Article

A study on herbaceous layer in an age series of restored mined land using cluster analysis

Shikha Uniyal Gairola[1], Prafulla Soni[2]
[1]Uttranchal College of Science and Technology, Sahastradhara Road , Dehradun, Uttarakhand, India
[2]Forest Ecology & Environment Division, Forest Research Institute, Dehradun, Uttarakhand, India
E-mail: shikhaa.fri@gmail.com

Received 25 December 2012; Accepted 28 January 2013; Published online 1 June 2013

Abstract
Vegetation may be described as the plant life of a region. The study of patterns and processes in vegetation at various scales of space and time is useful in understanding landscapes, ecological processes, environmental history and predicting ecosystem attributes such as productivity. Generalized vegetation descriptions, maps and other graphical representations of vegetation types have become fundamental to land use planning and management. They are widely used as biodiversity surrogates in conservation assessments and can provide a useful summary of many non-vegetation landscape elements such as animal habitats, agricultural suitability and the location and abundance of timber and other forest resources. Clustering vegetation data is well known machine learning problem which aims to partition the data set into subsets, so that the data in each subset share some common trait. Present study was done with an objective to study the successional changes in herbaceous vegetation in an age series of restored mined land and also analyzes them by subjecting the vegetation data to cluster analysis. The results of the study reveals that with widespread distribution and dominance of some of the prominent naturals invaders as component of both - the mined sites as well as the undisturbed natural site, the final composition of the community at the restored sites are compiled solely from the existing population of the species and the succession on restored area results in the similar community as that found on undisturbed forest in the same vicinity.

Keywords graphical representations; clustering; community composition; subsets; restored mined land site; undisturbed forest.

Proceedings of the International Academy of Ecology and Environmental Sciences
ISSN 2220-8860
URL: http://www.iaees.org/publications/journals/piaees/online-version.asp
RSS: http://www.iaees.org/publications/journals/piaees/rss.xml
E-mail: piaees@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

The classification of ecological species groups is one of the methods used for discerning vegetation-environment relationships together with an analysis of communities and individual species (Abella and Covington, 2006; Zhang, 2007, 2011; Zhang and Wei, 2009). Ecological species groups consist of co-occurring plant species sharing similar environmental affinities (Spies and Barnes, 1985; Godart, 1989;

Grabherr et al., 2003; Ozcelik et al., 2008). Such study identify the environmental gradients correlated with species distributions, classifies species assemblages occupying similar environmental complexes, and relates species distributions to management-oriented variables such as tree growth (Hix, 1988; Host and Pregitzer, 1991). Once species groups are developed for an area, their distribution can be used for inferring soil characteristics and other variables (Pregitzer and Barnes, 1982; Meilleur et al., 1992). Species groups have typically been constructed using combinations of field observations, inspection of tabular species-site matrices, and multivariate analyses such as cluster analysis (Spies and Barnes, 1985; Godart, 1989; Kashian et al., 2003). As in many multivariate studies in plant ecology, species groups are hypotheses about species distributions and their relationships to environmental factors. These hypotheses have practical value for estimating site conditions, and are tractable for refinement through experimental research developing causal relationships about species distributions (Pabst and Spies, 1998). On the other hand, different communities are characterized by distinct indicator species which show unique responses to the present environmental gradients.

Present paper focuses on the study of herbaceous vegetation on the basis of cluster analysis. Cluster analysis divides data into cluster that are meaningful and useful and helps in understanding relationships between and within the community. Classification of sites was done through cluster analysis. In the present study cluster analysis was done to distinguish the sites on the basis of herb layer.

The present study has been undertaken in restored area of rock phosphate mine at Maldeota in Doon Valley that has an elevation ranging from 650m to about 1050m above mean sea level (MSL). It is situated in the north east of Dehradun, Uttarakhand (India) at a distance of about 18km on the west bank of perennial river Bandal. The area affected by open cast mining was about 15 hectares till 1982 when ecorestoration was initiated. Ecological restoration of this mine site has been done by using integrated technical and biological measures (Soni and Vasistha, 1985). Present study was done in the year 2005 and 2006 and data was collected during post monsoon seasons during both the years. A comparative study of herbaceous vegetation has been done between a 23 years old restored site (site1), 22 years old restored site (site 2), 21 years old restored site (site3) and 20 years old restored site (site 4). For comparison an adjoining natural forest (site 5) has also been studied.

2 Materials and Methods

For the present investigation, the restored areas of different ages were selected, besides the adjoining natural forest (undisturbed by mining) as control site for comparing the impact of restoration and successional changes in shrubs in all age series of restoration. Five quadrat of 1×1 meter was laid in the selected sites according to quadrat method (Misra, 1968). Importance Value Index (IVI) was calculated separately for each species of the community. Importance Value Index (IVI) was calculated by the summation of relative values of frequency, density and dominance (Curtis and McIntosh, 1950; Curtis and Cottam, 1956; Phillips, 1959).

The formulae used for the various calculations were:

$$\textit{Density} = \frac{\text{Total number of individual of a species}}{\text{Total number of quadrats studied}}$$

$$\textit{Frequency\%} = \frac{\text{Number of quadrats of occurrence of a species}}{\text{Total number of quadrats studied}} \times 100$$

$$\textit{Abundance} = \frac{\text{Total no. of individuals of a species}}{\text{Number of quadrats of occurrence}}$$

3 Results

In site 1, during first year among herbaceous vegetation highest IVI was found for *Murraya koenigii* (97.18) while lowest IVI was calculated for *Achyranthes aspera* (9.52). During the second year of study the minimum IVI was observed for *Cynadon dactylon* i.e. 5.02 and maximum IVI was observed for *Ageratum conyzoides* (Table 1). In site 2, among herbs during the first year highest IVI was found for *Adhatoda zeylanica* (63.78) while lowest IVI was calculated for *Cymbopogon martini* (6.39). Similarly, during the second year of study the minimum IVI was observed for *Eupatorium glandulosum* i.e. 4.74 and maximum IVI was observed for *Lantana camara* (60.99) (Table 2). In site 3, among herbaceous vegetation in first year highest IVI was found for *Murraya koenigii* (74.24) while lowest IVI was calculated for *Corchorous aestuans* (6.76) (Table 3). During second year of the study minimum IVI was observed for *Aerva scandens* i.e. 9.03 and maximum IVI was observed for *Achyranthes aspera* (68.03) (Table 5.16). In site 4, among herbs in first year highest IVI was found for *Bidens pilosa* (81.61) while lowest IVI was calculated for *Frageria* (4.42). During second year of the study the minimum IVI was observed for *Murraya paniculata* i.e. 4.67 and maximum IVI was observed for *Murraya koenigii* (49.31) (Table 4). In site 5, among herbaceous vegetation during post-monsoon season in first year highest IVI was found for *Bidens pilosa* (118.49) while lowest IVI was calculated for *Ageratum conyzoides* (3.78). During second year of the study in minimum IVI was observed for *Rumex hastatus* i.e. 5.32 and maximum IVI was observed for *Achyranthes aspera* (77.06) (Table 5).

Cluster analysis divides data into cluster that are meaningful and useful and helps in understanding relationships between and within the community. Classification of sites was done through cluster analysis. In the present study cluster analysis was used to distinguish the sites on the basis of herb layer (RS in the figure denotes the restored sites).

Among herbs (Fig. 1) during the period of study, first division of the cluster was at 47.17% similarity segregating 22 years old restored site (site 2) from other four sites i.e. 23 years old restored site (site 1), 21 years old restored site (site 3), 20 years old restored site (site 4) and natural forest (site 5). This segregation may be due to the presence of *Agave sisalana* and *Deutizia staminia* in site 2 and absence of *Bidens pilosa*. The second division of cluster was at 39.62% which segregated site 3 from other study sites. This may be due to the presence of *Melia composita* seedling, *Corchorous aestuans, Oxalis corniculata, Urtica aphyla* and absence of *Oplismenus burmanii.*

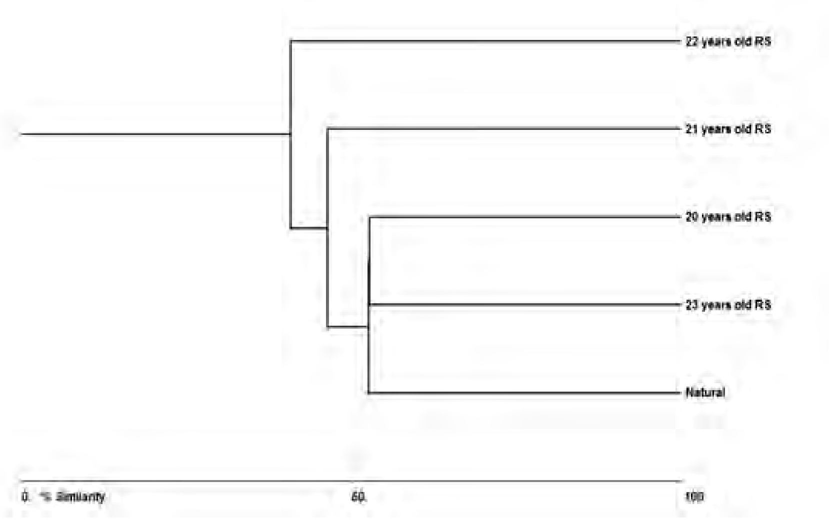

Fig. 1 Cluster analysis of herbs during study period.

Table 1 Floristic structure of herbs at site 1.

Herbs	**Frequency**		**Density ha^{-1}**		**Abundance**		**IVI**	
Year	**Ist**	**IInd**	**Ist**	**IInd**	**Ist**	**IInd**	**Ist**	**IInd**
Achyranthes aspera. L.	20.00	20.00	2000	2000	1.00	1.00	**9.52**	**8.53**
Adhatoda zeylanica Nees.	20.00	20.00	2000	2000	1.00	1.00	**9.69**	**9.67**
Aerva scandens Wall.	-	20.00	-	2000	-	1.00	-	**8.05**
Ageratum conyzoides Linn.	20.00	60.00	2000	12000	1.00	2.00	**21.80**	**42.57**
Artemisia vulgaris Linn.	-	20.00	-	2000	-	1.00	-	**8.98**
Bidens pilosa L.	20.00	80.00	22000	20000	11.00	2.50	**64.79**	**39.83**
Commelina benghalensis L.	-	20.00	-	2000	-	1.00	-	**5.61**
Cymbopogon martini Stapf.	20.00	-	4000	-	2.00	-	**13.15**	-
Cynadon dactylon (L.) Pers.	-	20.00	-	2000	-	1.00	-	**5.02**
Eupatorium glandulosum Michx.	-	20.00	-	2000	-	1.00	-	**6.00**
Lantana camara L.	-	100.00	-	14000	-	1.40	-	**50.77**
Malvestrum coromandelianum .Gareke.	-	20.00	-	2000	-	1.00	-	**6.44**
Mallotus philippensis (Lam.) Muell.-Arg.	20.00	-	2000	-	1.00	-	**12.08**	-
Murraya koenigii Spreng.	40.00	60.00	60000	10000	15.00	1.67	**97.18**	**32.31**
Murraya paniculata (L) Jacq.	20.00	20.00	2000	2000	1.00	1.00	**11.70**	**11.04**
Oplismenus compositus (L.) P. Beauv	20.00	40.00	2000	6000	1.00	1.50	**18.20**	**16.17**
Oxalis corniculata (L.) L	-	20.00	-	4000	-	2.00		**9.17**
Sida acuta Burm.	60.00	20.00	8000	2000	1.33	1.00	**30.65**	**5.48**
Sida humilis Willd.	20.00	40.00	4000	4000	2.00	1.00	**11.23**	**11.14**
Urena lobata L.	-	60.00	-	6000	-	1.00	-	**17.24**
Woodfordia fruticosa Kurz.	-	20.00	-	2000	-	1.00	-	**5.96**

Third division of cluster was at 51.41% which segregated site 4 from other sites. This may be due to the presence of *Frageria* sp., and *Randia dumetorum* in this site. The fourth division was observed at 52.25%. This division segregated site 1 from site 5. Presence of species like *Sida cordifolia, Adhatoda zeylanica* and *Oplismenus compositus* may be the reason for this segregation.

Table 2 Floristic structure of herbs at site 2.

Herbs	Frequency		density ha-1		Abundance		IVI	
Year	**I st**	**II nd**	**I st**	**II nd**	**I st**	**II nd**	**I st**	**II nd**
Achyranthes aspera L.	40.00	80.00	8000	10000	2.00	1.25	**26.77**	**22.44**
Adhatoda zeylanica Nees.	60.00	100.00	18000	22000	3.00	2.20	**63.78**	**38.59**
Aerva scandens Wall.	60.00	-	6000	-	1.00	-	**19.37**	-
Agave sisalana Perrine	20.00	-	2000	-	1.00	-	**6.40**	-
Ageratum conyzoides Linn.	20.00	-	4000	-	2.00	-	**8.23**	-
Barleria cristata Linn.	40.00	-	10000	-	2.50	-	**21.48**	-
Bidens pilosa L.	-	100.00	-	20000	-	2.00	-	**56.10**
Boehmeria platyphylla D.Don	20.00	40.00	6000	6000	3.00	1.50	**10.60**	**11.25**
Commelina benghalense L.	-	20.00	-	2000	-	1.00	-	**4.78**
Cymbopogon martini Stapf.	20.00	-	2000	-	1.00	-	**6.39**	-
Deutzia staminea R. Br. ex. Wall.	20.00	-	2000	-	1.00	-	**7.59**	-
Eupatorium glandulosum Michx.	20.00	20.00	2000	2000	1.00	1.00	**8.09**	**4.74**
Justicia simplex D.Don	20.00	60.00	4000	6000	2.00	1.00	**9.74**	**13.64**
Lantana camara L.	60.00	100.00	8000	36000	1.33	3.60	**27.23**	**60.99**
Mallotus philippensis (Lam.) Muell.-Arg.	20.00	-	2000	-	1.00	-	**10.66**	-
Murraya koenigii Spreng.	80.00	40.00	22000	8000	2.75	2.00	**46.21**	**15.41**
Oplismenus compositus (L.) P. Beauv	40.00	60.00	12000	8000	3.00	1.33	**20.39**	**27.70**
Oxalis corniculata (L.) L	-	20.00	-	2000	-	1.00	-	**5.72**
Desmodium gangeticum DC.	-	20.00	-	4000	-	2.00	-	**11.51**
Sida humilis Willd.	20.00	40.00	2000	4000	1.00	1.00	**7.08**	**9.89**
Toona ciliata M.Reem.	-	20.00	-	2000	-	1.00	-	**5.00**
Urena lobata L.	-	40.00	-	6000	-	1.50	-	**12.25**

4 Discussion

Among herbs (Site 1) *Murraya koenigii, Lantana camara, Ageratum conyzoides* and *Bidens pilosa* were the dominant herbs found in this site (Table 1). The invasion of large number of native species including trees, shrubs and herbs and grasses may attribute that the system is still progressing towards successional phase. Invasion in the successional phase is relatively easy than invasion in to climax phase of the system (Ramakrishnan, 1991). Among herbaceous vegetation (site 2) a total of 22 species were found and none of the planted species were found in the restored area (Table 2). This may be due to the process of natural succession. *Murraya koenigii, Adhatoda zeylanica, Oplismenus compositus Barleria cristata* showed the highest density.. In herbaceous vegetation *Bidens pilosa, Achyranthes aspera* and *Commelina benghalensis* were found dominant in site 3 (Table 3). Among herbaceous vegetation, during the study period in site 4 *Bidens pilosa*, *Cymbopogon martini*, *Murraya koenigii*, *Oplismenus compositus*, *Eupatorium glandulosum* and *Lantana camara* were the densest species found during the study period (Table 4). Due to restoration activity the diversity of the plant community generally increases. It was due to invasion of native plant species from surrounding areas as the site got ameliorated after restoration providing favorable condition for their establishment. Bhatt et al. (1991) and Banerjee et al. (1996) have supported these findings. In site 5 i.e. the natural forest *Bidens pilosa* had the maximum density. The maximum number of species in the natural site and the restored sites were similar which supports the fact that plant species from adjoining areas must have invaded the restored sites (Table 5).

Table 3 Floristic structure of herbs at site 3.

Herbs	**Frequency**		**density ha-1**		**Abundance**		**IVI**	
years	**I**st	**II**nd	**I**st	**II**nd	**I**st	**II**nd	**I**st	**II**nd
Achyranthes aspera L.	40.00	100.00	12000	20000	3.00	2.00	**17.78**	**68.03**
Adiantum (fern)	20.00	-	20000	-	10.00	-	**14.03**	**--**
Ageratum conyzoides Linn.	20.00	80.00	12000	24000	6.00	3.00	**9.65**	**45.32**
Aerva scandens Wall.	-	20.00	-	4000	-	2.00	-	**9.03**
Bidens pilosa L.	60.00	-	18000	-	3.00	-	**22.41**	-
Boerhavia diffusa L.	-	60.00	-	10000	-	1.67		**56.28**
Corchorus olitorius Linn.	20.00	-	6000	-	3.00	-	**6.76**	-
Commelina benghalensis L.	-	100.00	-	12000	-	1.20	-	**32.81**
Cyperus rotandrus L.	-	40.00	-	12000	-	3.00	-	**20.62**
Eupatorium glandulosum Michx.	-	20.00	-	4000	-	2.00	-	**31.09**
Lantana camara L.	20.00	100.00	6000	12000	3.00	1.20	**15.89**	**36.82**
Mallotus philippensis (Lam.) Muell.-Arg.	20.00	-	4000	-	2.00	-	**13.63**	-
Melia composita Willd. leaf.	20.00	--	2000	-	1.00	-	**7.53**	-
Murraya koenigii Spreng.	100.00	-	40000	-	4.00	-	**74.24**	-
Oplismenus burmannii (Retz.) P. Beauv.	100.00	-	46000	-	4.60	-	**41.40**	-
Randia dumetorum Lamk.	40.00	-	10000	-	2.50	-	**34.33**	-
Sida cordifolia Linn.	60.00	-	16000	-	2.67	-	**19.22**	-
Urtica aphyla L.	20.00	-	10000	-	5.00	-	**23.12**	-

Table 4 Floristic structure of herbs at site 4.

Herbs	**Frequency**		**density ha-1**		**Abundance**		**IVI**	
Year	**I**st	**II**nd	**I**st	**II**nd	**I**st	**II**nd	**I**st	**II**nd
Achyranthes aspera L.	80.00	40.00	10000	14000	1.25	3.50	**23.07**	**28.82**
Adiantum sp.	20.00	-	2000	-	1.00	-	**4.74**	-
Adhatoda zeylanica Nees.	-	20.00	-	2000	-	1.00	-	**9.05**
Aerva scandens Wall.	20.00	60.00	4000	12000	2.00	2.00	**6.46**	**26.82**
Ageratum conyzoides Linn.	20.00	40.00	4000	10000	2.00	2.50	**6.61**	**15.47**
Bidens pilosa L.	80.00	-	74000	-	9.25	-	**81.61**	-
Barleria cristata Linn.	20.00	-	2000	-	1.00	-	**4.75**	-
Boehmeria platyphylla D.Don	-	20.00	-	2000	-	1.00	-	**6.98**
Cissampelos pareira L. var. hirsute (DC.) Forman	-	40.00	-	6000	-	1.50	-	**11.62**
Cymbopogon martini Stapf.	20.00	-	46000	-	23.00	-	**40.91**	-
Diclyptera bupleuroides	20.00	-	6000	-	3.00	-	**7.84**	-
Eupatorium glandulosum Michx.	-	40.00	-	28000	-	7.00	-	**36.28**
Euphorbia hirta L.	-	40.00	-	6000	-	1.50	-	**11.54**
Frageria indica.	20.00	-	2000	-	1.00	-	**4.42**	-
Justicia simplex D.Don	20.00	-	4000	-	2.00	-	**5.93**	-
Lantana camara L.	20.00	40.00	2000	12000	1.00	3.00	**7.06**	**16.83**
Mallotus philippensis (Lam.) Muell.-Arg.	20.00	-	2000	-	1.00	-	**4.63**	-
Murraya koenigii Spreng.	80.00	100.00	20000	30000	2.50	3.00	**30.10**	**49.31**
Murraya paniculata (L) Jacq.	-	20.00	-	2000	-	1.00	-	**4.67**
Oplismenus compositus (L.) P. Beauv	80.00	40.00	44000	24000	5.50	6.00	**44.34**	**33.82**
Oxalis minuta Thunb.	20.00	-	6000	-	3.00	-	**8.90**	-
Sida humilis Willd.	40.00	60.00	12000	14000	3.00	2.33	**18.63**	**22.09**
Syzygium cumini (L.) Skeels	-	20.00	-	2000	-	1.00	-	**4.95**
Toona ciliata M.Reem.	-	20.00	-	2000	-	1.00	-	**5.49**
Urena lobata L.	-	20.00		8000	-	4.00	-	**11.01**

Table 5 Floristic structure of herbs in site 5.

Herbs	**Frequency**		**density ha-1**		**Abundance**		**IVI**	
Year	**I st**	**II nd**	**I st**	**II nd**	**I st**	**II nd**	**I st**	**II nd**
Achyranthes aspera L.	100.00	100.00	26000	44000	2.60	4.40	**39.05**	**77.06**
Adhatoda zeylanica Nees.	-	100.00		16000		1.60		**49.89**
Aerva scandens Wall.	40.00	60.00	16000	12000	4.00	2.00	**11.22**	**15.99**
Ageratum conyzoides Linn.	20.00	-	2000	-	1.00	-	**3.78**	-
Apluda mutica L..	40.00	-	10000	-	2.50	-	**9.84**	-
Barleria cristata Linn.	40.00	-	6000	-	1.50	-	**9.37**	-
Bidens pilosa L.	100.00	100.00	198000	24000	19.80	2.40	**118.49**	**35.95**
Boehmeria platyphylla D.Don	40.00	40.00	4000	4000	1.00	1.00	**7.81**	**8.38**
Commelina benghalensis L.	-	40.00	-	4000	-	1.00	-	**8.11**
Cyperus rotandrus L.	-	40.00	-	4000	-	1.00	-	**7.98**
Diclyptera bupleuroides	80.00	-	18000	-	2.25		**31.45**	
Eupatorium glandulosum Michx.	40.00	40.00	12000	6000	3.00	1.50	**22.37**	**17.48**
Ipomoea fistulosa Mart. ex Choisy	-	20.00	-	4000	-	2.00	-	**5.34**
Mallotus philippensis (Lam.) Muell.-Arg.	20.00	-	2000	-	1.00	-	**10.15**	-
Murraya koenigii Spreng.	-	60.00	-	12000	-	2.00	-	**38.84**
Oplismenus compositus (L.) P. Beauv	80.00	60.00	28000	6000	3.50	1.00	**21.20**	**11.92**
Oxalis corniculata (L.) L	-	40.00	-	4000	-	1.00	-	**8.34**
Randia dumetorum Lamk.	20.00	-	2000	-	1.00		**10.83**	-
Rumex hastatus D. Don.	-	20.00	-	4000	-	2.00	-	**5.32**
Sida humillis Willd.	20.00	40.00	4000	6000	2.00	1.50	**4.42**	**9.42**

Bhatt 1990 has reported the presence of *Eriophorum comosum, Pennisetum purpureum* and *Saccharum spontaneum* after 8 years of restoration in the same area but after 23 years of succession these species has been replaced by higher successional species. The critical examination of the data shows that although some of the planted species like *Agave sisalana, Dodonea viscosa* and *Rumex hastatus* are still present but their density has declined considerably through the entire period of successional development. The widespread dominance of natural invaders like *Eupatorium glandulosum, Desmodium gangeticum Artemisia vulgaris, Boehmeria platyphylla, Woodfordia fruticosa, Lantana camara* indicates that the restored site is proceeding towards similar characteristics of the adjacent natural forest. It is interesting to note that while natural invaders recorded an increase in the percentage contribution to overall density, the species introduced initially showed an increasing mortality. These findings support the earlier studies which show that planted species do not persist because local species required less maintenance and provide compatibility with surrounding sites (Luken, 1990).

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