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RAPID RANKING METHOD FOR PRIORITIZING RESTORATION BY EVALUATING HUMAN INFLUENCES ON THE STATUS OF SCRUB FOREST: A CASE STUDY

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Abstract

The main objective of this paper was to develop a quick ranking system for diagnosing degree of changes resulting from human influences on a rapidly declining natural scrub forest of the sub-Himalayan region. The naturalness in this paper is described on the basis of structural criteria of the dominant life form, represented by the bi-species climatic climax vegetation of *Olea ferruginea* and *Acacia modesta.* Plant communities delineated on the basis of vegetation classification were regrouped on the presence and absence of the two species into natural and sub-natural communities. Natural community was further delineated on the basis of departure from the benchmark to gauge the status of naturalness within this community. The final three staged index proposed was used to evaluate the status and extent of degradation in the forest and in identifying the factors that lead to its altered status to initiate an appropriate management plan for restoration.

Introduction

Natural communities are assemblage of perennial plants that have evolved to cope with climatic and edaphic extremes and in return enhance protective and productive capacity of the area. Unfortunately, over-consumption of these resources at an accelerated pace has not only eroded the country's economic base but also debilitated its life support ecosystems (Khan, 2003). The human population pressures, recent land price hike, current food crisis coupled with weak institution and poor policies are generally attributed to the decline of forest area in Pakistan (Anon., 1992). Ecosystem services are increasingly used for documenting values for biological resources (Costanza *et al*., 1997; Anon., 2005) and restoring these services, especially in fragile ecosystems, could help the society to embark on a course of ecologically sustainable development. Since social and ecological benefits of natural vegetation are intangible (Mc Neely, 1988) in these areas, therefore these otherwise public goods are available to the consumers at almost zero prices, resulting in large scale deforestation. A recent study (Khan, 2010a) in the fragile land suggested that forest carbon stores under remnants of natural vegetation are threatened by human induced stresses in the form of both reduced forest acreage and reduced carbon density.

The widespread Sub-Tropical Dry Forest of Pakistan is dominated by bi-species association of *Acacia modesta* Wall., and *Olea ferruginea* Wall. Cat. These forest covers vast tract of land in the Salt Range, Suleman range and the foot hills of the Himalaya west of the Jehlum. It merges southward with the Indus plain tropical thorn forest and upward with the Himalayan subtropical pine and temperate forest (Champion *et al*., 1965; Parker, 1918). Champion *et al*., (1965) highlighted the plight of Sub-Tropical Dry Evergreen Forest in Pakistan and its extensive degradation. Scrub forest unlike the adjacent thorn forest in the Indus plains (Khan, 1994 & 1996) has been traditionally given a high value, in both productive and protective terms, by naturalists (Ahmad *et al*., 2008; Champion *et al*., 1965; Parker, 1918). But unfortunately most of these views on the status of the forest type are essentially empirical and had never been quantified. A recent, more focused survey (Ahmad, 2010), provides detailed information and insight on the fast declining status and degradation of scrub forest in the Soan valley. It appears that the bulk of intact forests are now restricted to Government controlled reserved forests, and even there they are in various stages of degradation. The study also identified different man induced pressures and threats in the area due to absence of clearly defined rights of property which directly impinge on sustainable forest management. Furthermore permission to mine coal, salt, silica and limestone is affecting the forest directly and also indirectly by the associated labour and their livestock which are dependent on these forests for fuel wood and grazing. This research (Ahmad, 2010) also indicated that degradation of the forest is impacting the ecosystem services, as there is significant depletion in the amount of silt content, moisture, organic matter, nitrogen and phosphorus in the degraded stands as compared to forested area. It also shed some light on the economics of exploitation of the forest resources as about 5.0 million kilograms of wood was annually purchased by traders (2.5$ per 40 kilogram) from the local market, with a bulk made up of *Acacia modesta* and *Olea ferruginea.* In addition, the local people have rights to cut the colonizer, *Dodonaea viscosae*, and its continuous removal has set up a retrogressive cycle leading to desertification and invasion by exotics. Additionally, the entire valley seems to be under the sway of Parthenium and mesquite (both species, *Prosopis juliflora* and *Prosopis grandiflora)*, which has overwhelmed the native species of great cultural and ethnobotanical significance (Vehra & Khan, 2011; Shinwari *et al.*, 2011) and has changed the ecological nature of many natural communities in Pakistan (Khan 2010b; Irshad *et al*., 2008) resulting in loss of biodiversity.

Several studies in the last decade have proposed methods to assess and quantify naturalness and conservation significance of a variety of ecosystems for which criteria and indicators are widely used in evaluation, particularly when sustainable management is targeted (Grumbine 1994; Haq *et al*., 2011; Barry and Oelschaeger 1996; Angermeier 2000; Uotila *et al*., 2002; Colak *et al*., 2003; Sippi 2004; Machado 2004; Beasley *et al*., 2005, Bridge *et al*., 2005; Bartha, *et al*., 2006). The concepts of ecological integrity in land use and development planning often uses vegetation as a synthesis indicator of environmental circumstances (Loidi, 1994; Sumina 1994; Pimentael *et al*., 2000; Paillet *et al*., 2008). Naturalness as a descriptor of vegetation was also used to express distance from the climax or potential natural vegetation in order to measure disturbance and unnaturalness of vegetation, and also as an integrative measure for the impact of all human interventions on ecosystems (Sukopp *et al*., 1990; Attiwill, 1994; Kim *et al*., 2002; Khan, 1994; Khan, 2010b). Keeping in view the rapidly deteriorating status of the scrub forest the objective of this work, data for which is partially derived from Ahmad (2010), is to devise a rapid assessment method to gauge the present status in order to conserve and restore the natural vegetation as biological regulator on this fragile landscape with sloping gradient. Evaluation of the environmental health of the natural scrub forest requires maintenance of botanical integrity of the ecosystem, in the form of structural density of an intact bi-species climax association, in order to ensure that all its components and processes are intact. Therefore, attributes of structural criteria of bi-species groves of *O. ferruginea* and *A. modesta,* were used as a tool to recognize disturbances in the forest ecosystem.

In this study authors hope to achieve two main goals, firstly, to select the benchmark as indicators of natural attributes and then to quantify the deviation from the supposed natural state in terms of composition, structure and function, and secondly, to rank the forest according to their status and prioritize initiatives for effective mitigation measures according to the level of disturbance. It is hoped that this approach will popularize the native species and their remarkable biological values among the local people and planners.

Material and Methods

The study area: Salt Range, extends from the Jhelum River on the east to the Indus River in the west covering a length of about 150 miles. The Soan valley is considered as the heart of the Salt Range and it falls within the subtropical region with variable topography. Average height of the hills in this valley varies from 400 to 1000 m above sea level and the highest point in the range is Sakesar 1527m. The valley supports a complex of wetlands of which the lake "Khabeki" was declared as "Ramsar Wetland Habitat" for migratory birds by the Government of Pakistan in 1976 (Anon., 1994). The climate of valley is characterized by annual precipitation of 800 mm and most of it falls during the monsoon. The mean annual temperature is about 23. 6^{o}C, prolonged periods of drought are frequent during summer, and winters are accompanied by mild frost (Ahmad, 2002; Khan, 1960). The following three adjacent reserve forests in the Soan valley were selected (Fig. 1) to develop a rapid ranking method for evaluation.

Hayatul Mir (HM): the area of the forest is 1646.55 hectares. It is the only forest which has few compartments which are free of rights of any type of mining and quarring in the area. It is surrounded by the following settlements: Kalial and Bayyakh towns in the north, Ararra in the east, Nalli in south and Khura in the west.

Khura West (KW): the area of the forest is 351.93 hectares. Grazing and fuel wood collection rights are being practiced in the entire forest. It is surrounded by the following settlements: Chamnakki in west, Potha, Khura in the east, Kund in the south and Uchhala and Bhukki in the north.

Khura North (KN): the area of the forest is 186.71 hectares. It has common boundary with HM in the east. Grazing and fuel wood collection rights are being practiced in the entire forest. It is surrounded by the following settlements: Khura in west and Uchhala and Bhukki in the north with Bayyakh in the east.

Sampling methods: The sampling methods used in the three forests were planned in such a way as to get maximum representation of the entire forest. Each forest was divided into three zones i.e. boundary, mid and core areas. The zones were arbitrarily determined from interviews with the locals on the frequency of daily penetration of the graziers and their herds in the forest. The boundary area comprises of outer most one hundred meter belt along the boundary lines. The mid area zone, comprises of 100 meters belt from the end of boundary zone towards the start of the core area. The core area starts from the end of mid area. The interval between the sampling sites varied with the dimension of the forest. In KN and KW samples were taken across the entire core area whereas in HM the sample extends to the middle of the core. The intervals between the samples were 125m in KN and KW and 300m in HM. In fact, efforts were made to take a complete systematic design (Barbour *et al*., 1987) with reference to a grid in order to reflect homogeneity and maximum representation. But subjectivity crept in the design as it deliberately avoided vicinity of settlements, mining areas, drains, ravines and large boulders. Sampling units were based on Quadrat of 10m × 10m size, the number of quadrats also varied with the dimension of the forest: 51 quadrats were taken from HM, 36 from KW and 33 from KN. The following observations were made at each sampling unit: number of all tree species, diameter of all single bole and coppiced trees at breast height and percentage cover of trees and shrubs estimated on visual basis. Herb and grasses were not included in the analysis. Nomenclature of Stewart (1972) was applied for this work.

Vegetation analysis: Vegetation classification units based on modified version of Braun-Blanquet approach (Muller-Dombois & Ellengberg 1974) were taken from Ahmad (2010). The communities were further regrouped on the basis of presence or absence of either or both of the 2 climax species into natural and subnatural communities respectively. The status of natural community was further analyzed by using three indicators: number, diameter and cover of the tree species, to show the grades of naturalness within the forest. Finally an index, ranging from maximum to minimum naturalness was designed to refine and categorize forests in the larger context of disturbance. It was hoped that the presence of spatial extent of disturbance in these forests will also reflect the mitigation measures required to restore naturalness.

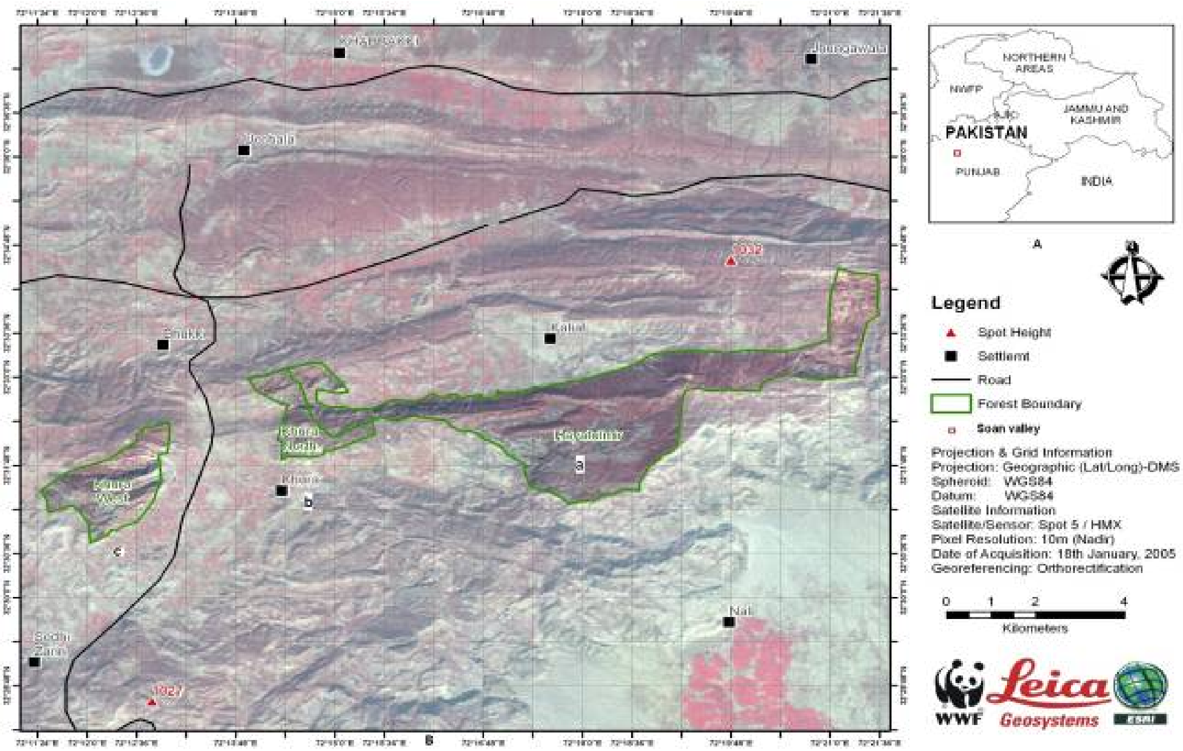

Fig. 1. Location of the Soan valley in the larger context (A) and the zoomed image (B) showing the location of the three forest under study (a: Hayatul mir, b: Khura west, c: Khura north).

Statistical analysis: Data recorded were analyzed by using SPSS 16 for windows. Mean number of trees, diameter and cover of all the quadrats falling in the four ranks of the three forests were compared by using one-way ANOVA and t-test. Multiple comparisons were made by using Tukey Honestly Significant Difference. Correlation between number of trees and other variables were made by Pearson's test.

Results and Discussion

Since the main objective was to develop the index of naturalness as a tool to assist in recognizing disturbances in this forest system, therefore, the results are discussed in sequence from delineating natural and sub-natural communities to finally developing a ranking system to analyze the extent of anthropogenic influence in the forest.

Delineating natural from sub-natural: On the basis of vegetation analysis on 120 samples the following five communities were initially delineated (Ahmad 2010), their percentage occurrences are referred to in the parenthesis: 1. *Olea ferruginea-Acacia modesta* (43%), *Olea ferruginea* (23%), *Acacia modesta* (20%), *Dodonaea viscosae- Justicia adhatoda* (9%). and a Residual community (6%). These five communities were then regrouped on the basis of natural and sub-naturalness status into the following 2 preliminary units:

1. Natural forest community**:** having both or either one of the climax species (*Olea ferruginea* and *Acacia modesta*), were considered having basic elements of naturalness and were grouped together irrespective of their dominance on particular aspect, to form the natural community.

2. Sub-natural: it comprises of the following two sub-units,

a) Successional community: dominated by colonizer species of *D. viscosae* and *J. adhatoda*.

b) Degraded community: dominated by mesquite on disturbed sites.

Zooming within the naturalness: two units were delineated on the basis of physiognomic characteristic, the natural and the sub-natural community. the large natural community (85%) by using three indicators further categorized the quality of naturalness. Correlation coefficients (Table 1) showed strong relationships between number and diameter (r = 0.926, 0.760 and 0.773 for HM, KW and KN, respectively, at $p<0.01$) as compared to number and cover (r = 0.727, 0.611 $p<0.01$ and 0.439 $p<0.05$ for HM, KW and KN, respectively). There was also a strong correlation between number, diameters and cover when all forests were considered together. Even here correlation between number of trees and diameter was more significant as compared to cover (with r = 0.898 and 0.692 at $p<0.01$ for diameter and cover respectively). This could be because in some places the trees are heavily lopped or coppiced, which has reduced the cover without affecting the number and the diameter of the trees.

Since the number of trees seems to be the ideal criterion for quick assessment therefore four ranks having ranges of trees were artificially created. First three ranks were statistically tested for correlation within the ranks for the three indicators to justify their segregation. Results of one-way ANOVA (Table 2) showed a non-significant difference in the mean values of number (*P*=0.707, 0.319 and 0.598 for Ranks I, II and III respectively), diameter and cover of the three forests within Rank I, II and III (*P*=0.465, 0.077 and 0.468 for diameters and *P*=0.236, 0.318 and 0.051 for cover percentages of Ranks I, II and III respectively), justifying their segregation into the ranks. Since Rank IV was absent in KN so data was analyzed by applying *t*-test and it showed that diameter and cover differed significantly ($p<0.05$) between HM and KW, which affirms that though the number is a good indicator for segregation but still cover and diameter can help in appreciating the attributes of an undisturbed benchmark, as represented in HM from the inferior heavily lopped sites in KW.

The comparison in the mean values of number, diameter and cover of the 3 forests between the ranks showed significant differences (*F* = 203.10, 93.48, 30.45 and P=0.000 for number, diameter and cover, respectively). But the multiple comparisons revealed non-significant differences in diameter and cover between rank II and III (Fig. 2). This shows that in spite of decrease in number of trees the less disturbed sites can retain diameter and cover similar to the disturbed sites having more trees. Since the presence of cover in spite of decrease in number could still confer resistance to mesquite invasion, therefore keeping in view the management measures required to restore such sites the ranking categories were simplified by merging the ranks II and III as degraded forest. Attributes of rank IV (especially of HM) are recognized as the benchmark of naturalness and since attributes of rank I represent the other extreme of degradation (with relics of climax species) and similarities with sub-natural community (domination by successional stages), was removed from the natural community and was placed in the early categorized sub-natural community.

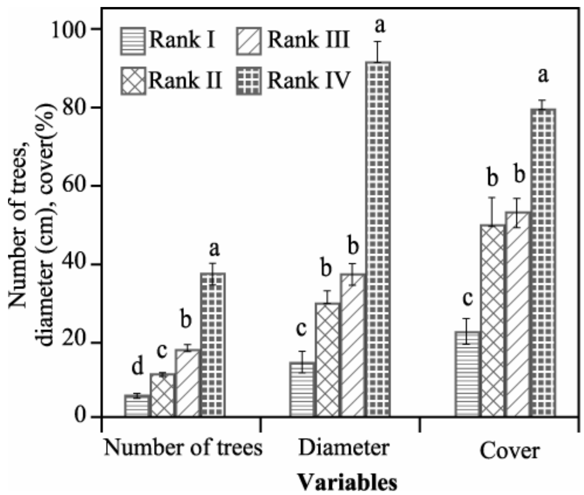

Fig. 2. Comparison of average number, diameter and cover of the trees in the quadrats falling in Rank I, II, III and IV of the three forests. Means followed by the same letter in a cluster are not significantly different at p>0.05 (Tukey H.S.D). Upper bars give ± 1 *S.E.*

Table 1. Correlation between number of trees and other measured variables of the three forests.

Site	Source of variance	Number of trees/quadrat	Diameter (cm)	Cover (%)
HM	Pearson Correlation	1	0.926**	0.727**
	Sig. (2-tailed)		0.000	0.000
	N	42	42	42
KW	Pearson Correlation	1	0.760**	0.611**
	Sig. (2-tailed)		0.000	0.000
	N	31	31	31
KN	Pearson Correlation	1	0.773**	0.439*
	Sig. (2-tailed)		0.000	0.028
	N	25	25	25
Combined Forest	Pearson Correlation	1	0.898**	0.692**
	Sig. (2-tailed)		0.000	0.000
	N	98	98	98

**=Correlation is significant at the 0.01 level (2-tailed)
*=Correlation is significant at the 0.05 level (2-tailed)

Table 2. Mean number, diameter (cm) and cover (%) of the trees in the quadrats falling in Rank I, II, III and IV of the three forests (± 1 *S.E.*).

Forest	Rank I			Rank II			Rank III			Rank IV		
	No. of trees	Diameter (cm)	Cover (%)	No. of trees	Diameter (cm)	Cover (%)	No. of trees	Diameter (cm)	Cover (%)	No. of trees	Diameter (cm)	Cover (%)
HM	5.20 ± 0.65	14.80 ± 3.00	22.20 ± 3.84	10.56 ± 0.51	27.25 ± 2.58	43.56 ± 5.34	18.20 ± 1.16	40.60 ± 5.41	53.40 ± 4.64	36.64 ± 2.75	91.45* ± 5.63	79.18* ± 2.92
KW	4.57 ± 0.69	18.14 ± 3.36	30.36 ± 4.71	10.50 ± 0.72	28.20 ± 4.47	44.60 ± 6.00	16.67 ± 0.67	34.33 ± 3.67	63.33 ± 3.33	28.75 ± 3.75	55.25 ± 4.03	56.50 ± 5.61
KN	5.17 ±	13.25 ± 2.10	20.75 ± 4.12	9.40 ±	18.30 ± 2.03	32.40 ± 6.21	17.67 ±	32.33 ± 2.96	40.67 ± 5.81	-	-	-

0.46	0.50	0.67

Means of measured variables in a column do not differ significantly ($p<0.05$) by one-way ANOVA
*Mean values of the two forests differ significantly $p<0.05$ as compared by *t*–test
HM - Hayat-ul-Mir, KW – Khura West, KN – Khura North

Interpreting the scale of naturalness in the forest: The following three interconvertible stages were finally derived from detailed analysis along with management options for each class.

1. Natural stage (Rank IV), the bench mark.
2. Degraded stage (Rank II & III), requiring simple management measures
3. Sub-natural stage, it was further categorized into the following sub-units to lay emphasis on the status and management efforts required for reforestation and eradication of the mesquite:

a. Successional stage with relic trees (Rank I)
b. Successional stage with no relics
c. both a and b invaded by mesquite

This categorization clearly shows that the naturalness as possession of attributes of the benchmark can be achieved if the damage done to the degraded stage by pervasive human activities can be managed and reversed, or otherwise it can degenerate into sub-natural stage, which would eventually be invaded by mesquite, eliminating the natural succession and shifting natural climax to monoculture of mesquite. The sub-natural stage, unlike the degraded forest, cannot be restored by simple management as it would essentially require a program based on eradication of mesquite followed by restoration by native species.

The three staged ranking scheme proposed here would also help in diagnosing biophysical status of the forest and its full natural and anthropogenic gradient as each stage can be weighed in terms of percentage of occurrence in the forest and in zones within it (Table 3). The boundary zones of the three forests show highest percentage of sub-natural stages as compared to mid and core zones, which seems to be directly related to the accessibility of the former zones to the local inhabitants as compared to the latter. It includes the entire boundary of KN (100%) and a high percentage of KW (75%) and HM (47%). The mid zones have generally higher representation of degraded stage as compared to sub-natural stage with the exception of KW where high percentage of sub-natural stage (67%), reflects proximity to settlements having ready access to the mid zone too. It appears that the sub-natural phase is more highly represented in the small forests of KN (64%) and KW (50%) as compared to larger HM (37%), indicating that extensive areas are available for restoration. Even the core zones of KN and KW have high representation of degraded (67% and 73% respectively) stages, indicating human induced influences in the entire small sized forests. Similarly, higher percentages of degraded stages in the mid and core zones of all the forests require simple but effective management program based on regulating coppice frequency and lengthening of grazing rotations, a practice that would increase standing volumes and contribute to the stability of mountain slopes and reduction of soil erosion potential.

It seems that HM is the only forest with greater concentration of benchmarks in the core area (44%), which seems to be because of its larger size and inaccessibility to locals of the core areas as compared to other two forests, but presence of mesquite in this forest would be a constant threat to the naturalness. Since mesquite has the ability to grow and reproduce and colonize more rapidly as compared to the native species therefore stopping its spread requires a mitigation plan focused on its eradication, as its negative impacts in the context of natural forest are much greater than its perceived economic advantages.

Table 3. Percentage of occurrences of the three stages in the three zones and their averages in the forest, the degenerated stage is further classified by small letters (a: successional stage with relict trees, b: successional stage, c: invaded by mesquite).

Stages	HM				KW				KN			
	Boundary	**Mid**	**Core**	**Average**	**Boundary**	**Mid**	**Core**	**Average**	**Boundary**	**Mid**	**Core**	**Average**
Natural	17.7	5.8	47	23.92	8.3	-	25.0	11.13	-	-	-	-
Degraded	30.5	58.8	29.5	40.30	16.6	33.3	66.6	38.92	-	73.3	46.2	39.83
Degenerated	47.0	35.4	23.06	35.78	74.9	66.6	8.0	49.95	100	27	51	59.33
	(18a, 29c)	(29.4a, 6c)	(12a, 11c)		(16a,59b)	(16a,50b)	(8a)		(18a,82b)	(9a, 18b)	(9a,42b)	

Conclusion

High percentages of degraded and sub-natural stages in the three forests under study shows that the natural environment has become overwhelmingly cultural, as the dynamic of the system is predominantly governed by the activity of humans, therefore special attention has to be paid, particularly to the zones of the forests where extent of sites altered and controlled by humans has increased. Since anthropogenic disturbances have lead to deterioration of this fragile ecosystem therefore knowledge of the nature and extent of the stages of disturbance regime would be essential to ensure quality productive and protective services to the inhabitants while planning to restore them back to their natural state. Despite the criticism of some theoreticians of conservation biology it appears that rapid assessment not only help in visualizing the urgency of conservation (Olivier & Beattie 1994) but as is shown in this study it can facilitates the comparison and assessments of stages in a continuously adjusting feedback process by diagnosing, degree of change, spatial extent of change and abruptness of change, directly reflecting human influence in the given forest and how they can be improved by sustained control, and or restoration. The stages can be used to cover the full natural-anthropogenic gradient in the context of basic impacts of forest exploitation by weighing them as more information becomes available in the context of land-use activities, infrastructure, cultivation, density of rural population, number of cattle or tractors per village etc., and finally it can be compiled and transferred to cartographic base to work on finer scales for restoration.

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