Land use - Land cover classification in Koothy village, the Western Ghats benchmark site for sustainable management of Below Ground Biodiversity (BGBD)

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ABSTRACT

The present study deals with the characterization of land use/land cover types in Koothy village, Kodagu District as part of the Below ground biodiversity project. The satellite remote sensing data has been used to for delineation of land use/land cover types. The Hybrid classification approach has been adopted for classification. Six different land use/land cover types were delimited in the study area using satellite data of IRS -1D- LISS III data of the year 2000. The coffee and cardamom plantations occupied major portion of the study area and they are the dominant land use/land cover types in the area. The natural forests represented by only 6% of the area. Phytodiversity was measured using 60 0.1 ha triangular plots. Phytodiversity was analyzed using diversity indices and importance value index. Highest Shannon-Wiener diversity was recorded for natural forests followed by coffee and cardamom plantations. Importance value index revealed the dominance of *Caryota urens* in natural forests, *Olea dioica* and *Grevillea robusta* in cardamom and coffee plantations, respectively. The soil parameters were analyzed according to standard methods. Physical properties of the soil in the study have similar characteristics across the land use/land cover types but chemical properties vary significantly ($P < 0.05$). Cluster analysis of the soil parameters showed two distinct group of land use/land cover types with natural forests, coffee and cardamom plantations as one group with greater similarities and other forming the second group which included paddy, acaccia plantation and grasslands. The present study gives an ideal environment for studying the above ground and below ground diversity and their interactions. Remote sensing techniques are very much useful for studying interdisciplinary aspects.

INTRODUCTION

Biodiversity, is the variety of living organisms considered at all levels of organization, from gene through species, to higher organization levels including habitats and ecosystems. Global Biodiversity Assessment (Heywood 1995) estimates the total number of animal and plant species to be between 13 and 14 million. It further records that, so far only 1.75 million species have been described and studied. UNEP-WCMC (2000) estimates around 270,000 species of vascular plants and 52,000 animals (vertebrates).

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The biological diversity is dwindling at an alarming rate in recent years due to the increasing anthropogenic pressure on natural habitat. The relationship between anthropogenic pressure and biodiversity is a complex. The holistic understanding of the complex mechanisms that control biodiversity, their spatial and temporal dynamics, requires synergetic adoption of measurement approaches, sampling designs, and technologies. In view of this, importance of satellite remote sensing, Global Positioning System (GPS), integrative tools, such as Geographical Information System (GIS), and information systems, is realized as a complimentary system to ground-based studies. One of the basic requirements for sustainable management is building up of information on the natural resources and process of utilization.

The primary goal in developing these products are to study the interaction between the above ground and below ground diversity and to better understand the role of human impacts on earth systems through land cover conversions.

REVIEW OF LITERATURE

Over the recent years, researchers have increasingly turned to use satellite remote sensing data to improve the accuracy of datasets that describe the geographic distribution of land cover /land use classes at regional and global scales (Townshend *et al*., 1991, DeFries and Townshend, 1994). Satellite remote sensing has played a pivotal role in generating information about forest covers, vegetation type and land use changes (Roy, 1993).

The use of Remote sensing as a tool for analyzing environmental, cultural and natural resource management characteristics is well documented (Dutt *et al*., 2002; Huimin *et al*., 2007; Nagendra, 2001; Lillisend and Kiefer 1987; Jenson 1989). An extensive study was conducted in the Indian sub-continent, covering three major bioclimatic regions, viz. Northeast India, Western Himalayas and Western Ghats, with the use of concepts of landscape analysis to identify biologically rich zones (IIRS, 2002)..

Satellite data have also been shown to be useful in monitoring forest vegetation vigor and species distributions (Walsh 1980; Benson and De Gloria 1985; Franklin *et al*. 1986). GIS provides the way to overlay different layers of data, the ecological conditions, the actual vegetation physiognomy and human pressure indices. The vegetation spectral response can also be used to infer various soil conditions.

Yang and Anderson (1996) used vegetation spectral responses to define management zones within fields. The management zones are an aid to soil sampling as they define logical boundaries for obtaining samples. Remotely sensed images are also being used in “directed soil sampling” where one can map “soil management zones” which would be sampled as separate units.

There is meager literature available on the analysis of phytodiversity across the natural and agro-ecosystems. In this context the present paper deals with the land use land cover classification using remote sensing and GIS and phytodiversity study including different life forms in Koothy village, Western Ghats, a bench mark site for studying the below ground biodiversity (BGBD) and its relativity with above ground biodiversity (AGBD) via soil interface. An analytical approach to relate the BGBD and AGBD with soil physio-chemical characters in natural and man-made agro ecosystem is attempted.

MATERIALS AND METHODS

Study area

The benchmark area, village Koothy (Somwarpet Taluk, Kodagu District) is located close to the northern boundary of the Karnataka part of the Nilgiri Biosphere Reserve (Figure 1). This biosphere reserve is the oldest reserve in the country established in the year 1986. It includes two of the ten bio-geographical provinces of India viz. West coast and Western Ghats.

The annual rainfall of the area ranges from 2000 to 3500 mm. Most of the rainfall is drawn from southwest monsoon during June-August period. Four seasons can be clearly distinguished: summer from March to May, monsoon from June to September, post-monsoon from October and November, and clear bright dry weather during December to February. The temperature begins to increase from March to April, with a mean daily maximum of 28.6^{o}C and mean daily minimum of 17.8^{o}C. Temperature on some individual days may be as high as 34 or 35^{o} C during April or May. The daily minimum temperature is lowest during January, dipping down to 9^{o} C.

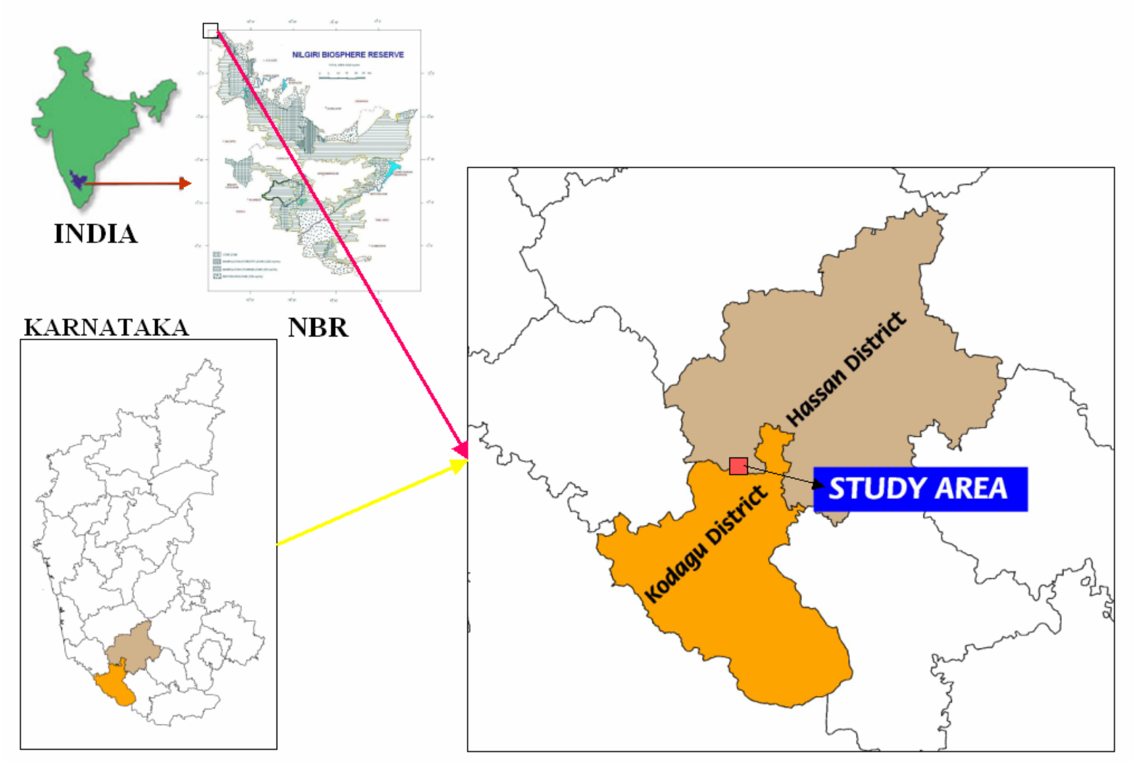

Figure 1: Location map of the study area – Koothy, Somwarpet taluk, Kodagu, Karnataka.

Major part of the study area was covered by coffee and cardamom plantations. The natural forests found in the periphery of the plantation and, are of Evergreen types with varying levels of degradation. There are few patches of *Acacia auriculiformis* plantation (monoculture) and grassy blanks. Rain fed agriculture is practiced in the valleys. Paddy is the major crop of rainy season. Chilly and short duration grain legumes are also grown in the summer season, utilizing the residual moisture together with sparse rainfall of Northeast monsoon.

Land use / Land cover mapping

Satellite data (IRS -1D- LISS III data of the year 2000, path 98 and row 64) was interpreted to prepare land use/land cover map of the study area at 1:50,000 scales. Hybrid classification approach was adopted. A mask was created for the almost non-overlapping classes (viz., agriculture areas and vegetated areas) obtained from unsupervised classification (using ***isodata*** algorithm). The vegetated areas were further classified into forests, grasslands, coffee/cardamom plantation and forest tree plantations by supervised classification (***maximum likelihood*** classification algorithm). The outputs obtained from unsupervised and supervised methods were merged to get the hybrid output. Classified output was draped over Digital Elevation Model

(DEM), misclassified patches identified and necessary corrections were incorporated. A 200 m grid was overlaid on the map and 60 intersection points were sampled for aboveground/belowground biodiversity studies. The sample points identified on the map were reached in the field using handheld ***Garmin 12*** Geographical Positioning System.

At each sampling point a triangular plot of the size 50 m x 50 m x 50 m was laid. Trees (saplings and seedlings are not considered for the study only trees with girth >= 30 cm at breast height were recorded) and shrubs were recorded (number of individuals of each species) in whole of the triangular plot. Herbaceous species were recorded in three 1 m x 1 m sub-plots at the three corners of the triangular plots. Diversity index was calculated for trees, shrubs and herbs separately using the following formula (Maguran 1988).

$$H' = \sum_{i=1}^{s} \left(\frac{n_i}{N}\right) \log_2 \left(\frac{n_i}{N}\right)$$

Where H' - Shannon-Wiener index of diversity

n_i - Number of individuals of i^{th} species

N - Total number of species present in that vegetation type

For studying species dominance in each land cover classes, Importance Value Index was calculated using relative frequency and Relative density.

IVI = Relative Frequency + Relative Density

$$\text{Relative Frequency} = \frac{\text{Frequency of the species}}{\text{Total frequency of all species}} \times 100$$

$$\text{Frequency} = \frac{\text{No. of plots in which species occur}}{\text{Total no of plots studied}} \times 100$$

$$\text{Relative Density} = \frac{\text{No. of individuals of the species}}{\text{Total no. of individuals of all species}} \times 100$$

The soils of the study region are fine, kalonitic kandi paleustalfs of the order alfisol. The texture of the soil is sandy loam. The soil samples collected from the two depths (0-10 cm and 10-30 cm) were analyzed for soil physico-chemical properties following standard methods (Anderson and Ingram, 1993). Cluster analysis was performed to study the similarities between the land cover classes. Stastistica for Windows software package was used for the study. Eleven-soil parameter was used to perform the cluster analysis with Ward's method as clustering technique and Euclidian distance as distance measure.

RESULTS AND DISCUSSION

Land use / Land cover types

Five land use – land cover types could be distinguished in the study area (Figure 2):

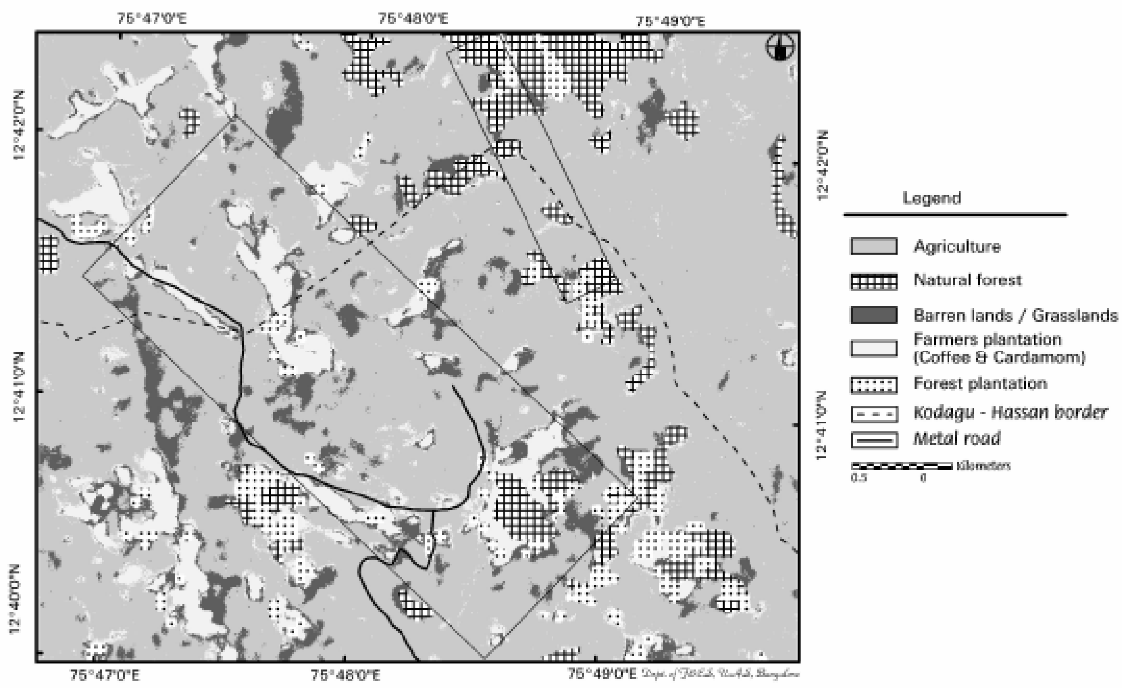

Figure 2: Land use / Land cover map of the study area based on interpretation of the Indian Remote Sensing Satellite data (IRS 1D LISS III of the year 2000).

(a) Natural forests - these are the patches of forests adjacent to coffee and cardamom plantations. The forest is of disturbed evergreen type.

(b) Cardamom/coffee plantations - because of similarity in spectral as well as contextual attributes, coffee and cardamom plantations were put together

(c) Forest tree plantations - these are the monoculture plantations of *Acacia auriculiformis* and are raised as part of the aforestation program in the open and in disturbed areas, to avoid the further encroachment of forestland for cultivation by farmers

(d) Agriculture – rain fed paddy is the main agriculture crop of the region

(e) Grasslands - these are the open patches found in slightly elevated regions and also adjoining agricultural areas.

The area distribution of the different land cover classes is given in figure 3.

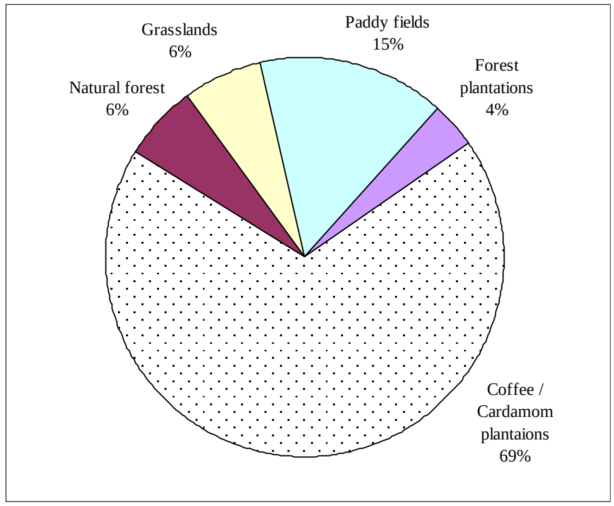

Figure 3: Area distribution of different land cover types based on satellite data

Phytosociological Analysis

The summarized data of phytosociological analysis is given in Table 1. A lower tree density in coffee plantations compared to cardamom plantations can be attributed to the regular thinning of trees in case of coffee but not in cardamom which performs better in highly shaded micro-environments. The herb density is more in forest plantations and grasslands. Shrub density is more in natural forest followed by cardamom plantations.

Variation in diversity (Shannon-Wiener index) is shown in Figure 4. The diversity value varies significantly ($P < 0.01$) across the land cover types for trees and herbs, but not for shrubs. Highest diversity value for trees and shrubs was observed in natural forests (index value of 5.6 and 3.9 respectively) while for herbs it was in forest plantations (index value of about 4.2).

A total of 113 tree species were identified from the study area and it was high in natural forests with 77 species followed by cardamom plantations with 73 species. Number of tree in coffee plantations is slightly lesser compared to cardamom and could be attributed to selective thinning in coffee plantations. *Caryota urens* is the dominant species in natural forests. *Olea dioca* and *Grevillea robusta* are the dominant in cardamom and coffee plantations respectively.

Thirty-one shrubs were identified from the study area. Out 31 species 22 species found in natural forests, 17 species in cardamom plantations, 10 species in coffee plantations and 6 species in grasslands. *Leea indica* is the dominant shrub in natural forests, cardamom plantations and coffee plantations, whereas *Lantana camara* is the dominant shrub in grasslands and forest tree plantations.

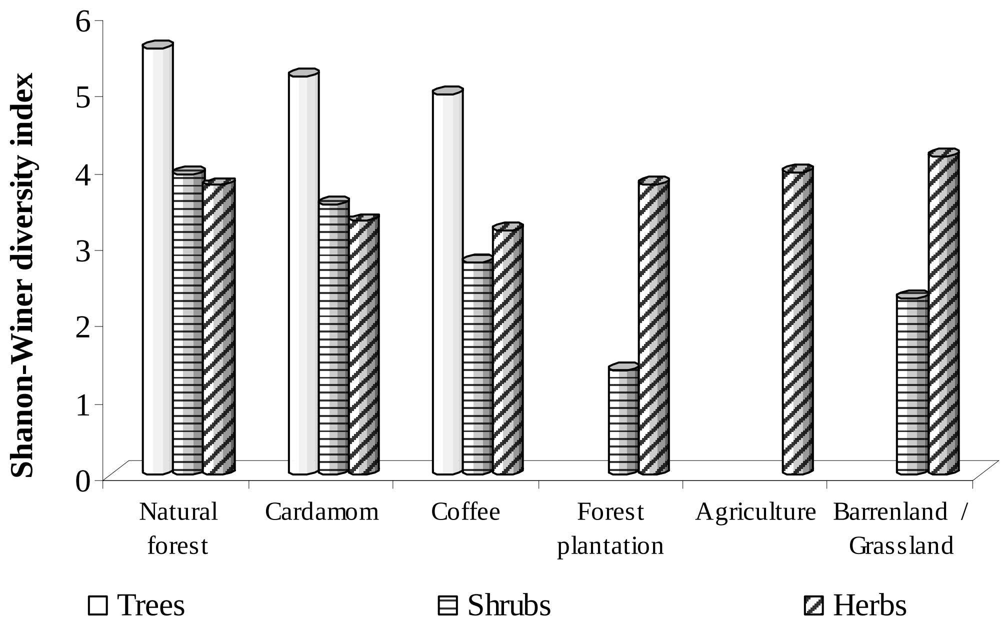

Figure 4: Species diversity (Shannon-Wiener index) across land cover classes

Since sampling is done in dry season much of the ground flora was mostly dried up. The ground flora varies with the season. The enumerated herb species accounted for 92 species. Highest number of herb species was recorded in paddy fields with 47 species and the enumeration was done after the harvesting of the crop, followed by grasslands with 37 species and least in natural forests. Though the herb density was high in forest plantations, the number of species was lesser compared to paddy fields and grasslands, and higher density of herb species could be attributed to the competitiveness of those herb species under *Acacia auriculiformis* cover. *Brachiaria milliformis* was the dominant herb in natural forests, cardamom and coffee plantations. *Panicum repens* is the dominant species in paddy fields and grasslands, whereas *Stachytarpheta indica* was the dominant species forest plantations.

The Importance Index Value of 5 dominant species from tree, shrub and herb community for all the land cover types is given in the Table 2.

Table 1: Phytosociological analysis of different land use systems

Land cover types	Parameters	Natural Forest	Farmer plantation		Forest plantation	Agriculture	Grasslands
			Cardamom	Coffee			
Tree community	No. Species	77	73	6	-	-	5
	Actual density	401	517	556	-	-	10
	Density (ha^{-1})*	411 ±18.22	367 ±17.44	321 ±15.43	-	-	46 ±01.41
	Shanon-Wiener Diversity $	5.6 ± 0.35	5.2 ± 0.33	4.9 ± 0.47	-	-	-
Shrub community	No. Species	22	17	10	3	-	6
	Actual density	74	53	30	9	-	16
	Density (ha^{-1})**	75 ±04.58	40 ±03.48	39 ±02.93	16 ±00.84	-	36 ±03.56
	Shanon-Wiener Diversity $$	3.9 ± 0.78	3.5 ± 0.84	2.8 ± 0.69	1.4 ± 0.45	-	2.3 ± 0.58
Herb community	No. Species	23	25	24	28	47	37
	Actual density	279	210	199	371	270	317
	Density (ha^{-1})***	146842 ±34.14	58333 ±06.33	76538 ±10.83	206111 ±25.54	122727 ±13.61	137826 ±17.72
	Shanon-Wiener Diversity $	3.9 ± 1.11	3.3 ± 0.51	3.2 ± 0.78	3.8 ± 0.56	3.9 ± 1.05	4.2 ± 0.5

* - Significant (P=0.01), ** - Significant (P=0.03) 7 *** - Non-significant (P<0.05)
$ - Significant (P= 0.00), $$ - Non-significant P<0.05)

Table 2: Importance Value Index of five dominant species in each land use for tree, herb and shrub community.

Land use type	Tree community	IVI	Herb community	IVI	Shrub community	IVI
Natural Forest	*Caryota urens*	10.92	*Brachiaria milliformis*	20.00	*Leea indica*	29.79
	Olea dioica	9.67	*Pteris sp*	10.91	*Dichapetalum gelonioides*	20.33
	Canthium dicoccum	7.86	*Justicia trinervia*	7.27	*Flacourtia indica*	18.98
	Artocarpus heterophyllus	7.61	*Maranata sp*	7.27	*Scelropyrum walichianum*	17.95
	Dimocarpus longan	7.55	*Blumea barbata*	5.45	*Nilgirianthus heyneanus*	14.93
Cardamom	*Olea dioica*	14.31	*Brachiaria milliformis*	24.60	*Leea indica*	48.81
	Litsea floribunda	14.17	*Justicia trinervia*	16.67	*Psychotria octosulcata*	20.90
	Caryota urens	14.03	*Pteris sp*	8.73	*Flacourtia indica*	19.69
	Cinamomum zeylanicum	11.23	*Asystacia gangetica*	8.73	*Maesa indica*	17.80
	Artocarpus heterophyllus	9.77	*Justicia sp. (glandular)*	7.94	*Nilgirianthus heyneanus*	13.35
Coffee	*Grevillea robusta*	17.98	*Brachiaria milliformis*	18.46	*Leea indica*	48.81
	Caryota urens	14.03	*Justicia trinervia*	12.31	*Lantana camara*	8.90
	Artocarpus heterophyllus	12.51	*Ageratum conyzoides*	7.69	*Memecylon malabaricum*	0.00
	Cinamomum zeylanicum	10.84	*Blumea barbata*	7.69	*Flacourtia indica*	19.69
	Acrocarpus fraxinifolius	10.84	*Achyranthes aspera*	6.15	*Maesa indica*	17.80
Forest plantation			*Stachytarpita indica*	17.35	*Lantana camara*	105.56
			Brachiaria milliformis	12.24	*Maesa indica*	66.67
			Centella asiatica	11.22	*Randia dumetorum*	27.78
			Blumea barbata	8.16		
			Sporobolus diander	6.12		
Agriculture			*Panicum repens*	10.53		
			Grangia maderaspatna	10.53		
			Centella asiatica	8.27		
			Blumea barbata	7.52		
			Cynodon dactylon	3.76		
Grassland			*Panicum repens*	9.48	*Lantana camara*	67.61
			Stachytarpita indica	8.62	*Phoenix himulis*	40.34
			Sporobolus diander	5.17	*Maesa indica*	30.68
			Borreria articularis	5.17	*Breynia retusa*	30.68
			Oldenlandia corymbosa	5.17	*Flacourtia indica*	15.34

Physical and Chemical properties of soil

Variation in the physical properties of the soil of different land use types were statistically non-significant ($P > 0.05$, Table 3). However, statistically significant variations were observed in the chemical properties of soil of different land use types (Table 4). The pH was comparatively low in grassland, *Acacia* Plantation and paddy (less than 6) than natural forest, coffee and cardamom plantations (more than 6). This could be attributed to the heavy rainfall in the area leading to washing of topsoil in grassland, *Acacia* Plantation and paddy thus lowering of the soil pH. But in natural forests, coffee and cardamom plantations, the presence of tree canopy and litter cover put a break to the leaching of topsoil, hence the soil pH is comparatively higher. Low organic matter in the soil also reduces the soil pH (Kataki, 2001). Continuous cropping may also reduce the soil pH (Maida and Chilima, 1981). Further, the acids produced by the soil microorganisms and the acidic exudates from the roots of higher plants also influence the soil pH (Nyle and Ray 2001). The exchangeable potassium is also higher in natural forest, coffee and cardamom plantation and are not on par with other land cover classes. But the exchangeable acidity and exchangeable sodium is markedly high in paddy fields compared to other land cover classes. Obviously, the soil organic carbon is higher in natural forest, coffee and cardamom plantations, because of the litter accumulation and canopy cover. Singh and Ganeshmurthy (1991) also noticed in Andaman Islands that organic carbon was higher in soils under forest cover and lowest in paddy fields, and intermediate in plantation.

Table 3. Physical properties of the soil in different ecosystem at Koothy, Western Ghats benchmark site.

Parameters	Natural Forest	Grasslands	Forest plantation	Farmers plantation		Agriculture	F-test
				Cardamom	Coffee		
Bulk density (g/cm^3)	1.20	1.42	1.41	1.17	1.270	1.21	NS
Sand	61.69	62.83	62.73	61.17	61.17	60.18	NS
Silt	26.35	23.17	23.93	24.28	25.1	23.6	NS
Clay	14.06	16.97	14.13	14.14	13.88	16.1	NS

Table 4. Chemical properties of the soil in different ecosystem at Koothy, Western Ghats bench mark site.

Parameteers		Depth	Natural Forest	Grassla nd lands	Forest plantation	Farmers plantation		Agriculture	F-test
						Cardamom	Coffee		
pH	Water extract	0-10 cm	6.2^{a}	5.57^{c}	5.51^{c}	6.31^{a}	6.16^{a}	5.30^{c}	S
		10-30 cm	6.21^{a}	5.57^{c}	5.56^{c}	6.16^{a}	6.18^{a}	5.50^{c}	S
	KCl extract	0-10 cm	5.24^{ab}	4.37^{c}	4.43^{c}	5.30^{a}	5.03^{ab}	4.21^{c}	S
		10-30 cm	5.13^{ab}	4.32^{c}	4.36^{c}	5.20^{a}	4.95^{ab}	4.42^{c}	S
Exchange Acidity (meq. 100 g-1)		0-10 cm	2.88^{ab}	7.06^{c}	7.16^{c}	2.5^{a}	3.21^{ab}	8.0^{c}	S
		10-30 cm	3.05^{ab}	6.75^{c}	6.66^{c}	2.07^{a}	2.75^{ab}	6.37^{c}	S
Organic –C (%)		1-10 cm	3.77^{ab}	2.28^{c}	2.33^{c}	4.01^{ab}	3.70^{a}	1.16^{c}	S
		10-30 cm	2.59^{ab}	1.80^{c}	1.73^{c}	3.14^{ab}	2.79^{a}	1.11^{c}	S
Total –N (%)		0-10 cm	0.48^{ab}	0.29^{c}	0.34^{ab}	0.50^{a}	0.47^{ab}	0.32^{c}	S
		10-30 cm	0.37^{a}	0.28^{c}	0.30^{ab}	0.44^{a}	0.40^{ab}	0.19^{c}	S
Exchange. Na C mol (P^{+}) kg-^{1} soil (1 M Ammonium acetate extraction)		0-10 cm	0.0041	0.0037	0.0035	0.0036	0.0052	0.0041	NS
		10-30 cm	0.0041	0.0036	0.0035	0.0037	0.0380	0.390	NS
Exchange K C mol (P^{+}) kg-^{1} soil (1 M Ammonium acetate extraction)		0-10 cm	0.659^{a}	0.364^{c}	0.228^{c}	0.634^{ab}	0.600^{ab}	0.178^{c}	S
		10-30 cm	0.432^{a}	0.228^{c}	0.680^{c}	0.680^{ab}	0.666^{b}	0.240^{c}	S

S - Significant, NS - Non-significant ($P<0.05$)
Mean values followed by the same superscript in each row do not differ significantly at P=0.05 level by DMRT

The cluster analysis showed two distinct groups with forest plantation, paddy and grassland as one group and natural forests, coffee and cardamom plantations as another group (Figure 5). This clearly indicates the similarity of soil parameters with respect the land use types.

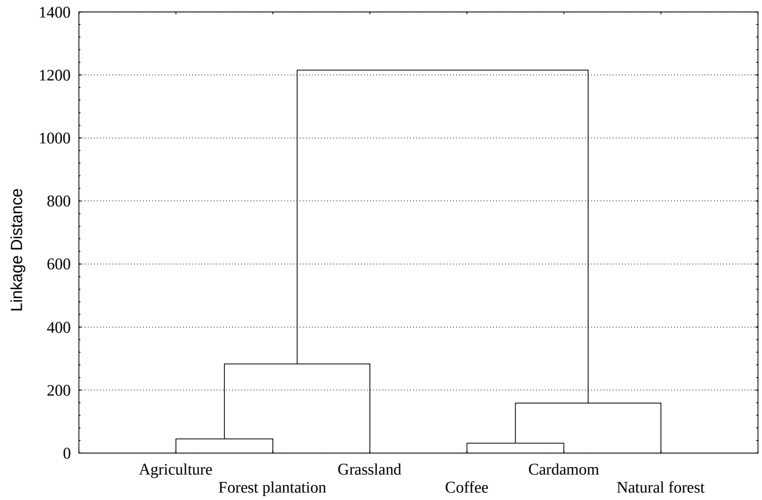

Figure 5: Cluster analysis of soil parameters with different land use systems

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