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Assessment of Vegetation Degradation : Status of Methodological Research

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Abstract Vegetation degradation manifests itself at plant, community and regional levels. Basic parameters at the plant level viz. habit, vigour, yield, litter, and seed bank; at the community level, viz. botanical composition, plant density, dominance, cover and extent, biomass and carrying capacity, quality and palatability, ecological status, age distribution and finally at the regional level viz. biological spectrum, dominance-diversity relations and stability, resilience, equilibrium status are discussed. Using these parameters a score card has been devised and presented in the paper for assessing degradation of vegetation.

Key words Vegetation, Degradation, Score card

Vegetation growing in an area has a definite structure and composition developed as a result of long term interaction with various abiotic and biotic factors. Any change in the status of these factors, especially biotic, perturbs the vegetation system. Persistent perturbations caused by biotic exploitation triggers such changes in vegetation that finally result in its degradation. Vegetation degration is manifested in a variety of parameters at individual plant, community and regional levels. Based on the available information, a scheme of assessing vegetation degradation is presented here.

Degradation assessment at the individual plant level

Degradation at individual plant level can be assessed through five plant parameters viz. habit, vigour, yield, standing crop of dead plant parts as well as litter and seed production and its storage in soil as seed bank.

Plant habit : Removal of plant parts results in deformed, stunted habit instead of normal habit. Foliage of herbaceous vegetation shows the signs of grazing and trampling. Fifty percent removal of available twigs, leaves and fruits of current years growth during the growing season and 65% removal during the dormant season indicate proper utilization (Anonymous 1976). Removal beyond this threshold, indicates beginning of degradation. Intensity of removal can be cate gorized as severe, moderate and none. *Salvadora oleoides, Capparis decidua* and *P. cineraria*, upon severe exploitation become a pin cushion head structure of up to 1 m height.

Plant vigour: Plant vigour is an expression of health and thriftiness of plants. Heavy grazing and browsing, too early use or too frequent cutting adversely affect the vigour. In the optimum situation, an individual plant should be able to attain the maximum size i.e. height and cover for the species.

The length, width, succulence and hairiness should be characteristic of the species. Fruits /seeds should be optimum in quantity and seeds should be filled if conditions were favourable. Departure from optimum vigour can be graded into severe, moderate and none depending upon the biotic intervention.

Plant yield : Repeated removal of herbage leaves very little for regrowth and regeneration. On the other hand, no removal may also inhibit growth of certain plants. Thus, certain degree of removal of plant biomass is essential for the further growth, specially of grasses. Considering 50-65% removal as allowable, the plant yield is expected to maintain a consistency over the years if climatic factors were similar. In such a situation, any decline in yield in a particular year is construed to result from past heavy removals. In the protected well managed rangeland, the apportionment of above and below ground biomass have been found to be in the ratio of 60-70 :30-40 (Mann & Shankar 1979). In degraded situations, 60-70% of biomass is accumulated belowground. Thus, if more than 50% biomass is canalized to roots, it can be concluded as degraded especially in arid range vegetation. Since plants having tuberous and bulbous roots store more biomass belowground in normal situations, these may be considered exception to this standard. In remainder plants, higher the biomass belowground, severe is the degradation with less aboveground yield.

Plant litter or residue : The excessive removal of herbage results in the absence of plant residue and it represents a severely degraded state. The scattered inadequate litter indicates moderate degradation and sufficient litter, no degradation.

Seed bank in soil : Repeated removal of herbage does not allow a particular plant to attain maturity and to set seeds, the seed contribution from this species to soil seed bank is obviously minimal. In due course of time, the proportion of seeds of this species in seed bank thus undergoes a change. Such a phenomena are common in arid rangelands where desirable and quite often climax species is first removed resulting in no seed contribution and subsequently poor regeneration of this species. Such deviations can be easily found out by taking soil cores, allowing all their seeds to germinate and finally counting seedlings of different species. Complete absence of seedlings of a climax species (of vegetation on surface) in soil cores studies indicates severe degradation. Absence of seedlings of desirable species indicate moderately severe degradation. Accordingly moderate and none categories can be framed by conducting local test studies.

Degradation assessment at the plant community levels

Cumulative changes in the population of individual plant species are finally manifested in communities. On the basis of response to stresses of grazing, browsing, lopping and cutting, Dyksterhius (1949) identified three major types of plants : (i) Decreasers-those plants which decrease due to continued grazing, (ii) Increasers -those which increase initially due to grazing and (iii) Invadors -those plants that are not part of the original plant community but invade and become prominent under the influence of disturbance. Corresponding terms for browse plants are preferred, desirable and undesirable (Anonymous 1976). These changes can be detected by comparing the existing community with the climax or plesioclimax (Gaussen 1959) that can occur on a particular piece of land.

Degradation of vegetation thus, has to be assessed in terms of degradation of both herbaceous and perennials compared to potential vegetation, together as well as separately. Further, degradation can be assessed at both, local and regional level. Different parameters that can be used for asessing degradation are described below.

Botanical composition : The percent of potential or climax species below certain level in the entire composition of herbaceous layer indicates the status of degradation. Severe, moderate and slight degradation are indicated by 1 < 10%, 10 < 25% and 25-40% proportion of potential or climax species (Stoddart et al. 1975).

Density : The absolute density of climax species declines as the degradation becomes gradually severe. Compared to natural, undegraded situations, a decline of 25, 50, 75% in the density of climax species indicates slight, moderate and severe degradation. The relative density (RD) of a species is a ratio of total number of individual of one species to that of total number of individuals of all the species in all the quadrats. Relative density gives better indication of the degradation status of a community. Here again, the RD of individual species in the climax vegetation is the standard with which the site is compared and the degree of departure can be graded into severe, moderate and no degradation (Table 7).

Hedging and browse lines : Removal of plant parts results in 'hedging' and 'browse lines' in case of woody perennials. Moderate hedging promotes growth. Severe hedging causes death of branches and sometimes even the whole plant may die. When single year's growth extends beyond old hedged contours, recent use has been heavy. It can be graded as given in Table 1.

Table 1 *Degradation Classes due to hedging*

Hedging	Degradation
Little or no evidence of hedging	None
Upto 50% plants show hedging	Moderate
More than 50% plants show hedging	Severe

This grading should be applied to individuals of climax species for more accuracy.

Browse lines are the marks upto which previous years grazing took place. The fresh growth normally starts and if ungrazed, reaches new height. But if it is grazed severely, current fresh growth shall be fully consumed and browse lines will not be visible. Here too, grading can be done. (Table 2)

Table 2 *Degradation classes in respect of browse lines*

Browse lines	Degradation
No browse lines distinguishable from distance. produ-ction on lower twigs similar to that of twigs beyond reach of animals	None
Browse lines apparent from distance, but lower twigs reasonably productive	Moderate
Browse lines strikingly evident, little or no production on twigs within reach of animals	Severe

The six ratings to ocularly evaluate browsing damage of woody perennials (Table 3) was proposed by Reid *et al.* (1990).

Cover and extent : Cover, vertical projection of plant canopy on to the ground, declines because of overexploitation. Studies in the Indian arid zone revealed that a decline of 30%, 31-55%, 56- 80% and over 80% in the total ground cover of plants indicate slight, moderate, severe and very severe degradation. These values correspond to total basai cover of 4-8%, 3-6%, 2%,1% and less than 1% respectively (Saxena 1988).

Cover of climax or potential herbaceous species is adversely affected due to its degradation. Its cover over 50, 40- < 50%, 20- < 40%, 5- < 20% and less than 5% have been categorized as showing none, slight, moderate, severe and very severe degradation, respectively (Bhimaya and Ahuja 1969; Babaev 1985).

Bare area : The cumulative effect of decline in density and cover is reflected in decline in the spatial extent of the community and increase in the bare areas. Bhimaya and Ahuja (1969) reported increase of 20% and 21-35% bare area in good and fair condition class rangelands. Considering fair condition as representing slight degradation, a further increase of bare area upto 21-40%, 41-70% and over 70% would indicate moderate, severe, and very severe degradation, respectively.

Dominance : In normal, undegraded situations the climax species have high dominance, expresed as relative importance value (RIV) followed by those of successional elements. Based on the pattern of dominance, five degradational classes (Table 4) can be framed

Instead of climax species, RIV of grazable species or other economically important species (Shankar 1977) can also be employed.

Biomass and carrying capacity : Status of aboveground biomass of a community is a foolproof indicator of status of its degradation. Since variability in biomass production is a funtion of quantity and distribution of rainfall in arid regions

Table 3 *Browsing damage of woody perennials in different degradation classes.*

Appearance of plants	Browsing damage	Rating
Plants normal in height and form, no evidence of utilization of current or previous years growth	Not browsed	0
Browsed stem over a small part of the canopy, otherwise plant normal in height and form	Scarcely browsed	1
Normal in height and form but stems or shoots browsed over most of the canopy, without disfigurement of the woody portions	Light	2
Complete canopy but some stems gnarled and disfigured owing to repeated browsing	Light to moderate	3
Normal in height but with irregular, incomplete canopy; the wood portions of stem disfigured and twisted	Moderate	4
Stunted, but with aerial stems much disfigured and twisted by repeated biting, above a low browsed crown	Moderately heavy	5
Pruned to a low crown near ground level (unless part of canopy protected by other plants)	Heavy	6

(Le Houerou *et al.* 1988), it is important to separate moisture-stress-induced decline in biomass from those induced by the biotic factors. Once this is acheived, one would know the amount of biomass under optimum soil moisture conditions and in undisturbed situations. Less biomass than this would indicate degradation. However, in real life situations, it is difficult to arrive at this aboveground biomass value because it requires long term protection, for example, 5-15 years on different habitats in Indian arid zone (Shankar 1983) to obtain pristine cover whose biomass, under optimum soil moisture, can then be treated as standard. This problem has been solved (Anonymous 1976) by comparing the biomass con tribution of climax species with that of other associates. Per cent contribution of biomass by climax species to the total biomass exceeding 50, 25-<50 10-<24, 5 to 10 and less than 5 indicate increasing degradation and can be given rating of 1, 2, 3, 4 and 5 respectively.

Table 4. *Relative Importance Value (RIV) of flimax species in different degradation classes*

RIV of climax species			Degradation
Herbaceous Layer	Ligneous Layer		
Over 25	Over 20	..	None
10-25	10-20	..	Slight
6-<10	6- < 10	..	Moderate
1-<5	1-<5	..	Severe
0	< 1	..	Very severe

Higher ratings indicate increasing degradation. Considering biomass yields on different habitats as given by Saxena (1988) as standard, biomass production upto 60%, 30%, 25% and 10% of standard can be classified as representing slight, moderate, severe and very severe degradation. Similar trends in biomass decline have also been reported by Babaev (1985) in respect of USSR desert, too.

In order to maintain a plant community in good health and at sustained biomass production, concept of carrying capacity, is employed. Carry-

Table 5 *Air dried forage production and carrying capacity of vegetation in different degradation clasess.*

Air dried forage Production ($t\ ha^{-1}$)	Permissible adult cattle units $100\ ha^{-1}$ (carrying capacity)	Condition class	Proposed degradation class
Over 1.5	25-30	Excellent	None
1.0-1.5	20	Good	None
0.75	17	Fair	Slight
0.50	13	Poor	Moderate
0.20	5	Very poor	Severe
0	0	–	Very severe (desertized)

ing capacity is the number of animals that can graze a piece of land on year round basis. Bhimaya and Ahuja (1969) reported carrying capacity of Indian arid rangelands while devising condition classification (Table 5).

This rating is based on the fact that when forage production declines by 50%, the degradation is only slight, because such a vegetation seems to have potential to quickly recover and regain optimum biomass production potential upon protection or optimum use.

It is pertinent to consider here the situation prevailing in woodlands and shrublands where besides grazing, browsing and cutting also take place. There can be two situations : (i) The current years production is not fully utilized, thereby resulting in biomass builds up even if 50-65% of current years biomass is removed. Removal beyond this thereshould may cause degradation. (ii) The current year's production or more is fully utilized (i.e. browed or cut) resulting in poor regeneration and decline in biomass over the years. In the extremes of situations, the ligneous elements will decline in number. In the absence of information on the dynamics of decline in the woody perennials biomass, it is proposed to use decline in total number of ligneous plants per ha. Following parallel from work in USSR (Babaev 1985), a decline of 25, 26-40, 41-60, 61-80 and over 80% in total number of ligneous plants indicate zero, slight, moderate, severe and very severe degradation, respectively.

Quality and palatability : Quality connotes a mix of characters employed to determine its suitability for a particular use. In respect of grazingland, quality would mean the palatability, the nutrient status and the mineral composition of the grazable material. An undisturbed stand of climax vegetation consists of appropriate number of palatable species having, quite often, optimum nutrient and mineral composition (Shankar *et al.* 1988). Upon grazing, the most palatable are consumed first. Repeated occurrences of these grazing bursts would ultimately remove majority or all of palatable species. Consequently, the mineral and nutrient composition of the animal diet becomes imbalanced. Though at present it is difficult to assess degradation status from quality attributes, it is felt that an indirect assessment of degradation is available for comparison. As an alternative, increase in unpalatable species can also be taken as indicator of degradation. Slight, moderate, severe, and very severe degradation can be inferred from increase in relative density of unpalatable species up to 40%, 41-61%,61-80% and over 80%.

Successional status : Upon degradation, the climax species decline and may ultimately disappear, giving way to species of lower successional levels. Severe degradation results in ultimate removal of even lower level successional species making land barren and desertified. Thus a suitable grading can be devised indicating status of climax species.

Table 6 *Reproduction status for key and low quality species in vegetation.*

Reproduction status	Description
Adequate	**For key species**
	Sufficient seedlings and young plants to maintain or increase status of species in a community.
Moderately adequate	Some seedlings and young plants present but not enough to maintain status of species in a community.
Little or none	The species is not reproducing. Plants mostly mature. Few or no seedlings or young plants.
	For low quality species
Excessive	More seedlings and young plants than required to maintain species in the community. Species obviously increasing.
Adequate	Sufficient seedlings and young plants to approximately maintain status of species in the community. Population static.
Little or none	Very few seedlings or young plants becoming established. Species is declining in the community.

Friedel (1988) however, considered that it is not the comparison of status of existing vegetation with that of its climax but the comparison of all sampled sites with one another using multivariate approaches (e.g. Gauch 1982) that produce classes as indicators of range condition or indicators of degradation (Kumar et al. 1987, Kumar & Shankar 1988, Shankar & Kumar 1988, Kumar 1990). Further, the climax species may not have the best or maximum production or desired quality compared to the sub climax species (Brown 1954).

Age distribution : Normally, individuals of all ages of a species should be present (i.e. mature, young and seedlings plants). It indicates that species is holding its own. If all plants are mature, the stand is not maintaining itself and will thin out as older plants die. Occurrence of plants in different age classes is a function of reproduction. USDA (Anonymous 1976) has devised a grading of reproduction in respect of key species and low quality species as given in Table 6.

Obviously, decreasing trend of key species and increasing trend of low quality species indicate degradation. Determining key and low quality species could be on the basis of field knowledge.

Regional level assessment of vegetation degradation

Assessment of degradation at community level on large number of sites gives a fair idea of status of degradation of a particular region. The whole regional dynamics, progressive or retrogressive can also be inferred. There can be three following parameters for regional level assessment.

Biological or life form spectrum : Raunkiaer (1934) believed that life form spectrum of the area is a reflex of its climate. Warm climates have higher percentage of phanerophytes, cold climates have more of chamaephytes and hemicryptophytes; deserts have predominance of therophytes (Smith 1980). Biotic disturbance and relative dryness tend to increase the percentage of therophytes (Cain 1950, Daubenmire 1968). Thus increase in

Table 7. *Score card for estimating vegetation degratation in arid and semi-arid lands.*

S.No.	Parameter	Ratings 1	2	3	4	Score 5
		(Values or range of parameters				
	For entire vegetation					
1.	Removal of plant parts (%)	Upto 65	66 – 75	76 – 85	86 – 95	over 95
2.	Bare surface area (%)	0 – 10	11 – 20	21 – 40	41 – 70	over 70
3.	Litter quantity	Heavy	Moderate	Sporadic	None	–
4.	Litter condition	Accumulating	Replacing	None	–	–
5.	Therophyte increase (%) over standard reported	25	26 – 50	51 – 75	76-90	over 90
6.	Decline in species richness (%)	25	26 – 50	51 – 75	76 – 90	over 90
7.	Age distribution (for key species)	Sufficient	Insufficient	Few	–	–
	For herbaceous component of vegetation					
8.	Vigour	Optimum	Slightly pedastalled	Pedastalled	Pale, highly pedastalled	–
9.	Seeds of climax sp. in soil	Abundant	Moderate	Slight	Sporadic	None
10.	Bot. sp. composition of climax	25 – 40	10 – < 25	1 – < 10	< 1	–
11.	Total basal cover (%)	4 – 8	3 – 6	2	1	< 1
12.	Basal cover of climax species (%)	Over 50	25 – < 25	20 – < 25	5 – < 20	< 5
13.	Relative importance value (RIV) of climax species	Over 25	10 – < 25	6 – < 10	1 – < 6	< 1
14.	Biomass contribution of climax species (%)	Over 50	25 – < 50	10 – < 25	5 – < 10	< 1
15..	Existing biomass as per cent of potential biomass	Over 60	40 – < 60	25 – < 40	10 – < 25	< 10
16.	Carrying capacity (ACU/100 ha)	20	17	13	5	None
17.	Grazing intensity	Light	Moderate	Heavy	Very heavy	–
	For woody perennial component of vegetation					
18.	Percent plants showing hedging	Absent	50	75	100	–
19.	Browse lines	Absent	Apparent	Evident	–	–
20.	Browsing damage	Light	Light to moderate	Moderate	Moderate to heavy	Heavy
21.	Increase in relative density of unpalatable species	10 – 20	21 – 40	41 – 60	61 – 80	> 80
22.	Relative density of key/climax sp.	40	30 – < 40	10 – < 30	1 – < 10	< 1
23.	RIV of key/climax species	Over 20	10 – < 20	5 – < 10	1 – < 5	< 1
24.	% decline in total no. of plants/ha	50	26 – 40	41 – 60	61 – 80	> 80
25.	Dominance diversity Curves	Lognormal	Partly lognormal	Lognormal to geometric	Geometric	–
					Total ratings scored	

Interpretation

Rating Scored	up to 25	26 – 50	51 – 70	71 – 90	Over 90
Degradation level	None	Slight	Modeate	Severe	Very Severe

therophytes compared to normal proportion in any region indicates degradation. Therophytes are annuals which complete their life cycle from seed to Interpretation. seed within one growing season of one year. The proportion of therophytes in many deserts of the world is now known. Percentage of therophytes in the west Indian desert has been reported upto 40 (Das & Sarup 1951) (1951) and 49 by Mertia (1975) in the extreme arid tract. Das and Aarup (1951) also reported thero phytic percent for Libyan desert as 42 and Cyrenaiea desert as 50. Thero- phytes in Death valley, California were 42% (Cain 1950), Ghardaya desert, Algeria, 58% (Cain 1950), Ooldea desert, south Australia, 35% (Cain 1950) and in the normal spectrum of the world, it was 13% (Raunkiaer 1934). Thus, once the percent therophytes of a region are known, an increase in their percentage subsequently is likely to be due to degradation.

Dominance diversity relations : Through continuous monitoring, collection and analysis of data, the changes in dominance types and diversity of an area can be detected. The basic measure of diversity (Whittaker 1975) is alpha diversity (i.e. total species richness in a unit area) and beta diversity (i.e. rate of change of species). Any decline in alpha diversity over time and increase in beta diversity during same period indicates degradation. Further, dominance diversity curves of the species (Whittaker 1965) could be either of the three types : (i) Geometric, (2) Lognormal and (3) Random niche. Sites showing lognormal curves are normally not degraded. Those showing geometric ones are highly degraded and random niche types indicate post maturity status. Dominance concentration (i.e. sum of square of decimal importance value) and equitability are other criteria for judging the status of community. These parameters alone or in combination can be employed for assessing vegetation degradation (Kumar 1987).

Stability, resilience and equilibrium

Degraded communities are fragile and succumb even to small scale perturbations. It is therefore important to understand these concepts.

The resilience is an ability to respond markedly to outside pressure but with a strong tendency to return to the original state once the pressure is lifted. Thus, there are no fundamental changes in the way, the system functions. The stability is a character denoting slow response of the system to outside pressures, particularly in response to reliable environmental stimuli such as assured rainfall. In both resilience and stability, basic phenomenon is changeability. The rate of change-forward or return is fast in resilient system compared to stable systems. It is important to understand that a change does not indicate disturbance of equilibrium. In fact reverse is considered true (Harrington et al. 1984). If a system changes, it achieves new equilibrium. It is now believed that what man perceives as change can merely be a shift in the point of balance. Thus any intervention in the arid ecosysthem should consider the fact that these have more resilience and less stability (hence fragile). It is important to distinguish changes that are within the bounds of resilience (i.e. dynamic equilibrium) and those which constitute a permanent change or degradation. According to Australian school (Harrington *et al.* 1984) since resilience implies ability to adjust to extrinsic pressures, the vegetation change per se is not an evidence of disruption of equilibrium of the system. On the other hand, they do not spell out at what level the vegetation change can be considered as an evidence of disruption of equilibrium or degradation. Noy Meir (1975) tried to solve this enigma through a herbivore-grass model and these concepts are yet to come to field level application. Evidences indicate that south African communal grazinglands having more resilience in extreme climatic and grazing pressure are less productive. The well managed grazing lands though with more productivity, will degrade rapidly if grazing pressure associated with drought pushes them to a different equilibrium point (Walker et al. 1981). Thus understanding resilience and its dynamics is an important area of work.

The score card for estimating vegetation degradation

The aforesaid parameters have been used in preparing a score card for assessing vegetation degradation as given in Table 7. This score card is improved and enlarged over the desertification monitoring score card of Shankar (1977) wherein only 7 parameters were proposed and range condition anaylsis score card wherein 14 parameters were used by Shankar and Kumar (1983) for site quality assessment in the Guhiya catchment.

The aforesaid parameters, are therefore, only illustrative and many more can be added to this list or deleted from it to construct the suitable score card depending upon the local ecological situations.

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