

Richness, Diversity and Evenness of Vegetation upon Rehabilitation of Gypsum Mine Spoiled Lands in the Indian Arid Zone

Suresh Kumar, K.D. Sharma, B.K. Sharma and L.P. Gough¹

Central Arid Zone Research Institute, Jodhpur 342 003, India.

Abstract: Richness, diversity and evenness of vegetation, after rehabilitation of gypsum mine spoils at Barmer were investigated in plots protected and planted one year and four years ago. There were four water harvesting treatments, viz., half-moon terraces, micro-catchments with 5% slope, ridge and furrow and control, wherein, indigenous and exotic trees and shrubs were planted at 5 x 5 m spacing. Sampling of the planted and natural vegetation, using quadrats and transects, revealed much less species richness in unplanted control as compared to all treatments and in all the years. The species richness that increased initially (within one year) gradually declined over time (during four year), though the extent varied in different treatments. The water harvesting treatment showing maximum initial increase in richness also showed maximum decline over time, though decline was more in annual species. Two perennial species increased in richness with time. This was further proved from the trends in diversity and evenness indices. It was concluded that natural successional process was accelerated by rehabilitation providing stability to the habitat.

Key words: Richness, diversity, evenness, rehabilitation, gypsum mine waste, arid.

Surface mining of gypsum leaves large areas devoid of plant cover and fertile top soil, making it a barren land. Since such barren areas are prone to wind erosion, especially in arid areas, their phytoreclamation is desirable. This also helps start succession on these lands. With successional progression, dynamic changes occur in the ecological diversity in terms of species richness, diversity and evenness. This write up discusses such trends in ecological diversity upon rehabilitation of gypsum mine spoil lands in Barmer district in the Indian arid zone.

Materials and Methods

The study area

The gypsum mines at Kavas (25.5° N, 71.4° E, 14 km NE of Barmer on Jodhpur - Barmer highway) were taken up for rehabilitation in 1992. The average annual precipitation at this site is 265 mm with 12-33 rainy days, mainly during June to September when 90% of the rainfall is received. The temperature ranges from 48.6°C in summer to almost 1°C in winter causing frosts. Gypsum is present here as sedimentary deposits in layers intercalated with clay bands, sand and silt.

¹USGS, Denver, U.S.A.

The rehabilitation work

The rehabilitation of these lands had been carried out in four plots of 1 ha each in 1992, and additional four such plots were added every year in 1993, 1994 and 1995. Each cluster of plot in each year had four different water harvesting treatments.

Control: Pit (60 cm³) was dug at 5x5 m spacing and filled with a mixture of pond silt, farm yard manure and local soil (2:1:1). The pit was planted with tree sapling and watered 10 L plant⁻¹.

Half moon terraces: Pit of the same size and at the same spacing was dug as in the control, but the soil from dug out pit was raised as mound in the shape of half-moon to harvest rain water in the pit, which were planted with same species saplings as in control. The half moons were so made as to utilize the local slope for harvesting water.

Micro-catchments: Two opposite micro-catchments of 3.5 m width on either sides and with 5% slope were structured to drain water into single row of plants. A total of 13 micro-catchments could be developed. Here, 60-90 cm auger holes of 10 cm width were made. The farm yard manure mixed with soil was refilled and planted with saplings and watered as in other treatments.

Ridges and furrows: 30 cm high ridges at 5 m distance were developed. These ridges had adjoining furrows, to receive water from the plot and the ridge. Plantation was carried out in furrows at 5 m interval in 1995 and by direct seeding in 1992.

Field sampling for ecological diversity

Sampling for presence and density of species was carried out in nested plots. Ten quadrats of 10 x 10 m size abutting each other in a row were laid diagonally (Kent and Coker, 1992) in each of the four treatments of the 1992 and 1995 plantation. Woody perennials in each quadrat were noted. The herbaceous vegetation was sampled for density in 1 x 1 m quadrat nested in one corner of each of the 10 x 10 m quadrat. Further, the cover of herbaceous vegetation was measured along a line transect (Curtis and McIntosh, 1950). This sampling was repeated for unplanted control paddock of the year 1995. The presence of species in all these sampling units was tabulated in order to arrive at the total species richness per hectare. The data in respect of woody perennials was subjected to analysis of richness using Menhinicks (1964) and Margalef's (1958) index. Diversity was estimated using Simpson's index (Simpson, 1949), Hills diversity numbers N1 and N2 (Hill, 1973) and Shannon's index (H') (Shannon and Weaver, 1949). Evenness was calculated using Pielou's evenness index (Pielou, 1977), Sheldon's evenness index (Sheldon, 1969), Hill's evenness index (Hill, 1973) and Alatalo's modified Hill's ratio (Alatalo, 1981).

Results and Discussion

Species richness

Comparing total number of species in each treatment revealed that the unplanted control of year 1995 (UC) had the lowest number of species, i.e., 15. The total species

Table 1. Species richness in different rehabilitation plots at Kavas

	UPC*	PC		MC		HM		RF	
		RP-1**	RP-4	RP-1	RP-4	RP-1	RP-4	RP-1	RP-4
Regenerated Annuals									
Grasses	4	5	5	6	3	6	4	6	4
Legumes	0	2	3	2	3	1	1	2	2
Others	1	1	3	6	2	2	3	5	1
Total	5	8	11	14	8	9	8	13	7
Regenerated Perennials									
Grasses	4	5	2	6	2	5	2	4	6
Legumes perennials	3	3	3	3	3	2	3	3	3
Other woody perennials	3	3	5	5	6	5	6	7	6
Total	10	11	10	14	11	12	11	14	15
Planted Perennials									
Legume woody perennials	—	4	6	5	3	5	5	6	5
Other woody perennials	—	4	5	5	4	3	5	2	3
Total	0	8	11	10	7	8	10	8	8
Sedges	—	—	—	1	—	—	—	—	—
Grand Total	15	27	32	39	26	29	29	35	30

*UPC = Unplanted control

PC = Planted control

MC = Micro-catchment

HM = Half moon terraces

** RP-1 = Rehabilitated plot 1 year ago

RP-4 = Rehabilitated plot 4 years ago

richness increased by 33% in planted control (PC), 40% in half-moon (HM), 80% in ridge furrows (RF) and 100% in microcatchment (MC) treatments of year 1995. Much of this increase in species richness has been in respect of annual grasses in the same order (Table 1). There has been an increase in perennials richness, again in the same order but increase was not as much as in annuals. The higher increase in species richness after one year of protection and plantation in microcatchment appears to be due to extensive soil working and land shaping that exposes the buried seed bank, as also the loosening of soil that offers a favourable niche to air borne propagules to germinate. Soil working is

comparatively less in ridge furrows and still less in half moons and almost absent in planted control. This resulted in appearance of species like *Euphorbia granulata*, *Polygala erioptera* in microcatchment and ridge furrow only.

By and large, different annual species appeared in different treatments. Strikingly, annual legumes which appeared in all the four treatments, were absent in the unplanted control.

The richness of naturally regenerated perennials also followed the same trend. The increase in richness of perennials in microcatchment was maximum, i.e., 50% over unplanted control, followed by that

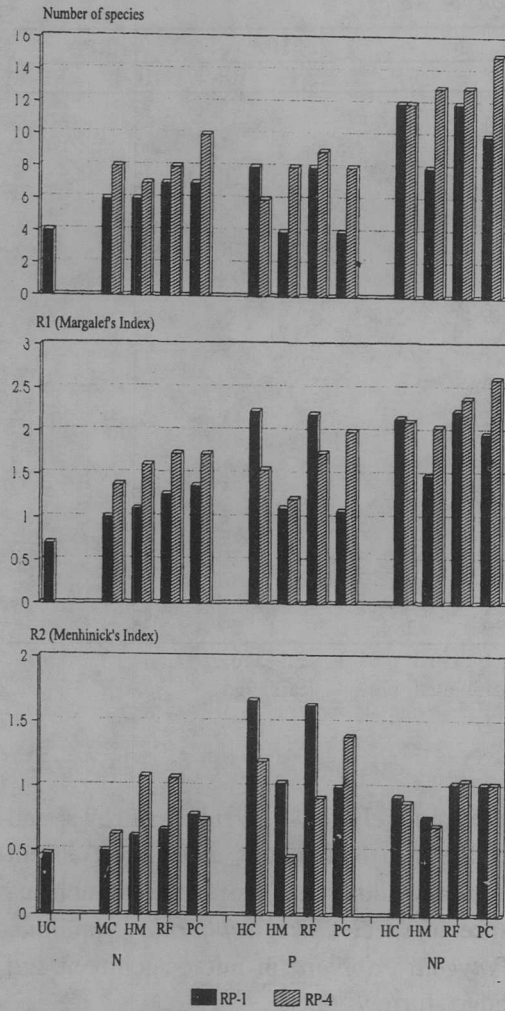


Fig. 1. Species richness in different rehabilitation plots at Kavas.

in ridge furrows (40%), half moons (20%) and planted control (10%). Among perennials, 40-45% richness was contributed by perennial grasses and 55-60% by woody perennials. Further, those species which naturally regenerated in unplanted control were absent in planted treatments such as *Citrullus colocynthis* and *Dichanthium an-*

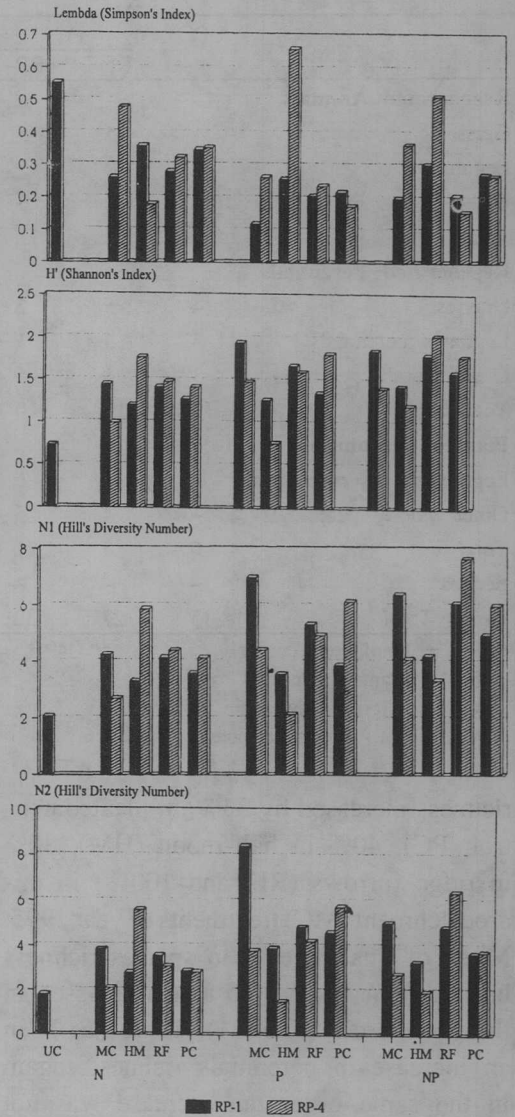


Fig. 2. Diversity in different rehabilitation plots at Kavas.

nulatum. This indicated that though species richness increases upon protection and plantation in one year old plots (RP-1), the species appearing in different treatments varied.

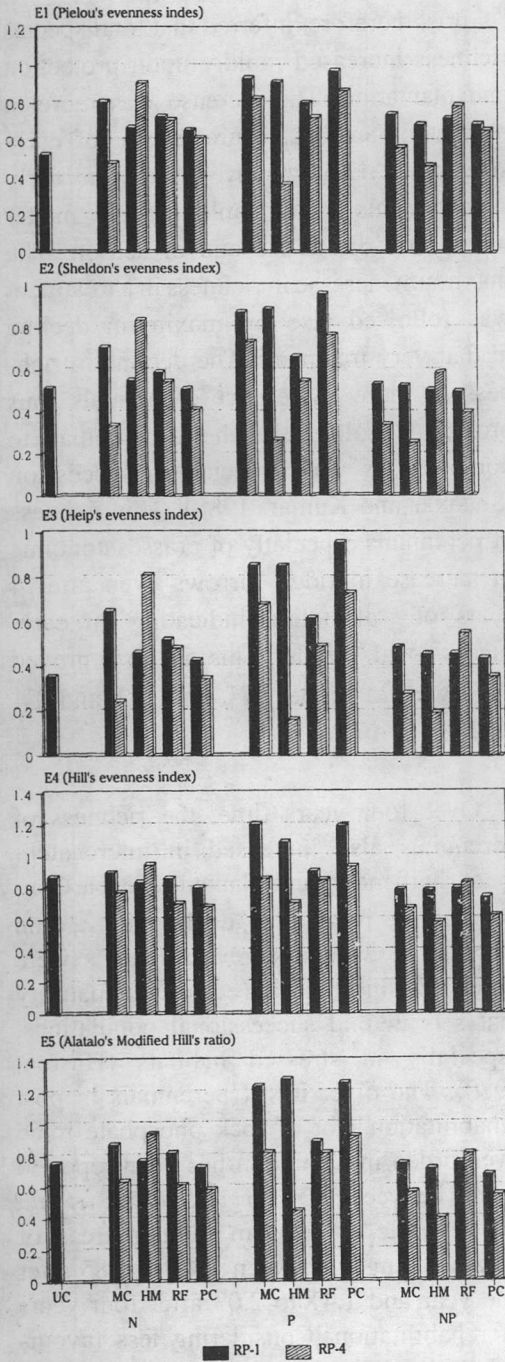


Fig. 3. Evenness in different rehabilitation plots at Kavas.

The richness of annuals and perennials showed different trends in four-year-old plots (RP-4) after protection and plantation. The decline in annual species in RP-4 compared to RP-1 was maximum in ridge furrows (46.15%), followed by that in microcatchments (42.85%), half-moons, (11.11%) and an increase of 37.57% in planted control. The perennial species richness declined by 26.6% in microcatchment and nearly by 9% in both, planted control and half-moons (Table 1). Ridge furrows recorded an increase of 7.14% in perennial's species richness.

Richness of naturally regenerated perennial grasses and woody perennials in RP-4 over RP-1, however, showed opposite trends. Richness of perennial grasses declined in RP-4 by over 60% in all treatments except ridge furrows, which showed an increase of 7.14%. On the other hand, richness of naturally regenerated woody perennials increased by 33.3% in planted control, followed by 28.5% in half-moons and 12.5% in microcatchment, and a decline of 10% in ridge furrows.

When both perennials (naturally regenerated and planted) and annual species were considered, decline in RP-4 over RP-1 was maximum, i.e., 33.3% in microcatchment, 14.3% in ridge furrows, and no decline in half-moon and an increase of 18% in planted control (Fig. 1). These trends, more or less, persist even when only naturally regenerated annuals and perennials are considered.

Impact of these trends on diversity and evenness were analysed for perennial vege-

tation because all planted species were perennials.

Simpson's index (λ), indicates concentration of dominance. Lower the value of λ , better is the sharing of dominance by many species. The naturally regenerated vegetation had higher λ than that of the planted species in both RP-1 and RP-4, and it declined when both naturally regenerated and planted species were considered (Fig. 2). It thus, emerged that with rehabilitation plantations, more species start sharing the dominance. That most adaptive will survive over time giving, dominance to fewer species as is characteristic of stressed habitats (Whittaker, 1965), is proved by higher values of both natural and planted woody perennials in RP-4 compared to RP-1, except in ridge furrows. This was also supported by Hills diversity number N1 and N2 (Fig. 2). N1 indicated abundant species and N2 the most abundant species. Both N1 and N2 were less in RP-4 than in RP-1, in case of both microcatchment and half-moon, indicating fewer species becoming abundantly dominant and hence higher. The N1 and N2 for RF and PC were more in RP-4 than in RP-1, still indicating a response of initial succession. The real clue, however, came from the trend of evenness indices. Almost all, E1 and E5 decline in respect of microcatchment and half-moon and increase in respect of ridge furrows and planted controls (Fig. 3). But when natural species and planted species were considered separately, all the evenness indices showed decline in RP-4 over RP-1 in all the treatments except in half-moons (Fig. 3).

It is, therefore, inferred that total species richness increased rapidly upon protection and plantation. The increase was more in respect of annuals, characteristic of early succession. Ecologically, these were early successional species which build organic matter when they die at the end of season. The maximum increase in richness in a treatment was followed also by maximum decline in that very treatment. The decline in richness is more in respect of annuals thus providing ecological niche to perennials to dominate, as was expected in succession (Shankar and Kumar, 1988). This richness of perennials especially of grasses continue to increase in ridge furrows even after 4 years of plantation indicating an early successional trends. This is also proved by lower λ , higher N1 and N2 and E1 to E5.

Over four years time, the richness of perennials also increased in microcatchment, half-moon and planted control. Concomitantly, instead of decline in λ , and increase in evenness, reverse trends were observed. This indicated ecosystem maturity that sets in mid successional populations, especially in stressed habitats (Huston, 1980). The diversity of perennials in post rehabilitation plot of rock phosphate mine overburden in Dehradun has been reported to be between 1.36 to 1.75 (Soni *et al.*, 1989) while in gypsum mining areas of Kavas it ranged between 1.43 to 1.85 after one year and 1.41 to 2.03 after four years of rehabilitation. Considering less favourable rainfall and moisture conditions at Kavas, than that at Dehradun, it can be safely inferred that the rehabilitation at

Kavas site had accelerated the process of natural succession to such an extent that even maturity trends were visible.

Acknowledgements

Authors are grateful to Director, CAZRI and Head, Division of Resources Survey and Monitoring, CAZRI, Jodhpur, for providing facilities and encouragements to carry out this work. Financial support from U.S. Department of Interior, Dryland Project, is gratefully acknowledged. Authors wish to record their appreciation for FCI, Jodhpur, for their continued support, Dr. F. Parveen, for identifying a few specimen, Sh. Pratul Gupta, for computer support, and the staff of the Plant Ecology Section for their ever cooperative field work.

References

- Alatalo, R.V. 1981. Problems in the measurement of evenness in ecology. *Oikos* 37: 199-204.
- Curtis, J.T. and McIntosh, R.P. 1950. The interrelationships of certain analytic and synthetic phytosociological characters. *Ecology* 31: 434-455.
- Hill, M.O. 1973. Diversity and evenness: A unifying notation and its consequences. *Ecology* 61: 427-432.
- Huston, M.A. 1980. Patterns of species diversity in an old field ecosystem. *Bulletin of the Ecological Society of America* 61: 110.
- Kent, M. and Coker, P. 1992. *Vegetation Description and Analysis*. Belhaven Press, London.
- Margalef, R. 1958. Information theory in ecology. *General Systematics* 3: 36-71.
- Menhinicks, E.F. 1964. A comparison of some species individuals diversity indices applied to samples of field insects. *Ecology* 45: 859-861.
- Pielou, E.C. 1977. *Mathematical Ecology*. Wiley, New York.
- Shankar, V. and Kumar, S. 1988. Vegetation of various desertic wasteland and its natural recovery. In *Wasteland Development and Utilization*, pp. 102-111. Scientific Publishers, Jodhpur.
- Shannon, C.E. and Weaver, W. 1949. *The Mathematical Theory of Communication*. University of Illinois Press, Urbana, IL, U.S.A.
- Sheldon, A.L. 1969. Equitability indices: Dependence on the species count. *Ecology* 50: 466-467.
- Simpson, E.H. 1949. Measurement of diversity. *Nature* 163: 688.
- Soni, P., Vashistha, H.B. and Om Kumar 1989. Biological diversity in surface mined areas after reclamation. *Indian Forester* 115(1): 475-482.
- Whittaker, R.H. 1965. Dominance and diversity in land plant communities. *Science* 147 : 250-260.