

Restoration of Degraded Pastureland Ecosystem in Semi-arid Rajasthan: A Study of Two Villages

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Abstract: The paper shows how degraded pastureland ecosystem was restored through adoption of silvopastoral mode of grassland development in Chhota Saradhana and Singhariya villages. It also shows how improved status of the ecosystem in terms of floral diversity and soil characteristics was maintained despite persistent drought that the region experienced for three years (2000-2003). It underscores the role of the community institution at the village level for sustainable management of the lands under new institutional practices.

Key words: Floral diversity, institutional renovation drought, soil characteristics, conservation.

Chhota Saradhana and Singhariya are villages, located in Ajmer district, show how the degeneration of grassland ecosystem was reversed and resilience restored through institutional renovation. The present paper examines how this happened in terms of physico-chemical characteristics of soil and floral diversity. The improvement is assessed in a comparative framework in that both protected grassland and the adjoining unprotected grasslands are taken in to consideration for analysis. The paper has three parts. Part I briefly explains about the steps taken by the village community to renovate traditional institutional practices. While part II analyses the extent and nature of floral diversity achieved in the protected grassland vis-à-vis the unprotected one, and examines whether there has been any improvement in the physico-chemical characteristics of soil in the protected land due to intervention. Part III presents a few conclusions.

Materials and Methods

A unique method of plantation was followed in that women were motivated to raise seedlings in the village nurseries that MMVS set up and involved school children to plant the saplings in the pastureland. Care was taken to protect the local species, including those that were gradually disappearing. The entire land considered to be wasteland not fit for cultivation and used to be considered as 'wasteland' a few years ago, was now full of these species that virtually brought much needed relief to the villagers to meet fuelwood crisis. The villagers took several other steps for conservation and growth of their pasturelands. Land preparation was one such step. The villagers of Chhota Saradhana earmarked 106 ha of grassland and fenced it with locally available materials such as stones. In the same way, 35 ha of permanent grassland of Singhariya was divided in to two plots and fenced. For the sake of analysis, these plots may be called Plot-A and Plot-C.

There was another 3.12 ha plot (Plot-B) that was under the ownership of the Revenue Department of Government of Rajasthan. The village community developed Plot-B exclusively for fuelwood plantation. Although Singhariya had 79 ha of permanent pastureland, village development society did not fence the entire land for its development. Some villagers from numerically large and socially powerful group encroached upon this land.

A large number of staggered trenches, contour bunds and check dams was constructed in both villages for rainwater percolation and soil conservation. An anicut was constructed inside the pastureland of Chhota Saradhana for conservation of rainwater and retention of soil moisture. The notable feature was that no assistance was sought from the government while carrying out the entire exercise. Due importance was given to the local knowledge and technology while combining them with the knowledge imparted by the outside agencies for the development of the pasturelands. Framing of rules was another significant step that was taken up by both village organizations.

Standard methods were followed to analyze floral diversity (Curtis, 1959; Simpson, 1949; Shannon and Weaver, 1963; Odum, 1971; Chapman, 1976). Quadrature method (10x10 m for trees and 1x1 m for grass) was used for sampling of vegetation of both grass and plant species. Topography of both protected and unprotected pasturelands was similar. Samples were collected during the months of February and August 2003. The villages under study passed through severe drought for three successive years before they

received normal rainfall during 2003. Floral diversity was examined based on Importance Value Index (IVI) and other indices. IVI was worked out to understand the hierarchical position of species based on frequency, density and dominance of these species in both types of land. The other indices include Similarity Index, Dominance/Diversity Index and Species Richness Index (SRI). The values obtained through IVI analysis were used for working out diversity/dominance index. All these indices are important in their own ways showing different aspects of floral diversity.

The physico-chemical characteristics of soil were also analyzed. Soil samples from both protected and unprotected pasturelands were collected for analysis adopting standard method of sampling at 25 cm depth in five replicates in April 2003. Grid sampling was done from topographically uniform surface of both protected and unprotected lands. Physico-chemical characteristics such as porosity, water holding capacity, pH, electrical conductivity, nitrogen, phosphorus, potassium, exchangeable Na, exchangeable K, exchangeable Ca, exchangeable Mg and organic carbon were analyzed following standard methods (Jackson, 1958; Black, 1965; Chapman and Pratt, 1961).

Results and Discussion

Floral diversity

Importance Value Index (IVI): In Chhota Saradhana, 25 trees and shrubs and 31 grass species were observed. Table 1 shows that IVI of *Prosopis juliflora* in protected pastureland was 54.9, which was maximum, followed by 25.4 (*Acacia nilotica*) and 16.7 (*Ziziphus nummularia*). Minimum IVI was

3.9 for *Embllica* (Table 1). The maximum IVI in unprotected pastureland was 167.4 in respect of *P. juliflora*, which was maximum. Although *P. juliflora* had maximum IVI in the protected pastureland, it had much smaller value as compared to that of the unprotected pastureland. The managing committee of the VDS of Chhota Saradhana and NGO were fully aware of the harmful effects of luxuriant growth of this plant on the growth of other species. Despite this, they planted it in the protected land thinking that such plants might help in retaining soil moisture (Yadav and Singh, 1970). Of course, this plant was not allowed to grow and cover more area in the protected land. However, this was not so in the case of the unprotected area. Further, Table 1 shows equal distribution of other plant species in protected pastureland, although IVI of these plants was low. The higher IVI of only three tree/shrub species in the unprotected pastureland of Chhota Saradhana indicates how fragile its ecosystem was.

Among grass and forbs *Dichanthium annulatum* had maximum IVI (71.33) followed by *Lasiurus syndicus* (49.62) and *Indigofera cordifolia* (26.89) in protected pastureland (Table 2). In unprotected pastureland IVI was maximum for *Tephrosia apollinea* (57.18) followed by *L. syndicus* (49.25), *Trichodesma indicum* (46.29) and *I. cordifolia* (43.49). Here again, one finds a large distribution of grass species with low IVI in the protected land as compared to that of the unprotected one.

In Singhariya, 25 trees and shrubs, and 35 grass species were recorded in the pastureland. This village had three plots that were protected. Plot-A and C were

used for grazing on rotation, while Plot-B was to meet fuelwood requirements. Maximum IVI was recorded for *Z. nummularia* in Plot-A and was followed by 25.5 for *P. juliflora*, 24.3 for *Euphorbia caducifolia*, 20.1 for *Acacia nilotica* and 18.9 for *Rhus mysurensis*. The IVI was minimum in respect of *Bauhinia racemosa* (3.55) and *Commiphora wightii* (3.55). In Plot-C, maximum IVI was observed in respect of *P. juliflora* (41.2) followed by *Z. mauritiana* (36.7), *Z. nummularia* (36.1) and *Capparis decidua* (34.09). Minimum IVI was recorded for *Salvadora persica* (4.63). In Plot-B, maximum IVI of 222.06 was found in respect of *P. juliflora* mainly due to its intensive plantation in this plot for meeting fuelwood needs of the villagers.

IVI for *P. juliflora* was also maximum in the unprotected pastureland (149.3). It is an important plant for arid ecosystem. Apart from retaining soil moisture, it can survive under extreme water stress condition and provide mulch to soil. It assumes considerable importance in reducing soil erosion. It is proven best for sand dune stabilization. Besides, villagers see its utility in fencing and for using it as fuelwood provided that its luxuriant growth is controlled.

Contrary to the findings that it increases soil alkalinity, evidences suggest that the soluble salt content declines where *P. juliflora* grows. This, in turn, reduces pH from 10.8 to 8.2, while organic matter rises from 0.54 to 2.87%. This is accompanied by a rise in nitrogen content of the soil in the upper 15 cm soil profile (Yadav and Singh, 1970). Thus, if palatable plants and grasses grow along with *P. juliflora*

Table 1. Importance value index of tree and shrub species in the protected and unprotected pasturelands

Importance value index	Chhota Saradhana		Singhariya			
	Protected	Unprotected	Protected			Unprotected
			Plot-A	Plot-B	Plot-C	
<10	<i>Hardwickia</i> , <i>Butea</i> <i>monosperma</i> , <i>Acacia senegal</i> , <i>Azadirachta</i> <i>indica</i> , <i>Rhus</i> <i>mysurensis</i> , <i>Acacia catechu</i> <i>Salvadora</i> <i>persica</i> , <i>Commiphora</i> <i>wightii</i> , <i>Z.</i> <i>rotundifolia</i> , <i>Inga</i> sp., <i>Anogeissus</i> <i>pendula</i> , <i>Tacomella</i> <i>undullata</i> , <i>Ailanthus</i> <i>excelsa</i> , <i>Emblica</i> sp.	<i>Dalbergia</i> <i>sissoo</i> , <i>Prosopis</i> <i>cinereria</i> , <i>Anogeissus</i> <i>pendula</i> <i>Calotropis</i> <i>procera</i> , <i>Z.</i> <i>rotundifolia</i> <i>Salvadora</i> <i>oleoides</i> , <i>Cordia</i> <i>gharaf</i> , <i>Ailanthus</i> <i>excelsa</i> <i>Commiphora</i> <i>wightii</i> , <i>Bauhinia</i> <i>racemosa</i>			<i>Prosopis</i> <i>cinereria</i> , <i>Tacomella</i> <i>undullata</i> , <i>Butea</i> <i>monosperma</i> , <i>Ailanthus</i> <i>excelsa</i> , <i>A.</i> <i>senegal</i> , <i>Cordia gharaf</i> <i>Commiphora</i> <i>wightii</i> , <i>Salvadora</i> <i>persica</i>	
10-20	<i>Ziziphus</i> <i>nummularia</i> , <i>Acacia</i> <i>leucapholea</i> , <i>Prosopis</i> <i>cinereria</i> , <i>Cordia gharaf</i> , <i>Salvadora</i> <i>oleoides</i> , <i>Capparis</i> <i>decidua</i> , <i>Z.</i> <i>mauritiana</i> , <i>Dalbergia</i> <i>sissoo</i> , <i>Euphorbia</i> <i>caducifolia</i>		<i>Rhus</i> <i>mysurensis</i> , <i>Azadirachta</i> <i>indica</i> , <i>A.</i> <i>leucaphloea</i> , <i>Z. mauritiana</i> , <i>Adhatoda</i> <i>vasica</i> S. <i>persica</i> , <i>A.</i> <i>catechu</i> , <i>A.</i> <i>senegal</i>			
20-40	<i>Acacia nilotica</i>		<i>Ziziphus</i> <i>nummularia</i> , <i>P. juliflora</i> , <i>Euphorbia</i> <i>caducifolia</i> <i>Capparis</i> <i>decidua</i> , <i>Acacia nilotica</i>	<i>Butea</i> <i>monos-</i> <i>perma</i> , <i>Capparis</i> <i>decidua</i> , <i>Euphorbia</i> <i>caducifolia</i>	<i>Z. mauritiana</i> , <i>Ziziphus</i> <i>nummularia</i> , <i>Capparis</i> <i>deciduas</i>	<i>Euphorbia</i> <i>caducifolia</i>

Table 1. contd...

Importance value index	Chhota Saradhana		Singhariya			
	Protected	Unprotected	Plot-A	Plot-B	Plot-C	Unprotected
20-40	<i>Acacia nilotica</i>		<i>Ziziphus nummularia</i> , <i>P. juliflora</i> , <i>Euphorbia caducifolia</i> , <i>Capparis decidua</i> , <i>Acacia nilotica</i>	<i>Butea monosperma</i> , <i>Capparis decidua</i> , <i>Euphorbia caducifolia</i>	<i>Z. mauritiana</i> , <i>Ziziphus nummularia</i> , <i>Capparis deciduas</i>	<i>Euphorbia caducifolia</i>
40-60	<i>Prosopis juliflora</i>	<i>Ziziphus nummularia</i>			<i>Prosopis juliflora</i>	<i>Ziziphus nummularia</i> , <i>Rhus mysurensis</i>
60-80		<i>Rhus mysurensis</i>				
80-100						
100-150						
Above 150		<i>Prosopis juliflora</i>		<i>Prosopis juliflora</i>		

harmful effects can be controlled through inhibiting downward leaching of salts.

In both protected and unprotected pasturelands of Singhariya maximum IVI of grasses and forbs in Plot-A was found in respect of *Dichanthium annulatum* (50.7) and *Eragrostis poaoides* (49.3). This was followed by *Lasiurus sindicus* (33.4) and *Mollugo nudicaulis* (20.7) (Table 2). The maximum IVI was recorded for *Eragrostis poaoides* at 171.2 in the unprotected land and 167.6 for Plot-B. In Plot-C, maximum IVI was recorded for *Diachanthium annulatum* (77.4) and minimum for *Corchores tridens* and *Heliopropium benghalensis* (0.67). The pattern of growth of both grass and forb species did not differ significantly between the protected pasturelands of both the villages. The largest number of these species was found to have

less than 10% IVI in all protected pasturelands (Table 2). There were, of course, some grass or forb species, which were not palatable. However, the incidence of growth of such grass species in the protected pasturelands appeared to be much lower than that in the unprotected pastureland.

Acacia nilotica, *Dalbergia sissoo*, *Salvadora persica* and *Prosopis cineraria* are some trees that help in maintaining moisture and nutrients in the soil and are suitable for arid regions. *Z. nummularia*, *Rhus mysurensis* and *Capparis decidua* are important shrub species of semi-arid areas and also provide fruits. The adoption of perennial xerophytes, as mentioned above, is more advantageous under stress conditions, while annuals can grow only under suitable conditions with certain degree

Table 2. Importance value index of grass and forb species of protected and unprotected pasturelands

Importance value index	Chhota Saradhana		Singharia			
	Protected	Unprotected	Protected			Unprotected
			Plot-A	Plot-B	Plot-C	
10-20	<i>Tephrosia apollinea</i> , <i>Cleome viscosa</i> , <i>Cynodon dactylon</i> , <i>Bulbostylis barbata</i> , <i>Dactyloctenium indicum</i>	<i>Cenchrus setigerus</i> , <i>Mollugo nudicaulis</i> , <i>Desmostachya bipinnata</i> , <i>Cleome viscosa</i>	<i>Trichodesma indicum</i> , <i>Borreria stricta</i> , <i>Tephrosia apollinea</i> , <i>Cenchrus setigerus</i> , <i>Cleome viscosa</i>	<i>Tephrosia apollinea</i> , <i>Aristida funiculata</i> , <i>Mollugo nudicaulis</i> , <i>Panicum turgidum</i> , <i>Trichodesma indicum</i> , <i>Borreria stricta</i>	<i>Dactyloctenium indicum</i> , <i>Cenchrus ciliaris</i>	<i>Evolvulus alsinoides</i> , <i>Borreria stricta</i> , <i>Aristida funiculata</i> , <i>Bulbostylis barbata</i> , <i>Zornia gibbosa</i> , <i>Heliopropium benghalensis</i>
20-40	<i>Indigofera cordifolia</i> , <i>Trichodesma indicum</i> , <i>Eragrostis poaoides</i> , <i>Evolvulus alsinoides</i>		<i>Lasiurus indicus</i> , <i>Mollugo nudicaulis</i>	<i>Dichanthium annulatum</i>	<i>Digera muricata</i> , <i>Cynodon dactylon</i> , <i>Cyperus kyllinga</i> , <i>Borreria stricta</i> , <i>Glossocardia bosvelea</i>	
40-60	<i>Lasiurus indicus</i>	<i>Tephrosia apollinea</i> , <i>Trichodesma indicum</i> , <i>Lasiurus indicus</i> , <i>Aristida funiculata</i> , <i>Indigofera cordifolia</i>	<i>Dichanthium annulatum</i> , <i>Eragrostis poaoides</i>			
60-80	<i>Dichanthium annulatum</i>				<i>Dichanthium annulatum</i>	
80-100						
Above 150				<i>Eragrostis poaoides</i>		<i>Eragrostis poaoides</i>

of rainfall accompanied by low temperature. It may be mentioned that in the absence of perennials, drought may degenerate seeds. In such a situation, growth prospects

of annuals may be constrained. From this point of view also, perennials impart stability to the dry land ecosystems.

Although dominance of one or two species with greater IVI shows type of climax vegetation. Large number of species, even with lower IVI, bears considerable importance for achieving greater diversity. Variation in type of species with reference to its morphology, growth pattern and reproductive behavior have implications for successional behavior of habitat. Complex relations of all species enhance interdependence that encourage survival of thorny species with reduced transpiration. Villagers appear to have succeeded in their conservation efforts as this vegetation survived drought for consecutive three years. Grasses and forbs also showed large variation with IVI.

However, *Cenchrus setigerus*, that was planted at the initial stage of intervention by the villagers, did not have higher IVI (Table 2). A variety of factors might have adversely affected germination and growth of this grass. While one may attribute it to overgrazing during drought years in the recent past, compaction of soil followed by heavy rainfall during the months of June and July, 2003 could be other responsible factors. In such cases, as it appears from field survey, natives were more suitable and adapted to the microenvironment even if it turns out to be hostile.

Although the unprotected land was not as rich as the protected one, it was richer than many other barren unprotected lands. However, what made the difference here was higher density of palatable species in the protected pasturelands of both the villages as compared to the unprotected ones. The higher number of non-palatable species in unprotected site is an indication

of overgrazing. It means as grassland ecosystem gets degraded, stock of palatable species tend to deplete while that of non-palatable species increases as latter are not preferred by livestock. In this process, a stage is reached where only non-palatable species survive. The intra specific and inter specific relations that exist in such vegetation community cause further degradation of the grassland ecosystem.

The analysis also reveals interspecific relations between several species such as *Dichanthium annulatum*-*Indigofera cordifolia*, *Borreria stricta*-*Eragrostis poaoides*, *Evolvulus alsinoides* and *Dactyloctenium indicum* in the protected pastureland of both the villages. It may be noted that *Dichanthium annulatum* and *Indigofera cordifolia* were dominant and palatable and had positive association with rest of the species mentioned above. The non-palatable species such as *Aristida funiculata*, which is harmful for grassland, were found largely with greater IVI in the unprotected pasturelands as compared to the protected ones. It inhibits nitrogen-fixing bacteria and thus creates a depleted nitrogen environment. This helps the species to avoid competition from species, that require nitrogen rich habitat (Murthy and Ravindra, 1975). Regular protection being provided to the common pasturelands also made a difference from the unprotected one in this regard.

Similarity Index: Similarity Index (SI) shows the extent of similarity in plants and grass species in both protected and unprotected pasturelands. The higher the number, higher the similarity between stands and vice versa. The SI was estimated: $2xc/A+B$, where C stands for common

species in two stands, A for number of species in A stand and B for number of species in B stand. The SI for grasses was 0.59 in Chhota Saradhana and 0.62 in Plot-A and 0.58 in Plot-C of Singhariya village (Fig. 1). One finds almost a similar pattern of grasses in the pastureland of both villages. The SI for grasses was more than that for trees (Fig. 1). Although similarity is shown in absolute terms, it fairly indicates the differences that exist between protected and unprotected plots.

Several factors were responsible for this. The area had been facing droughts for last three consecutive years. In addition, it may be noted that protected pasturelands were all opened for grazing during drought years, which restricted growth of some species was stalled in the protected pasturelands. Besides, *Cenchrus setigerus*, that was planted initially, was almost wiped out, as mentioned earlier, due to persistent drought. This may be a reason for higher similarity of grasses between protected and unprotected pasturelands. However, the incidence of overgrazing in Singhariya may be an additional factor for higher similarity of grasses in this village between protected and unprotected lands as compared to that of Chhota Saradhana.

A considerable dissimilarity in plants was noticed between protected and unprotected pasturelands of both the villages. The value of SI was as low as 0.21 in the case of the pastureland of Chhota Saradhana, while it was 0.28 for Plot-A, 1.0 for Plot-B and 0.34 for Plot-C in Singhariya village (Fig. 1). Lower the value of SI higher is the qualitative difference between protected and unprotected pasturelands. However, Plot-B of

Singhariya village had higher SI. This is desirable because *Prosopis juliflora* that grew in this plot also grew in the unprotected pastureland of this village.

Index of Dominance and Diversity: The diversity of species is the ratio of number of species to the importance value. Here, we are mainly concerned with the index of general diversity (H). In any plant community, a number of species may be found. However, a community is said to be ecologically more stable and diverse, as it grows old. Ecosystem may lose its stability if its natural process of succession is hindered. The case of grassland ecosystem under study is one such case that shows that such natural process of succession was stalled some years ago. However, after intervention was made to revitalize the same, plant communities achieved certain degree of diversity and, therefore, stability, if not climax.

Protected lands of both the villages were more diversified as compared to the unprotected ones taken both grass and tree species in to consideration (Table 3). Interestingly, diversity achieved in Chhota Saradhana was more than what was achieved in Singhariya. It was 2.4 in Chhota Saradhana, while it was 2.27, 1.03 and 1.90 in Plot-A, Plot-B and Plot-C, respectively, in Singhariya village. It indicates better management of the protected pastureland of Chhota Saradhana village. Needless to mention, diversity in the unprotected lands was much lower as compared to the protected lands (except Plot-B) of both the villages. It was 1.31 and 1.21 in Chhota Saradhana and Singhariya respectively. In Singhariya, dominance of plant and grass species

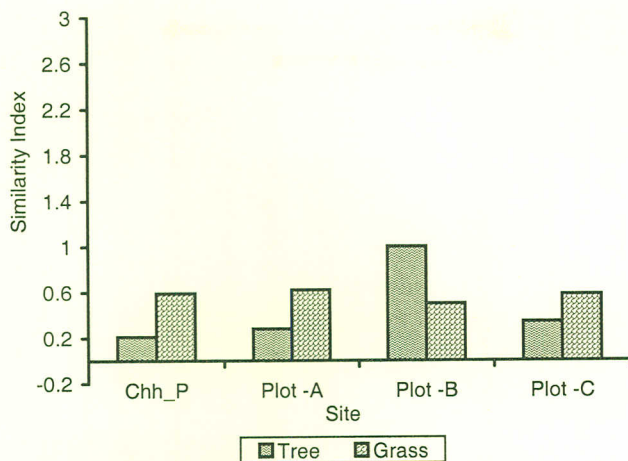


Fig. 1. Similarity Index of protected and unprotected pastureland.

together was 0.64 in the unprotected land, which was much higher than the protected Plot-A and C (Table 3). However, it was lower than Plot-B which was exclusively used for the plantation for *P. juliflora*. Dominance with lower index value indicates presence of variation in the protected lands while the higher value indicates lower diversity. Hence, presence of a large number of species with their fairly good distribution increases diversity. This has led the protected land to attain higher degree of stability. The SRI that shows diversity in terms of number of individual species along with their varieties supplements the above findings.

Species Richness Index: SRI was calculated based on the ratio of the number of species to the square root of number of total individuals. Figure 2 shows almost a uniform pattern for both grass and plant species in both villages. In Chhota Saradhana, SRI for plants in the protected pastureland was 2.7, while it was 2.2 in the unprotected land. Similarly for Singhariya, it was 2.4 (Plot-A), 2.1 (Plot-C) and 1.2 for unprotected

pastureland. As far as grass species are concerned, pattern of their presence was almost similar between the protected and unprotected pasturelands in both villages. Relatively higher SRI of grass shows that richness of grass species was higher in the protected land as compared to the unprotected ones in both the villages. However, it should be noted that SRI for trees was much higher than that of grass species in protected areas of both villages.

Similarly, in Singhariya where rotational or restricted grazing system was followed vegetative reproductive capacity differed depending upon grazing intensity. Even under rotational grazing system vegetative reproductive capacity seemed to have been maintained in respect of grass species such as *D. annulatum* that was accompanied by species such as *Cynodon dactylon* and *Evolvulus alsinoides*. All of them continued to have higher importance value. The vegetative reproductive capacity of *Dichanthium annulatum* increases when seed output and the sexual reproductive capacity decline either in the grazed or

Table 3. Index of dominance and diversity in the protected pastureland vis-à-vis unprotected one

Index	Chhota Saradhana		Singhariya			Unprotected
	Protected	Unprotected	Protected			
			Plot-A	Plot-B	Plot-C	
Dominance						
Grass	0.13	0.12	0.07	0.33	0.10	0.34
Trees	0.07	0.40	0.05	0.57	0.06	0.30
Total	0.20	0.52	0.12	0.90	0.16	0.64
Diversity (H)						
Grass	1.2	1.01	1.05	0.68	0.97	0.69
Trees	1.2	0.30	1.22	0.35	1.01	0.52
Total	2.4	1.31	2.27	1.03	1.98	1.21

transplanted grasslands (Ambhasht and Murya, 1970a,b). Thus, capacity of individual species may have significant influence in changing the vegetation dynamics of the grassland even in the event of persistent drought. This was supplemented by the increase in herbage above the ground in the controlled grazing system such as the one followed in Singhariya (Bhimaya *et al.*, 1967).

Soil characteristics

Porosity and water holding capacity:

Pore spaces are responsible for better growth of plants for they contain enough air and moisture. Porosity raises water-holding capacity. As the porosity of soil increases, moisture content and humus create suitable microenvironment for the survival of microorganism. Microorganisms are integral parts of biogeochemical cycle in that they make nutrients available for plants. They also degrade the biodegradable substances and help in weathering and soil formation.

In Chhota Saradhana, porosity was recorded at 44.92 ± 0.47 and $38.2 \pm 0.88\%$ in protected and unprotected pasturelands,

respectively (Fig. 3). Relatively lower percentage of porosity in the unprotected pastureland indicates higher availability of sodium in the soil because of the deflocculating of clay particles. High sodium adversely affects the physical properties of soil, reduces permeability and pore space (Black, 1968). The sodium content of soil in the unprotected pastureland is found to be significantly higher (0.42 ± 0.01 me/100 g) as compared to that of the protected pastureland (0.39 ± 0.008 me/100 g).

In Singhariya, results on porosity of the protected land were similar to those of Chhota Saradhana (Fig. 3). Here, porosity was maximum at $44.14 \pm 0.85\%$ in Plot-A followed by $38.5 \pm 0.85\%$ in Plot-C and $35.85 \pm 2.33\%$ in Plot-B. The porosity in the unprotected land was as low as $31.1 \pm 1.27\%$. Analysis of variance revealed significant difference between Plot-A and unprotected, Plot-C and unprotected. However, variance between Plot-B and unprotected land was not significant.

Water holding capacity is directly related to the porosity and was 53.02 ± 0.86 and

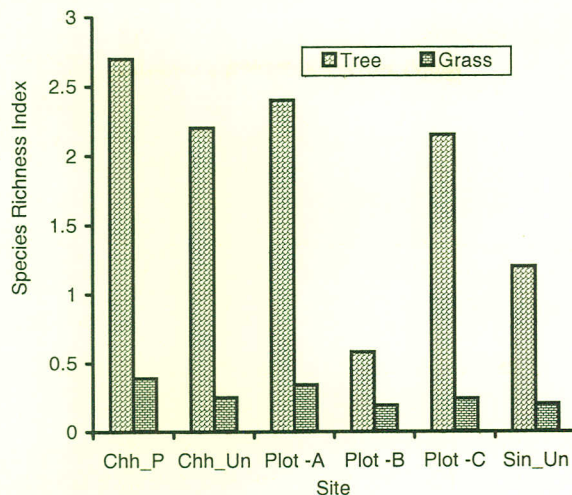


Fig. 2. Species richness index of protected and unprotected pastureland.

44.3±1.59% for protected and unprotected pastureland, respectively, in Chhota Saradhana (Fig. 3). Similarly, for Singhariya it was 52.04±1.59%, 43.65±0.35% and 47.85±0.21% in Plot-A, Plot-B and Plot-C, respectively. In unprotected land, it was as low as 41.35±0.5%. Higher sodium content of the soil in the unprotected land might have changed the physical properties of the soil and adversely affected its water holding capacity. Soil particles are reduced into hard prismatic surface leaving very little space. This in turn, reduces water-holding capacity (Hesse, 1970).

pH and electrical conductivity: The pH recorded was 7.02±0.34 for protected and 6.89±0.71 for unprotected pastureland in Chhota Saradhana. Although pH did not differ significantly but was lower in the unprotected site, perhaps, due to drier climatic conditions that prevailed during last three years. The surface soil layer contains higher sodium during dry months. Since upward movement of soil moisture

brings sodium to the surface. In any case, difference in pH was not statistically significant.

Soil pH was more or less same at both the sites in Singhariya. While, it was 6.64±0.4 in unprotected land, it was 6.85±0.88, 7.08±0.16, 6.78±0.35 in respect of Plot-A, Plot-B and Plot-C, respectively. Normally soil pH ranges between 6.5 to 8.5. Any deviation causes serious concern for plantations or/and reclamation due vulnerability either to acidity or alkalinity. Nevertheless, one must not ignore relatively improved pH of soil in the protected area even if it was inconsequential.

It is in this context that one may distinguish between soil of silvopastoral land and agriculture land. Crop lands are particularly prone to acidification, for cations such as Ca²⁺, Mg²⁺ and K⁺, which counterbalance excessive acidity. Due removal of cations with the crops, soil becomes increasingly acidic. However, in the case of silvopastoral land chances of

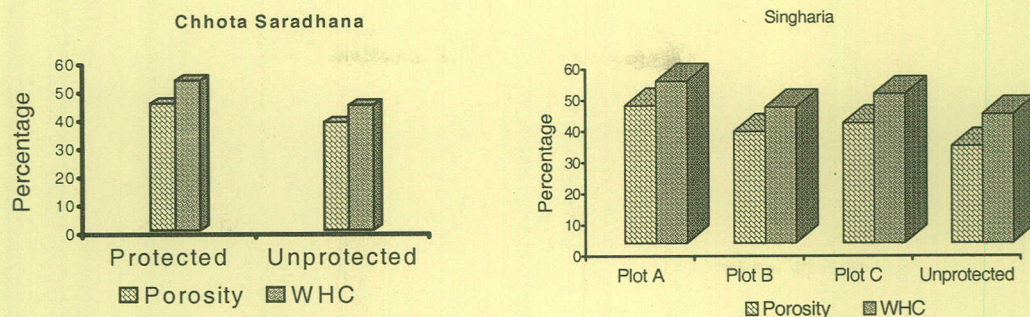


Fig. 3. Porosity and water holding capacity of protected and unprotected pastureland (percentage).

acidification of soil is relatively less because of regular litter fall that instantaneously nitrifies the land. This is more so with the protected pastureland.

The electrical conductivity was comparable and was 0.12 ± 0.03 and 0.10 ± 0.01 dS m^{-1} for unprotected and protected pastureland respectively. EC was 0.11 ± 0.02 , 0.1 ± 0.01 and 0.11 ± 0.007 dS m^{-1} in Plot-A, B and C, respectively.

N, P, K and organic carbon: Richness of soil fertility can be expressed also in terms of macronutrients including nitrogen, phosphorus, potassium and organic carbon (OC). There had been remarkable accumulation of OC in all the protected pasturelands as compared to the unprotected ones (Table 4). For example, in Chhota Saradhana its build up was 121% in the protected land over the unprotected, while it was 263.6% in both Plot A and C of Singharia village. The accumulation of OC in Plot-B was 63.6% that was much lower as compared to other protected pasturelands. As noted earlier, *P. juliflora* was the only plant in this plot and absence of competition resulted in its over-growth. However, one should bear in mind that

this plant also increases OC and N contents of the soil (Yadav and Singh, 1970). Their uses facilitate luxuriant growth of this plant. This may be the reason why increase in other nutrients under consideration was comparatively less than what was found in other protected pasturelands. There had been perceptible increase nitrogen, phosphorus and potassium in soil of the protected pastureland vis-à-vis unprotected ones (Table 4).

The nutrient status of soil in the protected pastureland of Chhota Saradhana was higher than that of the protected lands of Singharia. Nitrogen content of the soil in the pastureland of Chhota Saradhana was 142.6 ± 4.09 kg ha^{-1} while it was $139.42.07$ kg ha^{-1} in Plot-A of followed by Plot-C (134.00) of village Singharia (Table 4). Similarly, in respect of potassium it was 160.2 ± 1.48 kg ha^{-1} in Chhota Saradhana while it was 151.0 ± 2.12 in Plot-A, 116.5 ± 2.12 in Plot-B and 147.0 ± 1.41 kg ha^{-1} in Plot-C. ANOVA for all nutrients in both the villages were found to be significant.

Exchangeable Na, K, Ca and Mg: The pH and EC of soil of both protected and

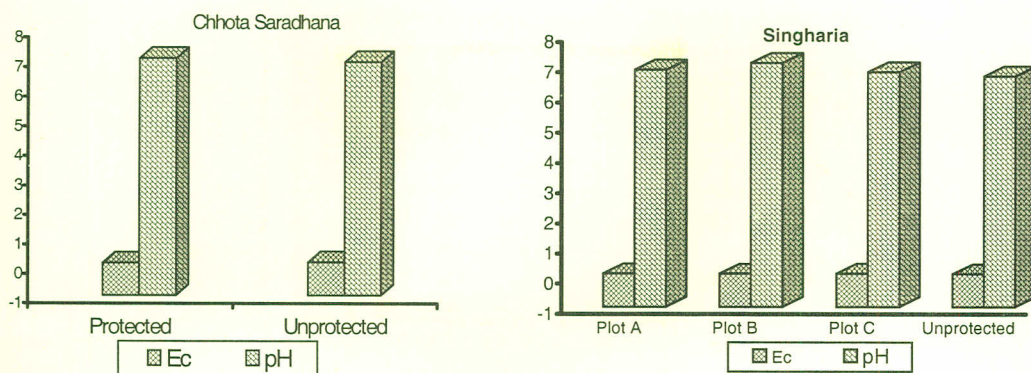


Fig. 4. pH and electrical conductivity ($DS\ m^{-1}$) of protected and unprotected pastureland (Singharia: Plot-A, Plot-B and Plot-C in protected area).

unprotected lands has already shown that the alkalinity and salinity is within the permissible limit. The exchangeable calcium content in soil was almost same for all protected and unprotected lands (Table 5). Limestone was the parent material. While calcium was utilized by vegetation in the protected land, it was continuously deposited in the unprotected land due to lower vegetation cover. This, along with other minerals, tends to exhibit higher deposits in lands where floral density is higher. In such cases physical, chemical and biological processes of weathering for soil formation are higher. However, it is uncertain whether higher concentration of such ions in the unprotected site would increase alkalinity in future for the same has poor organic content.

Results on exchangeable Na and K were similar to those on Na and K. In Chhota Saradhana, exchangeable K was 4.34 ± 0.29 and 3.42 ± 0.42 me/100 g in the protected and unprotected sites, respectively. Similarly, in Singharia, exchangeable K was more in Plot-A and Plot-C (Table 6).

Plot-B, however, showed a reduction of exchangeable K to the tune of 0.03 me/100 g for obvious reasons. Although exchangeable Mg was higher in all protected plots of Singharia vis-à-vis unprotected land, ANOVA shows that the difference was not significant at 5% level. However, unprotected land of Chhota Saradhana showed higher concentration of exchangeable Mg as compared to that of its protected land.

In a dry climate where evaporation exceeds precipitation, minerals, such as exchangeable Ca and Mg, have a tendency to move upward in the soil. However, presence of rich vegetation that maintains soil-water balance may be a reason why concentration of exchangeable Mg in the protected land of Chhota Saradhana was lower. Although concentration of exchangeable Mg was more in the protected land of Singharia as compared to the unprotected one, process through which accumulation of the same took place was similar. However, its lower concentration in the unprotected pastureland might be the result of leaching.

Table 4. Composition of N, P, K and organic carbon in protected and unprotected pasturelands

Index	Chhota Saradhana			Singhariya							
	Unpro- tected	Prot- ected	% Increase in the protec- ted land over the unprot- ected one	Unpro- tected	Plot A	% Increase in the protec- ted land over the unprot- ected one	Plot B	% Increase in the protec- ted land over the unprot- ected one	Plot C	% Increase in the protec- ted land over the unprot- ected one	
N	kg	118.6±	142.6±	20.2	98.5±	139.4±	41.5	105.5±	7.1	134.0±	36.0
	ha ⁻¹	5.03	4.09		2.12	2.07		0.71		0	
P	kg	9.84±	11.94±	21.4	6.9±	11.9±	72.4	7.8±	13.0	11.8±	71.0
	ha ⁻¹	0.24	0.15		0.28	0.08		0.28		0.14	
K	kg	108.58±	160.2±	47.5	106.5±	151.0±	41.7	116.5	9.3	147.0±	38.0
	ha ⁻¹	1.08	1.48		2.12	2.12		±2.12		1.41	
Organic carbon		0.19±	0.42±	121.0	0.11±	0.40±	263.6	0.18±	63.6	0.40±	263.6
		0.02	0.02		0.007	0.01		0.007		0.014	

Although concentration of sodium was higher in the unprotected lands calcium content was comparable. It was around 16 me/100 g in both protected and unprotected lands of both the villages. Therefore, soils in both types of lands of both villages did not appear to be on the wrong side of sodium content, as calcium deficiency was not observed. Hence, it is not always true that higher concentration of sodium necessarily leads to calcium deficiency in soil as reported by Threshow (1970). It depends on the degree of concentration of sodium and availability of other cations. Agarwal *et al.* (1982) have found similar relationship between sodium with potassium and calcium.

Conclusions

The paper shows how degraded pastureland ecosystem was restored through adoption of silvopastoral mode of grassland development. It also shows how improved

status of the ecosystem in terms of floral diversity and soil characteristics was maintained despite persistent drought that the region experienced during last three years. The higher nitrogen content and organic carbon in soil in the protected lands can be cited as examples in this regard. The soil and water conservation measures for grassland development as followed in the villages under study seemed to have improved organic carbon and fertility status of the soil. The revival of the pastureland ecosystem in a state like Rajasthan is inescapable. The state cannot dispense with its development implications. Hence, appropriate measures must be taken to restore degraded pastureland.

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Table 5. Composition of exchangeable ions in protected and unprotected pasturelands

Parameter	Chhota Saradhana		Singhariya			Unprotected
	Protected	Unprotected	Protected			
			Plot-A	Plot-B	Plot-C	
Ex Na*	0.39±0.008	0.42±0.01	0.36±0.03	0.42±0.01	0.37±0.04	0.44±0.04
Ex K*	4.34±0.29	3.42±0.42	4.48±0.32	3.02±0.02	4.05±0.21	3.05±0.07
Ex Ca*	16.18±0.13	16.78±0.28	16.4±0.56	16.7±0.0	16.8±0.21	16.7±0.14
Ex Mg*	2.08±0.11	2.60±0.27	2.04±0.21	1.95±0.21	2.05±0.07	1.70±0.14

* me/100 g.

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