Ecology of Degraded Vegetation and Its Recovery in the Indian Arid Zone

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Abstract

Natural vegetation in the Indian arid zone is sparse, spiny, bushy and stunted due to the adverse climate conditions and the presence of soils with a low nutrient level and low water-holding capacity. Excessive use associated with the increase of the human and livestock populations has further degraded this vegetation. Knowledge on the ecology of such degraded vegetation is essential to formulate to plans for its recovery. Degraded vegetation exhibits an altered composition, low vigour, low density and low cover. The above-ground biomass of degraded vegetation is four to six times lower than that of the undegraded one. The bulk of this low yield is contributed by annual grasses, annual forbs and perennial weeds which are unpalatable. Thus, the palatability and nutrient status of feeds from degraded vegetation decrease and become unbalanced. Dominance of species with a lower successional status in the degraded vegetation further decreases their ecological status as the majority of these species are therophytes and hemicryptophytes. The dominance-diversity relations become markedly different, with a geometric dominance-diversity curve characterising the degraded vegetation. Based on the ecological status of the degraded vegetation, its recovery requires protection varying from six to fifteen years in different habitats in the low, moderate and high rainfall zones within the Indian arid zone.

Introduction

Arid regions, where annual precipitation meets only one third of the annual water needs, cover nearly 4% of the global land surface. Although the primary productivity of these areas is low they support a population, quite often beyond the carrying capacity of land, which results in perturbations of the system. Persistent perturbations ultimately lead to such processes that degrade the pristine vegetation. Understanding the ecology of such degraded vegetation is essential so as to formulate plans for its recovery. An attempt has been made in this paper, to analyze the ecology of degraded vegetation based on the analysis of vegetation in the past fourteen years and its recovery in the Indian arid zone.

Environmental setting

The Indian arid zone is characterized by a low rainfall (100-400mm) which is highly erratic in both the spatial and temporal distribution. The wind velocity reaches 20-24km h^{-1} in summer. The temperatures are extremes : $-4°C$ in winter to 46°C in summer. Humidity is low (2-3%) and evapotranspiration very large.

Soils are either sandy, rocky or gravelly and shallow. Nearly 80-95% of the soil stratum consists of medium to fine sand with silt and clay components (Joshi, 1985). These soils are deficient in organic car-

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bon (0.1-0.2%) and nitrogen, medium in available phosphorus (11-23kg/ha), with a more than adequate content in potassium (60-111, 6kg/ha), adequate content in manganese (1-25 ppm), copper (0.3 to 2.4 ppm) and iron (1-10 ppm) (Joshi, 1985). The infiltration is high and the water-holding capacity is low.

The natural vegetation under such edaphic and climatic conditions is obviously sparse and stunted, spiny and bushy. Even this vegetation is highly degraded due to the increase in the human and livestock pressure. The human population in the arid Rajasthan increased by 279% from 1901 to 1981, when it originally numbered 13.48 million. Within the next twenty years, another rise of 46.9% is predicted (Venkateswarlu et al., 1992). On the other hand, livestock in terms of adult cattle head amounted to 6.83 million in 1956, 9.09m in 1977 and the number is projected to reach 10.02m in 1995 and 11.28m in 2000. Furthermore, there has been a 14.2% decline in grazing land. The decline in the grazing area on the one hand and increase in the livestock population on the other hand constitute a dual pressure, resulting in vegetation degradation.

Ecological changes in vegetation by degradation

1 Changes in species composition, cover and yield

The first impact of degradation is reflected in the changes in the species composition. The Indian arid region has a *Dichanthium-Cenchrus-Lasiurus* grass cover (Dabadghao and Shankarnarayan, 1973) and *Prosopis cineraria-Salvadora oleoides* tree cover (Champion and Seth, 1968) as the climax vegetation. Within this broad cover, there are numerous dominant communities depending on the habitat and biotic conditions. In the 300-400mm rainfall zone the *Dichanthium annulatum* type (Table 1) consists of three major subgroups: *D. annulatum-Desmostachya bipinnata* on sandy clay loam alluvial soils: *Eleusine compressa-D. annulatum-D. bipinnata* on sandy clay loam in the entire desert. There is also a specific cover of woody perennials (Table 1). Upon degradation, the dominant elements are reduced to a very low dominance or complete absence, whereas the associates are also quite often replaced by other species that belong to lower successional status (Table 1). Similar trends are observed in other major grass covers in different habitats (Table 1). Their cover and herbage yield decline by 2-8 times and 4-8 times, respectively (Table 2).

Thus, with the increase in the amount of rainfall from west to east within the Rajasthan desert, the *Lasiurus* type cover is replaced by the *Cenchrus* one and finally by the *Dichanthium* type. A similar spatial distribution is also reflected in the tree-shrub cover. Furthermore, the last two types, *Dactyloctenium* and *Aristida* types represent the ultimate degradation stages in the entire successional hierarchy. By and large, the associates in degraded lands are those belonging to the penultimate or still lower successional stages of these grazing lands. The majority of these species are annuals and therophytes or hemicryptophytes. The percentage of therophytes in the west Indian desert has been estimates at 49% by Mertia (1975) compared to 13% in the normal spectrum of the world (Raunkiaer, 1934). Therophyte percentage increases beyond 49% upon degradation.

2 Changes in status of climax species

In a stand, a certain quantum of climax vegetation (over 40%) is considered as a minimum to maintain grazing lands under good conditions. Values of less than 25-40%, 10-25% and 1-10% of the climax species in a grassland have been considered to indicate slight, moderate and severe degradation respectively (Stoddart *et at.*, 1975). Although there are a large number of examples of such studies in the Indian arid zone, these trends will be analysed with examples from two selected sites, one each from a low rainfall (125mm) site (LRS) and a high rainfall (388mm) site (HRS). The LRS showed a complete absence of climax grass *Lasiurus sindicus* in the degraded state whereas under non-degraded conditions it was the dominant grass (Table 3). Regarding woody perennials (Table 3) too, similar trends were observed.

Table 1 Vegetation types of Indian arid zone under degraded and non-degraded conditions

Rainfall (mm)	Habitats	Grass cover type	Associated herbage species Non degraded sites	Associated herbage species-Degraded	Associated woody perennials		Areas of occurrence
					Non-degraded sites	Degraded sites	
300-400 A	Sand clay loam to clay loam alluvium	*Dichanthium annulatum, Desmostachya bipinnata*	*Cynodon dactylon, Digitaria adscendens, Brachiaria ramosa, Tetrapogon tenellus*	*Aristida mutabilis, A. funiculata, Goniogyna hirta, Zornia diphylla, Indigofera cordifolia*	*Acacia nilotica, Prosopis cineraria, Balanites aegyptiaca, Capparis decidua, Salvadora oleoides*	*Mimosa hamata, Cassia auriculata, Crotalaria burhia, Calotropis procera*	N.Ganganagar, Nagaur, SE Sika pockets in Bali Jalore, Sirohi
B	Sandy loam soils-alluvium	*Eleusine compressa, Dichanthium annulatum, Desmostachaya bipinnata*	*Eragrostis poaoides, Cymbopogon jwaracusa, Eremopogon foleolatus, Indigofera cordifolia*	*Aristida sp., Cenchrus biflorus, Tragus biflorus, Dactyloctenium sindicum*	*Prosopis cineraria, Salvadora oleoides, Capparis decidua*	*Calotropis procera, Cassia auriculta, Indigofera oblongifolia, Crotalaria burhia*	Nagaur, Jodhpur Pali, Jalore, Sirohi
100-450	Saline clay loam	*Sporobolus marginatus, Dichanthium annulatum*	*Chloris virgata, Aleuropus lagopoaedes, Cressa cretica, Cynodon dactylon, Eleusine compressa, Cyperus sp.*	*Aeluropus lagopoades, Cressa cretica, Oropetium thomaeum*	*Salvadora oleoides, Acacia nilotica, Tamarix aphylla*	*Prosopis juliflora, Indigofera oblongifolia*	Saline low land in entire Indian arid zor
300-400	Sandy-sandy loam fossilized and stabilised dunes	*Sacharum spontaneum, Saccharum benghalense*	*Desmostachaya bipinnata, Cenchrus spp.*	*Aristida sp., Dactyloctenium sp., Indigofera cordifolia*	*Prosopis cineraria, Acacia jacquemontii*	*Sericostoma pauciflorum, Aerva pseudotomentosa, Crotalaria burhia*	Sikar, Nagaur, Churu, Jhunjhunu
250-350	Well-drained sandy alluvial soils	*Cenchrus ciliaris, C.setigerus*	*Eleusine compressa, Eragrostis sp.*	*C.biflorus, Aristida sp.*	*Prosopis cineraria, Acacia nilotica*	*Calotropis procera, Crotalaria burhia, Aerya pseudotomensa*	Churu, Jhunjhunu Sikar, part of Nagaur, Jodhpur Pali
Upto 200	Loose sandy soils	*Lasiurus sindicus*	*Eleusine compressa, Indigofera cordifolia, Tribulus alatus*	*Aristida funiculate, Cenchrus biflorus, Mollugo cerviana*	*P.cineraria, Tecomella undulata, Calligonum polygonoides, Z. nummufaria*	*Crotalaria burhia, Dipterygium glaucum, Lycium barbarum*	Bikaner, Jodhpur, Jaisalmer, Barme west Jodhpur and west Nagaur
125-350	Satabilised sand dunes with reactivated surface	*L. sindicus, Panicum turgidum*	*Cymbopogon jwarancusa, Cyperus arenarius*	*Aristida funiculata, Dactyloctenium sindicum*	*P. cineraria, Calligonum polygonoides*	*Dipterygium glaucum, Lycium barbarum*	Barmer, Jaisalme Bikaner, Jodhpur part of Jalore and Nagaur
150-300	Sandy gravelly plains	*Eleusine compressa, Dactyloctenium sindicum*	*Aristida sp., Tribulus terrestris*	*Oropetium thomaeum, Aristida mutabilis, Tephrosia sp.*	*Prosopis cineraria, Salvadora oleoides, Acacia leucophloea, Capparis decidua*	*Barleria prionitis, Rhus mysorensis, Lycium barbarum*	Jaisalmer, Bikaner, Jodhpur
125-350	All types of soils except saline	*Aristida sp., Eragrostis sp., Cenchrus biflorus*	*Oropetium thomaeum*	*Oropetium thomaeum*	*Capparis decidua, Ziziphus sp.*	*Prosopis juliflora*	Jalore, Jaisalmer, Jodhpur, Barmę Sirohi

Table 2 Vegetation cover and yield under degraded and non-degraded condition

Grass cover type	Herbage cover (%)		Herbage yield (kg/ha)	
	Non-degraded	degraded	Non-degraded	degraded
Dichanthium annulatum *Desmostachya bipinnata*	4−8	0.5−2	4,000	130−1,100
Eleusine-Dichanthium *Desmostachya bipinnata*	3−9	0.5−2	1,200−1,500	100−600
Sporobolus marginatus *Dichanthium annulatum*	4−7	1−3	1,400−2,600	300−500
Sachharum spontaneum *S.bengnalense*	4−7	1−3	1,400−2,600	300−500
Cenchrus ciliaris *C. setigerus*	4−6	1−2	2,000−2,500	300−400
Eleusine compressa *Dactyloctenium sindicum*	3−4	0.5−2	800−1,000	175−450
Lasiurus sindicus	5−14	2−4	4,000	400−500
L. sindicus-P. turgidum	5−8	2−3	1,500−2,000	300−450
Aristida-Eragrostis *C. biflorus*	2−3	0.1−1	500−800	100−200

3 Impact on plant density

Along with the degradation, the plant density declines. There could be two situations: The first few spurts of degradation in fact increase the density, mostly that of non-palatable and thorny species which Dyksterhuis (1949) called invaders. Due to severe degradation, thereafter even this number further declines and finally the land may become barren. For example, the total decline in density was 50% and 71.93% in the HRS and LRS, respectively (Table 3).

4 Impact on plant vigour

Vigour and cover of the plants are adversely affected by degradation. Hedging and browse lines are the obvious consequences. In both LRS and HRS the decline in the height of the species ranged from 17.24% to 76.47%. However a larger cover area per plant was recorded in degraded sites than in the non-degraded ones (Table 3). Similar trends have been reported by Shankar (1983) in a different habitat. The basal cover of herbage in the LRS was 3.32% under non-degraded conditions compared to 0.55% under degraded conditions. The decline of the woody perennials too, ranged from 8 to 25%, in relation to different species (Table 2). Similar trends have been reported in other locations, too (Shankar and Kumar, 1987a).

5 Impact on bare area

The decline in density and cover results in the increase in the bare area e.g., up to 164% in the HRS and 10.31% in the LRS. Finally the relative importance value (RIV) of the dominant climax species, e.g., in the LRS, is reduced to zero (Table 3). In a regional analysis of the vegetation covering a 41,000 km^2 area in the Jaisalmer district, the total cover of browse vegetation decreased by 1.5 to 9.54%, and the RIV of the climax species was much lower than normal (Shankar and Kumar, 1987a).

6 Impact on biomass and carrying capacity

Biomass decline is the ultimate result of degradation (Tables 2 and 3). Dry forage yield in the non-degraded sites in the 400mm rainfall zone was nearly three, six and seven times higher on hill, alluvium and piedmont sites in the Pali district, respectively (Kumar and Shankar, 1986). Even in the case of degradation, livestock graze and degradation becomes more severe and widespread. In fact, more than 70% of the grazing lands in Jaisalmer, Jalore and the Luni basin in western Rajasthan show a poor condition,

Table 3 Trend of density, height, cover per plant, relative importance value and total vegetation cover under degraded and non-graded conditions at two sites (Site 1: Golasani, Jalore district; Site 2: Sanu, Jaisalmer district)

Parameter	Site	Situation	Species 1	2	3	4	5	6	7	8
Density (plant/ha)	Site 1	ND*	120	40	60	10	320	20	–	–
		D	90	–	30	–	–	–	–	–
	Site 2	ND	–	–	40	10	–	70	450	–
		D	–	–	–	–	50	50	100	10
Height (m)	Site 1	ND	2.9	3.5	1.4	1.8	4.2	1.8	–	–
		D	2.4	–	1.4	–	–	–	–	–
	Site 2	ND	–	–	2.61	1.50	–	2.36	0.85	–
		D	–	–	–	–	–	2.90	0.20	0.15
Cover/plant (m^2)	Site 1	ND	13.3	2.9	1.7	0.9	15.3	0.9	–	–
		D	14.1	–	3.1	–	–	–	–	–
	Site 2	ND	–	–	10.8	2.8	–	5.9	0.8	–
		D	–	–	–	–	–	6.2	0.18	0.12
Relative Importance Value (RIV)	Site 1	ND	19.72	10.54	17.84	4.24	40.70	6.96	–	–
		D	67.22	–	32.78	–	–	–	–	–
	Site 2	ND	–	–	13.08	5.95	–	19.8	61.2	–
		D	–	–	–	–	–	32.58	53.25	–
Total vegetatiom cover/ha (m^2)	Site 1	ND	1596	116	102	9	4896	18	–	–
		D	1269	–	93	–	–	–	–	–
	Site 2	ND	–	–	432	28	–	413	360	–
		D	–	–	–	–	–	310	–	–

ND = Non-degraded; D = Degreaded.
1 = *Salvadora oleoides*; 2 = *Prosopis juliflora*
3 = *Capparis decidua*; 4 = *Lycium barbarum*
5 = *Acacia tortilis*; 6 = *Ziziphus nummularia*
7 = *Lasiurus sindicus*; 8 = *Panicum turgidum*

13% a good one, 14% a fair condition while 2-3% are in excellent condition (Shankar et al., 1988). A demand-supply analysis of forage for the entire Indian arid zone (Shankarnarayan and Kalla, 1985) revealed that the forage demand has been increasing from 1961 to 1981 (Table 4). In 1981, a total deficit of 61.06 and 35.75 lakh tons was experienced in Rajasthan and Gujarat, respectively. It was also concluded that if the crop residue components were excluded from these estimates, then, all the districts in all the years experienced a continuous deficit.

7 Impact on palatability

Since palatable species, like *Cenchrus setigerus, C. ciliaris, D. annulatum* and *L. sindicus* are preferred and removed first, the remaining vegetation is dominated by only less or non-palatable species like *Aristida* and *C. biflorus*. Since after shedding awns or before flowering, even these species are palatable, animals graze upon them and the land becomes bare.

8 Impact on mineral and nutrient composition of animal feeds

Since grasses and browse show a complementarity (Shankar et al., 1988) in availability (grasses available in the monsoon to post-monsoon periods while browse in winter, summer) as well as in the nutrient composition (Bhatia, 1983) (browse containing more than 10% of protein and 15% of crude fiber while

Table 4 Demand-supply imbalance for forage with crop residues in north-western Indian arid zone (in lakin tons)
Source: 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
Mehesana	−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
Mahendram	−1.76	−4.01	−4.25
Ambala	−5.32	−7.08	−7.89
Rohtak	−8.71	−11.72	−7.32
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
Jhunjhnu	+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

* 1 lakh = 100 thousand; + = surplus; − = deficit

grasses containing a lower amount) and mineral contents (four times more calcium in the browse with a deficiency of zinc and copper whose content is higher in grasses), removal of any one or both of these components results in the decrease of balanced and quality feed for animals.

9 Dominance-diversity relations

Dominance-diversity relations change upon degradation. It is well known that slight degradation increases alpha diversity before it actually declines due to severe degradation. In a study in the Bandi catchment of the upper Luni basin in the Rajasthan desert (Kumar and Shankar, 1987), diversity and equitability of woody perennials in different sites was studied (Fig. 1). Sites having degraded grass covers such as *Oropetium-Eragrostis* or *Dactyloctenium-Eleusine* type exhibited a low diversity and low equitability of woody perennials (Kumar and Shankar, 1987). Sites with an optimum cover of *Dichanthium-Desmostachya* showed an intermediate diversity and equitability. This finding was further confirmed by the fact that the dominance-diversity curves of the woody vegetation in a degraded site were geometrical while those of the non-degraded site, lognormal in distribution (Fig. 2). Similar trends were found in Jais-

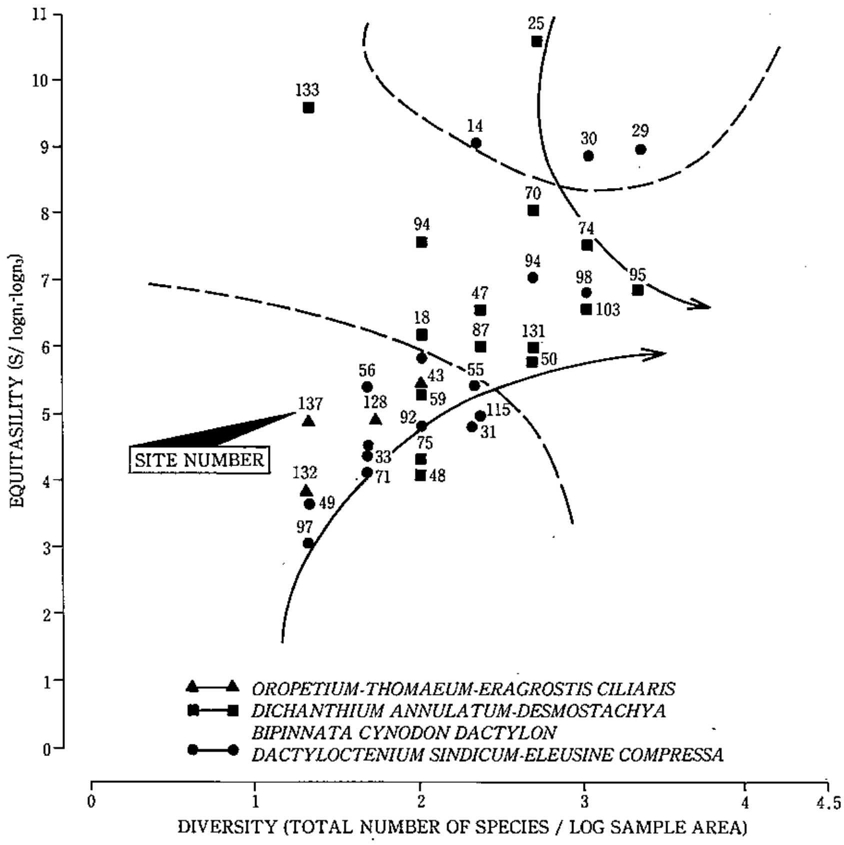

Fig. 1 Equitability-Diversity plot of eoody perennials on older alluvial plains

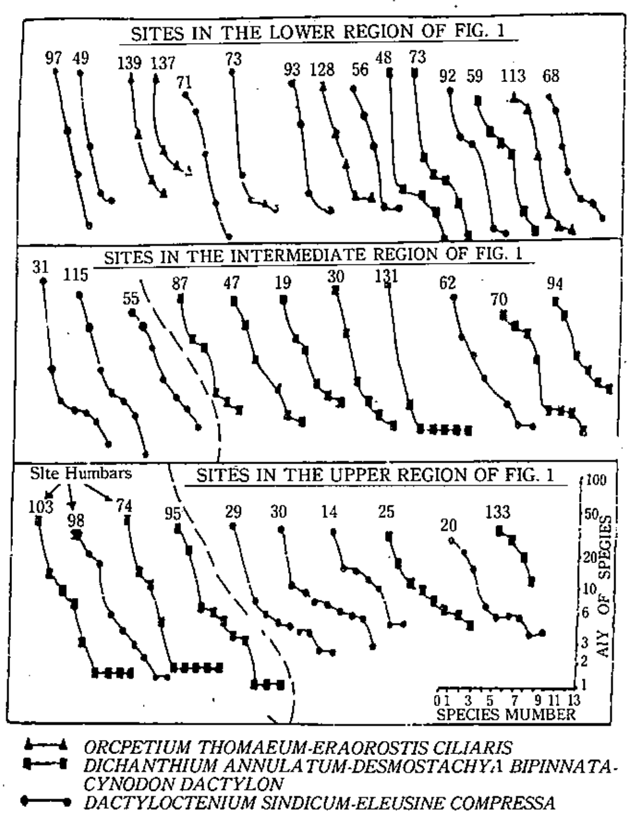

Fig. 2 Dominance-diversity curves of woody perennials on the older alluvial plains

almer, too (Kumar, 1990).

10 Impact on stability and equilibrium

Arid ecosystems are more resilient and less stable, hence fragile. Vegetational changes upon degradation that are within the bounds of resilience i.e., dynamic equilibrium, should be distinguished from those representing permanent changes due to degradation. To what extent permanent or resilient changes reflect degradation can not be determined because we do not know to what extent vegetation changes indicate a disruption of equilibrium. It is therefore, desirable to set up a benchmark as reference with which to compare existing vegetation. This benchmark could only be the potential vegetation that a piece of land can afford to support. Gaussen (1959) called it plesioclimax. The successional status of vegetation with respect to climax obviously reflects its ecological status.

11 Assessment of vegetation degradation

The proportion of decline in the climax vegetation as well as total vegetation compared to the plesioclimax can be measured through a variety of parameters (Kumar, 1992a). The exact mathematical relation between the dynamics of each parameter with respect to the increase of degradation has not yet been fully understood.

Remote sensing for monitoring vegetation degradation

A basic ground radiometric study in this direction has revealed that the spectral response of vegetation (Fig. 3) in a non-degraded site in Mohangarh (11.17% total cover, 1,162kg/ha dry matter yield) was different from that of the degraded site near Satyaya (3% total cover, 680kg/ha of dry matter yield). In fact, the reflectance at 450nm showed a negative but significant correlation with the total percentage of cover (Kumar, 1991) and total dry forage yield. Thus, it is possible to monitor vegetation degradation, using these inputs in digital image analysis, for the whole region.

Modelling the degradation

Attempts in this direction have, however been made by using multivariate techniques of classification and ordination of vegetation of Indian arid lands (Kumar, 1990). Multivariate analysis yielded such site and species groups that are indicators of the degradation status. This was also confirmed by the dominance diversity trends. The species groupings corresponded to the successional status which enabled to predict the degradation stage. Further evidence was supplied from the relative density of spiny species and browse species in these sites (Kumar, 1992b).

Vegetation recovery through protection

For studying the impact of protection on the regeneration of depleted vegetation, a large number of areas representative of all desert types of habitat were selected and their vegetation was monitored for as long as twenty years. Analysis of these data revealed (Shankar, 1983) that protection improved the grass cover and promoted the regeneration of shrubs and trees in the exclosures. These habitats acquired the potential vegetation of desired composition and biomass yield rather slowly and the duration required for this development varied from over 5 to 15 years (Table 5). Increase in herbage yield through protection ranged from 3 to 13 times in different habitats (Table 5).

Conclusion

Successional status of depleted vegetation indicates its overall ecological status. Prior to the adoption of multivariate approaches, the successional status of vegetation in a given site used to be considered as an indicator of the ecological status in isolation of other sites. With the use of ordination models it has become possible to identify groups of sites, having a similar ecological status. The development of these

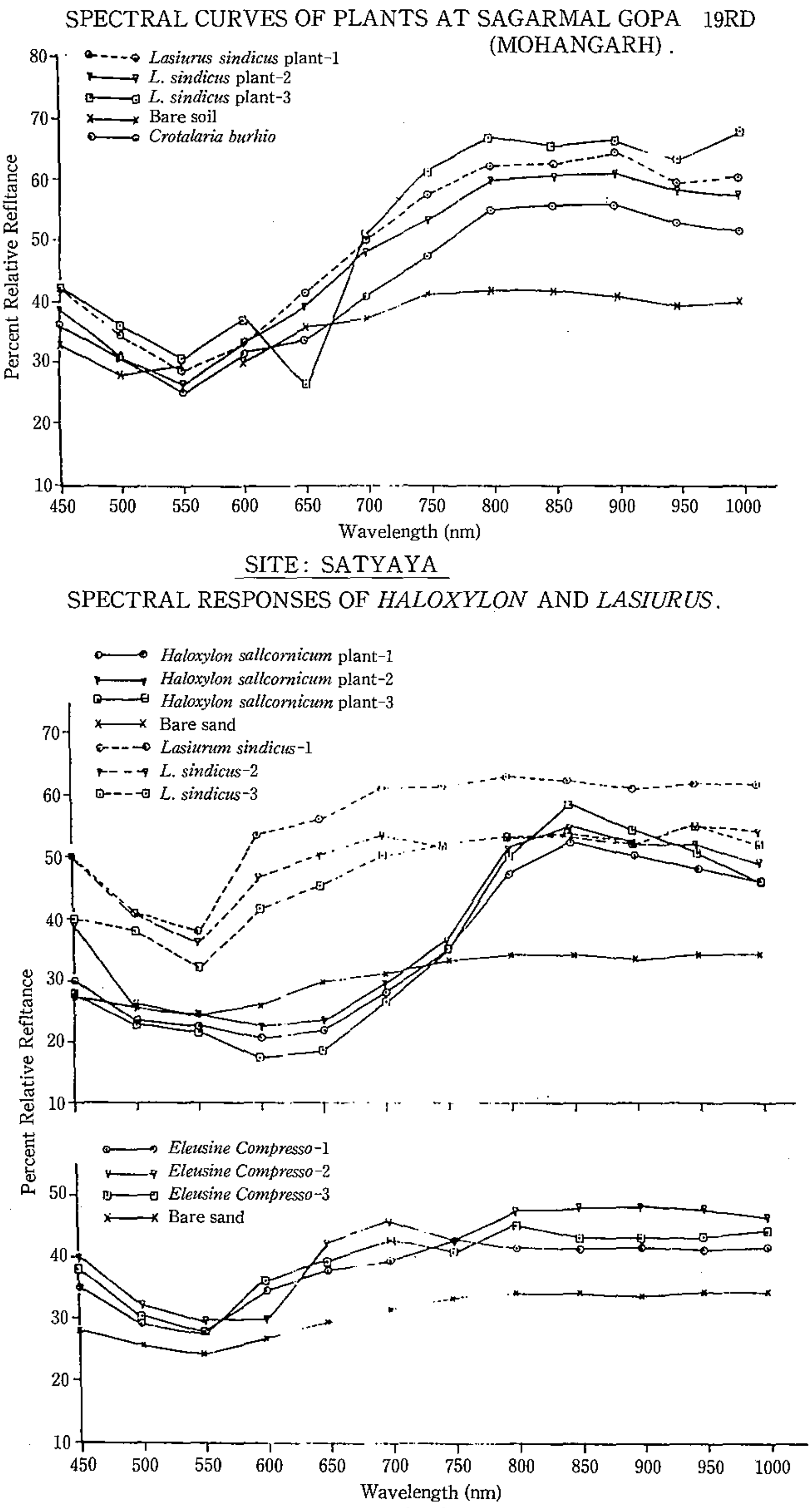
SPECTRAL CURVES OF PLANTS AT SAGARMAL GOPA 19RD (MOHANGARH).
Lasiurus sindicus plant-1
L. sindicus plant-2
L. sindicus plant-3
Bare soil
Crotalaria burhio
Percent Relative Refltance
Wavelength (nm)
SITE: SATYAYA
SPECTRAL RESPONSES OF HALOXYLON AND LASIURUS.
Haloxylon sallcornicum plant-1
Haloxylon sallcornicum plant-2
Haloxylon sallcornicum plant-3
Bare sand
Lasiurum sindicus-1
L. sindicus-2
L. sindicus-3
Eleusine Compresso-1
Eleusine Compresso-2
Eleusine Compresso-3
Bare sand
Percent Relative Refltance
Wavelength (nm)

Fig. 3

Table 5 Temporal limits to natural regeneration of vegetation in various desertic habitats in western Rajasthan (Shankar and Kumar, 1988)

Location	District	Rainl-fall (mm)	Landform	Soil texture	Duration of protection	Herbage yield (kg/ha)		Grasscover	Tree/shrub cover	Recom-mended protection (years)
						P	Unp			
Kalab Kalan	Pali	450	Hill	Gravelly	10	2159	644	*Chrysopogon fulvus*	*Acacia senegal*	5
Kaylana	Jodhpur	250	Hill (top)	Gravelly	20	94	15	*Aristida oropetium*	*Acacia senegal*	15
Kaylana	Jodhpur	250	Hill (slope)	Gravelly	20	170	18	〃	〃	12
Kaylana	Jodhpur	250	Hill (base)	Gravelly	18	197	15	*Eleusine compresaa*	*Maytenus sp. Z.nummularia*	6
Bhopalgarn	Jodhpur	250	Flat-buried pediment	Loamy	18	4100	1035	*Dichanthium-Cenchrus*	*Prosopis-Zizyphus*	
Jadan	Oali	450	-do-	-do-	18	1414	229	*Eremonogon-Aristida*	*Prosopis-Capparis*	6
Gajner	Bikaner	250	-do-	-do-	20	—	—	*Cenchrus-Aristida*	-do-	6
Chandan	Jaisalmer	150	Sandy undu-lating buried pediments	Sandy	20	4518	782	*Lasiurus sindicus*	*Haloxylon salicornicum*	7
Pali	Pali	450	Flat aggraded older alluvial plain	Clay-loam	18	1870	520	*Cenchrus* sp.	*Prosopis juliflora-Zizyphus*	5
Bisalpur	Sirohi	450	Flat aggraded older alluvial	Clay-loam	18	5400	1000	*Dichanthium annulatum*	*Acacia leucophloea-A.nilotica*	5

sites can then be planned with objectivity and precision.

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