxena, S. K. and Kolarkar, A. S.(1975): Integrated biological mapping as an aid to resource development in the Indian arid zone (Bikaner district - a case study). Ann. Arid Zone 14, 285-291.

Ahuja, L. D. (1975): Forage production with special reference to Arid Zone. Write up for National Commission on Agriculture, Govt. of Ind., New Delhi and Monograph CAZRI, Jodhpur.

Ahuja, L. D. and Bhimaya, C. P. (1966): Reseeding range lands for better production in Rajasthan. Ind. Fmg. 16(5), 19-23.

Ahuja, L. D. and Bhimaya, C. P. (1967): Germination studies of perennial grass seeds. Ann. Arid Zone. 6(2), 146-152.

Ahuja, L. D., Vangani, N. S. and Bhimaya, C. P. (1973): Range management studies. Effect of different soil conservation measures on range land production in arid zone. 43rd Ann. session National Academy of Sci. Ind., Jodhpur.

Anonymous (1966): Land transformation plan of Ahor block in western Rajasthan. Divisional Report No. 66/1, CAZRI, Jodhpur (Mimeo.), pp. 122.

Anonymous (1967): Land transformation plan-Jalore block in western Rajasthan. Divisional Report No. 67/1, CAZRI, Jodhpur (Mimeo.), pp.122.

Anonymous (1970): Land transformation plan of Chohtan Panchayat Samiti block in Barmer district, Rajasthan. Divisional report, CAZRI, Jodhpur, pp. 45.

Bharadwaj, D. P. (1961): The arid zone of India and Pakistan. A History of Land Use in Arid Regions. UNESCO, Paris, 143-174.

Bharucha, F. R. (1975): Plant associations in western Rajasthan. Environmental Analysis of The Thar Desert, 274-297.

Bhimaya, C. P. (1977): Ecosystem in Arid Zones. Desert Ecosystem and its improvement, CAZRI Monograph 1, 178-192.

Bhimaya, C. P., Kaul, R. N. and Ahuja, L. D. (1967): Forage production and utilization in arid and semi-arid range lands of Rajasthan. Proc. Joint Symp. Nat. Inst. Sci. Ind. and ICAR on Science and India's food problem, New Dehli, 215-223.

Bhimaya, C. P. and Ahuja, L. D. (1967): Effect of contour furrows on grassland production in western Rajasthan. Proc. Workshop in Soil Sciences, north-zone Hissar.

Biswas, M. R. and Biswas, A. K. (1980): Desertification. Pergammon Press, Oxford.

Blatter, E. and Hallberg, F. (1921): The flora of the Indian Desert. Journal of Bombay Natural History Society.

Champion, H. G. (1936): A preliminary survey of the forest type of India and Bruma. Ind. For. Research. (n. s.) Vol. 1, pp. 286.

Champion, H. G.and Seth, S. K. (1968): A revised survey of the forestry type of India. Manager of Publications, Delhi-6, pp. 404.

Chew, R. M. and Butterworth, B. B. (1964): Ecology of rodents in Indian Cove Joshua Tree National Monument, Calif, J. of Mammalogy, 45, 203-225.

Dabadghao, P. M. and Marwaha, S. P. (1962): Relative palatability studies on the important indigenous grass species of western Rajasthan. Ind. J. Agron, VII (1), 86-90.

Dhir, R. P. (1977): Soil degradation due to over-exploitated human effort. Annal of arid zone. 16 (3), CAZRI Jodhpur, 321-330.

Gaur, Y. D. and Satynarayan, Y. (1967): Phytosociological studies of the monsoon vegetation of rocky habitat. Ind. Forester. 93(12), 806-814.

Gupta, J. P. and Gupta, G. N. (1981): A note on wind erosion from a cultivated field in western Rajasthan. J. Ind. Soc. Soil Sci. 29 (2), 278-279.

Gupta, R. K. (1975): Plant life in the Thar, p. 202-236. In R. K. Gupta, and I. Prakash (eds.), Environmental analysis of Thar Desert, English Book Depot, Dehra Dun.

Gupta, R. K. and Saxena, S. K. (1971): Ecological studies on the protected and overgrazed range lands in the arid zone of west Rajasthan. J. Ind. Bot. Soc. 50IV, 289-300.

Gupta, R. K. and Saxena, S. K. (1972): Potential grassland types and their ecological succession in Rajasthan desert. Ann. Arid Zone II (3 and 4), 198 - 218.

Joshi, M. C. (1956): Plant ecology of Bikaner and its adjacent areas in comparison with rest of western Rajasthan.

Joshi, M. C. (1958): Preliminary survey of the sand dune vegetation of Palaniad and its neighborhood. J. Ind. Bot. Soc. 35, 237-246.

Kumar, S. (1991): Assessment of grazing resources and their demand-availability status through rain use efficiency analysis in arid land villages. Forage Res. 17 (1), 45-54.

Kumar, S. and Shankar, V. (1985): Vegetation ecology of Guhiya Catchment of the Upper Luni Basin, India, Tropical Ecology, 26, 1-11.

Kumar, S. and Shankar, V. (1986): Vegetation ecology of Bandi catchment in the Upper Luni Basin, western Rajasthan. In Proc. Abstracts Seminar of Society for Green Vegetation Research and CAS. Dept. of Botany, Banara Hindu University, Varanasi.

Kumar, S. and Shankarnarayan, K. A. (1988): Aerial seeding on sand dunes: Seedling survival and growth. J. of Trop. Frsty. Vol. 4 (11), 124-134.

Mann, H. S. (1978): Arid zone research in India-25 years. In Arid Zone Research and Development. Scientific Publishers, Jodhpur.

Mann, H. S. and Ahuja, L.D. (1975): Range management research in arid zone of India. Proc. Annual Meeting Society of Range Management, U.S.A.

Martia, R. S. and Bhandari, M. M. (1980): Vegetational adaptions in the extremely arid regions of the Indian Desert. Arid Zone Research and Development (ed. Mann, H. S.). 155-164. Scientific Publishers, Jodhpur.

Mathur, C. M. (1960): Forest types of Rajasthan. Indian For. 86(12): 734-739.

Mauer, R. (1967): Ecology of Perognathus formosus and associated rodents in an arid desert canyon in the Southern Mohave desert. Ph.D. Thesis, Univ. of Nevada.

Muthana, K. D. and Ahuja, L. D. (1973): Sand-dunes. The way to stabilize and Manage. Ind. Fmg. 23(3), 25-29.

Nair, N. C. and Joshi, M. C. (1956): Sand dune vegetation of Pilani and its neighborhood. Symp. Vegetation Types of India, Baroda, Abst., 2-3.

Nair, N. C. and Nathawat, G. S. (1957): Vegetation of Harshnath Aravalli hills. J. Bombay Nat. Hist. Soc. 54, 281-301.

Raheja, P. C. (1962): Range management. Gasamvardhana 10: Sarup, S. 1952. Plant ecology of Jodhpur and its neighborhood. A contribution to the ecology of north-western Rajasthan. Bull. Inst. Sci. India, 1, 223-232.

Sarup, S. (1953): Plant ecology of north-western Rajasthan. Proc. Intern. Symp. Desert Res. Jerusalem Special Publ. Res. Council, Israel, 2, 335-345.

Satyanarayan, Y. (1963): Ecology of Luni Basin. Ann. Arid Zone 2, 82-97.

Saxena, S. K. (1977): Vegetation and its succession in the Indian Desert. Desertification and its control. ICAR, New Delhi, 176-192.

Saxena, S. K. and Singh, S. (1976): Some observations on the sand dunes and vegetation of Bikaner district in western Rajasthan. Ann. Arid Zone 15, 313 - 322.

Sen, D. N. (1966): Ecology of the Indian Desert. 1. On the phytosociology of the vegetation of Jodhpur. Trop. Ecol. 7, 136-152.

Sen, A. K. (1986): Environment degradation in the Indian Desert. Desert Environment Conservation and Management. Jodhpur, 123-129.

Shankar, V. (1977): Measuring desertification through plant indicators. Desertification and its control. ICAR, New Delhi, 193-195.

Shankar, V. (1982): Shrublands of Indian arid zone. CAZRI monograph (unpublished Ms) CAZRI, Jodhpur.

Shankar, V. (1983): The depleted vegetation of desertic habitats: Studies on its natural regeneration. CAZRI monograph No. 21.

Shankar, V. and Bhati, N.S. (1977): Ecological studies on arid shrublands of western Rajasthan. pp. 32. In: Annual Progress Report, CAZRI, Jodhpur.

Shankar, V. and Kumar, S. (1980): Ecological survey of vegetation of Guhiya Catchment of Upper Luni Basin. In: Annual Progress Report, CAZRI, Jodhpur (in press).

Shankar, V. and Kumar, S. (1981): Ecological survey of vegetation of Bandi Catchment of Upper Luni Basin. In: Annual Progress Report, CAZRI, Jodhpur (in press).

Shankar, V. and Kumar, S. (1982): Plant resources, 193-212. In Shankar, V. and Kumar, S. 1983. Site quality assessment for silvipasture development in the Guhiya Catchment of the Upper Luni Basin. Forage Res. 9(1), 25-36.

Shankar, V. and Kumar, S. (1986): Top feed and fuel resources of Guhiya Catchment of the Upper Luni Basin and measures to upgrade them. Ind. J. Rangl. Mgmt. 7(2), 53-62.

Shankar, V. and Kumar, S. (1987): Herbage yield and carrying capacity of grass covers in the desert district of Jaisalmer. Trop. Ecol. 28, 239-245.

Shankarnarayan, K. A. (1977): Impact of overgrazing on the grasslands. Annals of arid zone. 16 (3), 349-359.

Shankarnarayan, K. A. (ed.), Report on basic and human resources survey of Guhiya catchments of the Upper Luni Basin, CAZRI, Jodhpur.

Shankarnarayan, K. A. , Cherian. A. and Gaur, Y. D. (1965): Ecology of dune vegetation of Ocean. J. Ind. Bot. Soc. XLIV (1), 37-50.

Shankarnarayan, K. A. and Kumar, S. (1986): Aerial seeding of sand dunes I. trends in seed germination and seedling distribution. J. of Trop. Frsty. Vol. 2 (1), 3-20.

Sharma, D. G. (1985): Ravine reclamation through aerial seeding. An appraisal, J. of trop. Forestry 1(1), 18-28

Tevis, Jr. L. (1958): Interrelations between the harvester ant, Veromessor pergandai, and some desert ephemerals. Ecology, 39, 695-704.

Tewari, J. C. (1982): Vegetation analysis along altitudinal gradients around Neonatal. Ph.D. thesis: Department of Botany, Kumaun Univ. Nat'l, India.

Wadia, D. N. (1960): The post glaciation desiccation of Central Asia. Natl. Inst. Sci. India Monogr., 10-25.

Went, F. W., Wheeler, J. and Wheeler,G. C. (1972): Feeding and digestion in some ants. Bioscience, 22, 141-145.

Whitfold, W. G. (1973): Demography and bioenagetics of herbivorous ants in a desert ecosystem as functions of vegetation, soil type and weather variables. US/IBP Desert Biome Reports, Vol. 3, 2.3.3.2, 1-63. Chapter 2.

V. Desertification Monitoring Using Remote Sensing Techniques

Atsushi Tsunekawa

1. Introduction

Our desertification study project has started in the 1992 fiscal year. Its object area is Rajasthan, India. Ecologists, social scientists, remote sensing technologists etc. in our Institute are going to join the study from their own point of view. Each study should have its originality in its own academic field and also should contribute to the whole desertification study.

The author had been dealing originally with development of environmental planning methodology using a geographic information system and recently has an interest in environmental monitoring and modeling using techniques of remote sensing and a geographic information system. Therefore the author aims to approach the desertification study project from such a technological background.

In the field of desertification study, the most important study subjects concerning remote sensing/GIS are thought to be development of desertification monitoring, development of famine early warning system, and development of land evaluation system and its application to environmental planning. Among them, the most pressing subject is the development of desertification monitoring using remote sensing techniques, and other items should be studied in the future.

This paper reviews existing theses on desertification monitoring especially using remote sensing. At first the word "desertification" would be defined to limit the extent of the object of monitoring. Next, the items of ground-based observation would be put in order. They are necessary as "ground truth data" for remote sensing, but they also have an important role in themselves for desertification study. Next, the state-of-the-art techniques of desertification monitoring using remote sensing would be reviewed. Finally, what subjects we should focus on in our study project would be discussed.

2. Process of Desertification

It is necessary to define the process of desertification strictly to monitor desertification objectively. Because desertification is caused by a combination of many causes and effects, the technique to monitor desertification depends on the definition of it.

For instance, if it may be assumed that there is a series of processes: construction of a well → promotion of settlement and population increase → over-pasturing and over cutting → vegetation degradation → remove of a sand dune. There might be a view to putting all these processes into a wide definition of desertification. However, if desertification is understood as "land degradation", it is appropriate to take the process of vegetation degradation and remove of a sand dune as fitting the narrow definition of desertification and to take other previous processes as causes of desertification.

Considered in this way, processes and modes of desertification in a narrow sense can be divided into four items as follows.

1) Vegetation degradation: This includes change of the species composition such as decrease of the tree species and useful species, and decrease of plant biomass.

2) Degradation of physical and/or chemical properties of soil: This includes salinization, alkalization, hardening, leaching, change of permeability, and other processes.

3) Soil erosion: This includes erosion of the soil surface caused by heavy rain and/or strong wind and the exposure of underlying rock to the surface.

4) Sand shifting and accumulation: This includes remove of old fixed dunes and burying of arable land by sand.

On the other hand, the causal factors of desertification processes described above include human factors such as population increase and over-pasturing and natural factors such as climate and soil.

3. Ground-based Observation

It is necessary to observe the following items on the ground concerning causal factors and desertification processes in desertification monitoring.

3.1. Grasp of causal factors

(1) Natural factors

- Climate: It is necessary to clarify the climatic change by collecting data on both present and past climatic conditions as much as possible. It is especially important to collect data on precipitation, temperature, wind direction, wind speed, and atmospheric pressure.
- Water environment: It is necessary to investigate the water level of lakes and marshes, the flowing water volume of rivers, and the ground-water level. Comparison with past records should be done, if possible.
- Soil moisture: It is necessary to investigate the soil moisture less than 2.0 m under the soil surface in order to evaluate the potential of crop productivity.

(2) Human factors

It is necessary to investigate items as follows by field survey, statistical analysis of existing material, social investigation, and other methods.

- Human population: Population composition by age and job.
- Livestock population: Population with position and area by the livestock species.
- Pasturing area: Area and productivity by crop species.
- Land use
- Land management: Plowing methods, fertilization methods, and land management methods.
- Cutting down of trees for fuel: Amount of cutting-down of each plant species.

3.2. Grasp of desertification processes

(1) Vegetation degradation: In the case of grass land, it is necessary to investigate the grass height, plant coverage, biomass, species composition, and ratio of plant species which can be used for environmental index. In the case of forest land, it is necessary to investigate the tree height, basal area, species composition, regeneration process by sprouting, and the number of seedlings per unit area, and clarify forest structure by making crown projection map and forest profile map. In the case of arable land, it is necessary to investigate species and productivity of planted crops, period for fallowing land, and amount of weeds.

(2) Degradation of physical and/or chemical properties of soil: It is necessary to investigate soil profile, electric conductivity (EC), content of

soil organism, and content of boron, concentration of soluble salts, EC, sodium absorption ratio (SAR), and concentration of boric acid of ground water, and the drain facilities.

(3) Soil erosion: Concerning water erosion - density of rills and gullies, state of land surface, erosion type, exposure ratio of subsoil, loss rate of surface soil, and amount of accumulated sand should be investigated. Concerning wind erosion - thickness of effective soil layer and root-sphere soil layer, increase rate of eroded area, erosion degree, amount of dust powders in the air, soil property and so on should be investigated.

(4) Sand shifting and accumulation : The position and the activity of the sand dune should be investigated.

4. Observation by Means of Remote Sensing Techniques

4.1. Vegetation monitoring on dry land

The significant characteristics of vegetation monitoring on dry land are caused by the low plant coverage and the large exposure of back ground soil. Therefore it is difficult to apply the spectral vegetation index based on the contrast of the reflection of red and infrared red which is used for comparatively humid region (Tueller, 1987).

There are some reports which maintain the effectiveness of the traditional vegetation index, for example, Foran (1987) reported that even in sparse vegetation area, the Landsat MSS band 5/7 ratio based on absolute reflectance was found to be linearly related to total plant cover, in central Australia. However, negative opinion is thought to be more general.

Due to Wilson and Tueller (1987) who studied the spectral reflectance values of Nevada range land plant communities, spectrally dark components exist in range land plant communities which decrease the brightness of a scene measured from the air, and shadows and litter are presumed to be the primary sources of spectral darkening.

Moreover, Huete and Jackson (1987) indicated that senesced grass and weathered litter were found to significantly alter the spectral response of the range canopy in the first four Thematic Mapper wavebands (0.45-0.52; 0.52-0.60; 0.63-0.69; 0.76-0.90 μm).

Then what techniques can be used instead of traditional spectral vegetation index on dry land?

The first approach is the application of the so-called darkening effect.

The second approach is a series of methods to detect changes in spectral and spatial variability. Pickup and Foran (1987) studied the range land in central Australia and indicated that the spatial auto-correlation function (ACF) and mean-variance plots of the Landsat MSS Band 5 / 7 ratio were found to be successful in separating cover responses typical of good, medium, and poor rainfall years.

The third approach directly applies spectral ranges from the red band. Ringrose and Matheson (1987) indicated that in savanna woodland environments, neither the near infrared over red ratio nor the darkening effect is singularly appropriate, and the most suitable indicators of range condition and degree of desertification can be obtained by directly applying spectral ranges from the red band.

The fourth approach uses a spectral mixing model. Smith *et al.* (1990b) tested a method in the semiarid Owens Valley, California and computed the fractions of vegetation, soils, and shading and shadow within the smallest resolution elements (30 x 30 m pixels) of the TM images by applying a mixing model based on laboratory and field reference spectra.

The fifth approach use a geographic information system (GIS). Smith *et al.* (1990a) isolated the effects on vegetation of the covering factors, net radiation, temperature, elevation, soil type, and precipitation by means of a GIS. Conversely, it is considered to be able to estimate vegetation based on the relationship between vegetation type and its related environmental factors.

4.2. *Monitoring of physical and chemical properties of soil*

It is thought that the most important matter in physical and chemical properties of soil in desertification area is the process of salinization. However, theses cannot be found which report on observation of soil salinization by remote sensing directly. But an indirect observation, which characterize the degree of salinity status by the vegetation growing at the place, might be possible. For example, Toth *et al.* (1991) indicated by the study in the Hortobagy region in east Hungary that the most characteristic six to seven vegetation association types related to the salinity degree are well identifiable based on their TM spectra using discriminant analysis/non hierarchical clustering with half - meter ground resolution.

On the other hand, Frazier and Cheng (1989) show by the study in the Palouse region of eastern Washington state that Landsat TM band ratios could be used as an indicator to map various levels of organic matter and iron oxides. However, since such techniques strongly depend on the spectral properties of soil in the object region, generalization of the method to other regions might be difficult.

In the observation of physics and chemistry of soil by remote sensing, the most interesting subject might be a monitor of surface soil moisture using microwave sensor. For instance, Becker and Choudhury (1988) using a satellite sensor (Nimbus-7 / SMMR), Jackson and O'Neill (1987) using an airborne passive microwave sensor, and Bruckler *et al.* (1988) using an optimal active microwave sensor on the ground, each show that surface soil moisture can be observed by remote sensing.

4.3. Monitoring of soil erosion

It is thought to be difficult to observe the soil erosion process directly, that is, to detect the changes by erosion; however, it might be possible to observe the eroded status.

For instance, Frazier and Cheng (1989) mentioned above estimated the eroded area by iron/carbon ratio indicator. Since erosion has caused paleosols to be exposed in this region, it is possible to estimate the eroded area by the indicator of exposed or nearly exposed paleosols. However, it has to be said once again that because the technique depends on the spectral properties of soil in the region, it might be difficult to generalize the technique to other regions.

On the other hand, Evans and Smith (1991) showed that they developed a technique to separate classes of surface roughness and vegetation cover in semiarid regions using Landsat Thematic Mapper (TM) and Synthetic Aperture Radar (SAR) data. Therefore it seems possible to estimate surface roughness caused by erosion by SAR, however, such reports could not be found.

4.4. Monitoring of sand shifting and accumulation

The following approaches are related to sand shifting and accumulation. The first approach identifies the region covered with sand or dunes. This is thought to be possible by means of visible/near IR sensor of Landsat, SPOT, and other satellites. However, it might be difficult to quantify the amount and the speed of sand-shifting without using airborne sensors because of the problem of spatial resolution.

The second approach discriminates active and inactive sand by remote sensing. Paisley *et al.* (1991) showed that visible and near-infrared (VNIR) spectral data can be used to discriminate inactive sand (dark and fine-grained) and active sand (less dark and quartz sand-size grains) populations in the Mojave Desert.

The third approach monitors the dust powders in the air. Takashima and Masuda (1987) computed emissivities of quartz and Sahara powders and showed that emissivity of quartz in NOAA - AVHRR Channel 5 is higher than that in Channel 4. However, it is a model experiment, and not observed actually.

5. Research Strategy in the Desertification Research Project

This paper has reviewed desertification monitoring using remote sensing from four viewpoints: vegetation, soil physics and/or chemistry, soil erosion, and sand shifting. And the following two conditions might be added in the case of the desertification study project.

The first condition is to use satellite sensors instead of airborne sensors. Because airborne sensor might be unavailable due to military reasons in Rajasthan, satellite remote sensing should be examined.

The second condition is that the study should contribute not only toward remote sensing technology, but also toward desertification study. Results in the field of desertification study should be sought, as the author has said at the beginning.

Considering the above conditions, the author suggests the following two subjects as the most efficient and appropriate for our study project.

The first subject is development of vegetation monitoring technique on dry land. It goes without saying that vegetation monitoring has a very high priority in the field of desertification study. However, as mentioned above, it is difficult to apply the same spectral vegetation index that is used traditionally for the purpose of vegetation monitoring in the comparatively humid regions, and some alternative techniques are suggested, but they are still in the stage of examination. Among them, application of a spectral mixing model might be considered to be hopeful. So far, researchers in our Institute have developed spectrum observation techniques on the ground using field spectral-meters. By using these techniques, spectral signatures of each component such as vegetation, shadow, and soil, could be measured, which would be the basis of a spectral mixing model.

The second subject is development of monitoring technique of surface soil moisture. Since surface soil moisture affects the plants growing on the soil and would be a strong factor to determine the vegetation type of the land, it is very important from the viewpoint of desertification study.

In 1992, Japanese satellite J-ERS-1 was launched. It bears a synthetic aperture radar (SAR) (L - band, spatial resolution of 18m x 18m, and swath of 75km) and an optical sensor. The L - band corresponds to the relatively long wavelength of the frequency 1-2 GHZ (15-30 cm of wave length) and it is thought to be suitable for the observation of soil moisture.

Moreover, because it carries a data recorder (it is different from E-ERS-1 and MOS-1), the data of all over the world can be collected in a few ground receiving stations. However, there is one problem. Soil moisture changes rapidly and easily affected by local rain fall.

Vegetation has seasonal change, but it cannot be much changed for a period of a few days. But surface soil moisture changes even in a day. Therefore, if it is considered as a series of desertification study, multi-temporal images should be analyzed. But another problem may be brought up, that is, data acquisition.

Moreover, development of famine early warning system caused by severe drought, and development of land evaluation system and its application to environmental planning are thought to be important subjects of study in the future.

Due to Hutchinson (1991), in sub-Saharan Africa, a number of early warning systems have been implemented for this purpose that monitor physical and social variables that may indicate the likelihood and magnitude of famine. Several famine early warning systems use satellite remote sensing data to supplement ground-based observations. In the future, similar systems should be implemented in Asian region, too.

On the other hand, concerning desertification prevention, a technology-oriented program represented by a big irrigation facility project has been considered. Overall environmental planning joined by residents is starting to be promoted (Kadomura et. al., 1991). In the basis, there is a concept of "sustainable land use". Therefore it is important to evaluate land potential exactly and connect it to overall environmental planning.

References

Becker, F., and Choudhury, B. J. (1988): Relative Sensitivity of Normalized Difference Vegetation Index (NDVI) and Microwave Polarization Difference Index (MPDI) for Vegetation and Desertification Monitoring, Remote Sens. Environ., 24, 297-311.

Bruckler, L., Witono, H., and Stengel, P. (1988): Near Surface Soil Moisture Estimation from Microwave Measurements, Remote Sens. Environ., 26, 101-121.

Evans, D. L., and Smith, M. O (1991): Separation of Vegetation and Rock Signatures in Thematic Mapper and Polarimetric SAR Images, Remote Sens. Environ., 37, 63-75.

Foran, B. D. (1987): Detection of Yearly Cover Change with Landsat MSS on Pastral Landscapes in Central Australia, Remote Sens. Environ., 23, 333-350.

Frazier, B. E., and Cheng, Y. (1989): Remote Sensing of Soils in the Eastern Palouse Region with Landsat Thematic Mapper, Remote Sens. Environ., 28, 317-325.

Hutchinson, C. F. (1991): Uses of satellite data for famine early warning in sub-Saharan Africa, Int. J. Remote Sens., 12(6), 1405-1421.

Huete A. R., and Jackson, R. D. (1987): Suitability of Spectral Indices for Evaluating Vegetation Characteristics on Arid Rangelands, Remote Sens. Environ., 23, 213-232.

Kadomura, H., Takeuchi, K., Ohmori, H., and Tamura, T. (1991): Environmental Change and Global Desertification (in Japanese), Asakura Shoten, Tokyo, pp269.

Jackson, T. J., and O'Neill, P. O. (1987), Temporal Observations of Surface Soil Moisture Using A Passive Microwave Sensor, Remote Sens. Environ., 21, 281-296.

Japan Environment Agency (1990): State of desertification and its countermeasurements (in Japanese), pp132.

Paisley, E. C. I., Lancaster, N., Gaddis, L. R., and Greeley, R. (1991): Discrimination of Active and Inactive Sand from Remote Sensing: Kelso Dunes, Mojave Desert, California, Remote Sens. Environ., 37, 153-166.

Pickup, G., and Foran, B. D. (1987): The Use of Spectral and Spatial Variability To Monitor Cover Change on Inert Landscapes, Remote Sens. Environ., 23, 351-363.

Ringrose S., and, W. (1987): Spectral Assessment of Indicators of Range Degradation in the Botswana Hardveld Environment, Remote Sens. Environ., 23, 379-396.

Smith, M. O., Ustin, S. L., Adams, J. B., and Gillespi, A. R. (1990a): Vegetation in Deserts: II. Environmental Influences on Regional Abundance, Remote Sens. Environ., 29, 27-52.

Smith, M. O., Ustin, S. L., Adams, J. B., and Gillespi, A. R. (1990b): Vegetation in Deserts: I.

A Regional Measure of Abundance from Multispectral Images, Remote Sens. Environ., 31, 1-26.

Takashima, T., and Masuda, K. (1987): Emissivities of Quartz and Sahara Dust Powders in the Infrared Region, Remote Sens. Environ., 23, 51-63.

Toth, T., Csillag, F., Biehl, L. L., and Micheli, E. (1991): Characterization of Semivegetated Salt-Affected Soils by Means of Field Remote Sensing, Remote Sens. Environ., 37, 167-180.

Tueller, P. T. (1987): Remote Sensing Science Applications in Arid Environments, Remote Sens. Environ., 23, 143-154.

Wilson, R. O., and Tueller, P. T. (1987): Aerial and Ground Spectral Characteristics of Rangeland Plant Communities in Nevada, Remote Sens. Environ., 23, 177-191

Annex Outline of Study Activities

I. Processes to Initiate Desertification Research Project

1. Overview of the Desertification Research Project

1. 1. Research Framework

The Desertification Research Project started in the 1990 fiscal year entitled as "Feasibility Study on the Environmental Assessment of Desertification in Arid and Semi-arid Areas", for which the National Institute for Environmental Studies played the role of a leading research organization. The Feasibility Study continued for two years till the 1991 fiscal year.

From the 1992 fiscal year, "Research on the Evaluation of Interaction between Desertification and Human Activities" has started as a three year program up to the 1994 fiscal year.

In the 1993 fiscal year, "Memorandum of Understanding between Indian Council of Agricultural Research and National Institute for Environmental Studies for Collaborative Research on Desertification" was signed between India and Japan, and we could start field studies with the support of Central Arid Zone Research Institute (CAZRI), Jodhpur.

1.2. Background of the Desertification Research Project

Japan Environment Agency has established research programs in the 1990 fiscal year for global environment in response to increasing awareness of global environmental problems. The Desertification Research Project has been funded by the budget.

2. Research Activities in the 1990 - 1991 Fiscal Year

(1) Establishment of the Advisory Committee for the Desertification Research Project

The Advisory Committee for the Desertification Research Project was set up in April 1991. The Committee collected information on research activities in China, Mongolia, Thailand, Africa and Australia, and discussed the directions of Japanese research research teams, in particular the National Institute for Environmental Studies.

At the first Committee meeting, members reported desertification research activities carried out by other government ministries and agencies. Through their explanations, we learned that the Science and Technology Agency had been carrying out desertification research covering a number of fields, focusing the deserts in China. This research had been carried out under the title of International Joint Research for the Clarification of Desertification Mechanisms using research fund for the promotion of science and technology.

At the second Committee meeting, we discussed about target areas for research, counterpart research organizations and research subjects. Two research fields were recommended as candidates. Both areas were in danger of desertification; the Maowusu Desert in the Inner Mongolian Autonomous Region in China and the Thar Desert around Jodhpur in west India.

The third Committee meeting was held at the National Institute for Environmental Studies on March 9, 1992. A report was made on a research trip to India and concrete courses of action were presented, including the way in which review work is conducted and the invitation of researchers in order to promote future joint research.

(2) Holding of the Desertification Symposium

On February 22, 1991, the first desertification symposium was held at the National Institute for Environmental Studies. At the symposium, the results of research on desertification, disappearing rain forests and the deterioration of soils in China, Mongolia, Africa, India and Thailand were released by the presenters in order to gain an understanding on the progress of desertification research. Discussions centered on the future direction of research, how field survey should be conducted and how research should be funded, and the role Japan should play in desertification research. About 50 desertification researchers from around the country attended the symposium, and the significance of desertification research was confirmed.

Titles of presentations and presenters were as follows;

(A) Desertification Issues and Countermeasures in China
Satoshi Matsumoto (Tokyo University)

(B) Mongolian Nature and the Gobi Project

Ryoko Imaoka (Osaka University of Foreign Studies)

(C) The Situation Concerning Desertification and Research Trends in Africa: Hiroshi Kadomura (Tokyo Metropolitan University)

(D) Desertification Issues and Research Trends in India
Kenzo Fujiwara (Hiroshima University)

(E) Soil Deterioration Issues in Thailand
Tadakuni Miyazaki (National Institute for Environmental Studies)

(3) Questionnaire on desertification research

A questionnaire on desertification research was conducted to obtain information from a wide range of researchers around the world. Key research points, deserts targeted for research, organizations assisting the research, joint researchers and international joint research were surveyed.

(4) Collection of papers on desertification research

We collected papers on desertification research and developed a database covering 75 foreign papers and 70 Japanese papers.

(5) Field survey in India (November 17 - 25, 1991)

Japanese delegations visited Central Arid Zone Research Institute (CAZRI) in Jodhpur, Rajasthan, and Central soil and Water Conservation Research and Training Institute in Dehra Dun, Uttar Pradesh, India to establish a joint research between India and Japan on desertification research in India.

The experimental field for the research in Jodhpur was thought to be better than that of in Dehara Dun because Jodhpur district is located just inside arid zone and the researchers of CAZRI has a vast knowledge and experience in the desertification study.

(6) Field survey in China (March 22 - April 6, 1992)

The researchers of National Institute of Agro-Environmental Sciences visited China for the future collaboration of desertification research. The details are described in the chapter 2.

(7) Publication of research report:
Towards solving the global desertification problem(1)

A report was published in March 1992 entitled "Towards Solving the Global Desertification Problem (1) - Feasibility study on the environmental assessment of desertification in arid and semi-arid areas".

The contents of the report are as follows;

(A) Outline of Research Activities

(B) First Desertification Symposium

(C) Collection of Documents and Papers of Desertification Research.

3. Research Framework in the 1992-1994 Fiscal Year

A new research program has started in the 1992 fiscal year based on the results of the Feasibility Study described above.

The title of the research is "Evaluation of Interaction between Desertification and Human Activities". It has three sub-themes as follows;

(1) Evaluation of biotic activities on desertification in arid and semi-arid areas

This sub-theme is carried out by National Institute for Environmental Study and Japan Wildlife Research Center. The counterpart organization in India is Central Arid Zone Research Institute (CAZRI).

Research field is the Thar Desert around Jodhpur in west India, where experimental sites are established in unprotected areas (cultivated land and pastures) and protected areas (areas prohibited against livestock) to meet the following objectives;

(A) To develop a method to recover vegetation by analyzing the plant species comprising the vegetation in each area and measuring the amount of vegetation.

(B) To clarify the water circulation in target areas using the energy balance method and the water balance method in the catchment basin in order to estimate the amount of available water resources.

(C) To observe the progress of desertification using satellite images.

(D) To survey socio-economic conditions in target areas, including population, agricultural systems and grazing pressure in order to clarify human factors in desertification.

(2) Evaluation of biotic activities on desertification in semi-arid and sub-humid areas

This sub-theme is carried out in eastern China and the effects of human activities are evaluated by clarifying the processes leading to desertification that are triggered by differences in the impact of human activities resulting from natural and socio-economic conditions.

(A) Assessment of the human effect on desertification and land degradation

This sub-sub-theme is carried out by National Institute of Agro-Environmental Sciences, Ministry of Agriculture, Forestry and Fisheries.

Field surveys are conducted in cultivated areas, pasture areas and settled areas. Desertification, as shown by the destruction of vegetation, soil erosion, illuviation of sand and the deterioration of the soil, is marked based on the kinds and remaining amounts of vegetation and changes in soil characteristics. At the same time, land cover and the progress of desertification are grasped using remote sensing analysis. Based on these results, the effects of human activities on desertification are evaluated.

(B) Assessment of socio-economic factors affecting desertification and land degradation in China

This sub-sub-theme is carried out by National Research Institute of Agricultural Economics, Ministry of Agriculture, Forestry and Fisheries.

The target is to evaluate the effects of human activities on the progress of desertification, with particular attention given to changes in social structure, production and management system and policies. The socio-economic effects of policies in areas where desertification is occurring is also evaluated.

(3) Comparative study of human activities on desertification in arid and semi-arid areas of different countries

National Institute for Environmental Studies plays a role of leading research organization and Tokyo Metropolitan University, Tokyo University, Kyoto University and Pacific Consultants Co. Ltd. join the research.

The target of the study is to compare the different counties and areas including East Asia, Southeast Asia, South Asia and Africa, and clarify the interaction of human activities and desertification.

4. Research Activities in the 1992-1993 Fiscal Year

(1) Desertification Research Project in India

Two grazing land sites, one on semi-arid was selected in Pali and another in hyper-arid area at Chandan of Jaisalmer. At each experimental site, both herbaceous and woody species were studied as to their composition, cover, density and vigor, dry matter production, seed dynamics, and phenology.

For water circulation study, rainfall, runoff, ground water recharge, soil moisture, etc. were monitored at each experimental site.

Mapping of land use and land degradation were carried out using LANDSAT TM and NOAA AVHRR image data of Thar Desert area.

For socio-economic study, a survey of the awareness for desertification was undertaken at a sample village Khabra Kharan in Osian to understand the causal factors between desertification and human activities.

(2) Desertification Research Project in China

(A) National Institute of Agro-Environmental Sciences studied some characteristics of desertification and land degradation in three areas of Eastern China by Landsat image analysis and field work. The desertification and land degradation in Eastern China are characterized mainly by climatic and edaphic conditions.

First, the Naiman area, located in the Inner Mongolian Autonomy Region in a semi-arid zone, is sand dune reactivated by wind processes. Second, the Lanxi area, in Zhejiang Province and a humid subtropical zone, is badlands resulting from surface erosion due to running water. This badlands is named the "red desert". And third, the Yuanmou area, in Yunnnan Province and a sub-humid zone, is also badlands formed by severe gully erosion. On the basis of image analysis, the total area of desertification and land degradation of test sites in these three areas scarcely changed for the recent twenty years. But the area around main settlements, roads and railways tended to recover, while degradation progressed outside of this area.

(B) National Research Institute of Agricultural Economics selected three areas in China: Naiman banner in Inner Mongolian Province. In the 1992 fiscal year, a field observation study was carried out in Naiman Banner, and preliminary field visits to two other areas and collection of published materials on national anti-desertification policy in China were also conducted. It was found that soil erosion in China is taking place at an alarming scale in spite of intensified policy efforts, and that the national greening campaign of denudated land has been operated in an extensive scale in Inner Mongolian Autonomous Region and Yunnan Province, of which effect remains to be seen.

(3) International comparative study

Four countries, Kenya, India, China, and Thailand were chosen for comparative study on desertification and land degradation in relation to human activities. Selected research fields were North Kenya, Thar Desert in India, Naiman Banner in Inner Mongolian Region in China, and Kohn Kehn area in Thailand.

To compare the causal factors of desertification in these experimental areas, a minimum data base system for information about desertification and land degradation was constructed. In this fiscal year, the research was concentrated on the collection and evaluation of data set of Thar Desert of India. The collected information for the minimum data set was concerning climate, soil and water, vegetation, land-use, socio-economic variables, and human disease status.

The second international symposium on desertification was held at March 22, 1994.

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References

Environment Agency(1993): Global Environment Research of Japan in 1992, pp123.

(San'ei Ichikawa, Japan Wildlife Research Center)

II. Research Organizations on Desertification in China

In order to select the collaborators and the research areas on desertification based on the program of the Environment Agency from the 1992 fiscal year, we visited China from March 22 to April 6, 1992. The purposes of this report are to introduce the six research organizations we visited and record the minutes of the discussion on the frame of joint study.

1. Department of Geography, East China Normal University

This department is the largest geographical laboratory in China and has about three hundred staffs. About one hundred of them are teaching staffs. There are about four hundred undergraduates and about one hundred postgraduates (including master and doctor course) per school year in this department. There are seven institutes attached to this department. For example, Remote- sensing institute, Institute for planning and improvement of National land, Environment institute and others.

2. *Lanqi Experiment Station of Soil and Water Conservation, Zhejiang*

This station is located on about 15 km southward from Lanqi and established in 1983. There are seven researchers in this station. Two research stations (Forestry, Tea) are adjacent to this station.

This area is widely covered with the Red Soil of the Quaternary period. This soil has following characteristics; density (1.3 g/cm), pH = 4.3, ratio of clay = 54 %. Trees for firewood and charcoal have been cut from about 1958. As the result of cutting, waste land (about 130,000 ha) called red desert occurred in this area. The surrounding area was also a waste land before establishment of this station. Now, there are six study sites for crop (size = 200 m, inclination = 15 degree) and five study sites for forestry (size = 400 m, inclination = 15 degree). The outflow amount of water , earth and sand has been observed at these sites.

The following is the result of this observation; (a) Immediately after the beginning of this observation, the outflow amount of earth and sand at the slope was 5,650 t/km /yr. Due to cultivation and plantation, the amount decreased rapidly. (b) After seven or eight years, the amount is now 100 t/km /yr and less by Terrace Cultivation and Contour Cultivation, though the amount is 406.0 t/km /yr at slope cultivating rape blossoms. There is little outflow at the plantation of orange and Sugi (*Cryptomeria japonica*). It should be pointed out that there is not any outflow at bamboo forest.

This region is famous for a growing district of a large mandarin. The outflow amount of earth and sand at mandarin plantation is now about 5.95 t/km /yr. Meanwhile, the outflow amount at this station is 1.65 t/km /yr by digging a ditch along a contour line and planting mandarin trees at high density. It is expected that farmers introduce this new plantation method into their own way.

After the improvement of soil, the soil pH is between 5.9 and 6.3. The amount of organic materials at ground layer is between 1 and 2.5 %

3. Institute of Desert Research, Academia Sinica, Lanzhou

This institute plays a leading role on the desert study in China and has various staffs on the field of nature, civilization, community and culture.

We visited Prof. Zhu Zenda and mainly discussed the joint research project. Prof. Zhu Zenda, recently retired from the head of institute, plays a leading role yet on study. He is a Professor of the Institute of Desert Research, the Institute of Geography, and the Chengdu Institute of Mountain Hazards and Environment, Chinese Academy of Science and Ministry of Water Resources. Now, he is also a chief researcher of the national science and technology research project on "Environment in the Fragile Ecological Zones and its Rehabilitation". The following is a meaning of fragile ecological zones: (environment) is deteriorated by the mutual action of nature and human beings, (Zhu Zenda, 1991). Prof. Zhu Zenda's view coincides with our view on desertification. It is considered that the fragile ecological zones in China is the east area out of the line connecting with east edge of Tibet and Da Hinggan Ling which has a intensive population and excessive economic power.

This institute is active on the international research exchange, and has been carrying out in various field between Japanese side. For example, NIAES and this institute have a joint research on desertification sponsored by Science and Technology Agency from 1990. The International Center for Research and Training on Desertification Control in China, is a regional organization of UNEP, was established on August 31, 1987 in this institute. Prof. Zhu Zenda also plays a leading role in this International Center.

4. Shapotou Desert Research and Experiment Station, Chinese Academy of Sciences

This Shapotou Station is one of the desert research and experiment stations which belong to Institute of Desert Research, Academia Sinica, Lanzhou. It is located about 200 km north-northeast of Lanzhou and around the Hwang Ho at south-east border of Tengger Desert (the fourth size in China). This region is a typical sand desert and is widely covered with dune of Barchan type. The purpose of this Shapotou station is to defend the railroad connecting Baotou and Lanzhou from 1956 against the dune and to promote the irrigation cultivation.

The plantation has succeeded with little amount of irrigation in this region, the total size of plantation is now 16 km long and 700 m wide. It was said that it is difficult to make forests in the region where the annual precipitation is less than 200 mm. Although that of this region is about 180 mm, the people in this region conquered the wall and got the special invention prize from the Chinese government in 1986.

The 50 m wide-planted forest along the rail way is irrigated by the water pumped up from the Yellow River. At the outside, fences utilizing branch of trees and straw of crops are set like a grid to stop the sand movement. After formation of the shell on the surface, the green-belt was formed planting forests of *Compositae* and *Sălicaceae*. The work succeeded at the fourth time after trial and error. The 20 species among 200 species experimented were proved to be effective, practically, four or five species are adopted.

Moreover, irrigated agricultural experiment is executed changing the amount of irrigation in the experimental station, and many kinds of crops and trees are cultivated. Especially, talking about the joint research with Japan, the study group headed by Dr. Toyama, honorary professor of Tottori University, succeeded the cultivation of grape in this region, and they are highly evaluated.

5. Institute of Geography, Chinese Academy of Sciences

It is the largest institute on geography and has about 600 staffs and 18 research units. The ratio of the natural geographers and the human geographers is four to one. The natural geographers are responsible for the basic research focusing on the process study, historical research aimed to restore the past environment, and making materials for the policy-making, because it belongs to the State Commission.

The studies are executed in the very wide area in China to study in the environmentally different area and level. The active studies are executed utilizing the remote sensing techniques using the aerial photographs and Landsat data, and Geographic Information System. Moreover, outside of China, studies in Asian and African regions are being executed, especially, Prof. Zhang Qingsong plays an important role as a member for the anarchic observation.

National Key Open Laboratory of Resource & Environment Information Systems (RIES) belongs to the institute. The laboratory succeeded the studies of analysis of flood at Tai Hu , evaluation of erosion in Loessial Plateau, and ecological and environmental analysis at Shelterbelt in North China. Other than them, there are large-scaled experimental water channel, experimental device for rain fall, and so on, study on erosion in Loessial Plateau region is proceeded.

6. National Environmental Protection Agency

The authorities correspond to Japan Environment Agency and the both organization repeats visits each other to deepen the exchange. We met Dr. Liu Yukai, Chief of Division, Department of Nature Conservation. The Agency set up the International Centre for Research and Training on Desertification Control in Institute of Desert Research, with the assistance of UNEP and Chinese Academy of Sciences.

Also, the authorities aims to ecological agriculture in the domestic agricultural field and they give an award to the farmers who cultivate their field conserving their environment. Therefore, they have strong interesting in the desertification/land degradation induced by the human activities, and they promised us to support the study project firmly.

References

Zhu Zenda (1991) : Fragile ecological zones in China and land degradation, Chinese Desert, 11(4), 11-22.

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