FINAL TECHNICAL REPORT – PHASE I

CONSERVATION AND SUSTAINABLE MANAGEMENT OF BELOWGROUND DIVERSITY IN THE KARNATAKA PART OF NILGIRI BIOSPHERE RESERVE

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SYNTHESIS REPORT

Conservation and Sustainable Management of Belowground Biodiversity

The research work carried out in the benchmark area, Koothy village of Somwarpet taluk is located in the Kodagu district of Karnataka. This bench mark area is situated very close to the Nilgiri Biosphere Reserve at the northern region and lies between $12^0 40^1 03^{11}$ N–$12^0 42^1 19^{11}$ N and $75^0 47^1 10^{11}$ E–$75^0 79^1 14^{11}$ E. The annul rainfall of the area ranges from 2000 mm to 3500 mm. Most of the rainfall is drawn from southwest monsoon during June-August period. The temperature begins to increase from March to April with a mean daily maximum of 28.6^{o}C and a mean daily minimum of 17.8^{o}C. The temperature on some days might be as high as 32 to 35^o C during April or May. The daily lowest temperature of around 9^o C is recorded during the month of January.

Coffee and cardamom plantations cover major part of the study area. The natural forests are found in the periphery of the plantations, which are evergreen with varying levels of degradation. A few patches of *Acacia auriculiformis* plantations (monoculture) and grassy blanks are found adjacent to the forests. Rain-fed agriculture is practiced in the valleys with one paddy crop every year during the rainy season. Additionally, crops like chilly and short duration grain legumes are also grown in summer utilizing the residual moisture and 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 scale. Hybrid classification approach was adopted. A mask was created for almost non-overlapping classes (*viz*., agriculture areas and vegetated areas) obtained from unsupervised classification (which algorithm??). The vegetated areas are further classified into forests, grasslands, coffee/cardamom plantations 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) (Plate 1), misclassified patches identified and necessary corrections were incorporated. Six land use – land cover types could be distinguished in the study area. They are natural forest, grasslands, acacia plantations, coffee plantations, cardamom plantations and paddy fields.

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.

A total of 60 sample points were distributed in two windows of size 6.4 sq km (4 x 1.6 km) and 0.8 sq km (0.4 x 2 km) so as to cover all the above said land cover types. Fifty-three sample points were distributed in the first large window and seven points in the second small window. Stratified sampling technique was adapted and two windows were selected, because the first large window that was selected did not have enough natural forests, grasslands and

Acacia plantations. Hence, additional window in the study site was selected to cover the required land use types.

The sample points were laid in the intersection point of the windows and were located in the ground using hand held ***Garmin 12*** GPS. These intersection points at which sampling could not be done due to the presence of a natural obstruction (presence of a tree, stone/water body etc.) were skipped and the next sampling was done in the next intersection point.

Population of different functional groups:

The population of *Azotobacter* and P-solubilizing microorganisms was much higher in natural forests except for AM fungi in terms of infective propagules and legume root nodulating bacteria in the pre-monsoon season (Table-1). In grasslands the number of infective propogules of AM fungi, the population of legume root nodulating bacteria (LNB) and *Azatobacter* showed a similar trend as in natural forests, whereas no such variation was observed between two seasons for the other groups. In Acacia plantations, LNB were high in the pre-monsoon season than in the post monsoon season. But *Azatobacter* & P- solubilizers showed a low degree of density, while the population of LNB and AM fungi were at very high levels. A similar trend in the population of studied microbial groups was observed in coffee and cardamom plantations and paddy fields as that of natural forests.

The density of population of *Azatobacter* is influenced both by the season as well as by the above ground diversity. The total diversity of trees, shrubs and herbs, which is maximum in natural forests has supported, highest population of *Azatobacter* colonies followed by cardamom and coffee plantations. The grasslands, Acacia plantations and paddy fields that exhibited a poor diversity in the aboveground vegetation has very low density of *Azotobacter*. The population of *Azotobacter* has remained at a high level during the pre-monsoon season compared to the post-monsoon season.

The population of P – solubilizing fungi and bacteria has shown to be in very low levels in all the ecosystems other than the natural forests. Only in natural forests, the influence of seasons is well established unlike in other ecosystems. In the study site area, the social forests, agricultural and fallow lands are not supportive of the establishment of this group and it requires further investigations to understand their ecology

In case of AM fungi, the pattern of colonization has remained more or less the same in all the ecosystems except in paddy where the levels are very low and not much variation is observed with respect to seasons. The spore density was found to be higher during both the pre and post – monsoon seasons in grasslands and Acacia plantations and was less than 50% of the density observed in all the other ecosystems irrespective of the seasons. The infective propogules were also more in Acacia plantations and least in paddy ecosystems. The above ground diversity seems to have much influence on the population of AM fungi rather than the soil structure.

The effect of season is more pronounced on legume nodulating bacteria in Acacia and coffee plantations where their maximum density was observed in the pre-monsoon season while it was in the post-monsoon season, very low density of this group was observed in the natural forests. Their density could be associated with the above ground legume plants that could promote the symbiotic association. But, the correlation for this factor is non-significant.

Earthworms that form the major soil macro fauna were found to be of least importance in pre-monsoon season and the collection had a very few earthworms of species of *Pantoscolex corethrurus* and some immature stages of the genus *Drawida*. Because of this, data is not reported for the pre-monsoon season. However, in the post-monsoon season 17 species of earthworms were collected from different ecosystems. The maximum species diversity and highest density of earthworms were recorded in coffee plantations followed by natural forests. The earthworm activity, their density and diversity were independent of the micro floral distribution in the representative ecosystems included in the study. No correlations could be drawn between the two groups except for LNB. Similarly, maximum distribution of earthworms during this season was restricted to 0 – 10 cm followed by 10 – 20 cm depth and very few earthworms were collected at 20 - 30 cm depth.

The litter feeders and organisms inhabiting 'O' horizon were predominant in the post-monsoon than in the pre-monsoon season. As in case of earthworms, the highest density and maximum diversity of litter organisms were found in coffee plantations. The litter cover of the highly diversified above ground flora in coffee plantations seems to be the preferred habitat for earthworms and litter fauna. The post-monsoon season having a moisture level suitable for their activity showed maximum diversity and density of earthworms and litter fauna. The soil fauna other than the earthworms were higher in 0 – 10 cm depth and their density and diversity was higher in coffee plantations in the pre-monsoon season. This was followed by cardamom plantations and natural forests. The population density and diversity of these invertebrates in paddy fields were on par with coffee plantations. Least populations of these organisms were found in grasslands and Acacia plantations.

The study suggests that the soil faunal structure changes with the seasons and soil invertebrates other than earthworms; especially different groups of arthropods with impervious cover and smaller body size were predominant in the dry season. The soft bodied earthworms without protective body cover and soft-bodied arthropods were predominant in the post-monsoon period.

In general, the itinerary of soil community structure at the study site has provided scope to judiciously modify the community structure to suit to promote low input agriculture.

Correlation between physical and chemical characters and functional groups:

The physical and chemical composition of the soil at the study site and the phosphatase activity in the soil samples as a biochemical parameter were considered to relate the different groups of organisms in the community to the existing edaphic factors (Table-2). It was found that AM fungi and *Azatobacter* in the pre-monsoon season showed significant positive correlation to organic carbon content of the soils whereas soil and litter invertebrates other than the earthworms showed a negative correlation to the organic carbon content whereas the population of earthworm was unaffected. The earthworms showed significant positive correlation to clay and silt content and negative correlation to the sand content that was not statistically significant. The existing earthworm population is highly influenced by the soil structure. Similarly, the other invertebrates showed positive correlation to clay and silt content and significant negative correlation to sand content. P-solubilizers and *Azatobacter* exhibited a significant positive correlation to sand content and negative correlation to clay and silt content. The results clearly show that these two groups require well aerated soils with high level of organic carbon for their existence and activity. Unlike as

in case of P-solubilizers, the bulk density also affected the colonization of *Azatobacter* and seasons seems to influence this relationship. Similarly, the influence of seasons on the response of invertebrates other than earthworms to bulk density is observed in this study. Legume nodulating bacteria are unaffected by the organic carbon content or the other soil physical properties other than the clay content that showed significant positive correlation in the pre-monsoon season and bulk density that showed significant negative correlation in the post-monsoon season.

The N levels in soils has significant positive influence on P-solubilizers, LNB and soil invertebrates other than earthworms in post-monsoon season and negative effect on *Azatobacter*. This is an indication to show that *Azatobacter* fails to establish itself in soils having high levels of inorganic N and thus the natural process of N- fixation is adversely affected. Just as *Azatobacter* is affected by high levels of N, P-solubilizers as well as *Azatobacter* are negatively affected by the total and available- P in the soil. Other than the highly positive response of LNB, the other microorganisms are unaffected by levels of K. The earthworms and other soil invertebrates have positive relationship with K levels in soils. As these organisms depend on highly degraded plant material, the K in the degraded matter at different levels of decomposition could be associated with this correlation.

From this correlation study, it is clear that the soil structure is responsible for the diversity and abundance of soil invertebrates and chemical properties for the abundance of important functional groups of microorganisms like N-fixers and P-solubilizers. The symbiotic groups like LNB are not directly affected by the edaphic factors.

Correlation between different functional groups:

The inter-relationships of different functional groups are tested by using correlation matrix (Table-3). The results have shown that these relationships among different groups are significantly negatively or positively correlated depending on the seasons and in some cases no such relationship was observed. The establishment of AM fungi is negatively affected by P-solubilizers and LNB in the post-monsoon season and by litter invertebrates in the pre-monsoon season. The P-solubilizers, N-fixing *Azatobacter* and LNB exhibited a positive relationship. LNB have a highly significant association with earthworms. Earlier studies carried out in our laboratory have shown such a stimulatory effect on nodulation in cowpea seeds treated with the coelomic fluid of earthworms and grown in pots amended with vermin-compost. (Unpublished data). Thus, burrows of earthworms coated with their body fluid under field conditions may have stimulatory effect on LNB. The other soil invertebrates and litter fauna show stimulatory effect only on *Azatobacter* and they also have a positive correlation with earthworm populations. Such observations have also been made under green house conditions.

Correlation between the above ground and belowground biodiversity:

The above ground flora mostly has a positive influence on soil micro flora whereas a significant influence of tree population on earthworms is observed. The other soil invertebrates are not much affected or negatively affected by the above ground flora (Table 4).

Benchmark Survey of the Study site village

The overall objective of the benchmark survey of the study site village Koothy in Somwarpet, Coorg district, Karnataka was to document farmers' present status of agricultural activities, their land holdings, livestock, economics of major crops/activities, resource inventory, their present farming practices related to BGBD, farmers awareness about BGBD etc.

The data for the benchmark survey was collected through a pre-tested structured schedule from a random sample of 60 out of 160 farm families of the study village. Sample respondent farmers were post classified as small, medium and large farmers based on their landholdings. A farmer with a landholding of less than 2 ha was considered as a small farmer, farmers with farm size between 2 ha and 4 ha were treated as medium farmers and those farmers who had land holdings more than 4 ha were reckoned as large farmers. The data were analyzed using simple statistical measures such as measures of central tendency (mean etc.), chi-square test etc.

The geographical area of Koothy village is about 962 ha. Agriculture accounts for about 68 per cent of the total village area compared to 19 per cent of forest area. More than 90 per cent of the village population is directly dependent on agriculture for their livelihood. The study region comprises of mostly marginal and small farmers who constitute more than 40 per cent, but the aggregate area owned by them was disproportionately lower. There is a greater inequity in the distribution of land holdings in the study area.

Livestock in the study village largely comprises of cows (23.23% of total livestock population), buffaloes (10.97%) and poultry (51.77%). Animal husbandry is not a major economic activity due to high level of humidity and low milk yield.

Major crops in the study village are paddy and horticultural crops including plantation crops. Paddy, the staple food crop, occupies about 24 per cent of the total net cropped area. Horticultural crops like chilies and other vegetables occupy significant area especially during the summer season. The study region is home for plantation crops like coffee, cardamom, pepper etc.

The literacy level in the village is very high as more than 90 per cent of the population as well as sample farmers have formal education. The mean literacy level of the farmers who have awareness about BGBD and those who do not have any awareness was almost the same. Most of the respondents were young farmers whose age was about 30 years. The major occupation of the respondents is agriculture and about one third of the families are engaged in agricultural wage labour. The average annual income of the farmers who have awareness about BGBD is higher (Rs. 61589) than those who do not have awareness about BGBD (Rs. 54304). Out of 60 sample respondents, about 42 per cent were small, 28 per cent medium and 30 per cent large farmers. The average size of land holding of small farmers is 0.9 ha while that of medium and large farmers is 1.5 and 4.35 ha, respectively. More than half (68.33%) of the farmers owned coffee plantations. About 48 per cent of the farmers owned cardamom plantations. About 13 per cent of the farmers owned both coffee and cardamom plantations in the study area.

It is surprising to note that only 45 per cent of the respondents have some knowledge and awareness about BGBD and their uses. The remaining 55 per cent of the

respondents do not have awareness about BGBD. In general, the farmers know the existence of various types of BGBD and some of them could identify their beneficial as well as harmful roles. The low awareness of BGBD among the farmers could largely be attributed to lack of sensitizing/extension programmes on the part of the developmental departments on BGBD programmes. The farmers do not have much knowledge about the N- fixing organisms and organisms involved in nutrient cycling. The common BGBD practices followed by the farmers in the study area are composting, green leaf manuring etc. Incorporation of weeds into the soil is another practice commonly followed by them. Ploughing back paddy crop stubbles and residues to the soil is another major BGBD practice followed.

The major reasons for non-adoption of BGBD practices by the farmers are lack of awareness of BGBD, their benefits, lack of technical know-how, non-availability of inputs locally and difficulty in the adoption of BGBD practices.

Table 1. Population density of above ground flora and soil biota in different land use types in year 2004 during pre and post- monsoon seasons.

Sl. No.	Flora / Fauna	Natural forests		Grasslands		Acacia plantations		Cardamom plantations		Coffee plantations		Paddy fields	
		Feb '04	Nov '04	Feb '04	Nov '04	Feb '04	Nov '04	Feb '04	Nov '04	Feb '04	Nov '04	Feb '04	Nov '04
	Above ground floral distribution												
1	Trees (density/ha)	411		46		-		367		321		-	
2	Shrubs (density/ha)	75		36		16		40		39		-	
3	Herbs (density/ha)	146842	176,000	137826	817,778	206111	369,444	58333	216,667	7653	8231,714	122727	649,16
	Soil microflora												
4	*Azatobacter* (cfu x 10^3 g^{-1} soil)	53	21	13	3	14	10	35	12	29	18	14	0
5	P-solubilizing fungi (cfu x 10^3 g^{-1} soil)	20	13	2	2	2	0	2	3	3	2	0	0
6	P-solubilizing bacteria (cfu x 10^3 g^{-1} soil)	9	2	2	2	1	2	1	1	1	1	1	0
7	AM fungal root Colonization pattern	59	72	64	68	57	64	64	49	66	57	47	33
8	AM fungal spore density (No. g^{-1} soil)	201 (27)	373 (33)	641 (24)	654 (27)	767 (22)	616 (26)	176 (19)	275 (26)	258 (23)	316 (25)	184 (16)	201 (13)
9	Infective propogules (No. g^{-1} soil)	305	559	690	839	775	737	177	407	260	443	215	184
10	LNB (x 10^2 g^{-1} soil)	2	4	8	12	35	0	11	25	125	20	4	14
	Soil fauna												
11	Earthworms (No. / m^2)	*	79 (8)	*	35 (8)	*	65 (6)	*	50 (1)	*	152 (11)	*	58 (8)
12	Soil invertebrates (No. / m^2)	4052 (27)	878 (19)	219 (13)	275 (12)	993 (14)	632 (16)	4579 (27)	777 (23)	3436 (25)	390 (21)	1549 (12)	523 (16)
13	Litter invertebrates (No. / 100 g)	3 (13)	18 (23)	1 (11)	17 (18)	1 (7)	3 (12)	5 (23)	25 (22)	1 (13)	31 (22)	11 (11)	23 (19)
14	Pitfall traps	46 (2)	1 (2)	31 (2)	8 (2)	54 (1)	4 (1)	35 (3)	2 (2)	32 (2)	4 (2)	33 (2)	2 (2)

Mean values of population density of different groups of two seasons is considered along with species diversity to provide the soil community structure at Nilgiri Biosphere (North)

*Samples recovered were negligible for reporting and hence not recorded

Table 2. Correlation matrix between the soil properties and functional groups

Soil Property	VAM		PSM		LNB		*Azatobacter*		S. invertebrates		L. invertebrates		Earthworms
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons		Seasons
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Post
Clay	-0.464*	-0.555*	-0.305	-0.497*	0.545*	0.057	-0.746*	-0.095	0.561*	0.182	-0.546*	0.437*	0.646*
Silt	-0.494*	-0.604*	0.352	-0.715*	0.341	-0.359	-0.860*	-0.298	0.638*	-0.071	-0.210	0.638*	0.408*
Sand	0.408*	0.601*	0.342	0.793*	-0.203	0.116	0.871*	0.314	-0.827*	0.083	0.374	-0.718*	-0.295
Bulk density	0.918*	0.935*	-0.287	0.314	0.105	-0.598*	0.576*	-0.654*	-0.608*	0.825*	0.831*	-0.603*	-0.179
Phosphotase activity	0.652*	0. 567*	-0.509*	0.867*	0.146	-0.136	0.882*	0.149	-0.806*	-0.279	0.449*	-0.797*	0.164
Organic carbon	0.431*	0.408 *	0.686*	0.989*	0.017	0.392	0.890*	0.517*	-0.735*	0.142	-0.004	-0.732*	0.136
Nitrogen	-0.262	0.069	0.407*	0.599*	0.179	0.579*	0.398	-0.813*	-0.479*	0.821*	-0.325	-0.460*	0.282
Potassium	-0.354	-0.029	-0.060	0.302	0.684*	0.337	-0.011	0.473*	-0.350	0.718*	-0.391	-0.350	0.716*
Total phosphorus	-0.649*	-0.499*	-0.532*	-0.811*	0.214	-0.091	-0.941*	-0.151	0.662*	0.267	-0.363	0.631*	0.177
Available phosphorus	-0.449*	-0.375	-0.748*	-0.632*	0.215	-0.111	-0.880*	-0.363	0.622*	0.132	-0.273	0.622*	0.111

Table 3. Correlation matrix between the functional groups

Organism	VAM		PSB		LNB		*Azatobacter*		S. invertebrates		L. invertebrates		Earthworms
	Seasons		Seasons		Seasons		Seasons		Seasons		Seasons		Seasons
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Post
VAM	1.00	1.00	-0.121	0.710*	-0.099	-0.341	-0.533*	-0.193	-0.772*	-0.378	-0.586*	-0.618	0.306
PSM	0.004	-0.556*	1.00	1.00	-0.332	0.902*	0.780*	0.301	0.362	-0.817*	-0.127	0.083	0.013
LNB	0.455*	-0.598*	-0.352	0.902*	1.00	1.00	0.028	0.911	0.173	-0.830*	-0.433*	0.390	0.910*
Azatobacter	0.300	-0.193	0.780*	0.301	-0.028	0.111	1.00	1.00	0.859*	0.184	-0.113	0.833*	0.291
S. invertebrates	0.320	0.259	0.362*	-0.817*	0.173	-0.830*	0.859*	0.184	1.00	1.00	0.067	-0.527*	0.402*
L. invertebrates	-0.784*	-0.038	-0.127	0.083	-0.433*	0.390	-0.113	0.833*	0.067	-0.527*	1.00	1.00	-0.286
Earthworm	0.306	0.306	0.013	0.013	0.910*	0.910	0.291	0.291	0.402*	0.402	-0.286	-0.286	1.000

Table 4. Correlation matrix between belowground biodiversity with above ground biodiversity

Organism	Trees		Shrubs		Herbs	
	Seasons		Seasons		Seasons	
	Pre	Post	Pre	Post	Pre	Post
VAM	-0.622*	-0.373	-0.176	0.469*	0.787*	0.400*
PSM	0.516*	0.379	0.806*	0.653*	0.652*	0.224
LNB	0.216	0.095	-0.006	0.563*	0.379	-0.298
Azatobacter	0.923*	0.540*	0.874*	0.441*	0.518*	-0.300
Soil invertebrates	0.934	-0.199	0.598*	-0.479*	-0.501*	-0.633*
Litter invertebrates	0.199	-0.494*	-0.479*	-0.182	-0.418*	-0.232
Earthworm	-	0.433*	-	0.206	-	-0.299

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

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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).

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 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 goals in developing these products are to meet the needs of the modeling the community and to attempt to better understand the role of human impacts on earth systems through land cover conversions.

REVIEW OF LITERATURE

Over recent years, researchers have increasingly turned to remotely sensed 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 a). Satellite remote sensing has played a pivotal role in generating information about forest covers, vegetation type and land use changes (Roy, 1993).

Most extensive application of satellite remote sensing technique has been reported using coarse and medium resolution datasets from sensors like NOAA-AVHRR, SPOT-VEGETATIO, ERS and IRS-WIFS (Roy, 2002).

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The use of Remote sensing as a tool for analyzing environmental, cultural and natural resource management characteristics is well documented (Richason 1983; Holz 1985; Colvell 1983; Lo 1986; Campbell 1987; 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). Dutt et al (2002) brought out the role of fragmentation and disturbance levels in assessing the Biological richness and ecological uniqueness along Western Ghats of India using remote sensing and GIS. Ranganath et al. (2002) used GIS and remote sensing to delineate the diverse habitats and vegetation of Hassan district of Western Ghats, highlighting a variety of parameters playing a major role in formation of diverse vegetation types and fragmented system in a ecologically sensitive region. The study also highlighted ecosystem uniqueness, species richness and biological value. Several models could be generated using these datasets.

Udaya Laksmi et al. (1998) used remote sensing and GIS for decision-making and to derive meaningful output for plant resources conservation and their management. Nagendra (2001) used the remotely sensed data for effective delineation of conservation priority area in Western Ghats, India. Natarajan et al (2003) delineated conservation priority sites for the effective management of forest resources in Chitteri hills, Tamilnadu using remote sensing and GIS. They have used various layers such as species richness, endemic and red listed plant species, biotic pressure and social economic value. Joshi et al (2004) analyzed the cover dynamics with respect to topography using geospatial tools, which also helps in delineating conservation areas. Ganeshaiah & Uma Shaanker (2003) generated contours of distribution patterns of *Bamboo, Ochlandra, Rattans*, medicinal plants and major NTFP products, which aimed at conservation of important species. Riemann Hershey (1996) used geo-statisitical techniques, viz. kriging or sequential Gaussian conditional simulation to create an interpolated dataset a map of individual species distribution (10 species in Pennsylvania) from known sample information.

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 annul rainfall of the area ranges from 2000 mm to 3500. 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 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.

Major part of the study area 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 scale. 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

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

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

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

The soil samples collected from the two depths (0-10 cm and 10-30 cm) were analysed 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:

(a) Natural forests - these are the left out areas 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 the species *Acacia auriculiformis* and are raised 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/Barren lands - these are the open patches found in slightly elevated regions and also adjoining agricultural areas.

Area distribution of the different land cover classes is given in Figure 3.

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 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 species tree species were identified from the study area and it was more in natural forests with 77 species followed by cardamom plantations with 73 species. No. of tree species in coffee plantations is slightly less compared to cardamom because of selective thinning in coffee plantations. *Caryota urens* is the dominant species in natural forests. *Olea dioca* and *Grevillea robusta* are the dominant species cardamom and coffee plantations respectively.

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

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 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 is high in forest plantations, but the number of species is less compared to paddy fields and grasslands, at it may be attributed to the selectivity of few herb species under *Acacia auriculiformis* cover. *Brachiaria milliformis* is 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 are given in the table 2.

Physical and Chemical properties of soil

All the physical properties of the soil did not vary significantly ($P > 0.05$ level) (Table 3). The pH is comparatively less in grassland, *Acacia* Plantation and paddy and high in natural forest, coffee and cardamom plantations. 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 & 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 The chemical properties of the soil is given in table 4 for all land use types.

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.

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Table 1: Phytosociological analysis of different land use systems

Land cover types	Parameters	Natural Forest	Farmer plantation		Forest plantation	Agriculture	Barrenlands / 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

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

Parameters	Natural Forest	Grasslands / Barren lands	Forest plantation	Farmers plantation		Agriculture	F-test
				Cardamom	Coffee		
Bulk density (g/cm^3)	1.2 ±0.14	1.42 ±0.15	1.41 ±0.17	1.17 ±0.13	1.270 ±0.17	1.21 ±0.14	NS
Sand	61.69 +4.96	60.83 +6.05	62.73 +6.28	61.17 +4.62	61.09 +9.48	60.18 +7.63	NS
Silt	26.35 +2.9	23.17 +5	23.93 +5.47	24.28 +3.75	25.1 +4.59	23.6 +2.58	NS
Clay	14.06 +5.77	16.97 +7.6	14.13 +5.61	14.14 +4.98	13.88 +6.98	16.1 +5.76	NS

NS - Non-significant

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

Parameteers		Depth	Natural Forest	Grasslands / Barren lands	Forest plantation	Farmers plantation		Agriculture	F-test
						Cardamom	Coffee		
pH	**Water extract**	0-10 cm	6.2 ±0.30^{a}	5.57 ±0.31^{c}	5.51 ±0.19^{c}	6.31 ±0.20^{a}	6.16 ±0.25^{a}	5.30 ±0.15^{c}	S
		10-30 cm	6.21 ±0.28^{a}	5.57 ±0.37^{c}	5.56 ±0.2^{c}	6.16 ±0.19^{a}	6.18 ±0.32^{a}	5.50 ±0.15^{c}	S
	KCl extract	0-10 cm	5.24 ±0.49^{ab}	4.37 ±0.28^{c}	4.43 ±0.28^{c}	5.30 ±0.32^{a}	5.03 ±0.54^{ab}	4.21 ±0.21^{c}	S
		10-30 cm	5.13 ±0.54^{ab}	4.32 ±0.14^{c}	4.36 ±0.16^{c}	5.20 ±0.37^{a}	4.95 ±0.53^{ab}	4.42 ±0.31^{c}	S
Excha. Acidity (meq. 100 g-1)		0-10 cm	2.88 ±1.49^{ab}	7.06 ±4.3^{c}	7.16 ±3.14^{c}	2.57 ±1.27^{a}	3.21 ±1.30^{ab}	8.0 ±2.31^{c}	S
		10-30 cm	3.05 ±2.20^{ab}	6.75 ±2.87^{c}	6.66 ±2.16^{c}	2.07 ±0.95^{a}	2.75 ±1.48^{ab}	6.37 ±1.49^{c}	S
Organic –C (%)		1-10 cm	3.77 ±0.92^{ab}	2.28 ±0.51^{c}	2.33 ±0.48^{c}	4.01 ±0.80^{ab}	3.70 ±0.73^{a}	1.16 ±0.54^{c}	S
		10-30 cm	2.59 ±1.26^{ab}	1.80 ±0.53^{c}	1.73 ±0.48^{c}	3.14 ±0.75^{ab}	2.79 ±0.88^{a}	1.11 ±1.05^{c}	S
Total –N (%)		0-10 cm	0.48 ±0.16^{ab}	0.29 ±0.06^{c}	0.34 ±0.08^{ab}	0.50 ±0.10^{a}	0.47 ±0.11^{ab}	0.32 ±0.16^{c}	S
		10-30 cm	0.37 ±0.12^{a}	0.28 ±0.07^{c}	0.30 ±0.05^{ab}	0.44 ±0.15^{a}	0.40 ±0.07^{ab}	0.19 ±0.01^{c}	S
Excang. Na (kg ha-1)		0-10 cm	2.14 ±0.45	1.95 ±0.38	1.80 ±0.17	1.86 ±0.65	2.71 ±0.82	2.16 ±0.25	NS
		10- 30 cm	2.14 ±0.62	1.87 ±0.25	1.84 ±0.12	1.91 ±0.69	1.98 ±0.33	2.06 ±0.16	NS
Exchang. K (kg ha-1)		0-10 cm	576 ±420.59^{a}	318 ±262.82^{c}	200 ±76.89^{c}	553.84 ±233.19^{ab}	525 ±257.69^{ab}	156 ±101.82^{c}	S
		10- 30 cm	709.33 ±226.41^{a}	378 ±358.97^{c}	200 ±127.59^{c}	594.46 ±309.55^{ab}	582 ±315.95^{ab}	210 ±229.39^{c}	S

S - Significant, NS - Non-significant

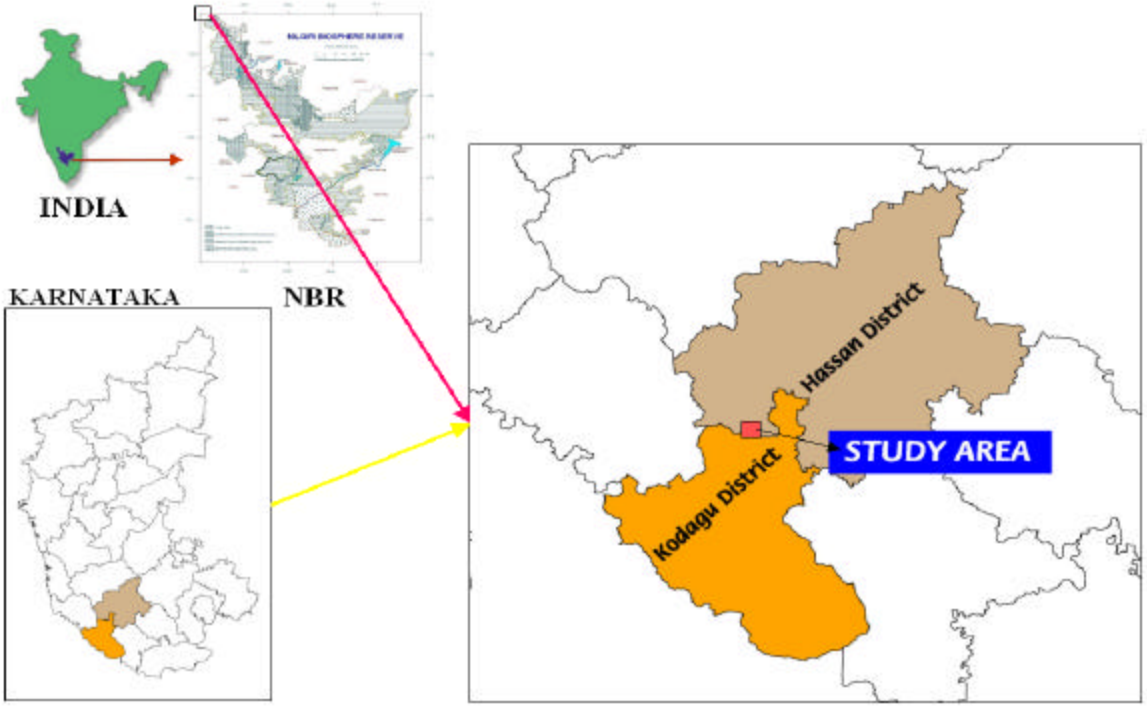

Figure 1: Location map of the study area – koothy, Somwarpet taluk, Kodagu, Karnataka.

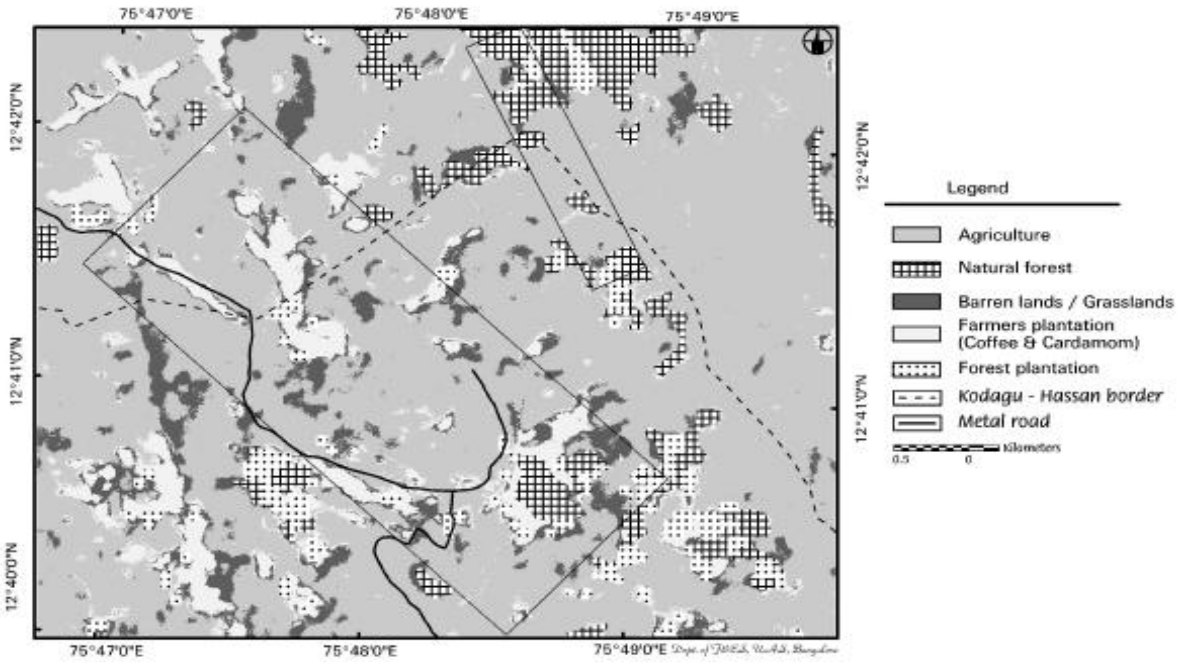

Figure 2: Land use / Land cover map of the study area based on interpretation of the Indian Remote Sensing Satellite data (IRS 1D LISS III of the year 2000).

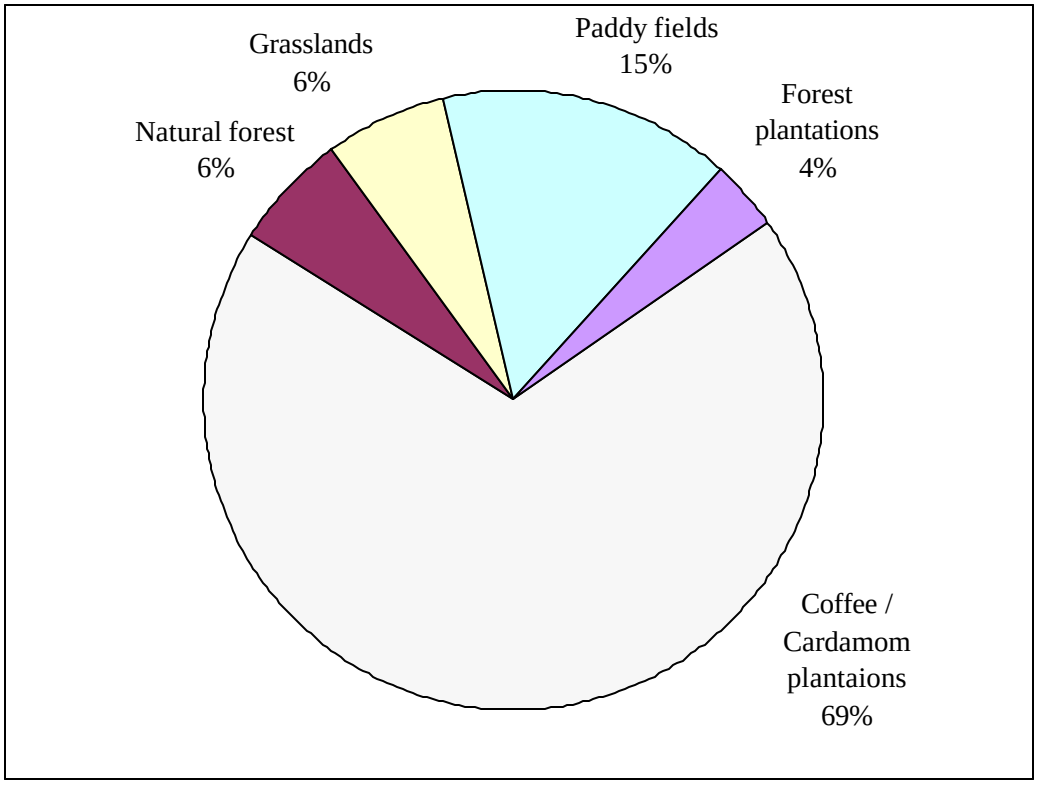

Figure 3: Area distribution of different land cover types based on satellite data

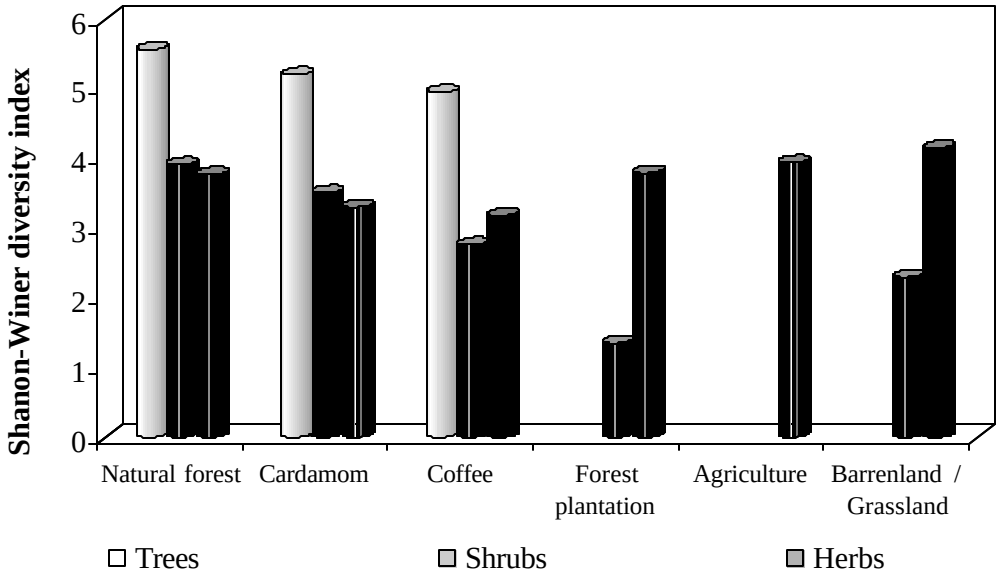

Figure 4: Species diversity (Shannon-Wiener index) across land cover classes

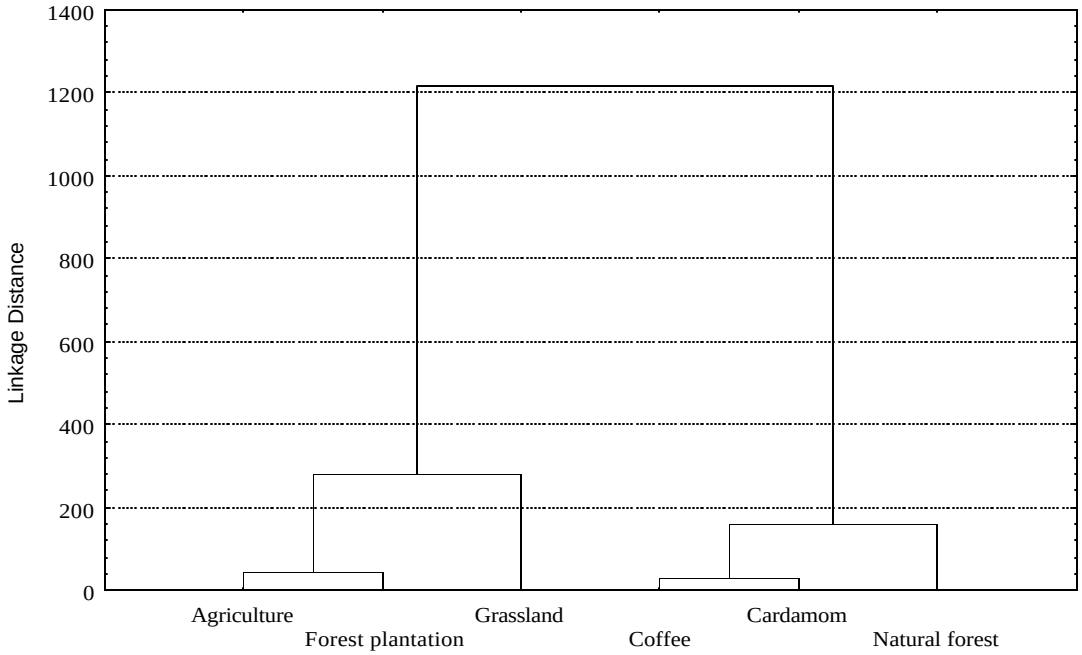

Figure 5: cluster analysis of soil parameters with different land use systems

Abundance and Diversity of AM fungi across a gradient of Land use types in Western Ghats

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ABSTRACT

A study was taken up in the Werstern Ghats near Koothy village of Somavarpet taluk of Coorg district, Karnataka to know the impact of land use types on AM fungi. There were no significant differences in root colonization in six different land use types during pre-monsoon season. But, during post-monsoon season, AM root colonization was significantly more in natural forests and grasslands compared to all other land use types. AM root colonization was significantly more in post-monsoon season compared to pre-monsoon season. AM spore density and infective propagules were significantly more in grasslands and forest plantations compared to all other land use types during both the seasons. Further, the spore density and infective propagules were more during post-monsoon season compared to pre-monsoon season except in paddy fields. Sand, bulk density, total N, organic C, alkaline and acid phosphatases positively correlated with AM fungal activity while clay, silt, K, total P and available P were negatively correlated with AM fungal activity. Fifty-six and sixty-seven species of AM fungi were identified during pre and post-monsoon season respectively. The AM species spore abundance was more during post-monsoon season compared to pre-monsoon season. During both the seasons *G.fasciculatum* was distributed in maximum number of points followed by *G.geosporum* during pre-monsoon and *G.mosseae* during post-monsoon season. AM fungal species diversity was more during post-monsoon than during pre-monsoon seasons and it was more in natural forests and grasslands compared to other land use types in both the seasons. Species richness index was more during post-monsoon than during pre-monsoon season. During both the seasons species richness index for AM fungi was more in natural forests and least in paddy fields.

INTRODUCTION

A.B. Frank (1885), German Botanist first coined the term “mycorrhiza” which literally means “fungus root” to describe the mutualistic association between roots of higher plants and certain fungi. AM fungi exist in two different phases, inside the root and in the soil. The intraradical mycelium consists of hyphae and other fungal structures, such as arbuscules and vesicles; the extraradical mycelium forms spores, explores soil and new areas for colonization and absorbs nutrients (Tommerup and Sivasithamparam, 1990).

AM fungi come under the class Zygomycetes, under the order Glomales. The order Glomales is divided into 2 sub-orders Glomineae and Gigasporineae. The sub-order Glomineae has four families namely Glomaceae, Acaulosporaceae, Paraglomaceae and Archeosporaceae (Pirozynski and Dalphe, 1989). Further, Glomaceae has a genus *Glomus*,

Acaulosporacaeae is having two genera *viz*. *Acaulospora* and *Entrophospora,* Archaeosporaceae is having a genus *Archaeospora* and Paraglomaceae is having a genus *Paraglomus*. The suborder Gigasporineae is having only one family Gigasporaceae. Gigasporaceae includes the genera *Gigaspora* and *Scutellospora.*

Taxonomic groupings of Glomalean fungi are mainly based on stable and discrete morphological characters of fungal mycelium and spores (Morton and Benny, 1990). Further, variations in morphological characters are known to be a reflection of either developmental constraints within the organism or selective constraints imposed by the external environment (Morton, 1990).

These fungi form the main component of soil microbiota in most agro-ecosystems. Hence AM fungi have been shown to have a strong influence on plant species diversity. Since these fungi are obligate symbionts, their population and diversity are determined by the plant species present in the given ecosystem. Apart from plant species, human activities also affect these fungi. In a given ecosystem these fungi play an important role in carbon allocation, nutrient cycling and maintenance of diversified ecosystem (Doss and Bagyaraj, 2001). The presence of these fungi and their genetic and functional diversities are important for both plant community and ecosystem productivity.

Improved plant growth due to inoculation of plants with AM fungi has been demonstrated especially under P deficient condition. The growth improvement is mainly because of enhanced P uptake. AM fungi can also enhance tolerance or resistance to root pathogens and abiotic stresses such as drought and metal toxicity (Bagyaraj & Varma, 1995).

There is no clear indication that only certain AM fungi exist in the tropical regions of the Indian Sub-continent. Information on the distribution and frequency of occurrence of specific AM fungi in the Western Ghat area is very scarce. Surveys carried out in different parts of India have revealed the distribution of different genera of AM fungi. Vasanthakrishna *et al.*, 1994 emphasized the fact that *Glomus* species were dominant in the root zone soils of tree species in Western Ghats of Karnataka. Byra Reddy *et al.* (1994) examined mycorrhizal root colonization in 59 forest tree species. The intensity of colonization was high in four species, moderate in 23 species and low in 32 species. Lakshmipathy *et al.* (2004) isolated *Glomus etunicatum* from the root zone soil of cashew. Therefore, it appears that occurrence of AM fungi in different forest tree species defines ecological niches to that particular tree species, thus determining plant community composition.

Muthukumar and Manian, 1993 found *Glomus* species being the dominant in the root zone soils of tree species in Western Ghats of Kerala. Raman *et al.* (1993) observed the association of AM fungi with 14 plant species in a magnetic mine spoil poor in available P. Spores of *G. fasciculatum* and *Gigaspora giganlea* were the predominant species. Similarly, the rhizosphere soil samples of 20 species of tree legumes in the reserve forest of Alger hills in the Eastern ghats of Tamil Nadu were found to contain altogether 21 species of AM fungi belonging to six genera *viz*. *Acaulospora, Entrophospora, Gigaspora, Glomus, Sclerocystis* and *Scutellospora* (Santhaguru *et al*., 1995).

Vijayalakshmi and Rao (1988) found that the spores of *G. mosseae* and *G. macrocarpum* var. *macrocarpum, Gigaspora margarita var. macrocarpum, Sclerocystis, clavispora, S. pakistanica, S. rubiformis* and *S. sinuosa* were found to be associated with the rhizosphere of certain members of the families Asteranceae and Amaranthaceae growing on infertile, red latertic soils of Andhra pradesh .

Sharma *et al*. (1987) isolated eight species of AM fungi belonging to the genera *Glomus*, *Gigaspora* and *Sclerocystis* in the rhizosphere of trees in a sub-tropical evergreen forest of North East India. Of the eight species, *Sclerocystis* ma*crocarpum* and *Gigaspora gregaria* were the first report from India. Kiran Balal *et al.* (1989) examining 17 different plant species from Indian desert in Rajasthan observed, *Glomus* and *Gigaspora* as the dominant genera associated with those plants. Venkataraman *et al.* (1990) while studying the distribution of AM fungi in the acid soils of North Eastern India found that the hilly soils contained a fewer spores, *Scutellospora nigra, Sclerocystis rubriformis* and *Glomus macrocarpum* being the most abundant species. Bhradwaj *et.al.* (1997) reported that the spores of *Glomus, Gigaspora, Sclerocystis* and *Acaulospora* were more abundant in sandy soils compared to loamy sands in Haryana, the most abundant being *Glomus* and *Gigaspora*. Bhadauria *et al.* (1998) found, spores of *Glomus* spp., *Gigaspora* spp. and *Slerocystis* sp. in barren low vegetation soils with pH ranging from 8.0-10.4.

In tropical soils, application of organic matter either in the form of FYM, compost or organic amendments stimulated the proliferation of AM fungi (Harinikumar and Bagyaraj, 1989). This was attributed to the low organic matter content in tropical soils. Harinikumar and Bagyaraj (1988) found that addition of organic amendments such as paddy straw, maize straw and pongamia leaf increased the mycorrhizal activity. Of the three amendments studied, addition of pongamia leaf encouraged AM fungi to the maximum, followed by maize straw. Baby and Manibhushan Rao (1996) while studying the influence of organic amendments on AM fungi in relation to rice sheath blight disease caused by *Rhizoctonia solani* under greenhouse conditions found that organic amendments increased AM spore density, and intensity of colonization whilst rice sheath blight disease was decreased. Green leaf manure stimulated arbuscular development in rice plants. Mycorrhizal formation and sporulation were higher in healthy rice plants than in infected plants.

High P availability is reported to be negatively correlated with AM fungal activity (Krishna and Bagyaraj, 1982). But, an insoluble source of P like rock phosphate when applied at 100 ppm P level resulted in more infective propagules of *Glomus fasciculatum* (Sreenivasa and Bagyaraj, 1989). Balakrishna *et al*. (2001) reported that application of inorganic fertilizers affected native AM fungal spore density, infective propagules and percent root colonization in a finger millet- maize-fallow crop rotation system.

Studies conducted on the effect of mono and mixed cropping systems with soybean and maize on AM fungal population in soil, revealed that mixed cropping of soybean and maize stimulated the proliferation of AM fungi, compared to mono-cropping of maize or soybean (Harinikumar *et al.*, 1990). One of the reasons for higher propagule density under mixed cropping was attributed to more intensive rooting of soil in the

mixed system. Additionally, through higher plant density, nutrients are extracted faster from the soil, thereby stimulating AM fungal reproduction.

Graminaceous and leguminous crops are generally believed to increase AM fungal population, while non-mycotrophic plants decrease the population. Harinikumar and Bagyaraj (1988) reported that growing of non mycorrhizal hosts like mustard or leaving the land fallow reduced the propagules of AM fungi in soil. In contrast, use of a crop which is strongly mycorrhizal increase their numbers.

Cropping season also seems to have a considerable impact on the AM fungal development in the soil. The practice that has negative impacts on AM fungi is over winter bare fallow. This removes potential host roots, from which the fungi could receive sugar during mild fall and spring weather, thereby decreasing viability and ability of the fungi to colonize the next crop. An over winter cover crop may not only be useful for the mycorrhizal fungi but will also boost the amount of AM fungi in the soil. Harinikumar and Bagyaraj (1988) and Mallesh and Bagyaraj (1991) showed that AM fungi sporulate during winter in the tropics. The optimum temperature for sporulation by mycorrhizal fungi appears to be around 25^0 C. Avid-Iqubal *et al.* (1997) showed fluctuations in AM fungal association and spore populations in tomatoes, rice, wheat and beans. The predominant AM fungi associated were *Glomus mosseae*, *Glomus constrictum* and *G. fasciculatum.* The population of fungal spores was highest during early summer and late winter while colonization was high from February to May and from the end of July to September. However, studies concerning the abundance and diversity of AM fungi as affected by different land use types under topical conditions are scarce. Hence, the present study was undertaken in Western Ghats, Karnataka.

MATERIALS AND METHODS

The benchmark area selected for this study is located in the southern part of India, which has a tropical type of climate. The 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 scale. Following the hybrid classification approach, a mask was created for almost non-overlapping classes (*viz*., agricultural areas and vegetated areas) obtained from unsupervised classification (isodata algorithm). The vegetated areas were further classified into natural forests, grasslands, coffee/cardamom plantations and acacia 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.

A total of 60 sample points were distributed in two windows of the size 6.4 sq km (4 x 1.6 km) and 0.8 sq km (0.4 x 2 km) so as to cover all the above said land cover types. Fifty-three sample points were distributed in the first large window and 7 points in the second small window. Stratified sampling technique was adapted and two windows were selected,

because the first large window that was selected did not have enough natural forests, grasslands and *Acacia* plantations. Hence, additional window in the study site was selected to cover the required land use types.

The sample points were laid in the intersection point of the windows and were located in the ground using hand held ***Garmin 12*** GPS. The intersection points at which sampling could not be done due to the presence of a natural obstruction (presence of a tree, stone/water body etc.) were skipped and the sampling was done in the next intersection point.

Six land use-land cover types could be distinguished in the study area. They are; natural forests, grasslands, acacia plantations, coffee and cardamom plantations and paddy fields. For collecting the soil samples, a triangle of 50 x 50 x 50 m was laid at each sampling point. The center point of the triangle was marked and from this central point at a distance of three meters, three soil cores of 0-20 cm depth was taken using a soil core, avoiding the litter above the ground. Similarly, at a distance of six meters from the center, another three soil cores of 0-20 cm depth were taken as explained above. Thus, at each sampling point six soil cores were collected and these six soil core samples were mixed together to form a composite sample per sampling point. These soil samples were stored at 5^0 C in a refrigerator for further microbiological analysis. At each sampling point, the roots present in the soil sample were collected to determine the AMF root colonization. Soil sampling was done during February-march (pre-monsoon) and October-November (post monsoon) during the year 2004.

Soil samples were collected at nine sampling points from natural forests, eight sampling points from grasslands, six sampling points from acacia plantations, thirteen sampling points from cardamom plantations, sixteen sampling points from coffee plantations and eight sampling points from paddy fields.

The roots were stained with trypon blue as per the procedure given by Philips and Hayman (1970) with modifications by Kormanik et *al.*, (1980) for assessing AM fungal colonization. The determination of per cent mycorrhizal colonization was carried out by the gridline intersection method (Giovannetti and Mosse, 1980). The extramatricular chlamydospores produced by AM fungi in soil were estimated by wet sieving and decanting method (Gerdemann and Nicholson, 1963). The number of infective propagules in soil was estimated by the most probable number method (Porter, 1979).

The identification of AM fungi was carried out by "host baiting technique". The composite samples obtained from the sampling points were brought to the laboratory. The test soil sample was mixed with sterile sand soil (1:1) mix [50 % test soil sample + 50 % sterile sand soil mix] and planted with suitable trap plants. A mixture of sorghum and cowpea were preferred. After three months, the potting mix was wet sieved and the spores were observed under a compound microscope.

Morphologically similar spores were picked and population of each spore type was enumerated. Spores of each type were brought into pot culture by funnel technique after surface sterilization of the spores (Nicolson, 1975). Surface sterilization of isolated spores was done with an aqueous solution containing 200-ppm streptomycin sulphate and

2% chloramine T. The spores were mounted on a glass slide in lacto- glycerol. They were later identified, with the help of "Manual for identification of VA mycorrhizal fungi" by Schenck and Perez (1990) and the INVAM website by Joe Morton. http://invam.caf.wvu.edu

The Shanon -Weaner index was calculated using the formula

$$H^1 = \sum_{i=1} (ni/N) \log_2 (ni/N)$$

Where ni= Number of individual of the species
N= Total number of individuals of all species

The similarity index was calculated using the formula

$$S = S + (n-1/n)K$$

Where S= observed total number of species
n= Total number of quadrats
K= Number of unique species

RESULTS

Population of arbuscular mycorrizal fungi (AMF) in different land use types

AMF per cent root colonization

The root colonization by AMF during pre-monsoon and post-monsoon seasons in different land use types is given in table 1. Significant differences were not observed in root colonization between different land use types during pre-monsoon season but, were highest in roots collected from cardamom plantations (65.82%) followed by coffee plantations (64.41%), grass lands (63.65%), natural forests (59.27%), acacia plantations (57.38%) and was least in paddy fields (47.22%). Whereas, the Per cent root colonization by AM fungi during post-monsoon season was significantly high in roots collected from natural forests (72.10%) and grass lands (68.22%) compared to acacia plantations (64.25%), coffee plantations (56.58%), cardamom plantations (49.09%) and was least in roots collected from paddy fields (33.32%).

A comparison of root colonization due to AM fungi in different land use types in pre and post-monsoon seasons revealed, that root colonization was more in pre-monsoon season (59.72%) compared to post-monsoon season (57.26%). However, the root colonization was significantly higher in post-monsoon season compared to pre-monsoon season in natural forests, grasslands and acacia plantations while it was more during pre-monsoon season in coffee plantations, cardamom plantations and paddy fields.

AMF spore density and infective propagules

The spore density of soil samples collected from different land use types during pre and post-monsoon seasons is given in table 2. The spore density in soils collected from acacia plantations (767.00 spores 50^{-1}g soil) was significantly higher compared to natural forests (201.00 spores 50^{-1} g soil), cardamom plantations (176.00 spores 50^{-1} g

soil), coffee plantations (258 spores 50^{-1}g soil) and paddy fields (184.00 spores 50^{-1}g soil), while the spore density in soils collected from acacia plantations was on par with grasslands (641.00 spores 50^{-1}g soil) in pre-monsoon season.

While in post-monsoon season, spore density in soils collected from grasslands (653.75 spores 50^{-1}g soil) and acacia plantations (615.83 spores 50^{-1}g soil) were significantly higher compared to that of natural forests (373.77 spores 50^{-1}g soil), cardamom plantations (275.30 spores 50^{-1}g soil), coffee plantations (315.63 spores 50^{-1}g soil) and paddy fields (200.62 spores 50^{-1}g soil).

The average mean spore density of all the land use types at two different seasons was higher during post-monsoon season (405.00 spores 50^{-1}g soil) compared to pre-monsoon season (371.00 spores 50^{-1}g soil). In soils collected from natural forests, cardamom and coffee plantations AMF spore density was significantly higher during post-monsoon season (373.77 spores 50^{-1}g soil, 315.63 spores 50^{-1}g soil and 275.30 spores 50^{-1}g soil respectively) compared to pre-monsoon season (201.00 spores 50^{-1}g soil, 258.00 spores 50^{-1}g soil and 176.00 spores 50^{-1}g soil respectively). While in grasslands, acacia plantations, coffee plantations and paddy fields even though spore density was more during post-monsoon than during pre-monsoon season, it was not statistically significant.

The infective propagules in soil samples collected from different land use types during pre and post-monsoon seasons are given in table 3. The infective propagules in soils collected from acacia plantations (775.00 I.P. g^{-1} soil) and grasslands (690.00 I.P. g^{-1} soil) were on par with each other and significantly higher compared to natural forests (305.00 IP 50^{-1}g soil), cardamom plantations (177.00 I.P. g^{-1} soil), coffee plantations (260.00 I.P. g^{1} soil) and paddy fields (215.00 I.P. g^{-1} soil). A similar trend was also observed in the post-monsoon season where in the infective propagules in soils collected from grasslands (838.75 I.P. g^{1} soil) and acacia plantations (736.66 I.P. g^{1} soil) were statistically on par with each other and were significantly higher compared to natural forests (558.80 I.P. g^{-1} soil), coffee plantations (442.50 I.P. g^{-1} soil), cardamom plantations (407.07 I.P. g^{-1} soil) and paddy fields (183.75 I.P. g^{-1} soil).

The mean infective propagules in soils collected from all the land use types were more during post-monsoon season (527.92 IP 50^{-1}g soil) compared to pre-monsoon season (403.66 IP 50^{-1}g soil). Further, AMF infective propagules were statistically higher in natural forests (558.80 IP 50^{-1}g soil) and cardamom plantations (407.07 IP 50^{-1}g soil) during post-monsoon season compared to pre-monsoon season, while such significant differences were not observed in other land use types between seasons.

The influence of soil physical, chemical and bio-chemical properties on different mycorrhizal components was studied. The correlation matrix between the soil properties and different components of AM fungi over different land use types is given in the table 4. Among the soil physical properties, sand and bulk density had a positive influence on AM fungal root colonization, spore density and infective propogules, while the clay and silt content had a negative influence on root colonization, spore density and infective propagules. Among the chemical properties of the soils, organic-C had a significant positive influence on the formation of AMF in soil while on the other hand total P and available P had a negative influence on AMF formation. The bio-chemical properties of

the soil like the acid and alkaline phosphatase activities were positively correlated with the activity of AM fungi.

Isolation and characterization of AM fungi in different land use types

Altogether, there were 212 isolates of AM fungi isolated from these six land use types and these included 39 from natural forests, 35 from grasslands, 27 from acacia plantations, 37 from cardamom plantations, 52 from coffee plantations and 22 from paddy fields in pre-monsoon season. In the post-monsoon season there were 286 isolates, comprising of 55 from natural forests, 48 from grasslands, 36 from acacia plantations, 54 from cardamom plantations, 72 from coffee plantations and 21 from paddy fields. Further, these isolates were identified up to the species level based on the morphological characteristics of chlamydospores (Table 5 and plate–1).

Frequency of distribution and AMF species abundance over two different seasons

The frequency of distribution of AMF species in sixty sampling points across six different land use types during pre and post-monsoon seasons is given in the table 6. During pre-monsoon season, of the 58 AM fungal species identified, *G.fasciculatum* was distributed in maximum number of sampling points (24), followed by *G.geosporum* (19), *G.mosseae* (11), *A.bireticulata* & *G.maculosum* in ten sampling points each, *A.dilalata* and *G.hoi* in eight sampling points each, *A.mellea, A.scrobiculata* and *G.multicaulis* in six sampling points each, *G.halonatum* and *G.macrocarpum* in five sampling points each, A*.dilatata, G.citricolum, G.constrictum, G.etunicatum, G.heterosporum, G.magnicaulis, G.manihotis, G.monosporum* and *G.pansihalos* in four sampling points each, *A.nicolsoni, A.spinosa* and *G.diaphanum* in three sampling points each. *Gi.albida, G.albidum, G.australe, G.borreale, G.delhiens, G.fulvum, G.globiferum, G.intraradices, G.invermaium, G.macrocarpum, G.tenebrosum* and *S.persica* in two sampling points each and the remaining species were present in only one sampling point each. During the post-monsoon season, among the 67 different AM fungal species identified, *G.fasciculatum* was present in maximum number of sampling points (28) followed by *G.mosseae* (19), *G.geosporum* (17), *G.aggregatum* (15), *A.scrobiculata* (13), *A.lacunosa* (10), *G.diaphanum* and *G.hoi* in nine sampling points each; *G.maculosum* and *G.multicaulis* in eight sampling points each, *A.mellea* in seven sampling points; *G.citricolum* and *G.lacteum* in six sampling points each; *G.constrictum, G.etunicatum, G.halonatum, G.intraradices* & *G.radiatum* in five sampling points each; *A.dilatata, A.nicolsoni, G.caledonium, G.heterosporum, G.manihotis, G.monosporum* and *G.ambisporum* in four sampling points each. *A.spinosa, G.magnicaulis* and *G.pansihalos* in three sampling points each. *A.appendicula, A.delicata, G.albidum, G.australe, G.borreale, G.claroidem, G.delhiense, G.fulvum, G.globiferum, G.invermaium, G.macrocarpum* and *Gi.margarita* in two sampling points each. The remaining AM fungal species were present in only one sampling point each.

Majority of the AM fungi were present in maximum number of sampling points during post-monsoon than during the pre-monsoon season, while a few species *viz. G.geosporum, G.maculosum, G.pansihalos, Gi.albida* and *S.persica* were present in maximum number of sampling points during pre-monsoon than post-monsoon season. Some of the AM fungal species like, *A.spinosa, A.trappei, G.albidum, G.australe, G.boreale, G.delhiens, G.fulvum, G.globiferm, G.halonatum, G.heterosporum, G.invermaius, G.macrocarpum, G.monosporum, G.manihotis, G.multisubstensum,*

G.pachycaulis, G.pustulatum, G.segmetatum, G.tortuosum, G.verrucosa, G.versiforme, S.calospora were distributed in equal number of sampling points during both the seasons.

The AM fungal species abundance over different land use types during the pre and post-monsoon seasons is presented in table 7. The abundance was higher during post-monsoon season than the pre-monsoon season. During post-monsoon season, majority of the species produced their chlamaydospores abundantly in soil compared to pre-monsoon season. A few species *viz. A.delicata, A.morrowae, G.albidum, G.fulvum, G.magnicaulis* produced more chlamaydospores during pre-monsoon season than post-monsoon season. Chlamaydospores of *A.laevis, Entrophospora schenckii, G.caledonium, G.clarum, G.leptotichum, G.reticulatum, G.ambisporum, Gi. rosea, S.heterogama* were not noticed during pre-monsoon season while during post-monsoon season chlamaydospores of *G.deserticola* and *G.tenebrosum* were not observed.

Diversity of AM fungi in different land use types

The diversity index for AMF species in different land use types during pre and post- monsoon seasons is given in the table 8. Shannon-Wiener diversity index during pre-monsoon season was higher in natural forests (4.41) compared to grasslands (4.20), acacia plantations (3.99), coffee plantations (3.80), cardamom plantations (3.57) and paddy fields (3.26).

During post-monsoon season also a similar trend existed and the Shannon-Wiener diversity index was significantly more in natural forests (4.59) compared to acacia plantations (4.26), cardamom plantations (4.08), coffee plantations (4.04) and paddy fields (3.01).

A comparison of the Shannon-Wiener diversity index revealed, that it was significantly higher in post monsoon season (4.07) compared to pre-monsoon season (3.87). Further, even in different land use types the diversity index was significantly higher in post-monsoon season compared to pre-monsoon season except in paddy fields.

Jacknife's species richness index of AM fungi in different land use types during pre and post monsoon seasons is presented in the table 9. During pre-monsoon season AMF richness was more in natural forests (43.00) followed by acacia plantations (38.67), grasslands (37.13), coffee plantations (30.44), and paddy fields (25.63) and was least in cardamom plantations. In post-monsoon season AMF species richness index was more in natural forests (51.67) followed by grasslands (48.50), acacia plantations (41.83), cardamom plantations (37.08), coffee plantations (34.37) and least in paddy fields (20.87).

Jacknife's species richness index was higher during post-monsoon season than during pre-monsoon season in all the land use types except in paddy fields where the species richness index was higher in pre-monsoon season (25.63) than in post-monsoon season (20.87).

DISCUSSION

Population of AM fungi in different land use types

AMF root Colonization

The results on the mycorrhizal root colonization during pre-monsoon season indicated, that there were no significant differences between different land use types. However, significant differences were observed during post-monsoon season. The root colonization was significantly higher in natural forests and grasslands compared to the other land use types. These variations in AM root colonization in different land use types in this study could be due to changes in soil type, nutrient content, soil moisture regimes, soil disturbances, and plant species present and their root system. Janos and Read (1992) have reported that root densities in the top five centimeters of tropical species favoured mycorrhization in soils. Similarly, agricultural practices such as pesticide application, cropping sequences and soil disturbances had variable effects on AM colonization (Harinikumar and Bagyaraj, 1989; Balakrishna *et al.*, 2002).

The root colonization was significantly higher in natural forests, grasslands and acacia plantations while significantly lower root colonization was observed in cardamom and coffee plantations and paddy fields in the post-monsoon season compared to that of pre-monsoon season. This could be attributed to the fact that, with the onset of rains in the post-monsoon season, significant moisture prevailed in the soil; this favoured better root growth of plant species, which might have enhanced AMF root colonization. This is in confirmation with the results of Pande and Tarafdar (2004) who also found that AMF colonization increased with rainfall and relative humidity in the atmosphere. However, seasonal variations also cannot be ruled out. The work carried out by Harinikumar and Bagyaraj (1988b) in mango and subabul and Mallesh and Bagyaraj (1991) in cardamom have revealed that the extent of root colonization by native AM fungi was higher in winter season (in tropics) as compared to summer. But, our studies are quite contradictory as far as cardamom and coffee plantations and paddy fields are concerned. This could be attributed to the fact that the roots observed for colonization in our studies were from the soils of these plantations / fields and not the roots as such of a particular plant species.

AMF spore density and infective propagules

In the present study, it was observed that there were variations in AM fungal spore density and infective propagules in different land use types during different seasons. It was found that the spore density and infective propagules were significantly more in soils of grasslands and acacia plantations compared to natural forests, cardamom and coffee plantations and least in paddy fields in both the seasons. In grasslands, the root system is fibrous with lot of roots spreading at the top 20-30 cms depth, which could have favoured better mycorrhization, in turn resulted in more sporulation and infective propagules of AM fungi. Whereas, in natural forests, cardamom and coffee plantations, even though lot of diversity of plant species is present, they are dominated by dicotyledonous plants without much graminacious species and much of the active roots are concentrated beyond 20-30 cms depth. This could be one of the reasons as to the

spore density and infective propagules being less in these land use types. Janos and Read (1992) have also reported that root densities in the top five centimeters of tropical species favoured better mycorrization in soils. In support of these findings, studies conducted in different land use types else where in natural systems have also been reported. Picone (2000) recorded more sporulation by AM fungi in pastures compared to forests. They also found, that AM fungi that sporulated in pastures had small spores while that have sporulated in forests have big spores. Further, spore density and infective propagules in pastures were found to be more compared to secondary forests (Fischer *et al.*, 1994). Sieverding and Leihnar (1984) reported that a combination of graminaceous and leguminous crops generally increase mycorrhizal populations. They found that, root infection and sporulation in case of cassava increased by intercropping with legumes. In another study, on the effect of mono-cropping and mixed cropping with soybean and maize on AM fungal population, mixed cropping stimulated the proliferation of AM fungal hyphae and spore production (Harinikumar *et al.*, 1990). In the present study also, there is co-existence of graminaceous and leguminous species in acacia plantations, acacia itself being a legume. Therefore, the higher spore density and infective propagules that is observed in this study could be due to the co-existence of legumes and grasses. While, in paddy fields, cardamom and coffee plantations the lower number of spores and infective propagules could be attributed to the application of inorganic fertilizers, pesticides and other cultural practices. Several such studies have also indicated that addition of fertilizers, pesticides and weedicides reduced the mycorrhizal spores and infective propagules (Hayman, 1975; Reeves *et al*., 1979; Ocampo and Hayman, 1980; Ahmad, 1989; Boddington and Dodd, 2000; Balakrishna *et al.*, 2001).

A comparison of the spore density and infective propagules in the present study has indicated, that the spore density and infective propagules were significantly more during post-monsoon than in pre-monsoon season in natural forests and coffee and

cardamom plantations while they were on par with each other in other land use types.In the present study, there has been significantly higher number of spores and infective propagules in natural forests, cardamom and coffee plantations while in other land use types though there was higher number of spores and infective propagules in the post-monsoon season, they were on par during post-monsoon season. Similar results have also been reported earlier by many workers, who have observed that the spore density and infective propagules were higher in winter than in summer. (Harinikumar and Bagyaraj, 1988b; Mallesh and Bagyaraj, 1991; Picone, 2000).

Soil physical, chemical and biochemical properties also influenced AM fungal root colonization, spore density and infective propagules. Sand and bulk density had a positive influence, while clay and silt content had a negative influence on AM fungi. Similarly, Pande and Tarafdar (2004) also found a positive correlation between spore abundance and bulk density of the soil. In sandy soils, plant roots proliferated better because of good aeration; there by enhanced the spore production. Johnson *et al.* (1991) have also reported a decrease in spore density with increasing clay content but, increase in spore density with increasing organic C. However, in our studies organic C and N content had a positive influence on AM fungi while the total P and available P had a significant negative influence on AM fungal activity. Similar results have also been observed by Johnson and Wedin (1997) wherein, AM colonization and spores were

higher in forest soils as soil C, N and K contents were higher. Pande and Tarafdar (2004) have also found that AMF spore density was correlated with organic C, rainfall and relative humidity of the atmosphere. Koide (1991) reported that high P content (>9ppm) reduced mycorrhizal colonization and spore production. Further, Lakshmipathy *et al.* (2002 and 2003) while studying AM colonization in medicinal plants of Western Ghats also obtained similar results.

A significant positive correlation existed between mycorrhizal activity and phosphatase activity. Mycorrhizal colonization is known to alter the inherent phosphorus supply by increasing the phosphatase activity in the rhizosphere (Azcon *et al*., 1982). The present study upholds the observations made by earlier workers (Lakshmipathy *et al.*, 2003; Sumana and Bagyaraj, 1996).

Isolation and characterization of AM fungi in different land use types

In the present investigation, the AM fungal isolates were identified into 58 species during pre-monsoon and 65 species during post-monsoon season from six land use types. The variation in the number of AMF species during different seasons could be due to changes in the moisture regimes in soil and other climatic conditions. During pre-monsoon season soil moisture was less and atmospheric temperature was high while in the post-monsoon season it was *vice-versa*. Such variations in species composition have also been observed by others. Lovelock *et al.* (2003) recorded more number of species during rainy season as compared to summer season. There was a strong shift in mycorrhizal communities and their numbers over time. Similar results were also reported by Husband *et al.* (2002) who found less number of species in summer, which got increased in the wet season. They suggest, that during wet season a large number of newly germinated seedlings were there, hence there were more number of species present. Therefore, it appears that a few species, which may appear the moment seeds of some plant species regenerate, may also vanish along with the plant species. In other words there could be some AMF species, which have a close association with some plant species. This could be one of the reasons for the variations in species composition in pre and post-monsoon seasons in the present study.

During both the seasons, a number of AMF species were recorded in natural forests, grasslands and acacia plantations than in cardamom and coffee plantations and paddy fields. Such variation in AMF species composition with different land use types has also been reported by Schenck and Kinloch (1980). He recorded highest number of species (12) from sorghum fields and least from woodlands. Oehl *et al.* (2003) while studying the impact of land use types have also reported, that the AMF species composition was highest in the grasslands, lower in the low and moderate input arable lands and lowest in the lands with intensive continuous maize mono-cropping. Certain other studies have also indicated that the number of species were more in undisturbed areas than the disturbed areas. Stutz (2003) reported that AMF species were more in undisturbed desert plantations than in disturbed areas such as urban residential, urban non-residential and agricultural lands. Similarly, Picone (2000) reported while studying the AMF species composition in Nicaragua and Costa-Rican forests and pastures, found similar species composition in both forests and pastures, while Mendez *et al.* (2001) noticed higher AMF species composition in pasture soils than in cultivated soils. Even in the present study, similar results have been observed wherein the species composition

was high in natural forests and grasslands and to some extent in acacia plantations which are more or less undisturbed, because these plantations are almost 10 years old and have not been subjected to disturbance from then. Whereas, in coffee plantations and paddy fields the species composition was less because of intensification of agricultural practices. In fact, according to Skinner and Bowen (1974) and Schenck *et al.* (1989), agricultural systems contained fewer species of AM fungi than natural grasslands.

AMF species frequency of distribution and spore abundance

AMF species spore abundance was more during post-monsoon than during pre-monsoon season. Majority of the species produced more number of chlamydospores during post-monsoon than during pre-monsoon season. A few species like *A.delicata, A.morreae, G.albidum, G.fulvum* and *G.magnicaulis* produced more chlamydospores during pre-monsoon compared to post-monsoon season. Chlamydospores of *A.laevis, E.schenckii, G.caledaneum, G.clarum, G.leptotichum, G.reticulata, G.ambisporum, Gi.rosea, G.heterogama* were not at all detected in pre-monsoon season, but present only during post-monsoon season, while *G.deserticola* and *G.tenebrosum* were present only during pre-monsoon season but were not detected in post-monsoon season. This kind of variation in AM fungal species composition over different seasons could be attributed to adoption of specific AMF species to a particular climatic condition and soil moisture regimes. Sampling of soils over seasons has revealed that some AM fungal species sporulated better during wet season while some species sporulated during dry season. Lovelock (2003) also observed that the relative abundance of spores of *Acaulospora* was lower than that of *Glomus,* during wet season and found that *Glomus* produced relatively more spores at highest seasonal rainfall. Further, he also suggested that during wet season a number of plant species with profuse rooting favoured the sporulation of AMF species. Sanders and Fitter (1992) opined that the composition of plant community might also affect mycorrhizal fungi causing differential reproduction and survival, which will definitely act as a selective force on the composition of AM fungi.

The frequency of distribution of AMF species in sixty sampling points across six different land use types during pre and post-monsoon seasons is given in the table 22. During pre-monsoon season, of the 58 AM fungal species identified, *G.fasciculatum* was distributed in maximum number of sampling points (24), followed by *G.geosporum* (19), *G.mosseae* (11), *A.bireticulata* & *G.maculosum* in ten sampling points each, *A.dilalata* and *G.hoi* in eight sampling points each, *A.mellea, A.scrobiculata* and *G.multicaulis* in six sampling points each, *G.halonatum* and *G.macrocarpum* in five sampling points each, A*.dilatata, G.citricolum, G.constrictum, G.etunicatum, G.heterosporum, G.magnicaulis, G.manihotis, G.monosporum* and *G.pansihalos* in four sampling points each, *A.nicolsoni, A.spinosa* and *G.diaphanum* in three sampling points each. *Gi.albida, G.albidum, G.australe, G.borreale, G.delhiens, G.fulvum, G.globiferum, G.intraradices, G.invermaium, G.macrocarpum, G.tenebrosum* and *S.persica* in two sampling points each and the remaining species were present in only one sampling point each. During the post-monsoon season, among the 67 different AM fungal species identified, *G.fasciculatum* was present in maximum number of sampling points (28) followed by *G.mosseae* (19), *G.geosporum* (17), *G.aggregatum* (15), *A.scrobiculata* (13), *A.lacunosa* (10), *G.diaphanum* and *G.hoi* in nine sampling points each; *G.maculosum* and *G.multicaulis* in eight sampling points each, *A.mellea* in seven sampling points;

G.citricolum and *G.lacteum* in six sampling points each; *G.constrictum, G.etunicatum, G.halonatum, G.intraradices* & *G.radiatum* in five sampling points each; *A.dilatata, A.nicolsoni, G.caledonium, G.heterosporum, G.manihotis, G.monosporum* and *G.ambisporum* in four sampling points each. *A.spinosa, G.magnicaulis* and *G.pansihalos* in three sampling points each. *A.appendicula, A.delicata, G.albidum, G.australe, G.borreale, G.claroidem, G.delhiense, G.fulvum, G.globiferum, G.invermaium, G.macrocarpum* and *Gi.margarita* in two sampling points each. The remaining AM fungal species were present in only one sampling point each.

Majority of the AM fungi were present in maximum number of sampling points during post-monsoon than during the pre-monsoon season, while a few species *viz. G.geosporum, G.maculosum, G.pansihalos, Gi.albida* and *S.persica* were present in maximum number of sampling points during pre-monsoon than post-monsoon season. Some of the AM fungal species like, *A.spinosa, A.trappei, G.albidum, G.australe, G.boreale, G.delhiens, G.fulvum, G.globiferm, G.halonatum, G.heterosporum, G.invermaius, G.macrocarpum, G.monosporum, G.manihotis, G.multisubstensum, G.pachycaulis, G.pustulatum, G.segmetatum, G.tortuosum, G.verrucosa, G.versiforme, S.calospora* were distributed in equal number of sampling points during both the seasons. These seasonal variations could be attributed to changes in climatic conditions, soil moisture regimes and change in plant species during two different seasons. In fact, Schenck and Kinloch (1980) also noticed incidence of AM fungal species over different periods of time over the years; the spores of *Gi. margarita* increased while the spores of *Gi.gregaria* and *Gi.gigantia* decreased and spores of *G.macrocarpum* and *G.fasciculatum* observed during one season disappeared in the next season.

Difficulties in predicting the levels of indigenous AMF populations in different soils arise from the large number of factors that can affect their contribution, activity and survival. These include soil fertility, soil moisture, pH, plant susceptibility, light intensity, altitude, soil organic matter, depth and soil disturbance; physical movement by water, earthworms and the soil microfauna. The wide range of AM fungi in many natural habitats suggest a degree of ecological equivalence between species (Hayman, 1978; Molina *et al.* 1978). Likewise, similar agricultural soils growing the same crop may contain different species. Furthermore, chemicals added to agricultural soils can change the species composition as well as the total size of the mycorrhizal population and the indigenous mycorrhizal populations of natural soils are often very sensitive to soil amendments. Further, it is quite evident that AMF generic distribution pattern varies with the soil type, vegetation, season and change in land use types. In the present study, at landscape level *Glomus* and *Acaulospora* were present in all the land use types whereas the genus *Gigaspora* was present in grasslands, acacia and coffee plantations and paddy fields while *Scutellospora* was present in natural forests, acacia, cardomom and coffee plantations and paddy fields. The genus *Entrophospora* was present only in grasslands during post-monsoon season. Of the sixty sampling points *Glomus* was present in all the sampling points during both the seasons while *Acaulospora* was present in only 50-60% of the sampling points. On the other hand, *Gigaspora, Scutellospora* and *Entrophospora* were present in very few sampling points. This is in accordance with the earlier studies made so far by several workers who have reported the preponderance of species of *Glomus* and *Acaulospora* in Indian soils under tropical conditions. (Thapar and Khan, 1985; Raghupathy and Mahadevan, 1993; Muthukumar and Udaiyan, 2000; Mohan,

2003). Several surveys made by other workers in other parts of Western Ghats also recorded *Glomus* and *Acaulospora* as the dominant genera of AM fungi (Muthukumar and Manian, 1993; Vasanthakrishna *et al.*, 1994; Sumana *et al.*, 2002). Mohan (2003) recorded 47 species of *Glomus* and 16 species of *Acaulospora* from soils under forest plantations in Western Ghats. Probably, soil pH may play a crucial role in the distribution of these fungi. Porter *et al.* (1987) have reported that *Glomus spp*. was of rare occurrence in Western Australia due to high pH. This suggests, that the wide distribution of *Glomus* and *Acaulospora* could be pH dependent and this could be one of the reasons why these genera are predominant in the present study where the pH of the soils is acidic.

Diversity of AM fungi in different land use types

Mycorrhizal fungi are likely to be affected by plant community composition (Janos, 1980; Kormanik *et al.*, 1980). Baylis (1962) observed that soil from the rooting zone of a tree, which bore abundant mycorrhiza readily infected seedlings, although soil from beneath a species that is rarely infected did not. The arbuscular mycorrhizal populations may readily respond to the proportion of mycotrophic plants in a community because the fungi cannot live without hosts. The lower spore production is probably associated with the ability of the fungus to spread by hyphal growth from root to root, and thus save the energy needed for sporulation (Janos, 1975). In the present study, variation in Shannon-Wiener diversity index of AM fungal species in different land use types was noticed. Diversity index of AM fungi was significantly more in natural forests and grasslands than in acacia, cardamom and coffee plantations and paddy fields in both the seasons but diversity index of AM fungi was statistically on par with each other in grasslands, acacia, cardamom and coffee plantations. In paddy fields, diversity index was statistically low compared to all other land use types. Diversity index of AM fungi during post-monsoon season was significantly more compared to diversity index during pre-monsoon season. This kind of variation in diversity of AM fungi in different land use types and during different seasons was noticed even in earlier studies. Picone (2000) has reported that the AMF diversity indices for forest and pastures were similar. Similar kinds of results were also obtained in the present study, where the diversity index of AM fungi in natural forests and grasslands was on par with each other. However, the diversity index between grasslands and paddy fields were significantly different. Oehl *et al.* (2003) in their study also recorded highest mycorrhizal diversity index in grasslands compared to moderate and low input arable lands and intensive continuous maize mono-cropping. Carpenter *et al*. (2001) in their study on spore density and diversity of AM fungi in different land uses found that diversity of AM fungi changed due to change in land use types. Further, they also found a decrease in AM fungal diversity due to erosion and deforestation but it got re-equipped after three years of vegetative regeneration. This upholds our observations that there exists a significant difference in mycorrhizal diversity between different land use types. Further, acacia plantations, which have been established in abandoned soils, have also shown a good diversity which is a similar observation made by Oehl *et al.* (2003). However, Johnson and Wedin (1997) did not find any significant difference in AMF diversity due to change in land use types. Guadarrama and Alvarez-Sanchez (1999) did not find a significant effect of season on diversity of AM fungi, but observed variation in diversity over different sites in tropical rain forests. But, our studies have shown significant differences in diversity indices even between seasons.

It is a very well established fact, that the plant species differ in their degree to which they support AM fungi (Kruckelman, 1975: Bagyaraj and Manjunath, 1980). There is a clear indication from this study that natural forests, grasslands and acacia plantations supported the highest number of spores and infective propagules and in turn the diversity of AM fungi. This could be attributed to the fact that the natural forests also have a good diversity of plant species, which in turn could contribute to the higher diversity index for AM fungi. However, it is quite possible that due to lower fertility status of the soils of natural forests in the study, there could have been an increased dependence of plants on mycorrhizae for growth and survival which lead to the development of a diverse species of AM fungi.

In the present study, it was observed that there were differences in AMF species richness between different land use types as well as between different seasons. In both the seasons AMF species richness index was more in natural forests followed by acacia plantations, grasslands, coffee and cardamom plantations and least in paddy fields. The lower species richness index for paddy fields could be due to intensive agricultural practices. Many other studies have also shown that application of fertilizers, pesticides, tillage and other soil disturbances have shown to decrease mycorrhizal population and diversity (Kruckelman, 1975; Hayman, 1980). The species richness index was higher during post-monsoon than during pre-monsoon season. In natural forests due to plant species richness and their diversity, supported more number of mycorrhizal species. In addition, the low fertility status of the soils in natural forests, acacia plantations and grasslands in our studies required an increased dependence of plants on mycorrhizae for growth and survival, which facilitated the growth of a diverse species of AM fungi. Blaszkowski (1994) found varied species richness for different plants grown in different places of Hel peninsula of Poland. High average species richness was recorded in soils sampled under Cupressaceae followed by Rosaceae, Graminae. Anderson *et al.* (1989) reported spore density and fungal types were positively correlated with species richness index. Christensen (1989) found higher heterogeneity in plant species in Hel peninsular than that of Dune sites as examined by others and this was responsible for higher species richness index in Hel peninsula. Since, sporulation of AM fungi is seasonal (Gemma, 1988), the sampling period determines the species richness index as it has been observed in this study.

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Table 1. AM fungal root colonization pattern in different land use types during pre - monsoon and post monsoon seasons

Land use types	Root colonization		
	Pre-monsoon	**Post-monsoon**	**F- test at 0.05%**
Natural forests	59.27	72.10[a]	* (6.37)
Grasslands	63.65	68.22[ab]	N.S
Acacia plantations	57.38	64.25[b]	* (5.82)
Cardamom plantations	64.41	49.09[d]	* (4.88)
Coffee plantations	65.82	56.58[cd]	* (4.90)
Paddy	47.22	33.32[e]	***** (9.99)
F test at 0.05%	NS	*	-
Season mean	59.72	57.26	N.S

Note: Values in parenthesis represents C.D. at 0.05%

Table 2. AM fungal spore density in different land use types during pre and post-monsoon seasons

Land use types	Spore density (No. g^{-1} soil)		F- test at 0.05%
	Pre-monsoon	Post-monsoon	
Natural forests	201.00[cd]	373.77[c]	* (116.00)
Grass lands	641.00[ab]	653.75[a]	N.S.
Acacia plantations	767.00[a]	615.83[ab]	N.S.
Cardamom plantations	176.00[cdef]	275.30[d]	* (60.54)
Coffee plantations	258.00[d]	315.63[d]	N.S.
Paddy fields	184.00[cde]	200.62[e]	N.S.
F-test at 0.05%	*	*	-
Seasons mean	371.00	405.00	* (31.44)

Note: Values in parenthesis represents C.D. at 0.05%

Table 3. AM fungal infective propagules in different land use types during pre and post-monsoon seasons

Land use types	Infective propagules (No. g^{-1} soil)		F-test at 0.05%
	Pre-monsoon	Post-monsoon	
Natural forests	305.00[c]	558.80[c]	* (128.40)
Grass lands	690.00[ab]	838.75[a]	N.S.
Acacia plantations	775.00[a]	736.66[ab]	N.S.
Cardamom plantations	177.00[cd]	407.07[d]	*(95.77)
Coffee plantations	260.00[cd]	442.50[d]	*(68.76)
Paddy fields	215.00[cd]	183.75[e]	N.S.
F-test at 0.05%	*	*	
Seasons mean	403.66	527.92	N.S.

Note: Values in parenthesis represents C.D. at 0.05%

Table 4. Correlation matrix between soil properties and components of AM fungi in different land uses types

Soil properties	Root colonization (%)	Spore density (50^{-1}g soil)	Infective propagules (I.P. $^{-1}$ g soil)
Clay	-0.039	-0.067	-0.086
Silt	-0.203	-0.237	-0.142
Sand	0.122	0.151	0.091
Bulk density	0.068	0.302*	0.446*
Alkaline phosphatase	0.647**	0.456*	0.400*
Acid phosphatase	0.836**	0.486*	0.465*
Org. C	0.796**	0.379*	0.465*
Nitrogen	0.115	0.058	0.103
Potassium	0.065	-0.073	-0.079
Total phosphorus	-0.279*	-0.308*	-0.232
Available phosphorus	-0.441*	-0.366*	-0.224

Table 5. Characterization of AM fungal types obtained from different land use types during pre and post-monsoon seasons

Sl. No.	*Shape*	Size (µ)	Colour	Spore wall size (µ)	No. of spore walls	Spore surface	No. of subtending hyphae	*AMF species*
1	Oval	120	Yellow	6	2	Granular	-	*A.appendicula* Spain, Sieverding & Schenck sp. nov.
2	Oval	120	Yellowish green	3	-	Globular	-	*A.bireticulata* Rothwell and Trappe sp. nov.
3	Oval	128	Yellow	8	5	Granular	-	*A.delicata* Walker Pfeiffer & Bloss sp. nov.
4	Oval	140	Yellowish brown	20	2	Smooth	-	*A.dilatata* Morton sp. nov.
5	Oval	130	Yellow	8	2	Rough	-	*A.lacunosa* Morton sp. nov.
6	Globose	145	Yellowish brown	5	3	Smooth	-	*A.laevis* Gerdemann & Trappe sp. nov.
7	Oval	110	D. Yellow	7	2	Granular	-	*A.morrowe* Spain et Schenck sp. nov.
8	Oval	90	Yellow	8	5	Granular	-	*A.mellea* ***Spain et Schenck sp. nov.***
9	Oval	120	Yellow	8	3	Granular	-	*A.nicolsoni* nov. sp.
10	Oval	145	Yellow	6	4	Granular	-	*A.scrobiculata* Trappe sp. nov.
11	Oval	120	Yellow	7	2	Granular	-	*A.spinosa* Walker & Trappe sp. nov.
12	Oval	100	Yellow	8	2	Granular	-	*A. trappei* sp. nov.
13	Oval	60	Hyaline	6	3	Smooth	-	*E.schenckeii* Sieverding & Toro sp. nov.
14	Oval	90	Yellow	7	2	Smooth	1	*G.aggregatum* Schenck & Smith sp. nov.
15	Ellipsoidal	80-110	D. Yellow	5	2	Granular	1	*G.albidum* Walker & Rhodes sp. nov.
16	Global	135	Brown	9	3	reticulate	1	*G.ambisporum* Smith & Schenck sp. nov.
17	Ellipsoidal	140	Dark yellow	11	2	Smooth	1	*G.australe* (Berk) Berch comb. nov.
18	Pear	135 x170	Honey	10	1	Rough	1(22 µ)	*G.boreale* nov. sp.
19	Globose	165	Yellowish brown	10	1	Smooth	1	*G.caledonium* Trappe & Gerdemann, comb. nov
20	Ellipsoidal	70-110	Yellow	10	2	Smooth	1	*G.canadense* nov. sp.
21	Ellipsoidal	70-105	Honey	8	2	Ornamented	2(12µ)	*G.citricolum* Tang et Zang sp. nov.
22	Oval	105	Yellow	80	3	Smooth	1	*G.claroideum* Schenck & Smith sp. nov.
23	Globose	180	Yellow	13	2	Globular	1	*G.clarum* Nicolson & Schenck sp. nov.

Contnd…

Contnd…

Sl. No.	*Shape*	Size (µ)	Colour	Spore wall size (µ)	No. of spore walls	Spore surface	No. of subtending hyphae	AMF species
24	Cylindrical	155x35	Brown	5	2	Smooth	1	*G.clavispora* Trappe sp. nov.
25	Ellipsoidal	80-130	Brown Yellow	9	2	Granular	1	*G.constrictum* Trappe sp. nov.
26	Ellipsoidal	110x 150	Dark Yellow	10	2	Rough to smooth	1	*G.delhiense* Mukerji & Bhattacharjee sp. nov.
27	Oval	120-140	Light Brown	12	3	Smooth &	1	*G.deserticola* Trappe, Bloss & Menge sp. nov.
28	Pear	120	Yellow	9	2	Granular	1	*G.diaphanum* Morton & Walker sp. nov.
29	Oval	110	Yellow	6	2	Smooth	1(9µ)	*G.dimorphicum* Boyetchko & Tewari sp. nov.
30	Oval	110	Yellow	4	2	Globular	1	*G.etunicatum* Becker & Gerdemann sp. nov.
31	Oval	90-115	Yellow	8.5	1	Smooth	1(10 µ)	*G.fasciculatum* (Thaxt. sensu Gerd.) Gerd. & Trappe comb. nov.
32	Ellipsoidal	100-160	Yellow	10	3	Smooth	1(12 µ)	*G.fulvum* (Berk) pat. comb. nov.
33	Oval	100	Honey	11	4	Smooth	1	*G.geosporum* (Nicolson & Gerdemann) Walker stat. nov.
34	Oval	120	Yellow	10	4	Smooth	1	*G.gerdemannii* Rose, Daniels & Trappe sp. nov
35	Oval	230	Brown	38	3	Granular	1	*G.globiferum* Koske et walker sp. nov.
36	Oval	200	Brown reddish	10	2	Granular	1	*G.halonatum* Rose & Trappe sp. nov.
37	Oval	95-120	Yellow	10	3	Granular	1	*G.heterosporum* Smith & Schenck sp. nov.
38	Oval	100	Brown	10	2	Granular	1	G.hoi ***Berch & Trappe sp. nov.***
39	Oval	80-100	Brown	9	2	Dark granular	1	*G.intraradices* Schenck & Smith sp. nov.
40	Oval	80	Yellow	8	4	Granular	1	*G.invermaium* Hall sp. nov.
41	Oval	125	Hyaline	7	4	Granular	-	*G.lacteum* Rose & Trappe sp. nov.
42	Globose	145	Yellow	8	2	Granular	1	*G.leptotichum* Schenck & Smith sp. nov.
43	Elliptical	70-120	Golden Yellow	10	2	Globular	1	*G.macrocarpum* Tul. & Tul. sp. nov.
44	Oval	240	Yellow	35	2	Smooth	1	*G.maculosum* Miller et Walker sp. nov.
45	Globose	130	Orange	14	2	Smooth	1	*G.magnicaulis* Ger Hall sp. nov.
46	Oval	190	Yellow	13	2	Smooth	1	*G.manihotis* Howeler, Sieverding et Sehenck n.sp.
47	Oval	210	Yellow	10	2	Smooth	1	*G.monosporum* Gerdemann & Trappe sp. nov.
48	Oval	110	Yellow	12	2	Smooth		*G.mosseae* (Nicol. & Gerd.) Gerdemann & Trappe comb. nov

Contnd…

Sl. No.	*Shape*	Size (µ)	Colour	Spore wall size (µ)	No. of spore walls	Spore surface	No. of subtending hyphae	AMF species
49	Oval	122	Dark yellow	9	2	Rough	1	*G.multicaulis* Gerdemann & Bakshi sp. nov.
50	Oval	110x 130	Dark	-	1	Rough	1(15µ)	*G.multisbstensum* Mukherji & Battachrjee sp. nov.
51	Ellipsoidal	40-60	Yellow	4	2	Smooth	1	*G.pachycaulis* Wu & Chen. sp. nov.
52	Globose	120	Yellow	7	2	Smooth	1	*G.phansihalos* Berch et Koske sp. nov.
53	Oval	90	Yellowish	8	2	Smooth	2	*G.pustulatum* Koske, Friese, Walker et Dalpe sp. nov.
54	Ellipsoidal	90-160	Brown-reddish	11	2	Smooth	2	*G.radiatum* (Thaxta) Trappe & Gerdemann comb. nov.
55	Global	135	Brown	13	2	Reticulate	1	*G.reticulatum* Bhattacharjee & Mukerji sp. nov.
56	Oval	170	Yellow	6	-	Ornamented	1	*G.scintillans* ***Rose & Trappe sp. nov.***
57	Oval	80-110	Golden Yellow	6	2	Granular	1	*G.segmentatus* Trappe, Spooner & Ivory sp. nov.
58	Irregular	130-170	Dark	17	2	Smooth	1	*G.tenebrosum* (Thaxter) Berch combo. nov.
59	Oval	210	Yellow	15	2	Granular	1	*G.tortuosum* Schenck & Smith sp. nov.
60	Oval	240	Honey	8	1	Smooth	1	*G.verrucosa* (Koske & Walker) Walker & Sanders. comb. nov.
61	Oval	135	Yellow	8	2	Smooth	-	*G.versiforme* (Karsten) Berch comb. nov.
62	Oval	210	Dark Brown	8	-	Smooth	1	*Gi.albida* Schenck & Smith sp.nov.
63	Oval	290	Brown	10	-	Granular	-	*Gi.margarita* Beker & Hall sp. nov.
64	Oval	245	Light yellow	8	2	Globular	1	*Gi.rosea* Nicolson & Schenck sp. nov.
65	Oval	230	G. Yellow	5	1	Rough	1	*S.calospora* (Nicolson & Gerdemann) Walker & Sanders comb. nov.
66	Global	210	Yellowish brown	7	2	Smooth	1	*S.heterogama* (Nicol. & Gerd.) Walker & Sanders comb. nov.
67	Oval	320	Yellow dark	8	-	Granular	1	*S.persica* (Koske & Walker) Walker & Sanders comb. nov.

Note: A – *Acaulospora*, **E**- *Entrophospora*,**G**- *Glomus*, **Gi** – *Gigaspora*, **S** - *Scutellospora*

Table 6. Frequency of distribution of different species of AM fungi over the landscape during pre and post-monsoon seasons

AMF species	Frequency of distribution (out of 60 sampling sites)		Distribution (%)	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
A.appendicula	1	2	1.66	3.30
A.bireticulata	9	18	15.00	30.00
A.delicata	1	2	1.66	3.30
A.dilatata	4	4	6.60	6.60
A.lacunosa	8	10	13.33	16.66
A.laevis	ND	4	ND	6.60
A.morrowe	1	1	1.66	1.66
A.mellea	6	7	10.00	11.66
A.nicolsoni	3	4	5.00	6.60
A.scrobiculata	6	13	ND	21.66
A.spinosa	3	3	5.00	5.00
A.trappei	1	1	1.66	1.66
E.schenckii	ND	1	ND	1.66
G.aggregatum	5	15	8.30	25.00
G.albidum	2	2	3.30	3.30
G.ambisporum	ND	4	ND	6.60
G.australe	2	2	3.30	3.30
G.boreale	2	2	3.30	3.30
G.caledonium	ND	4	ND	6.60
G.canadense	1	2	1.66	3.30
G.citricolum	4	6	6.60	10.00
G.claroideum	1	2	1.66	3.30
G.clarum	ND	1	ND	1.60
G.clavispora	1	1	1.66	1.60
G.constrictum	4	5	6.60	8.30
G.delhiens	2	2	3.30	3.30
G.desertico la	1	ND	1.66	ND
G.diaphanum	3	9	5.00	15.00
G.dimorphicum	1	1	1.66	1.60
G.etunicatum	4	5	6.60	8.30
G.fasciculatum	24	28	40.00	46.66
G.fulvum	2	2	3.30	3.30
G.geosporum	19	17	31.66	28.33
G.gerdimannii	1	1	1.66	1.66
G.globiferum	2	2	3.30	3.30
G.halonatum	5	5	8.30	8.30
G.heterosporum	4	4	6.60	6.60
G.hoi	8	9	13.33	15.00

Contnd…

AMF species	Frequency of distribution (out of 60 sampling sites)		Distribution (%)	
	Pre-monsoon	**Post-monsoon**	**Pre-monsoon**	**Post-monsoon**
G.intraradices	2	5	3.30	8.30
G.invermaium	2	2	3.30	3.30
G.lacteum	5	6	8.30	10.00
G.leptotichum	ND	1	ND	1.66
G.maculosum	9	8	15.00	13.33
G.macrocarpum	2	2	3.30	3.30
G.magnicaulis	4	3	6.60	5.00
G.manihotis	4	4	6.60	6.60
G.monosporum	4	4	6.60	6.60
G.mosseae	11	19	18.33	31.66
G.multicaulis	6	8	10.00	13.33
G.multisubstensum	1	1	1.66	1.66
G.pachycaulis	1	1	1.66	1.66
G.phansihalos	4	3	6.60	5.00
G.pustulatum	1	1	1.66	1.66
G.radiatum	3	5	5.00	8.30
G.reticulatum	ND	3	ND	5.00
G.scintillans	1	1	1.66	1.66
G.segmentatus	1	1	1.66	1.66
G.tenebrosum	2	ND	3.30	ND
G.tortuosum	1	1	1.66	1.66
G.verrucosa	1	1	1.66	1.66
G.versiforme	1	1	1.66	1.66
Gi.albida	2	1	3.30	1.66
Gi.margarita	1	2	1.66	3.30
Gi.rosea	ND	1	ND	1.66
S.calospora	1	1	1.66	1.66
S.heterogama	ND	1	ND	1.66
S.persica	1	1	1.66	1.66

Note**: A** – *Acaulospora*, **E**- *Entrophospora,* **G**- *Glomus*, **Gi** – *Gigaspora*, **S**- *Scutellospora,* **ND** – Not Detected

Table 7. Abundance of spores of different species of AM fungi in sampling points during pre and post-monsoon seasons

AM fungal species	Spore abundance (No. 50g^{-1} soil)	
	Pre-monsoon	**Post monsoon**
A.appendicula	35 ± 26.71	89 ± 23.92
A.bireticulata	837 ± 216.43	1678 ± 269.29
A.delicata	410 ± 99.61	83 ± 28.48
A.dilatata	249 ± 94.03	394 ± 109.96
A.lacunosa	736 ± 109.94	1106 ± 166.61
A.laevis	ND	256 ± 37.9
A.marrowe	235 ± 76.75	231 ± 94.30
A.mellea	598 ± 143.06	925 ± 230.87
A.nicolsoni	137 ± 110.55	200 ± 55.69
A.scrobiculata	283 ± 82.55	808 ± 205.92
A.spinosa	231 ± 123.17	478 ± 123.17
A.trappei	124 ± 64.15	160 ± 64.15
E.schenckeii	ND	40 ± 16.32
G.aggregatum	221 ± 60.51	1547 ± 342.95
G.albidum	535 ± 137.44	529 ± 151.46
G.australe	190 ± 62.87	294 ± 82.42
G.borreals	110 ± 40.82	180 ± 73.48
G.caledonicum	ND	582 ± 201.81
G.canedense	75 ± 27.35	117 ± 31.22
G.citricolum	150 ± 42.12	911 ± 142.14
G.claroideum	60 ± 19.18	138 ± 39.78
G.clarum	ND	97 ± 39.60
G.clavispora	13 ± 5.3	58 ± 23.67
G.constrictum	325 ± 153.09	346 ± 131.23
G.delhiens	25 ± 10.20	366 ± 149.41
G.deserticola	73 ± 29.8	ND
G.diaphanum	123 ± 39.78	268 ± 38.04
G.dimorphicum	17 ± 6.94	42 ± 17.14
G.etinicatum	341 ± 66.32	729 ± 113.37
G.fasciculatum	1713 ± 237.31	4362 ± 366.04
G.fulvum	270 ± 91.84	259 ± 105.73
G.geosporum	1154 ± 120.97	2030 ± 255.55
G.gerdimanii	15 ± 18.37	61 ± 24.90
G.globiferum	21 ± 13.6	117 ± 31.57
G.halonatum	441 ± 82.5	557 ± 178.95
G.heterosporum	597 ± 165.81	467 ± 107.51
G.hoi	532 ± 127.21	591 ± 87.37
G.intraradices	ND	716 ± 177.99
G.invermaians	286 ± 101.02	317 ± 81.84
G.lacteum	179 ± 86.18	588 ± 99.13

Contnd…

AM fungal species	Spore abundance (No. 50g^{-1} soil)	
	Pre-monsoon	**Post monsoon**
G.leptotichum	ND	24 ± 9.79
G.macculosum	236 ± 86.60	646 ± 129.19
G.macrocarpum	18 ± 203.30	380 ± 155.13
G.maculosum	302 ± 64.54	402 ± 127.21
G.magnicaulis	453 ± 90.31	262 ± 70.09
G.manihotene	123 ± 36.29	297 ± 58.93
G.meridium	ND	554 ± 246.81
G.monosporum	238 ± 52.05	290 ± 75.32
G.mosseae	857 ± 251.11	2900 ± 232.66
G.multicaulis	200 ± 45.96	1466 ± 141.40
G.multisubstensum	30 ± 11.02	58 ± 23.67
±*G.pachycaulis*	28 ± 11.43	103 ± 42.04
G.phansihalos	270 ± 59.52	285 ± 57.06
G.pustulatum	20 ± 6.94	109 ± 44.49
G.radiatum	159 ± 65.28	565 ± 152.65
G.scintillans	70 ± 23.67	49 ± 20.00
G.segmentatus	30 ± 36.74	98 ± 40.00
G.tenebrosum	209 ± 85.32	ND
G.tortuosum	55 ± 16.73	51 ± 87.77
G.uelum	ND	457 ± 32.65
G.verrucosa	25 ± 9.38	129 ± 52.66
G.versiforme	30 ± 11.02	146 ± 59.60
Gi.albida	160 ± 108.8	340 ± 115.22
Gi.margarita	18 ± 58.78	117 ± 30.93
Gi.rosea	ND	39 ± 15.92
S.calospora	15 ± 4.89	105 ± 42.86
S.heterogama	ND	52 ± 21.22
S.persica	71 ± 55.26	258 ± 105.32
Total Mean	**219**	**483**

Note**: A** – *Acaulospora*, **E**- *Entrophospora,* **G**- *Glomus*, **Gi** – *Gigaspora*, **S**- *Scutellospora*, **ND –** Not Detected

Table 8. AM fungal species diversity in different land use types during pre and post-monsoon seasons

Land use types	No. of AMF species		Shannon-Wiener Diversity index	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Natural Forests	27	33	4.41	4.59
Grasslands	24	27	4.20	4.45
Acacia Plantations	22	26	3.99	4.26
Cardamom Plantations	19	26	3.57	4.08
Coffee Plantations	23	25	3.80	4.04
Paddy Fields	16	13	3.26	3.01

Table 9. Jacknife's species richness index for AM fungi in different land use types during pre and post-monsoon seasons

Land use types	No. of sampling points		Unique species		Species richness index	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Natural Forest	9	9	18	21	43.00	51.67
Grasslands	8	8	15	20	37.13	48.50
Acacia plantations	6	6	20	19	38.67	41.83
Cardamom plantations	13	13	8	12	24.38	37.08
Coffee plantations	16	16	9	10	30.44	34.37
Paddy fields	8	8	11	9	25.63	20.87

Abundance and diversity of legume nodulating bacteria (*Rhizobium*) across a gradient of different land use types during pre and post monsoon seasons in Western Ghats, Karnataka, India

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ABSTRACT

Soil samples and nodules from field grown legumes were collected from six different land use types *Viz*., natural forests, grasslands, acacia plantations, cardamom plantations, coffee plantations and paddy fields in Western Ghats, Karnataka to study the abundance and diversity of legume root nodulating bacteria during pre and post-monsoon seasons. The population of rhizobia as determined by MPN technique varied significantly in different land use types in both pre and post-monsoon seasons. The distribution of the rhizobial population as estimated by MPN technique in terms of percentage over benchmark area has revealed that, there was more distribution of cells in the coffee plantations (92.3%), followed by acacia plantations (3.94%) grasslands (1.07%), cardamom plantations (0.78%), paddy fields (0.69%) and least in natural forests (0.39%) in the pre-monsoon season and in the post-monsoon season, maximum distribution of rhizobial cells was in cardamom plantations (87.44%) followed by paddy fields (3.90%), grass lands (3.59%), coffee plantations (2.64%), acacia plantations (1.32%) with least distribution of in natural forests (1.03%).

During the pre-monsoon season 53 isolates were recorded in all the land use types from out of 60 sampling points, from the legumes grown in the field as well as by using cowpea as trap crop. Similarly, during the post-monsoon season, a total of 55 isolates were recorded in different land use types. The maximum number of isolates was recorded from cardamom plantations (12) and least in acacia plantations (6) during the pre-monsoon season. During the post monsoon season also the maximum number of isolates was recorded in cardamom plantations (10) and least in acacia plantations (6). Further, there were only two isolates from legumes grown naturally in the field during pre-monsoon season in paddy fields and two isolates each from paddy fields, grasslands and natural forests in the post-monsoon season. In general, the distribution of rhizobia in terms of acid producing/fast growers and alkali producing/slow growers indicated that the alkali producing/slow growers were higher compared to acid producing/fast growers in all the land use types studied during both the seasons, using trap crop and field grown legumes.

INTRODUCTION

Biological nitrogen fixation offers a better alternative over chemical fertilizers as the process, besides supplying nitrogen to crop, enriches soil nitrogen content and maintains soil health and productivity (Reddy and Reddy, 2004).

The symbiosis between the root nodule bacteria of the genus *Rhizobium* and legumes is of special significance to legume husbandry as seed inoculation with effective strains of *Rhizobium* could meet the partial nitrogen requirement of legumes and hence reduction in dependence of external nitrogen inputs.

Before the introduction of molecular taxonomy for identification of bacteria, bacteria which induced morphologically distinct outgrowths called nodules on the root surface of leguminous plants (except *Parasponia*) were collectively called as rhizobia. However, following development of molecular techniques, it was discovered that apart from rhizobia, many other bacteria such as *Burkholderia* and *Ralstonia* from ? ? proteobacteria and other bacteria from ? - proteobacteria such as *Methylobacterium* and *Blastobacter* can also induce nodules on legumes. Accordingly, all bacteria that nodulates leguminous plants are at present collectively called as legume nodulating bacteria (LNB).

Variability in the environment and management practices of legumes is likely to be associated with diversity in LNB, an aspect that has received only marginal attention in India (Manvika Sahgal and Johri, 2003). However, very little work is carried out in India on the population dynamics and diversity of LNB in different agro-climatic conditions in different soils.

Kumar Rao and Dart (1979) reported that continuous cultivation of paddy has an adverse effect on *Rhizobium* survival. Kumar *et al.* (1997) reported that cultivation of legumes led to an increase in the population of rhizobia in soil. They suggested that the nodules of leguminous plants decay after maturity and as a result of that, rhizobial cells were released in the soil atmosphere. Hegde (1983) determined the red gram (*Cajanus cajan*) rhizobial population in 14 soil samples from different places in Karnataka using siratro and red gram as trap plants. The population ranged from 1.8×10^2 cfu g^{-1} to 2.6×10^5 cfu g^{-1} of dry soil. Population changed as with soil depth, soil types and cropping patterns. In alfisol, it was found that the population declined with depth and reduction was more pronounced below 100 cm in the soil profiles. Similar patterns have also been observed in vertisol fields (Kumar Rao and Dart, 1981). This work was under taken to study the diversity among the LNB in the Western Ghats, Karnataka of India, with the following objectives 1) to determine the rhizobial population in different land use types 2) to make an inventory of rhizobia from the hilly regions of Western Ghats. 3) Isolation of rhizobia from nodules collected from different legumes of different land use types 4) morphological and physiological characterization of rhizobia.

MATERIAL AND METHODS

Collection of soil samples

The benchmark area selected for this study is located in the southern part of India which has a tropical type of climate. The 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 scale. Following the hybrid classification approach, a mask was created for almost non-overlapping classes (*viz.*, agricultural areas and vegetated areas) obtained from unsupervised classification (isodata algorithm). The vegetated areas were further classified into natural forests, grasslands,

coffee/cardamom plantations and acacia 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.

A total of 60 sample points were distributed in two windows of the size 6.4 sq km (4 x 1.6 km) and 0.8 sq km (0.4 x 2 km) so as to cover all the above said land cover types. Fifty-three sample points were distributed in the first large window and 7 points in the second small window. Stratified sampling technique was adapted and two windows were selected, because the first large window that was selected did not have enough natural forests, grasslands and *Acacia* plantations. Hence, additional window in the study site was selected to cover the required land use types.

The sample points were laid in the intersection point of the windows and were located in the ground using hand held ***Garmin 12*** GPS. The intersection points at which sampling could not be done due to the presence of a natural obstruction (presence of a tree, stone/water body etc.) were skipped and the sampling was done in the next intersection point.

Six land use-land cover types could be distinguished in the study area. They are; natural forests, grasslands, acacia plantations, coffee and cardamom plantations and paddy fields. For collecting the soil samples, a triangle of 50 x 50 x 50 m was laid at each sampling point. The center point of the triangle was marked and from this central point at a distance of three meters, three soil cores of 0-20 cm depth was taken using a soil core, avoiding the litter above the ground. Similarly, at a distance of six meters from the center, another three soil cores of 0-20 cm depth were taken as explained above. Thus, at each sampling point six soil cores were collected and these six soil core samples were mixed together to form a composite sample per sampling point. These soil samples were stored at 5^0 C in a refrigerator for further microbiological analysis. Soil sampling was done during February-march (pre-monsoon) and October-November (post monsoon) during the year 2004.

Soil samples were collected at nine sampling points from natural forests, eight sampling points from grasslands, six sampling points from acacia plantations, thirteen sampling points from cardamom plantations, sixteen sampling points from coffee plantations and eight sampling points from paddy fields.

MPN counts/method

The population of rhizobia in the 60 soil samples collected from different land use types was determined by following MPN technique. For this, growth pouches were made by using germination papers and had holes at the top folded side of the paper. The pouches were inserted into polypropylene bags and arranged in the slots of the rack. The

opening of the pouch was sealed with non-absorbent cotton to prevent contamination through dust. Each rack could accommodate thirty growth pouches. Healthy seeds of cowpea were surface sterilized using sodium hypo-chloride solution (3%) for one to two minutes and washed serially, three to four times and pre- germinated using water agar medium.

Then, 30 ml of Hoagland's plant nutrient solution was added to each of the growth pouches and sterilized in an autoclave. Pre- germinated seeds of cowpea were placed in the holes of the growth pouches. Four-fold dilution of soil samples were prepared (10^{-1}, 4^{-1}, 4^{-2}, 4^{-3}, 4^{-4}, 4^{-5}, 4^{-6}) and one ml of each dilution was added to each of the four replicated growth pouches. These growth pouches were then kept in the green house and observed periodically and replenished the nutrient solution whenever it was necessary. Nodulation was evident after three weeks. Final observation was made after four weeks and presence (+) or absence (-) for nodules was recorded (Somasegaran and Hoben, 1985).

Isolation of rhizobia from nodules

The nodules thus obtained from the cowpea plants grown in growth pouches from MPN technique as well as those obtained from field (*Mimosa* sp, *Crotolaria* sp and *Desmodium* sp) were washed in running water and surface sterilized by 1% sodium hypochlorite solution for about 2-3 minutes and then washed serially for 4-6 times with sterilized water. These nodules were crushed in a sterile test tube containing about 1 ml of 0.85% sterile saline with sterilized glass rod and streaked on YEMA medium with congored and incubated for 2-5 days and observed for colourless or white colonies presumed to be *Rhizobium*. A loopful of the inoculum from the isolated single colony was purified by streak plate method. The inoculum from isolated single colony on streak plates was transferred to YEMA slants for further studies.

Authentication

Authentication of the isolates presumed to be *Rhizobium* was made by inoculating the pre- germinated cowpea seeds with liquid *Rhizobium* cultures grown on YEMA broth for 7 days, in growth pouches as explained earlier. Those isolates that initiated nodulation in cow pea plants were considered as rhizobia.

Characterization of rhizobia as acid producing/fast growing or alkali producing/slow growing

The isolates of rhizobia after authentication test were streaked on plates containing YEMA medium with bromo thymol blue indicator. If the original green colour turned to blue colour it indicated the alkali producing/slow growers, if the green colour turned to yellow it indicated the fast growing/acid producers (Somasegaran . and Hoben, 1985).

RESULTS

The population of rhizobia as determined by MPN technique in different land use types is presented in Table 1. The population of rhizobia ranged from 0.08×10^2 to 3.5×10^2 cells g^{-1} soil in natural forests, 0.65×10^2 to 15×10^2 cells g^{-1} soil in grass lands,

2.5 $\times 10^2$ to 67.5$\times 10^2$ cells g^{-1} soil in acacia plantations, 0.06$\times 10^2$ to 22.5$\times 10^2$ cells g^{-1} soil in cardamom plantations, 0.06$\times 10^2$ to 250 $\times 10^2$ cells g^{-1} soil in coffee plantations and 0.08$\times 10^2$ to 7.2$\times 10^2$ cells g^{-1} soil in paddy fields during the pre-monsoon season.

The maximum mean population was recorded in the coffee plantations (125 $\times$ 10^2 cells g^{-1} soil) followed by acacia plantations (35$\times 10^2$ cells g^{-1} soil), cardamom plantations (11.28 $\times 10^2$ cells g^{-1} soil), grasslands (7.82 $\times$ 10^2 cells g^{-1} soil), paddy fields (3.64 x 10^2 cells g^{-1} soil) and least in natural forests (1.75 $\times$ 10^2 cells g^{-1} soil).

During the post-monsoon season, the population of rhizobia ranged from 1.25 x 10^2 to 10.5 x 10^2 cells g^{-1} soil in natural forests, 0.65 x 10^2 to 55 x 10^2 cells g^{-1} soil in grass lands, 1.25 x 10^2 to 14.0 x 10^2 cells g^{-1} soil in acacia plantations plantations, 0.65 x 10^2 to 250 x 10^2 cells g^{-1} soil in cardamom plantations, 0.9 x 10^2 to 20 x 10^2 cells g^{-1} soil in coffee plantations and 1.75 x 10^2 to 36 x 10^2 cells g^{-1} soil in paddy fields. Maximum population of rhizobia was observed in cardamom plantations (25 x 10^2 cells g^{-1} soil) followed by coffee plantations (20.00 x 10^2 cells g^{-1} soil), paddy fields (14.10 x 10^2 cells g^{-1} soil), grasslands (12.10 x 10^2 cells g^{-1} soil) natural forests (3.82 x 10^2 cells g^{-1} soil) and least was observed in acacia plantations (0.15 x 10^2 cells g^{-1} soil).

The number of isolates of rhizobia obtained from six different land use types is presented in Table 2. The results indicated that during the pre-monsoon season 53 isolates were recorded in all the land use types from out of 60 sampling points, from the legumes grown in the field as well as by using cowpea as trap crop. Similarly, during the post-monsoon season, a total of 55 isolates were recorded in different land use types. The maximum number of isolates was recorded from cardamom plantations (12) and least in acacia plantations (6) during the pre-monsoon season. During the post monsoon season also the maximum number of isolates was recorded in cardamom plantations (10) and least in acacia plantations (6). Further, there were only two isolates from legumes grown naturally in the field during pre-monsoon season in paddy fields and two isolates each from paddy fields, grasslands and natural forests in the post-monsoon season.

The distribution of the rhizobial population as estimated by MPN technique in terms of percentage over benchmark area has revealed that, there was more distribution of cells in the coffee plantations (92.3%), followed by acacia plantations (3.94%) grasslands (1.07%), cardamom plantations (0.78%), paddy fields (0.69%) and least in natural forests (0.39%) in the pre-monsoon season and in the post-monsoon season, maximum distribution of rhizobial cells was in cardamom plantations (87.44%) followed by paddy fields (3.90%), grass lands (3.59%), coffee plantations (2.64%), acacia plantations (1.32%) with least distribution of in natural forests (1.03%) (Table 3).

In the pre-monsoon season, the distribution of fast growing rhizobia in different land use types *viz*., natural forests, grasslands, acacia plantations, cardamom plantations, coffee plantations and paddy fields were 22, 25, 33.3, 23, 18.75 and 25 per cent respectively, while the slow growing rhizobia it were 78, 75, 66.7, 76.9, 81.12 and 75 per cent respectively.

In the post-monsoon season, the distribution of acid producing/fast growing rhizobia in different land use types *viz*., natural forests, grasslands, acacia plantations,

cardamom plantations, coffee plantations and paddy fields was 22.00, 25.00, 16.70, 23.00, 25.00 and 12.50 per cent respectively, while for the alkali producing/slow growing rhizobia it was 78.00, 75.00, 83.30, 77.00, 75.00 and 87.50 per cent respectively (Table 4).

The distribution of rhizobia isolated from field grown legumes was only in paddy fields and all of them belonged to acid producing/slow growers and accounted for 100 per cent during pre-monsoon. The distribution of rhizobia isolated from field grown legumes during post- monsoon season was only in natural forests, grasslands and paddy fields. In terms of per cent distribution the alkali producing/slow growing isolates accounted for 100 per cent each in natural forests and grass lands while in paddy fields the fast growing and slow growing isolates rhizobia were 50 per cent each respectively (Table 4).

In general, the distribution of rhizobia in terms of acid producing/fast growers and alkali producing/slow growers, indicated that the alkali producing/slow growers were higher compared to acid producing/fast growers in all the land use types studied during both the seasons, using trap crop and field grown legumes.

All the 108 isolates of rhizobia (53 from pre-monsoon and 55 from post-monsoon season isolated using trap plant and field grown legumes) obtained from different land use types were characterized and presented in Table 5. In natural forests and grass lands the colonies of the isolates showed almost similar characters. They were small, round colonies, growth appeared in 48-72 hrs. Some isolates were acid producing/fast growers and some were alkali producing/slow growers. In acacia and cardamom plantations, the colonies of the isolates showed almost similar characters such as small to medium and round with raised colonies with more slime production. These isolates were slow growing/alkali producers. In coffee plantations, the colonies of the isolates were small, round and growth appeared in 48-72 hrs with slime production. Some isolates were acid producing/fast growers and some were slow growing/alkali producers. The fast growing colonies appeared within 48 hrs. In paddy, the colonies were raised, small to medium, round to oval in shape with plenty of slime production and growth appeared within 24-48 hrs.

DISCUSSION

Legume *Rhizobium* symbiosis is one of the biological N_2-fixing systems and is the most cost effective means of N addition to terrestrial ecosystem. But, to certain extent the survival of these organisms in nature largely depends on the genetic and physiological traits of the organisms in addition to the environmental conditions brought about by cultivation practices. This study deals with the effects of land use changes on the diversity and survival of rhizobia.

The population of rhizobia varied significantly in different land use types during the pre-monsoon season. This could be attributed to the fact that different plant community composition characterizes different land use types, which in turn result for differences in population due to differences in the rhizosphere effect exhibited by different plant communities. Such variations in the rhizosphere effect was observed even among the serotypes of *R. leguminosarum* bv. trifolii in a Abiqua silty loam soil in arable

and pasture soils under legumes. Further, the magnitude of the sub clover rhizosphere effect varied seasonally and among serotypes (Leung *et al*., 1994). Hegde (1983) while studying the population dynamics of red gram rhizobia in different agro-climatic zones of Karnataka suggested that the population of rhizobia varied with soil depth, soil type and cropping pattern. In the present study, one of the two land use types is dominated by mono-cropping of only acacia plantations and the other has a large number of diversified plant species in addition to coffee plantations. Therefore, it appears that the variations in population of rhizobia could also be due to land use types. Such variations in land management have also been observed by Palmer and Young (2000) while comparing the population dynamics of *R. luguminosarum* after a long-term arable cultivation with that under permanent grassland.

However, it cannot be ruled out that the population of other microorganisms stimulated by the plant Community will have differential effects on these bacteria. Li and Alexander (1986) suggested that the extent of inhibition of rhizobia is related to the growth of the rhizosphere bacteria.

But, in the post-monsoon season a similar trend was not observed in the population of rhizobia, which is very difficult to be explained. Though, there was an increase in the population in most of the land use types significant decrease in the population was observed in acacia and coffee plantations. The decrease in population in acacia plantations could be attributed to the fact that the cells of rhizobia might have been washed-off from higher elevations to valleys along with the topsoil as there is very meager undergrowth in these plantations. A similar analogy may also hold good for higher population in paddy fields as it may receive rhizobial cells washed-off from the hills. However, the decrease in population in coffee plantations could be due to the application of agricultural chemicals that are usually taken up in the post-monsoon season. Similar inhibitory effects due to application of insecticides, herbicides, and nematicides, at different concentrations have been known to affect inoculated rhizobia in broad bean plants (Salem *et al*., 1976).

In the present study, the number of rhizobial isolates recorded during pre and post- monsoon season were almost same in different land use types except that they are either slow growing or fast growing. In spite of a drastic reduction in the population in coffee and acacia plantations compared to natural forests, grasslands, cardamom plantations and paddy fields, the number of isolates remained the same. It is very difficult to attribute any reason for this, as number of isolates alone doesn't decide the population dynamics of these organisms.

The physiological characterization of these isolates has revealed that most of these isolates belonged to slow growing/alkali producing rhizobia in all the land use types in both the seasons. The pH of the soils under the present study is quite acidic (5.5). Therefore, it is quite possible that these isolates produced alkali, a mechanism by which microorganisms adopt themselves to changes in the environment (Atlas and Bartha, 1998).

To conclude, though there has been diversity of rhizobia in terms of fast and slow growing isolates, in depth studies leading to molecular characterization are needed to further classify them into species.

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Table 1. Population of legume root nodulating bacteria (*Rhizobium*) in different land use types as determined by MPN technique (x 10^2 cells g^{-1} soil) during pre and post- monsoon seasons.

Land use types	Pre-monsoon				Post-monsoon			
	Min	Max	Average	SD	Min	Max	Average	SD
Natural forests	0.08	3.50	1.75	±1.42	1.25	10.50	3.82	±3.58
Grassland	0.65	15.00	7.82	±5.48	0.65	55.00	12.10	±17.34
Acacia plantations	2.50	67.50	35.00	±6.23	1.25	14.00	0.15	±4.37
Cardamom plantations	0.06	22.50	11.28	±26.29	0.65	250.00	25.00	±78.24
Coffee plantations	0.06	250.00	125.00	±62.40	0.90	20.00	20.00	±6.70
Paddy fields	0.08	7.20	3.64	±2.73	1.75	36.00	14.10	±11.63

Table 2: Isolates of legume root nodulating bacteria (*Rhizobium*) from trap plant and fields of different land use types during pre and post-monsoon seasons.

Land use types	Pre-monsoon		Post-monsoon	
	Trap plant	Field grown	Trap plant	Field grown
Natural forests	9	-	9	2
Acacia plantations	6	-	6	-
Cardamom plantations	12	-	10	-
Coffee plantations	8	-	8	-
Paddy fields	8	2	8	2

Naturally field grown legumes were *Desmodium, Crotalaria* sp. and *Mimosa* sp.

Table 3. Distribution of legume root nodulating bacteria (*Rhizobium*) as determined by MPN technique in different land use types during pre and post-monsoon Seasons.

Land use types	Pre-monsoon (%)	Post-monsoon (%)
Natural forests	0.39	1.03
Grassland	1.07	3.59
Acacia plantations	3.94	1.32
Cardamom plantations	0.78	87.44
Coffee plantations	92.3	2.64
Paddy fields	0.69	3.90

Per cent distribution = population as per MPN technique in a particular land use type multipliedby 100 and divided by total number of cells in all the land uses.

Table 4: Relative abundance of fast growing/acid producing and slow growing/alkali producing bacteria in different land uses

Land uses	Pre-monsoon season				Post-monsoon season			
	Distribution (%)				Distribution(%)			
	Trap crop		Field legumes		Trap crop		Field legumes	
	Fast /acid	Slow/ alkali	Fast/ acid	Slow/ alkali	Fast/ acid	Slow/ alkali	Fast/ acid	Slow/ alkali
Natural forests	22.00	78.00	-	-	22.00	78.00	-	100
Grassland	25.00	75.00	-	-	25.00	75.00	-	100
Acacia plantations	33.30	66.70	-	-	16.70	83.30	-	-
Cardamom plantations	23.00	76.90	-	-	23.00	77.00	-	-
Coffee plantations	18.75	81.12	-	-	25.00	75.00	-	-
Paddy fields	25.00	75.00	-	100	12.50	87.50	50	50

Table 5. Characters of leguminosae root nodulating bacteria (*Rhizobium*) from different landuse types.

Land use types	Colony characters
Natural forests	Small, round colonies, growth appeared in 48-72 hours, produced slime, some were fast growing/acid producers and some were slow growing/alkali producers.
Grasslands	Small, round colonies, growth appeared in 48-72 hours, produced slime, some were fast growing/acid producers and some were slow growing/alkali producers.
Acacia plantations	Small, round colonies, growth appeared in 48-72 hours, produced more slime, slow growing /alkali producers.
Cardamom plantations	Raised, small to medium size colonies, growth appeared in 48-72 hours, produced slime, slow growin g/alkali producers.
Coffee plantations	Most colonies were small, round, and some colonies were bigger, growth appeared in 48-72 hours, produced slime, some were fast growing/acid producers and some were slowing/ alkali producers.
Paddy fields	Raised colonies, small to medium in size, round to oval in shape, produced more slime and growth appeared in 24-48 hours.

Population and Diversity of *Azotobacter* and PO_4 -solubilizing Microorganisms in Different Land Use Types in Western Ghats of Karnataka

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ABSTRACT

The impact of different land use types on population and diversity of *Azotobacter* in various land use types *viz*., natural forests, grasslands, acacia plantations, cardamom plantations, coffee plantations and paddy fields were studied during pre and post-monsoon seasons in Western Ghats, Koothy village of Somwarpet taluk, Coorg district. The population of *Azotobacter was* maximum in natural forests and least in grasslands in both the seasons. The population of *Azotobacter* was significantly higher in the pre-monsoon season compared to the post-monsoon season in all the land use types except in acacia plantations. The *Azotobacter* isolates were identified as *Azotobacter vinelandii* and *A. chroococcum* based on the morphological and physiological characters. The population of PO_4-solubilizing bacteria was maximum in natural forests and least in cardamom plantations in pre-monsoon season and there were no significant differences in the population between different land use types in post-monsoon season. The population of PO_4- solubilizing bacteria was significantly higher in natural forests, coffee plantations and paddy fields in the pre-monsoon season compared to the post-monsoon season, but, lower in the pre-monsoon season in other land use types. There were nine isolates of fungi and two isolates of bacteria capable of solubilizing insoluble phosphate on the Sperber's medium. Of the nine fungal isolates one belonged to the genus *Fusarium*, five to the genus *Aspergillus* and three to *Penicillium*. The bacterial isolates could not be characterized, but designated as PSB-1 and PSB-2.

INTRODUCTION

Soil microorganisms form a very peculiar and remarkable living community and are the driving force of most terrestrial ecosystems, because of their capacity to control the turnover and mineralization of organic substrates. Soil harbors a variety of beneficial microorganisms such as N_2- fixers, PO_4- solubilizers and plant growth promoters. Since, major portion of the applied inorganic nitrogenous fertilizers is lost due to leaching and denitrification, N_2-fixation studies assume particular significance (Sanchez, 1976). Heterotrophic free-living nitrogen fixers like *Azotobacter, Beijerinckia, Derxia etc.* are important due to their wide occurrence in soils and rhizosphere of different crops.

The population of *Azotobacter* in Indian soils rarely exceeds 10^4 to 10^5/g soil. Their occurrence in soil is known to depend on various soil factors like pH, moisture content, depth, availability of nutrients, organic matter content of the soil *etc.* (Krishnamurthi, 1962). Similarly, Rangaswami and Sadasivam (1969) reported a positive correlation between *Azotobacter* population with organic mater, available phosphorus and pH of soils. They also reported, the predominance of *Azotobacter indicus* in acidic soils while *Azotobacter chroococcum* in neutral-alkaline soils.

Edward and Tripathi (1972) recorded a higher number of azotobacters in the rhizosphere of wheat and hybrid napier grass than in the non-rhizosphere soil. Shivappashetty and Patil (1975) isolated *Azotobacter* from the root and rhizoplane soil samples of local grasses and identified them as *A. chroococcum*, *A. beijerinckii* and *A. vinelandii*. Bhide and Purandare (1979) observed the presence of *Azotobacter* like organisms within the TTC reduced root cells of aseptically grown and surface sterilized *Cynadon dactylon* and found them to fix 4.2 to 4.6 mg N per gram of sucrose. Similarly, an appreciable amount of acetylene reducing activity was observed by Dobereiner (1979) in excised roots of *Erillgratis ferugina* where the organism responsible resembled *Azotobacter* like organism termed ER -2021. Tikhe *et al*. (1980) have also observed the occurrence of *Azotobacter chroococcum* in intra cortical cells of commonly occurring monocot plants and grasses, showing N_2- fixation to the extent of 3.0 to 6.0 mg per gram of sucrose in 4-5 days. Iswaran and Marhwa (1982) isolated *Azotobacter chroococcum* from the cortical cells of roots, nuts, stems and leaves of *Cyperus rotundus* and found them to fix 5.2 to 6.8 mg N/g of sucrose. N_2- fixing bacteria like *Azotobacter vinelandii*, *Erwinia herbicola* and *Enterobacter cloacae* have been isolated from roots, stem and leaves of sugarcane (Gracolli *et al*., 1983). Bopaiah (1987) while studying the occurrence of microorganisms associated with root regions of coconut reported the distribution of *Azotobacter* both under mono and mixed cropping systems of coconut. Tippannavar and Reddy (1989) also detected the presence of *Azotcbacter chroococcum* in the roots, stem and leaf tissue of aseptically grown wheat seedlings whereas Reddy *et al*. (1991) isolated *A. chroococcum* from the stem and leaves of aseptically grown seedlings of six sorghum cultivars. Sengupta and Sengupta (1992) isolated *Azotobacter* from roots and rhizoplane soil samples of local grasses, and identified them as *A. chroococcum, A, beijerinckii* and *A. vinelandii*. Raghuramulu (2001) also reported the occurrence of *Azotobacter* in soils of coffee plantations.

Phosphorus is another major element for the growth of plants and microorganisms. But, only an extremely small quantity is present as water-soluble P in soil available to plants. On the other hand, insoluble inorganic and organic forms of phosphorus which constitutes a large portion of P in soil is non available to plants. Soil phosphates are rendered available by soil microorganisms through the mineralization of phosphate rich organic compounds. Many fungi and bacteria are potential solubilizers of bound phosphates in soil.

Louw (1970) observed a large population of gram negative, non-spore forming, rod shaped bacteria in the rhizosphere of wheat and lupines which actively dissolved insoluble mineral phosphate compounds. Nair and Rao (1977) isolated phosphate solubilizing *Pseudomonas* and *Aspergillus sp*. from the rhizosphere of coconut and cocoa and their occurrence was related to available phosphorus content of soil. Actively growing *Zostera marina* plants are reported to harbour tricalcium phosphate solubilizing bacteria to the extent of 4×10^8 cells/g dry root weight (Craven and Hayaska, 1982).

The occurrence and activity of PO_4- solubilizing fungi from coconut plantation soils was investigated by Thomas *et al*. (1985) and found lateritic, alluvial and clayey soils harbored higher PO_4-solubilizing fungi than in sandy soils and recorded fungi of the genera *Aspergillus* and *Penicillium.* Bopaiah (1985) also reported that the soils collected from root regions of arecanut palms (at 0-30 cm depth) grown in Karnataka also harbored

PO_4- solubilizing fungi *viz*., *Aspergillus* and *Penicillium*. Studies on the distribution of PO_4-solubilizing bacteria in coconut plantation soils revealed that clayey soils harboured less population than lateritic, alluvial and sandy soils. *Pseudomonas* sp., *Micrococcus* sp., *Bacillus subtilis, Corynebacterium* sp. and *Alkaligenes* sp. were the PO_4-solubilizing bacteria in coconut rhizosphere soils. Comparatively low numbers of bacteria capable of solubilizing insoluble phosphates in clayey soils might be due to the interaction of a number of physico-chemical factors (Thomas and Shantaram, 1986). Kucey (1987) reported that the species belonging to the genera *Pseudomonas* and *Penicillium* were the major PO_4-solubilizers in forest soils.

Many workers have reported *in vitro* solubilization of insoluble phosphate by soil microorganisms. Mehta and Bhide (1970) tested 149 cultures of soil fungi and found that among them 42 showed the ability to solubilize TCP in culture from 22 to 98%. Gaur *et al*. (1973) observed the PO_4-solubilization by three strains of *Bacillus sp., Aspergillus flavus* and *A. carbonum* and found that these could dissolve only negligible amount of rock phosphate but all the cultures solubilized fairly good amounts (25.2-118.4mg) of TCP. Thomas *et al*. (1985) recorded the ability of MPS by rhizosphere organisms of coconut to the extent of 26-74 per cent of TCP in 5-15 days in Pikovskaya's broth. The *Pseudomonas* sp. isolated from arecanut rhizosphere recorded phosphate solubilization to an extent of 40.05 per cent whereas fungal isolate *Aspegillus sp.* was capable of solubilizing inorganic phosphate to an extent of 45.6 per cent (Bopaiah, 1985). Gaur (1990) reported that a strain of *Pseudomonas striata* could able to solubilize 24-58 per cent of TCP in liquid cultures. Illmer *et al.* (1995) reported that *Aspergillus niger, Penicillium simplicissimum, Pseudomonas* sp. and *Penicilliim aurantigriseum* were very effective in solubilizing rarely soluble $AlPO_4$. Tricalcium phosphate solubilization activity of some yeasts was examined and found that Pi releasing efficiency varied from 5.45 mg to 8.88 mg of $P_2 O_5$ on the 5^{th} day of growth (Narsian and Patel, 1995).

MATERIAL AND METHODS

The benchmark area selected for this study is located in the southern part of India, which has a tropical type of climate. The 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 scale. Following the hybrid classification approach, a mask was created for almost non-overlapping classes (*viz*., agricultural areas and vegetated areas) obtained from unsupervised classification (isodata algorithm). The vegetated areas were further classified into natural forests, grasslands, coffee/cardamom plantations and acacia 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.

A total of 60 sample points were distributed in two windows of the size 6.4 sq km (4 x 1.6 km) and 0.8 sq km (0.4 x 2 km) so as to cover all the above said land cover types. Fifty-three sample points were distributed in the first large window and 7 points in the second

small window. Stratified sampling technique was adapted and two windows were selected, because the first large window that was selected did not have enough natural forests, grasslands and *Acacia* plantations. Hence, additional window in the study site was selected to cover the required land use types.

The sample points were laid in the intersection point of the windows and were located in the ground using hand held ***Garmin 12*** GPS. The intersection points at which sampling could not be done due to the presence of a natural obstruction (presence of a tree, stone/water body etc.) were skipped and the sampling was done in the next intersection point.

Six land use-land cover types could be distinguished in the study area. They are; natural forests, grasslands, acacia plantations, coffee and cardamom plantations and paddy fields. For collecting the soil samples, a triangle of 50 x 50 x 50 m was laid at each sampling point. The center point of the triangle was marked and from this central point at a distance of three meters, three soil cores of 0-20 cm depth was taken using a soil core, avoiding the litter above the ground. Similarly, at a distance of six meters from the center, another three soil cores of 0-20 cm depth were taken as explained above. Thus, at each sampling point six soil cores were collected and these six soil core samples were mixed together to form a composite sample per sampling point. These soil samples were stored at 5^0 C in a refrigerator for further microbiological analysis. At each sampling point, the roots present in the soil sample were collected to determine the AMF root colonization. Soil sampling was done during February-march (pre-monsoon) and October-November (post monsoon) during the year 2004.

Soil samples were collected at nine sampling points from natural forests, eight sampling points from grasslands, six sampling points from acacia plantations, thirteen sampling points from cardamom plantations, sixteen sampling points from coffee plantations and eight sampling points from paddy fields. These soil samples were used to enumerate, isolate and assess the functional diversity of *Azotobacter* and PO_4 – solubilizing microorganisms.

Enumeration and isolation and identification of *Azotobacter*

The populations of *Azotobacter* in the soil samples collected from different land use types was enumerated by the standard dilution plating technique using Wakman's medium 77. The plates were incubated at 30^0C for 4-5 days and the number of colonies were counted and expressed per gram of dry soil. The representative colonies that have developed were purified by streak plate method and preserved on slants containing the same medium for further studies. The isolates of *Azotobacter*, thus obtained, were identified based on colony characteristics like the size, texture and colony morphology, cell characters like size, shape, cyst formation and physiological characters like production of slime and pigments. Based on these characters, the isolates of *Azotobacter* were identified up to the species level.

Efficiency of N_2 – fixation by species of *Azotobacter*

The species of *Azotobacter* thus obtained were studied for their efficiency to fix N_2. For this, one ml of 24 hour old cultures of *Azotobacter* species were inoculated to 50 ml of sterilized Norri's nitrogen-free glucose broth in duplicate flasks. The flasks were

incubated at 30 ± 2^0C for 10 days and the amount of N_2- fixed g^{-1} glucose consumed was determined. Total N in the broth was analyzed by semi-micro kjeldhal method as per the procedure outlined by Jackson, 1973 using Gerhardt auto analyzer.

Enumeration, isolation and Identification of PO_4-solubilizing microorganisms

The population of PO_4- solubilizing microorganisms in soil samples collected from different sampling points was used for enumeration and isolation of PO_4-solubilizing microorganisms by the standard plating technique using Sperber's hydroxy apatite medium. The plates were incubated for 4 -5 days and those colonies that produced a zone of solubilization around them were purified by streak plate method. The isolates of bacteria or fungi thus purified were maintained on slants containing nutrient agar or potato dextrose agar respectively for further studies. The PO_4- solubilizing fungi were identified up to the generic level by observing the growth of the fungus for mycelial characteristics and fruiting bodies under the microscope and comparing them with the diagrams provided in the manual of soil fungi by Gilman, 1966. The bacterial isolates were simply mentioned as PSB-1 and PSB-2 isolates.

Phosphate solubilizing ability of the isolates

The phosphate solubilizing cultures were grown in 50 ml of Pikovskaya's broth (Pikovskaya, 1948) in 250 ml conical flasks and incubated at 30^0 C by inoculating one ml of 48 hr old cultures under stationary conditions. Two replicate flasks were maintained for each isolate. After 10 days of incubation, the culture broth was used for the estimation of available- P content. A set of uninoculated control flasks were also maintained and used for the estimation of available- P. The change in pH of the medium was measured using a pH meter. The available-P content in the broth was estimated by chloro-molybdic acid blue colour method (Jackson, 1973).

RESULTS AND DISCUSSION

Population of *Azotobacter* in different land use types

The population of *Azotobacter* in different land use types in pre and post-monsoon seasons is presented in table 1. The results indicated that during pre-monsoon season the population of *Azotobacter* was significantly higher in natural forests, cardamom and coffee plantations and least was found in grasslands. The population ranged from 52.80×10^3 to 12.80×10^3 g^{-1} soil. During the post-monsoon season also a similar trend was observed. The population ranged from 21.20×10^3 to 0.5×10^3 g^{-1} soil. Krishnamurthi (1962) reported that the number of *Azotobacter* in Indian soils rarely exceed 10^4 to 10^5 / g soil. Even, in the present study the population has rarely exceeded 10^3 g^{-1} soil. It is well known that the occurrence of *Azotobacter* in soils is known to depend on various soil factors like pH, moisture content, depth, availability of nutrients, organic matter content of soils etc. Thomas *et al.* (1991) reported moderately higher population of *Azotobacter* in coconut plantation soils, which they attributed to the root exudates of coconut providing a better microenvironment for their proliferation. Probably, the higher population of *Azotobacter* found in the present study could also be due to stimulation of these organisms in these land use types as they are always covered by a large number of plant species which contribute to the addition of organic matter through leaf litter. A positive correlation between *Azotobacter* population and organic

matter content of soil was reported by Rangaswami and Sadasivan (1969). The lower population density in grasslands could be due to lower organic matter content and in paddy fields due to a higher water regime that result in anaerobic conditions that doesn't favour this highly aerobic organism. But, in the present study, though the soils are acidic, their population was high.

A comparison of the population in two different seasons indicated that the population of *Azotobacter* was significantly higher in pre-monsoon season compared to post-monsoon season in all the land use types except in acacia plantations. The lower population during post-monsoon could be attributed to higher water regimes in these soils thus creating an anaerobic condition which doesn't favour the growth of *Azotobacter*.

Species diversity and their efficiencies in N_2-fixation of the genus *Azotobacter*

The results on the morphological and physiological characters of the species of *Azotobacter* are presented in table 2. The N_2-fixing genus is well represented in various land use types. These isolates were identified as *Azotobacter vinelandii* and *A. chroococcum* based on the morphological and physiological characters and were found to fix 5.04 and 7.10 mg of N g^{-1} of glucose consumed respectively. Similarly, species of *Azotobacter* were isolated by several workers from various ecosystems (Rubenchick, 1963; Mishustin, 1970 and Dobereiner, 1976). Further, the work conducted by Iswaran and Marhwa (1982) and Tikhe *et al.* (1980) reported N_2-fixation of 3.0 to 6.0 and 5.3 to 6.8 mg N g^{-1} of glucose respectively by different *Azotobacter* species isolated from monocot roots and roots of *Cyperus rotandus* respectively, and this support results of the present study.

Abundance of species of *Azotobacter* in different land use types in pre and post monsoon seasons.

The abundance of species of *Azotobacter* in different land use types in pre and post-monsoon seasons is presented in table 3. During the pre-monsoon season the abundance of *A. vinelandii* was maximum in natural forests followed by cardamom plantations, coffee plantations, paddy fields, grasslands and least in acacia plantations (393.93 X 10^4, 328.90 X 10^4, 272.00 X 10^4, 103.04 X 10^4, 90.64 X 10^4 and 85.98 X 10^4 respectively). Whereas in the post-monsoon season *A. chroococcum* was not at all detected in acacia plantations. But, maximum population was found in coffee plantations followed by cardamom plantations, natural forests, grasslands and paddy fields (189.92 X 10^4,128.96 X 10^4, 81.99 X 10^4, 12.00 X 10^4 and 12.00 X 10^4 respectively).

During the post-monsoon season *A. vinelandii* was not detected in paddy fields. But, maximum population was noticed in cardamom plantations followed by coffee plantations, natural forests, acacia plantations and grasslands (130.91 X 10^4, 124.96 X 10^4, 104.96 X 10^4, 61.98 X 10^4 and 11.00 X 10^4respectively) whereas, *A. chroococcum* was not at all detected in acacia plantations and paddy fields. Maximum population was observed in natural forests followed by coffee plantations, cardamom plantations and grasslands (85.95 X 10^4, 64.96 X 10^4, 26.00 X 10^4 and 10.96 X 10^4 respectively).

The abundance of *A. vinelandii* in both the season was higher compared to A. chroococcum in all the land use types. Further, the population of *A. vinelandii* and *A. chroococcum* were higher in the pre-monsoon season compared to post-monsoon season in all the land use types. This could be attributed to the fact that the moisture regimes

prevailed during pre-monsoon season could be more favorable for the growth and multiplication of *Azotobacter* species than the post-monsoon season which is more anaerobic due to higher moisture regimes. The higher populations of *A. vinelandii* and *A. chroococcum* in natural forests, cardamom plantations and coffee plantations could be due to a dense vegetation in these land use types that also contribute to a higher organic matter content to these land use types. Rangaswami and Sadasivan (1969) have found a good positive correlation between *Azotobacter* population and organic matter content in soils. The complete absence of either *A. vinelandii* or *A. chroococcum* could be due to standing water in paddy fields due to cultivation of paddy in the post-monsoon season.

Population of PO_4-solubilizing fungi in different land use types

The population of PO_4-solubilizing fungi in different land use types in pre and post-monsoon seasons is presented in table 4. The population of PO_4-solubilizing fungi was significantly higher in natural forests in the pre-monsoon season compared to paddy fields. The population ranged from 20.01 to 0.06×10^3 g^{-1} soil. However, in the post-monsoon season significantly all the land use types were on par with each other except paddy fields, which were significantly lower, compared to other land use types. This could be due to high organic matter content that serves as a C source for a vast majority of saprophytic organisms, which could also be potential PO_4-solubilizers in addition to decomposition of forest litter. This is in confirmation with the observations made by Ahmed and Jha (1968) and Forster and Freier (1988) who found a higher population of PO_4-solubilizing fungi in forest soils. The population ranged from 13.20 to 0.06 x 10^3 g^{-1} soil. The population was significantly higher in pre-monsoon season compared to post-monsoon season in natural forests, acacia plantations and cardamom plantations while in other land use types significantly lower population of PO_4-solubilizing fungi was observed in pre-monsoon season compared to post-monsoon season.

Population of PO_4-solubilizing bacteria in different land use types

The population of PO_4-solubilizing bacteria in pre and post-monsoon seasons in different land use types is presented in table 5. The population of PO_4-solubilizing bacteria was found to be significantly higher in natural forests, grasslands, acacia and coffee plantations in pre-monsoon season. The population ranged from 9.30 to 0.70×10^3 g^{-1} soil. Agnihotri (1970) reported the highest population of PO_4-solubilizing bacteria from forest soils. Illmer and Schinner (1991) also reported a higher population of *Pseudomonas* sp. in forest soils of Austria. Several other workers have also reported significantly higher population of PO_4-solubilizing bacteria in several ecosystems; *Pseudomonas* in coconut plantations (Nair and Subbarao, 1977); in tea plantations (Patgiri and Bezbaruah, 1990); *Pseudomonas* in areacanut plantations (Bopaiah, 1985). While, in post-monsoon season there were no significant differences in population of PO_4-solubilizing bacteria, which could be attributed to high moisture content in the study area. The population ranged from 2.30×10^3 g^{-1} soil in grasslands to 0.06×10^3 g^{-1} soil in paddy fields.

A comparison of the population of PO_4- solubilizers during different seasons indicated that significantly higher population was observed in natural forests, coffee

plantations and paddy fields in the pre-monsoon season compared to the post-monsoon season. But, significantly lower population in the post-monsoon season was recorded in acacia plantations, cardamom plantations and grasslands.

Diversity of PO_4-solubilizing microorganisms in different land use types

There were nine isolates of fungi and two isolates of bacteria capable of solubilizing insoluble phosphate on the Sperber's medium. Of the nine fungal isolates one belonged to the genus *Fusarium*, five isolates belonged to the genus *Aspergillus* and three isolates belonged to *Penicillium*. The bacterial isolates could not be characterized, but designated as PSB-1 and PSB-2. Several other workers have also reported species of *Fusarium* and *Aspergillus* capable of PO_4- solubilization in the soils of Western ghats (Thomas *et al*., 1985; Thomas and Shantaram, 1986).

Efficiency of PO_4-solubilization of PO_4- solubilizing microorganisms isolated from different land use types

The zone of solubilization on hydroxy apatite medium and solubilization of TCP and change of pH in media inoculated with PO_4-solubilizing microorganisms isolated from different land use types are presented in table 6. The results indicated that among the different PO_4-solubilizing microorganisms, the fungi *Fusarium* sp. produced a significantly bigger zone of solubilization (32mm) with highest solubilization of tri-calcium phosphate (23.67 mg Pi/100ml media) with highest drop in pH (2.91) compared to other fungal and bacterial isolates, followed by *Aspergillus* sp. which showed a zone of solubilization of 19, 19, 14 mm and 17.82, 17.02 and 17.99 mg TCP solubilized per 100 ml medium respectively. Barthakur (1978) reported that *Fusarium solani* isolated from rice rhizosphere was able to solubilize insoluble phosphates. Arora and Gaur (1979) also reported that *A.awamori* was able to solubilize higher amounts of tri-calcium phosphate compared to *Penicillium digitatum*. The least solubilization was observed with *Penicillium* sp. and PSB-2 which showed zones of solubilization of 15 and 14 mm and 15.74 mg and 9.32 mg of TCP solubilized per 100 ml of medium respectively, with drop in pH of 3.00 and 5.75 respectively.

Table 1. Population of *Azotobacter* in different land use types during pre and post-monsoon seasons

Land use types	Population (cfu X $10^3 g^{-1}$ soil)		CD at 0.05%
	Pre-monsoon season	Post-monsoon season	
Natural forests	52.80 (7.14)[a]	21.20 (4.23)[a]	0.87
Grasslands	12.80 (3.05)[c]	2.80 (1.37)[b]	0.934
Acacia plantations	14.33 (3.27)[b]	10.30 (2.35)[a]	1.36
Cardamom plantations	35.20 (5.75)[a]	12.10 (2.81)[a]	0.77
Coffee plantations	28.80 (5.30)[a]	17.80 (2.07)[a]	0.72
Paddy fields	14.40 (3.26)[b]	0.0 (0.70)[c]	0.91
F-test at 0.05 %	*	*	-

Note: The values in the brackets are the transformed values using the square root transformation v x + 0.5

Table 2. Morphological, physiological characters of species of *Azotobacter* isolated from different land use types

Character studied	*Azotobacter vinelandii*	*Azotobacter chroococcum*
Colony type	Smooth, circular, slimy	Smooth, circular, slimy
Pigmentation	Nil	Brownish black
Cyst	Present	Present
Lipoid bodies	Distributed	Distributed
Catalase activity	Positive	Positive
Utilization of carbon compounds		
Starch	++	-
Mannitol	+++	+++
Rhamnose	-	++
N_2-fixation(mg N g^{-1} glucose)	5.04	7.10

Note: – = No growth, ++ = Good Growth, +++ = Very good growth.

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Table 3: Abundance (cfuX10^4) of *Azotobacter* in different land use types in pre and post-monsoon seasons

Organism	Pre-monsoon season						Post-monsoon season					
	Land use types						Land use types					
	NF	**GL**	**ACP**	**CAP**	***COP***	**PF**	**NF**	**GL**	**ACP**	**CAP**	**COP**	**PF**
A.vinelandii	393.93	90.64	85.98	328.90	272.00	103.04	104.96	11.00	61.98	130.91	124.96	ND
A.chroococcum	81.99	12.00	ND	128.96	189.92	12.00	85.95	10.96	ND	26.00	64.96	ND

Note: **NF**: Natural forests, **GL**: Grasslands, ACP: Acacia plantations, **CAP**: Cardamom plantations

COP: Coffee plantations, **PF** :Paddy field, ND: Not detected

Table 4. Population of PO_4- solubilizing fungi in different land use types during pre and post-monsoon seasons

Land use types	Population (cfuX10^3 g^{-1} soil)		CD at 0.05%
	Pre-monsoon season	Post-monsoon season	
Natural forests	20.01 (4.18)[a]	13.20 (2.08)[a]	0.560
Grasslands	2.10 (1.18)[c]	1.50 (1.20)[a]	0.596
Acacia plantations	2.00 (1.45)[c]	0.30 (0.84)[a]	0.316
Cardamom plantations	1.50 (1.19)[d]	3.20 (0.70)[a]	0.366
Coffee plantations	2.70 (1.62)[b]	2.10 (1.43)[a]	0.273
Paddy fields	0.06 (1.07)[c]	0.10 (0.77)[b]	0.376
F-test at 0.05%	*	*	

Note: The values in the brackets are the transformed values using the square root transformation v x + 0.5

Table 5. Population of PO_4- solubilizing bacteria in different land use types during pre and post monsoon seasons

Land use types	Population (cfuX10^3 g^{-1} soil)		CD at 0.05%
	Pre-monsoon season	Post-monsoon season	
Natural forests	9.30 (2.60)[a]	2.20 (1.37)	0.65
Grasslands	2.00 (1.17)[a]	2.30 (1.14)	0.58
Acacia plantations	1.30 (1.07) [a]	1.80 (1.56)	0.563
Cardamom plantations	0.70 (0.95) [c]	0.80 (0.70)	0.171
Coffee plantations	1.40 (1.21) [a]	0.90 (1.01)	0.23
Paddy fields	1.20 (1.15) [b]	0.06 (0.77)	0.252
F-test at 0.05%	*	NS	

Note: The values in the brackets are the transformed values using the square root transformation v x + 0.5

Table 6. Efficiency of PO_4-solubilization inoculated with PO_4-solubilizing microorganisms isolated from different land use types

Genus	Zone of solubilization (mm)	TCP solubilized (mg Pi/ 100 ml media)	pH
Fusarium sp.	32	23.67^{a}	2.91^{f}
Aspergillus sp. 1	19	17.82^{b}	3.17^{ef}
Penicillium sp.1	15	15.74^{d}	3.00^{f}
Penicillium sp.2	15	16.91^{bcd}	2.98^{f}
Aspergillus sp.2	14	17.26^{bcd}	3.46^{d}
Penicillium sp.3	16	16.43^{bcd}	4.31^{c}
Aspergillus sp.3	14	17.99^{b}	3.57^{d}
Aspergillus sp.4	19	17.02^{bc}	3.13^{ef}
Aspergillus sp.5	16	15.96^{cd}	3.41^{de}
PSB-1	17	16.09^{cd}	5.36^{b}
PSB-2	14	9.32^{e}	5.75^{a}
CD at 0.05%	-	1.498	0.358

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Abundance of soil invertebrates across a gradient of land uses in Western Ghats

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INTRODUCTION

Soil biota comprise communities of both Microflora and fauna which together perform a number of different function in the below ground. The activity of these organisms ensures the decomposition of organic matter in soil. Their activities depend on the quality and quantity of organic matter and a wide range of physical, chemical and microclimatic factors inherent to the soil sub ecosystem. The abundance and diversity of soil biota are influenced by properties of the natural soil environment as well as those induced by human being.

Ants form major component of soil and litter dwelling organisms in the forest floor. Several species of ants have specific construction of nests to adapt to local conditions. Experts from outside the country and later on specialists have made systematic works on Indian ants initially from India too (Veeresh and Mushtak Ali, 1990). The feeding habits of ants are varied and complex. Many ants are predaceous, with some species specializing to feed on termites (Shivashankar, 1985). Sometimes ants also attain pest status on some economically important plants.

Termites are another integral group of soil dwelling organisms, which contribute towards the enrichment of tropical soils. Out of 2700 and odd species of termites from the world, only less than 15per cent are regarded as harmful and others are probably helping in the process of improving the soil productivity. Out of 280 species of termites known from India only about 40 species are reported to cause damage crops and forest plantations (Varma, 1990). It is reported that termite mound soil is sometimes used as fertilizer in tropical cropping system. It is also argued upon that the soil properties may also depend upon the availability of the termite-modified soil in the mound and may not always result in increased growth of plants.

The beneficial effect and diversity and composition of termites in a forest plantation were studied by Swaran (2004). His studies revealed that in a young eucalyptus plantation, out of the fourteen termite species collected based on transect sampling, only four species were attacking the eucalyptus and the rest of the species were probably involved with the process of decomposition alone. The study by Basu *et al.* (1996) indicated that maximum number of termite species in the evergreen forests (10) and minimum in disturbed forests (4). It is generally held that species diversity will be less in physically controlled ecosystem compared to biologically controlled ecosystem. However, it need not be true with all the organisms. Studies carried out in Indonesia using the transect protocol showed that termite species richness and abundance are positively correlated with reduction in canopy cover (Jones and Eggleton, 2000).

The order Coleoptera (beetles) is the largest order of insects worldwide and also in the tropical forests, mainly in terms of number of species. The immature stages of the beetle are soil dwelling organisms and many of them can destroy the root of plants. The feeding habit of beetles

varies viz., predators, detritivores, scavengers etc. These are insects associated with mainly soil or organic matter associated with soil (Rajgopal and Prasad Kumar, 1993: Joseph, 2003). Agricultural intensification is undertaken with the aim of maximizing the crop yield. Efforts to achieve this aim involve a purposeful reduction in species-richness (Swift and Anderson, 1993), particularly that of native plants and pests that lower crop productivity. However, the decline in species richness and diversity that result from agricultural intensification extend well beyond those species that are reduced intentionally. Numerous studies have shown that agricultural management decreases soil biodiversity and alters the structure of soil biological communities as compared with native forest or grassland ecosystems.(Prabhoo.1971 and 1976; Hazra,1976 and 1991; Singh and Mahajan,1981,Sarkar,1990; Sengupta and Sanyal,1991; Paul et al., 1993; Uddhav et al.,1993) .Many of the practices involved in converting natural forest ecosystems to various monoculture impose perturbation on the ecosystem that may lead to considerable loss of soil organic matter and microbial biomass. For example, cultivation of various tree plantations viz., *Dalbergia sisso* (Vats and Handa, 1983), Eucalyptus (Reddy and Venkaiah, 1990), oak (Sharma et al., 1984), Sal (Chattopadhyaya and Roy, 1993), pine (Reddy, 1989), neem (Reddy, 1992), rubber (Chakraborti and Bhattacharya, 1993) resulted in reduction in the composition of Microflora and faunal communities compared to evergreen natural forest (Hazra, 1982;Chakraborti and Bhattacharya, 1996;Raina et al., 1981;Singh and Mahajan, 1981). These changes can be attributed to at least three factors commonly associated with agricultural intensification 1) an increase in the frequency and magnitude of perturbations that result from land use change and site preparation (deforestation, burning or removal of plant residue, cultivation etc)(Pai and Prabhoo,1981; Sengupta and Sanyal,1988; Darlong and Alfred,1991; Parihar,1995)

2) a reduction in the quantity and diversity of organic resources returned to the soil(Annadurai,1988 ; Gupta,1994) 3)The use of agrochemicals (Joy and Bhattacharya,1981; Kumar and Agarwal,1983; Sharath babu and Gupta,1986; Rajagopal et al., 1990; Joy and Chakraborti,1991). It is widely accepted that conversion of native forest or grassland systems to arable cropping results in a decline in soil biodiversity. The structure of decomposer habitats is strongly influenced by the composition, diversity and architecture of vegetation cover, factors which are likely to influence the structure of decomposition communities. By its very nature, agricultural intensification seeks to lower plant diversity in exchange for maximizing the primary productivity of selected crops. With this background, an experiment was carried out to evaluate the effect of conversion of natural forest into arable land on soil below ground biodiversity and ecosystem function.

MATERIALS AND METHODS

The experiment was carried out in the village Koothi of Somavarpet taluk in Kodagu District, Karnataka, India. The benchmark area is located near Nilgiri biosphere reserve (Westernghats, a biodiversity hotspot). The study area falls with in the geographical limits of 12° 40^{I} 03^{II} N-12° 42^{I} 19^{II} N and 75°47^{I} 10^{II} E -75°79^{I} 14^{II} E. The annual rainfall of the area ranges from 2500 –3500 mm and the bulk of the rainfall is got from South west monsoons between June and August. Major part of the study area covered by Coffee and cardamom plantations. The natural forests found in the periphery of the plantation are Evergreen types with varying levels of degradation. There are few patches of *Acacia auriculiformis* plantation *(*monoculture). Grassy blank are found adjacent to the forests. Rain fed agriculture is practiced in the valleys and is

composed of paddy in rainy season. Some of the subsidiary crops like chilly and green gram are grown in the summer season with available residual moisture. Sixty sampling points were selected randomly situated 200m apart in two windows (1.6 X 4 km). The number of sampling points in each ecosystem were 9,8,6,16,13 and 8 in natural forest, grassland, Acacia, coffee, cardamom and paddy, respectively.

The following methods were followed to collect different litter and soil fauna.

Litter samples (200g) were collected in a quadrate (1×1 m) at three angels of the triangle in each sampling point for the extraction of fauna. Four soil samples (400g each) to a depth of 0-5 cm on each arm of the triangle per sampling point were collected for the extraction of fauna. Soil samples to a depth of (0-10, 10-20 and 20-30 cm) were also collected in each monolith (center of 6 m radius circle – 25X25X30 cm) per sampling points for the extraction of soil fauna. Hand sorting method was used to collect macro fauna from the soil. Soil and litter (labeled) samples were stored in the polyethylene covers. The samples were shifted to the laboratory on the same day.

Litter and soil samples were placed in the high gradient modified Mcfadyen funnel (mesh size 0.9 cm^2) for the extraction of fauna. Electric bulbs (25w) were used as heat and light source. The extracted fauna were collected 48 hours after exposing the samples to the heat and light stimuli. The extracted fauna were observed under stereo binocular for further classification of fauna and counting of each group. Abundance was worked out.

In addition to the hand sorting method to collect termites in monoliths, a one time line transect sampling method was also employed for termites (modified from Eggleton *et al.*, 1997). The transect (10X2m) was on each arm of the triangle. This was divided into 10 contiguous sections (each 1 x 2m in area). Each section was sampled. Within each sections the following microhabitats were searched: - surface soil up to 10 cm depth, dead logs, dead branches and twigs; earthen sheeting on dead logs and tree stumps. Soldier and worker castes of termites were collected. The collected termites were placed in vials containing 70 per cent alcohol and labelled with the section number. The second sampling procedure (November 2004) was little modified as per the instruction from the head quarters. Semi-quantitative transect (2×20 m) was restricted to one arm. Termites were identified upto genus level with the available taxonomic keys.

Pitfall traps

Ants, beetles, and other macro fauna were collected from the pitfall traps (10 cm dia) with 1% detergent placed at three angles of triangle in each sampling point. The macro fauna were collected 48 hours after setup of the pitfall traps. The samples were separated according to taxonomic character and each group was counted. Biomass of the same was recorded. Abundance and relative abundance of each group was worked out.

The second sampling procedure (November2004) was little modified as per the instruction from the head quarters. Three pitfall traps and quadrates (1×1 m) were distributed on the transect at equal distance on one arm. Four composed soils samples with litter (0-5 cm) composed by 3 sub-samples of each quadrate of circle were drawn for the extraction of soil fauna.

RESULTS

Litter invertebrates

Abundance:

The higher abundance of litter invertebrates was noticed in paddy ecosystem (10.55 invertebrates / 100 g of litter) during February 2004. This was followed by cardamom ecosystem (4.93 invertebrates / 100 g). The invertebrate's population in paddy litter was significantly higher compared to the population in coffee, grassland, natural forest and acacia litter (Table.1).

The abundance of litter invertebrates varied from 3.08 (Acacia) to 30.73 (coffee) invertebrates /100g of litter during November 2004. The preference of litter of acacia by invertebrates was least than other litters. However, there were no significant differences in abundance among the litter (Table 2).

Relative abundance:

The relative abundance of soil acari was maximum and minimum in paddy (85.86%) and coffee litter (28.38%), respectively during February2004. However, paddy litter registered least relative abundance of insects (13.94%) and non-insects (0.2%) compared to other ecosystems. Higher relative abundance of insects and non-insects were noticed in coffee ecosystem (Table 3).

The relative abundance of litter acari varied from 67.57 (Acacia) to 81.76% (paddy) during November 04. However, the insects and non-insects relative abundance was less in paddy. These two preferred coffee (31.52%) and natural forest (2.41%), respectively (Table.4).

Abundance:

The soil invertebrate's abundance varied from 218.90(grass land) to 4579.03 (cardamom) invertebrates / m^2 of soil during February 2004. The latter ecosystem soil harboured significantly higher invertebrates compared to grassland, paddy and acacia ecosystems. Natural forest soil provided significantly good habitat for soil invertebrates compared to acacia and grassland. Coffee ecosystem is better for the survival of invertebrates compared to Acacia (Table 1).

The grassland also registered lower soil invertebrate's abundance (274.70 / m^2) during November 2004. The highest fauna was noticed in the natural forest (877.64 /m^2). No significant difference in abundance of meso fauna was noticed among rest of the land uses and natural forest (Table 2).

Relative abundance:

The relative abundance of acari was higher in Acacia plantation, but all the ecosystems recorded more than 53% of acari during February 2004. The members of class Insecta comprised of more than 30% in all ecosystem. Higher insects were collected in paddy ecosystem soil (41.90%). Maximum non-insects of fauna were noticed in cardamom ecosystem and it was minimum in cultivated (paddy) and afforested land (Table.5). However, the relative abundance of fauna varied during November 2004(Table 6). The acari relative abundance varied from 31.34 (paddy) to 68.11 %(grass land). The insects and non-insects were more abundant in all the land uses when compared to the February 2004 samples, except in grassland.

Occurrence of soil invertebrates:

Natural forest and cardamom ecosystem soils provided shelter for 27 groups of invertebrates during February 2004(Table 7). This was followed by coffee plantation (25 groups of invertebrates). Intensive cultivated land (paddy) registered only 12 groups of invertebrates. Fragile fauna viz. Protura was noticed only in natural forest, cardamom and coffee soil ecosystem. Similarly, the cardamom ecosystem also harboured more invertebrates (23 groups) during November 2004(Table8). The least preferred ecosystem by the invertebrates was grassland (12 groups).

Occurrence of litter invertebrates:

The occurrence of litter invertebrates groups varied from 7 (Acacia) to 23 (cardamom) groups. The latter ecosystems followed by natural forest, coffee, paddy and grassland (Table 9). However, it varied from 12 (Acacia) to 23(Natural forest) groups during November 2004(Table 10). The occurrence of litter fauna increased in cardamom, coffee, paddy, grassland and Acacia land use during November 2004 than February collections. This may be due to presence of sufficient organic matter along with litter moisture apart from most of them complete their life cycle during post –monsoon period.

Distribution of soil invertebrates at different soil depths (Monolith)

The top organic matter rich soil (0-10cm) of natural forest, cardamom and coffee recorded more invertebrates / 100g of soil compared to other ecosystems during February 2004. The Acacia and paddy soil recorded 0.12 and 0.5 invertebrates / 100g of soil. The lower depth of monoliths of (10-20and 20-30 cm) grassland, Acacia and paddy registered poor representation of soil invertebrates compared to other ecosystems(Table 11). This indicates the accumulation of organic matter with less disturbance to natural forest, cardamom and coffee ecosystem soil.

Soil invertebrates were abundant at 0-10 cm soil layer in paddy ecosystem (3.75 invertebrates / 100 g) compared to other ecosystems during November 2004(Table 12). Cardamom, natural forest, grassland, coffee and Acacia followed this. Gradual reduction in invertebrate's abundance was noticed in the lower depths of soil (10-20 and 20-30 cm). The variation of invertebrate's abundance may be due to variation in soil organic matter and moisture content.

Termites:

The occurrence of termites in the pitfalls kept in the plantation of Karnataka was very low. The reason may be due to capturing of termites along with the predatory ant or carabid beetles (Table. 13).

Termites were relatively abundant in the top layer of soil of grassland (4.35%) and were not found in any other land uses. Similarly, litter samples collected in grassland and plantation also had termites compared to the rest of the land uses. (Table.14) Termites foraging on grasses and its shallow roots may be the reason for the occurrence. Apart from this, the exposure of grassland to sunshine, which created suitable condition (soil moisture) for termite foraging, compared to other land uses where the soil moisture was more due to rain just 2 days prior to sampling. The concentration of termites on the top layer may be due to accumulation of more litter and majority of the termite's species are litter feeders. The occurrence of termites in other depths may be due to species-specific feeding habit or presence of termites in the foraging galleries.

However, the termites were not found in any monolith layers in Karnataka. This may be due to seasonal effect (February2004) where soil and litter moisture was less. More than this dominance of *odontotermes* species which are very active and sensitive to little disturbance. The movement of these towards nest may be the reason for the absence (Table15). Termites are also not preferred more soil moisture. This can be seen in Table16, where the soil and litter samples did not contained termites in February 2004(dry season). However, these were present only in grassland and plantation in November 2004 (wet season).

Termite's diversity

Odontotermes genus dominated in all the land uses in Karnataka. Five species of *Odontotermes* and three other genera were collected in natural forest. Similarly, four species *Odontotermes* and two other genera were present in plantation. The monoculture of acacia (forest plantation) harboured only three species of *Odontotermes* and only one other genus. The same thing holds good for grassland. Cropland provided shelter for *Odontotermes* genera (Table 17). Occurrence of termite species was less during November 2004. This may be due to high soil moisture and rainfall, which occurred two days prior to sampling. The present observations are in conformity with the findings of Parihar (1995) where he noticed reduction in termites diversity in cultivated land compared to forest.

Ants

Pitfall catches

Abundance:

Ant population in the pitfall catches was more in forest plantation (53.50 ants per pit fall) and it was followed by natural forest (45.33 ants per pitfall), Plantation, grassland and cropland in Karnataka during February 2004. However, the catches were less during November 2004.Pitfall traps kept in grassland recorded more number of ants (8.12) and was followed by forest plantation (4.33), coffee (3.25), cropland (1.87), cardamom (1.58) and natural forest (0.88) (Table13). This may be due to excess of soil moisture during rainy season. Which prevented the ant's activity. This observation in Nilgiri biosphere revealed that the ants' activity decreased in cultivated land compared to undisturbed land.

Relative abundance:

The relative abundance of ants was maximum in Forest plantation (92.08 of pitfall catches) and was followed by coffee (91.42%), cardamom (89.64%), natural forest (89.05%), grassland (83.84%) and croplands (79.86%) (Table14).

However, the soil samples collected in croplands provided good shelter for ants (29.85%) compared to natural forest (8.47%), grassland (8.70%), coffee (3.48%), cardamom (3.39%) and forest plantation (3.36%) (Table 14) on the other hand, the litter sample of plantation registered more ants population (4.71%) and was followed by coffee, cardamom, cropland, natural forest, forest plantation and grassland. The variation in these may be due to distribution of prey or food source and congenial atmosphere for the nest construction. Ants were collected in low population in two layers of monolith of natural forest (0-10& 20-30cm) of Karnataka (Table 15).

The abundance of ants was maximum in soil samples (0-5 cm) collected in forest plantation (16.24/m^2) in Karnataka during February 2004 and was followed by natural forest (7.96/m^2), coffee (5.095/m^2), cardamom (4.42/m^2) and grassland (2.54/m^2) The cropland soil was

free from ants (Table16). However, the ants' population was more in cropland soil (39.81/m^2) during November 2004 compared to cardamom (20.70 m^2), natural forest (18.47/m^2), grassland (5.73/m^2), forest plantation (5.09/m^2) and coffee (1.27/m^2). On the other hand, the litter samples of coffee recorded maximum ants (10.24/100g) followed by natural forest and grassland (1.27 each/100g). Ants were not present in forest plantation & cropland litters. However, maximum ants were observed in cropland (82.17/100g) followed by natural forest (25.79/100g), grassland (19.74/100g) and forest plantation (3.50/100g) during November 2004.

Biomass of ants

The pitfall kept in forest plantation registered maximum biomass of ants (3.80g / trap) and was followed by grassland (0.56g/trap), cropland, plantation and natural forest of Karnataka. (Table 18).

Distribution of ants' species.

Twenty-one species of ants were present together in the coffee and cardamom plantation (Table.19) and was followed by natural forest (15 species), cropland (13 species), forest plantation (12 species) and grassland (9 species) during February 2004. However, pit fall traps kept in natural forest recorded seven species of ants during November 2004 compared to coffee, cropland, grassland (six species each), forest plantations (five species) and cardamom (three species) (Table 19).

From the species richness it is very clear that the natural forest harboured ants belong to five sub families, whereas the plantation, cropland, and forest plantation provided the shelter for the ants belong to four sub families. Grassland registered only ants belong to three subfamilies (Table20 and 21).

Beetles:

Abundance:

The pit fall kept in cropland trapped 3.62-beetles/ traps and was followed by grassland (1.37 beetles), natural forest (1.0 beetle), cardamom (0.53), coffee (0.32 beetles) and plantation (0.42 beetles). Traps kept in forest plantation were from beetles during February 2004. The beetles' catches in all land uses were less than 0.5 in November 2004. The beetles trapped were carabid, tenebrionid and staphylinid beetles (Table 13).

The relative abundance of beetle was maximum in croplands (5.30-beetle/ trap) during February 2004and was followed by grassland (5.06 beetle/trap), natural forest (1.53beetle /trap), forest plantation (0.86 beetles/trap), cardamom (1.53) and coffee (1.34 beetles/trap) (Table14). The dominance of predatory beetles was noticed in cropland and grassland.

The soil of natural forest recorded 4.16% of beetles and was followed by croplands (3.48%), coffee (3.48%), cardamom (3.39%), forest plantation (2.48%) and grassland (2.41%). However, the litter recorded less relative abundance of ants compared to the soil samples. Beetle abundance was more in cardamom (8.89%) & coffee (8.54%) compared to natural forest (2.28%), cropland (2.05%), grasslands (1.60%) and forest plantation (1.20%) (Table 14).

The top layer of monolith of natural forest, cropland and grassland recorded beetles, including grubs. In general the abundance of beetles was less in the entire top layer monoliths of different land uses (Table15). Beetles were more abundant in top and middle layers of monoliths

of cropland (3.42) than forest soil during premonsoon period. Similarly, all three depths of monoliths of cropland provided good shelter for beetles compared to forest soil (Table 15).

The abundance of beetles was more in the samples of croplands (29.93/m^2) compared to cardamom (23.88 / m^2), natural forest (18.79/m^2), coffee (13.37/m^2), forest plantation (3.82/m^2) and grasslands (2.55/m^2)(Table 16). Similarly, the litter sample of cropland (89.81/m2) also recorded higher population of beetles and was followed by natural forest (18.79/m^2), cardamom (3.51/m^2), forest plantation (3.50/m^2), coffee (2.16 /m^2) and grasslands (1.27/m^2). These results indicated that the top layer of soil (0-5cm) and litter provided shelter for many beetles and grubs, which are important predator and scavengers.

The biomass of beetles was more in croplands (0.36g/trap) and was followed by plantation, natural forest and grasslands in Karnataka during February 2004 (Table 18).

Relative abundance of soil invertebrates (Individual groups)

Acari dominated faunal composition in all the soils of different land uses during Feb2004 (Table 22) Relative abundance of detrtitivors Cryptostigmata was maximum in paddy where soil moisture and paddy roots, straw and other incorporated litter were in optimum quantity. It varied from 23 to 27% in other ecosystems except Acacia. In Acacia the diversity of food supply (including grass) was less with low soil moisture. In other ecosystems the availability of diversity of food along with optimum soil moisture and shade play important role in the distribution of Cryptostigmata. Relative abundance other Acari group was maximum in Acacia (54.54%). It varied from 13.51 (Paddy) to 35.32% (Coffee). The dominance of other acari compared to other invertebrates may be due to its varied feeding habit viz. Fungivores, predators, detrtitivors etc. These two groups followed by Collembola whose relative abundance was noticed upto 15.28%. Acacia and grassland recorded least relative abundance may be due to less food diversity and more exposure to light. Ants, beetles grubs, Dipteran maggots and Coccids occupied substantial composition in the soil food web. Similarly, Acari (other acari & Cryptostigmata) dominated in all the ecosystems when compared to other invertebrates (Table 23) during November 2004. However, the Collembola abundance was quite high in all the ecosystems when compared to February sampling. This may be due to the availability of organic matter and soil moisture during observation period. Diplurans, ants, beetles grub, dipterans maggot, Symphylans and centipede formed other major groups.

Relative abundance of litter invertebrates:

Litter invertebrates colleted during both Feb. and November 2004 dominated by Acari (Table24 and 25). Maximum relative abundance of other acari was noticed in Acacia and Natural forest during February and November 2004, respectively. However, cryptostigmatids abundance was more in paddy and grassland during February and November 2004, respectively. Collembolans were present only in Acacia and paddy litter during Feb.2004. However, its presence was noticed in all the ecosystems during November 2004 (Table 24 and 25). This may due to availability litter moisture during just concluded rainy season (November) compared to moisture content in February month. Other invertebrate abundance was less than 20% during both sampling season. Similarly, Badejo *et al.,* (1998) observed that the chemical composition of plant residues, as well as soil temperature and moisture content play important role in determining the density of microarthopods. Vats and Narula (1990) reported that different species of collembolan responded differently to change in pH. Further, Hazra (1976) concluded

that factors like moisture and organic carbon content always showed significant positive correlation with dominant species of Acari and Collembola.

CONCLUSION

Soil invertebrates' community proffered abundant and diversified food source with optimum soil/litter moisture for their survival. Any disturbance to the ecosystem resulted in lower soil invertebrates' population especially fragile invertebrate like proturans, collembolans and Symphylans.Termites play an important role in the tropical ecosystem. Any disturbance to the ecosystem resulted in reduction in termite species. Complete elimination of one or two sub families of ants was noticed across the gradient of land uses in western ghat. The coleopterans distribution was not uniform, but the major predatory beetles were trapped in the cropland and grassland.

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Table 1. Abundance of soil invertebrate in litter (0 cm)and soil(0-10cm) of different ecosystem (Feb.04)

Land cover	Abundance	
	Soil (# /m^2)	Litter (# /100g)
Natural forestsF	4052.02 ± 1881.20	2.51 ± 4.42
Grasslands	218.90 ± 141.93	1.06 ± 1.35
Acacia plantations	992.65 ± 833.4	0.72 ± 1.30
Coffee plantations	3435.80 ± 1678.25	1.09 ± 1.37
Cardamom plantations	4579.03 ± 1683.12	4.93 ± 7.92
Paddy fields	1548.70 ± 916.5	10.55 ± 14.53

Table 2. Abundance of soil invertebrates in litter (0cm) and soil (0-10) of different ecosystems (Nov.04)

Land cover	Abundance	
	Soil (# /m^2)	Litter (# /100g)
Natural forestsF	877.64 ± 641.77	18.05 ± 25.42
Grasslands	274.70 ± 193.69	17.47 ± 24.07
Acacia plantations	631.69 ± 254.41	3.08 ± 7.31
Coffee plantations	390.16 ± 314.79	30.73 ± 48.49
Cardamom plantations	776.61 ± 521.67	25.46 ± 28.37
Paddy fields	533.48 ± 496.42	23.41 ± 22.02

Table 3. Relative abundance of litter invertebrates in different ecosystems (Feb. 04)

Type	Acacia	Cardamom	Coffee	Grassland	Paddy	N. Forest
Acari	51.62	43.68	28.38	52.00	85.86	53.84
Insects	45.15	49.14	57.33	42.00	13.94	32.06
Non-insects	3.23	7.18	14.29	6.00	0.20	14.10

Table4. Relative abundance of litter invertebrates in different ecosystems (Nov. 04)

Type	Acacia	Cardamom	Coffee	Grassland	Paddy	N. Forest
Acari	67.57	79.69	66.98	80.82	81.76	75.28
Insects	30.63	18.66	31.52	17.62	16.87	22.31
Non-insects	1.80	1.65	1.50	1.56	1.37	2.41

Table 5. Relative abundance of soil invertebrates in different ecosystems (Feb. 04)

Type	Acacia	Cardamom	Coffee	Grassland	Paddy	N. Forest
Acari	67.38	55.32	61.97	57.15	57.56	53.94
Insects	32.06	30.57	32.73	37.49	41.90	36.16
Non-insects	0.53	14.11	5.30	5.36	0.54	9.90

Table 6. Relative abundance of soil invertebrates in different ecosystems (Nov. 04)

Type	Acacia	Cardamom	Coffee	Grassland	Paddy	N. Forest
Acari	36.13	32.49	46.43	68.11	31.34	46.78
Insects	56.31	51.10	45.41	28.99	61.17	38.70
Non-insects	7.56	16.41	8.16	2.90	7.49	14.52

Table7. Occurrence of soil invertebrates in different ecosystems (Feb. 04)

Group	Natural forest	Cardamom	Coffee	Acacia	Grassland	Paddy
Mesostigmata	P	P	P	P	P	P
Cryptostigmata	P	P	P	P	P	P
Collembola	P	P	P	P	A	P
Diplura	P	P	P	P	A	A
Psocids	P	A	A	A	A	A
Leafhoppers	P	A	A	A	P	P
Bugs	P	P	P	P	P	A
Moth flies	P	P	P	P	P	P
Isopods	P	P	P	P	A	A
Other flies	P	P	P	P	P	A
Dipteran maggots	P	P	P	A	A	P
Ants	P	P	P	P	P	A
Wasps	P	P	A	A	P	A
Beetles	P	P	P	P	P	P
Staphylinids	P	P	P	A	A	P
Beetle grubs	P	P	P	P	P	P
Caterpillars	A	P	P	A	A	P
Thrips	P	P	P	A	A	A
Coccids	P	P	P	P	A	A
Earwigs	A	P	P	A	A	P
Cockroach	P	P	P	A	A	A
Spiders	P	P	P	P	P	P
P. scorpions	P	P	P	A	A	A
Millipedes	P	P	P	A	A	A
Centipedes	P	P	P	A	A	A
Symphylans	P	P	P	A	P	A
Earthworms	A	P	A	A	A	A
Protura	P	P	P	A	A	A
Midges	P	A	A	A	A	A
Termites	P	P	P	P	P	A
Total no. present	**27**	**27**	**25**	**14**	**13**	**12**

Table 8. Occurrence of soil invertebrates in different ecosystems (Nov. 04)

SL No.	Groups	Acacia	Cardamom	Coffee	Grassland	Natural Forest	Paddy
1	Mesostigmata	+	+	+	+	+	+
2	Cryptostigmata	+	+	+	+	+	+
3	Collembola	+	+	+	+	+	+
4	Diplura	+	+	+	+	+	+
5	Psocids	+	+	+	-	+	-
6	Leafhopper	-	-	+	-	-	-
7	Bugs	+	+	+	-	-	+
8	Moth flies	-	-	+	-	+	-
9	Isopods	-	+	-	-	-	-
10	Other flies	-	+	-	+	+	+
11	Dipteran maggots	+	+	+	-	+	+
12	Ants	+	+	+	+	+	+
13	Wasps	-	-	-	-	+	+
14	Beetles	+	+	+	+	+	+
15	Staphylinids	+	+	+	+	+	+
16	Beetle grubs	+	+	+	+	+	+
17	Termites	-	-	-	+	-	-
18	Coccids	+	+	+	-	-	-
19	Earwigs	-	+	-	-	-	-
20	Cockroach	-	+	+	-	-	-
21	Spiders	+	+	+	-	+	+
22	P. scorpions	-	+	+	+	+	-
23	Millipedes	-	+	+	-	+	+
24	Centipedes	+	+	+	+	+	-
25	Symphylans	+	+	+	-	+	+
26	Earthworms	+	+	+	-	+	+
27	Protura	-	+	-	-	-	-
Total no. present		**16**	**23**	**21**	**12**	**19**	**16**

Note: + : Presence
- : Absence

Table 9. Occurrence of litter invertebrates in different ecosystems (Feb. 04)

Group	Cardamom	Natural forest	Coffee	Paddy	Grassland	Acacia
Mesostigmata	P	P	P	P	P	P
Cryptostigmata	P	P	P	P	P	P
Collembola	P	A	A	P	A	A
Diplura	P	A	P	A	A	A
Psocids	P	P	P	A	P	A
Bugs	P	P	P	A	A	A
Moth flies	P	P	P	P	A	A
Other flies	P	A	P	A	P	P
Dipteran maggots	A	A	A	P	P	A
Ants	P	P	P	A	P	A
Beetles	P	P	P	P	P	A
Staphylinids	P	A	A	P	A	A
Beetle grubs	P	P	P	P	A	P
Caterpillars	P	P	A	A	A	A
Thrips	P	P	P	P	P	P
Coccids	P	A	A	A	P	P
Cockroach	P	A	P	A	A	A
Spiders	P	P	P	P	P	A
P. scorpions	P	P	A	A	A	A
Symphylans	P	A	A	P	P	P
Earthworms	P	P	A	A	A	A
Protura	P	A	A	A	A	A
Mealy bugs	P	A	A	A	A	A
Crickets	P	A	A	A	A	A
Total no. Present	**23**	**13**	**13**	**11**	**11**	**7**

Note: P : Presence
A : Absence

Table 10. Occurrence of litter invertebrates in different ecosystems (Nov. 04)

SL No.	Groups	Acacia	Cardamom	Coffee	Grassland	Natural Forest	Paddy
1	Mesostigmata	+	+	+	+	+	+
2	Cryptostigmata	+	+	+	+	+	+
3	Collembola	+	+	+	+	+	+
4	Diplura	-	+	+	+	+	+
5	Psocids	+	+	+	+	+	+
6	Bugs	+	+	+	+	+	+
7	Moth flies	-	+	-	+	+	-
8	Isopods	-	+	+	-	+	-
9	Other flies	+	+	+	+	+	+
10	Dipteran maggots	+	+	+	+	+	+
11	Ants	+	+	+	+	+	+
12	Wasps	-	-	+	-	-	-
13	Beetles	+	+	+	+	+	+
14	Staphylinids	-	+	+	+	+	+
15	Beetle grubs	-	+	+	+	+	+
16	Caterpillars	+	+	+	-	+	+
17	Thrips	+	+	+	+	+	+
18	Termites	-	-	+	+	-	-
19	Coccids	-	+	-	+	-	+
20	Cockroach	-	-	+	-	+	-
21	Spiders	+	+	+	+	+	+
22	P. scorpions	-	+	+	+	+	+
23	Millipedes	-	-	+	-	+	+
24	Centipedes	-	+	+	-	+	-
25	Symphylans	-	-	-	-	+	+
26	Protura	-	+	-	-	+	-
Total no. present		**12**	**22**	**22**	**18**	**23**	**19**

Note: + : Presence
- : Absence

Table11. Distribution of soil invertebrates at different soil depths in different ecosystems (Monoliths, Feb.04)

SL No.	Ecosystem	Abundance (# /100g)				
		No. of sampling Point	Soil depth (cm)	Range	Total	Mean
1	Natural forest	9	0-10	1-38	31.75	3.52 ± 3.06
			10-20	1-17	8.50	0.94 ± 0.74
			20-30	1-11	9.50	1.05 ± 1.52
2	Grassland	8	0-10	1-2	3.00	0.34 ± 0.35
			10-20	1-11	3.25	0.40 ± 0.46
			20-30	0	0.00	0.00± 0.00
3	Acacia	6	0-10	0-1	0.75	0.12 ± 0.12
			10-20	1-2	0.75	0.12 ± 0.27
			20-30	0	0.00	0.00± 0.00
4	Coffee	16	0-10	1-66	48.25	3.01 ± 3.27
			10-20	1-36	27.50	1.71 ± 2.96
			20-30	1-15	8.25	0.51 ± 0.61
5	Cardamom	13	0-10	1-50	39.75	3.05 ± 4.07
			10-20	1-32	18.75	1.44 ± 1.41
			20-30	1-12	8.50	0.65 ±0.55
6	Paddy	8	0-10	1-5	4.00	0.50 ± 0.41
			10-20	1-2	0.75	0.09 ± 0.17
			20-30	0-1	0.25	0.03 ± 0.08

Table 12. Distribution of soil invertebrates at different soil depths in different ecosystems (Monoliths, Nov.04)

SL No.	Ecosystem	Abundance (# /100g)				
		No. of sampling Point	Soil depth (cm)	Range	Total	Mean
1	Natural forest	9	0-10	1-38	21.75	2.41 ±1.99
			10-20	1-17	6.25	0.69 ± 0.63
			20-30	1-11	5.75	0.63 ± 0.97
2	Grassland	8	0-10	1-2	14.50	1.81 ± 2.31
			10-20	1-11	10.50	1.31 ± 1.02
			20-30	0	7.50	0.93± 1.44
3	Acacia	6	0-10	0-1	9.25	1.54 ± 1.67
			10-20	1-2	8.75	1.45 ± 1.43
			20-30	0	2.50	0.41 ± 0.43
4	Coffee	16	0-10	1-66	28.50	1.78 ± 1.47
			10-20	1-36	14.00	0.87 ± 0.72
			20-30	1-15	8.25	0.51 ± 0.93
5	Cardamom	13	0-10	1-50	32.25	2.48 ± 2.65
			10-20	1-32	14.75	1.13 ± 1.04
			20-30	1-12	3.25	0.25 ± 0.32
6	Paddy	8	0-10	1-5	30.00	3.75 ± 3.73
			10-20	1-2	22.75	2.84 ± 2.26
			20-30	0-1	14.00	1.75 ± 1.63

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Table 13. Abundance of Termites, Ants and Beetles (Pitfall catches

Land use	Termites	Ants	Beetles
Nilgiri Biosphere, Karnataka			
1) Natural forests	--	45.33±51.02 (0.88±1.52)	1.0±1.05 (0.22±0.41)
2) Forest Plantation	--	53.50±46.98 (4.33±3.19)	- (0.0)
3) Cardamom	0.3±0.82	34.46±33.81 (1.58±2.09)	0.53 ± 0.49 (0.33±0.47)
4) Coffee	--	31.93 ± 48.24 (3.25 ± 4.76)	0.31±0.46 (0.37±0.48)
5) Crop lands	--	28.50±57.37 (1.87±2.61)	3.62±6.34 (0.25±0.66)
6) Grasslands/fallow	--	30.00±21.93 (8.12±11.46)	1.37±2.91 (0.37±0.99)

Figures in the parentheses are results of November 2004.

Table 14. Relative abundance of termites, ants and beetles

Land use	Pitfall catches	
	Ants	Beetles
1) Natural forests	89.05 (22.86)*	1.53 (5.71)*
2) Forest Plantation	92.08 (61.22)	0.86 (0)
3) Coffee	91.42 (48.60)	1.34 (3.74)
4) Cardamom	98.64 (37.25)	1.54 (3.92)
5) Crop lands	79.86 (54.84)	5.30 (3.23)
6) Grasslands/fallow	83.84 (73.14)	5.06 (3.66)

Figure in the parentheses are Nov-2004 samples

Table 14. Relative abundance of termites, ants and beetles

	Soil (0-5 cm)*			Litter (0 cm)*		
	Termites	Ants	Beetles	Termites	Ants	Beetles
i)	0	8.47	4.16	0	2.22	2.28
ii)	0	3.36	2.80	0	1.80	1.20
iii)	0	3.48	7.64	0	3.65	8.54
iv)	0	3.39	7.87	0	2.39	8.89
v)	0	29.85	3.48	0	4.71	2.05
vi)	4.35	8.70	2.41	0.12	1.80	1.60

* November 2004 samples

Table 15. Abundance of termites, ants and beetles in different soil depths

Land use	Soil depth	Ants	Termites	Beetles
i) Natural Forest	0-10	0.125±0.33	-	1.22±2.14
	10-20	-	-	-
	20-30	0.125±0.33	-	-
ii) Forest plantations	0-10	-	-	-
	10-20	-	-	0.16±0.37
	20-30	-	-	-
iii) Cardamom	0-10	-	-	-
	10-20	-	-	-
	20-30	-	-	-
iv) Coffee	0-10	-	-	-
	10-20	-	-	0.04±0.20
	20-30	-	-	0.04±0.20
v) Grass land	0-10	0.25+_0.66	-	0.125±0.33
	10-20	-	-	-
	20-30	-	-	-
vi) Croplands	0-10	-	-	0.75±0.82
	10-20	-	-	-
	20-30	-	-	0.125±0.33

Table16.Abundance of termites, ants and beetles in soil and litter of different Land uses (Feb.2004).

Land use	Soil (No./m^2)			Litter (no./100g)		
	Termites	Ants	Beetles	Termites	Ants	Beetles
a) Karnataka						
1) Natural forests	-	7.96 (18.47)	18.79 (26.43)	-- (0)	1.27 (25.79)	18.79 (69.11)
2) Forest Plantation	-	16.24 (5.09)	3.82 (13.05)	-- (0)	-- (3.50)	3.50 (7.00) 3.51
3) Cardamom	-	4.42 (20.70)	23.88 (35.35)	--	2.63	2.16
4) Coffee	-	5.09 (1.27)	13.37 (15.28)	0.17	10.24	89.8
5) Crop lands	-	-- (39.81) 2.54	29.93 (14.65)	-- (0)	-- (82.17)	(107.01) 1.27
6) Grasslands	- (2.86)	(5.73)	2.55 (4.77)	-- (1.27)	1.27 (19.74)	(52.87)

Figures in the parentheses are results of November 2004.

Table 17. Distribution of Termites species in different land uses of Nilagiri biosphere

Sl. No.	Species	Natural Forests	Forests	Plantations	Crop lands	Grasslands
1	*Odontotermes horni*	? ?	? ?	? ?	*	? ?
2	*O. wallonensis*	? ?				
3	*O. obesus*				?	? ?
4	*O. sp.1*	? ?	? ?	? ?	?	? ?
5	*O. sp.2*	? ?	? ?	? ?	*	*
6	*O.sp.3*	*	*	? ?		
7	*O. sp.*					? ?
8	*Dicuspiditermes sp.*	? ?	? ?	? ?		
9	*Pericapritermes sp.*	? ?				
10	*Nasutitermes sp.*	? ?		? ?	*	
11	*Trinervitermes sp.*					
12	*Heterotermes sp.*					
13	*Labiocapritermes sp.*					
14	*Microtermes sp.*			*		*

? ?February 2004 collection*? November 2004 collection

Table 18. Comparative account of termites, ants and beetles biomass in different land usepattern

Land use	Biomass (g/pitfall)		
	Termites	Ants	Beetles
Nilgiri biosphere Karnataka			
1) Natural forests	--	0.22±0.22	0.038±0.05
2) Forest Plantation	--	3.80±7.28	--
3) Cardamom	--	0.26±0.23	0.056±0.08
4) Coffee	--	0.25±0.25	0.021±0.05
5) Crop lands	--	0.37±0.54	0.36±0.89
6) Grasslands		0.56±0.42	0.028±0.04

Table 19. Distribution of ants species in different land uses of Nilagiri biosphere

	Species	Nat. Forests	Forests	Plantations	Crop lands	Grasslands
1	*Aenictus sp.*	?	?	?		
2	*Aphenogaster sp.*	?	?	?		?
3	*Camponotus angusticolis*	? ?		?	? ?	
4	*C. parius*	?	?	?	? ?	? ?
5	*C. sericeus*	? ?	? ?	? ?		? ?
6	*Crematogaster dhorni*	?		?	?	
7	*C. wroughtoni*	? ?	?	?	?	
8	*Diacamma rugosum*	? ?	? ?	? ?	? ?	? ?
9	*Dolichoderus sp.*	?		?		
10	*Mesoponera sp.*	?				
11	*Monomorium sp.*	?	?	?	?	
12	*Oecophylla smaragdina*	?		?		
13	*Pheidolegeton affinis*	?		?		
14	*Pheidole sp.*	? ?	? ?	? ?	? ?	? ?
15	*Tetramorium sp.*	?		?		
16	*Odontoponera sp.*			? ?		
17	*Pachycondyla sulcata*		?	?		? ?
18	*P. sp.*			?		
19	*Polyrhachis illandata*			?		
20	*Prenoleps sp.*			?		
21	*Harpegnathus saltator*		?	?		
22	*Pheidolegeton diversus*			?		
23	*polyrhachis exercita*		?	?		
24	*Diacamma cyaneiventre*		?		?	? ?
25	*Anochetus graeffei*					? ?
26	*Pachycondyla luteipes*				? ?	? ?
27	*Monomorium scabricepes*				?	
28	*Pachycondyla esseronoda*				?	
29	*Tetramorium walshi*				?	
30	*Myrmicaria sp.*					
31	*Pseudoponera sp.*					
32	*Lobopelta sp.*					
33	*Anoploleis sp.*					
34	*Tetraponera sp.*					
35	*Paratrechina sp.*					
36	*Leptogenys sp. (chinensis)*					
37	*Cardiocondyla sp.*					
38	*Odontomachus*					
39	*Transmorium sp.*					
40	*Leptogenys diminuta*					
41	*Leptogenys luteipes*					

Table 20. Distribution of Ant species in different ecosystems (Feb. 04)

	Number of ant species					
Subfamily	Natural forest	Cardamom	Coffee	Acacia	Grassland	Paddy
Dolichoderinae	1	1	-	-	-	1
Dorylinae	1	-	-	1	-	-
Formicinae	4	5	7	4	2	3
Myrmicinae	7	6	5	4	2	5
Ponerinae	2	4	-	3	5	4
Total	**15**	**16**	**12**	**12**	**9**	**13**

Table21. Distribution of Ant species in different ecosystems (November, 2004)

	Number of ant species					
Subfamily	**Natural forest**	**Cardamom Plantations**	**Coffee Plantations**	**Acacia Plantations**	**Grassland**	**Paddy Fields**
Formicinae	**2**	**1**	**-**	**-**	**2**	**2**
Myrmicinae	**2**	**1**	**2**	**1**	**1**	**1**
Ponerinae	**3**	**1**	**4**	**5**	**3**	**4**
Total	**7**	**3**	**6**	**6**	**6**	**7**

Table22. Relative abundance of soil invertebrates in different ecosystems (Feb2004)

Groups	Acacia	Cardamom	Coffee	Grassland	Natural Forest	Paddy
Other acari	54.54	32.00	35.32	26.98	27.23	13.51
Crypto stigmata	12.83	25.05	27.06	23.80	27.23	45.40
Collembola	0.53	10.45	15.28	0.00	10.25	5.40
Diplura	0.00	0.64	0.05	0.00	0.35	0.00
Psocids	1.06	0.05	0.00	0.00	0.08	0.27
Leafhopper	0.00	0.00	0.00	4.76	0.08	0.00
Bugs	0.53	0.37	0.11	1.58	0.26	0.00
Moth flies	2.13	0.32	0.35	17.46	0.35	0.27
Isopods	0.00	0.00	0.00	0.00	0.09	0.00
Other flies	0.53	0.43	0.35	4.76	0.44	0.00
Dipteran maggots	17.64	0.70	0.58	1.58	2.03	10.54
Ants	2.67	1.18	1.93	1.58	2.56	0.00
Wasp	0.00	0.16	0.00	0.00	0.00	0.00
Beetles	1.06	1.02	0.70	3.17	1.94	4.05
Staphylinids	0.00	1.40	0.41	0.00	0.88	1.08
Beetle grubs	3.20	3.98	3.63	9.52	2.90	17.02
Caterpillars	0.00	0.05	0.23	0.00	0.00	1.62
Thrips	0.00	0.16	0.11	0.00	0.08	0.00
Termites	0.00	0.00	0.00	0.00	0.00	0.00
Earwigs	0.00	0.05	0.11	0.00	0.00	0.27
Coccids	2.67	8.56	8.26	0.00	9.90	0.00
Cockroach	0.00	0.05	0.23	0.00	0.08	0.00
Spiders	0.53	0.64	0.46	1.58	0.61	0.54
P. scorpions	0.00	1.13	0.87	0.00	1.23	0.00
Symphylans	0.00	10.12	3.63	3.17	7.00	0.00
Protura	0.00	1.40	0.23	0.00	4.24	0.00

Table 23. Relative abundance of soil invertebrates in different ecosystems (Nov. 04)

Groups	Acacia	Cardamom	Coffee	Grassland	Natural Forest	Paddy
Mesostigmata	31.93	22.71	22.96	31.88	28.63	17.91
Cryptostigmata	4.20	9.78	23.47	36.23	18.15	13.43
Collembola	32.77	11.04	12.76	5.80	11.69	11.94
Diplura	1.68	2.52	1.02	1.45	1.21	2.99
Psocids	0.84	0.95	4.59	0.00	0.40	0.00
Leafhopper	0.00	0.00	0.51	0.00	0.00	0.00
Bugs	1.68	0.63	0.51	0.00	0.00	0.75
Moth flies	0.00	0.00	1.02	0.00	0.40	0.00
Isopods	0.00	0.32	0.00	0.00	0.00	0.00
Other flies	0.00	1.26	0.00	1.45	0.40	2.24
Dipteran maggots	1.68	4.73	6.12	0.00	3.23	2.24
Ants	3.36	10.73	1.53	8.70	8.47	29.85
Wasps	0.00	0.00	0.00	0.00	0.40	0.75
Beetles	3.36	9.78	6.12	1.45	5.24	3.73
Staphylinids	0.84	1.58	4.59	2.90	3.63	2.24
Beetle grubs	4.20	6.62	5.10	2.90	3.63	4.48
Termites	0.00	0.00	0.00	4.35	0.00	0.00
Coccids	5.88	0.32	1.02	0.00	0.00	0.00
Earwigs	0.00	0.32	0.00	0.00	0.00	0.00
Cockroach	0.00	0.32	0.51	0.00	0.00	0.00
Spiders	0.84	0.32	0.51	0.00	1.21	0.75
P. scorpions	0.00	0.95	1.02	1.45	1.21	0.00
Millipedes	0.00	2.52	2.55	0.00	2.42	0.75
Centipedes	2.52	6.31	1.53	1.45	4.84	0.00
Symphylans	3.36	3.47	0.51	0.00	4.44	4.48
Earthworms	0.84	2.52	2.04	0.00	0.40	1.49

Table 24. Relative abundance of litter invertebrates in different ecosystems (Feb2004)

Groups	Acacia	Cardamom	Coffee	Grassland	Natural Forest	Paddy
Other acari	48.38	29.28	27.77	30.00	18.86	36.87
Cryptostigmata	3.22	12.70	11.80	22.00	37.73	41.00
Collembola	3.22	0.00	0.00	0.00	0.00	0.29
Diplura	0.00	0.27	0.69	0.00	0.00	0.00
Psocids	0.00	4.41	3.47	2.00	4.71	0.00
Bugs	0.00	0.82	1.38	0.00	0.94	0.00
Moth flies	0.00	0.22	1.38	0.00	0.94	0.29
Isopods	0.00	0.00	0.00	0.00	0.00	0.00
Other flies	6.45	0.27	5.55	4.00	0.00	0.00
Dipteran maggots	0.00	0.00	0.00	10.00	0.00	1.47
Ants	0.00	3.86	2.77	2.00	0.94	0.00
Beetles	0.00	6.07	10.41	2.00	5.66	0.29
Staphylinids	0.00	0.27	0.00	0.00	0.00	0.29
Beetle grubs	6.45	12.70	6.94	0.00	10.37	18.87
Caterpillars	0.00	0.54	0.00	0.00	4.71	0.00
Thrips	19.35	21.82	15.27	14.00	3.77	0.00
Termites	0.00	0.00	0.00	0.00	0.00	0.00
Coccids	9.67	0.27	0.00	8.00	0.00	0.00
Cockroach	0.00	0.27	0.69	0.00	0.00	0.00
Spiders	0.00	4.41	11.80	4.00	7.54	0.58
P. scorpions	0.00	0.82	0.00	2.00	3.77	0.00
Symphylans	3.22	0.54	0.00	0.00	0.00	0.00
Protura	0.00	0.27	0.00	0.00	0.00	0.00

Table 25. Relative abundance of litter invertebrates in different ecosystems (Nov. 04)

Groups	Acacia	Cardamom	Coffee	Grassland	Natural Forest	Paddy
Mesostigmata	45.05	26.84	24.77	26.74	46.52	40.35
Cryptostigmata	22.52	52.85	42.21	54.08	28.76	41.41
Collembola	9.01	3.60	12.00	7.31	5.15	2.43
Diplura	0.00	0.39	0.07	0.12	0.50	0.15
Psocids	1.80	0.68	0.03	0.48	0.50	0.15
Bugs	6.31	0.19	0.30	0.24	0.50	0.08
Moth flies	0.00	0.15	0.00	0.12	0.30	0.00
Isopods	0.00	0.24	0.44	0.00	0.10	0.00
Other flies	0.90	0.39	0.10	0.60	0.30	0.46
Dipteran maggots	1.80	0.15	1.32	0.84	1.01	0.38
Ants	1.80	2.63	10.24	1.80	2.22	4.71
Wasps	0.00	0.00	0.14	0.00	0.00	0.00
Beetles	3.60	3.17	1.45	0.96	2.32	1.44
Staphylinids	0.00	0.34	0.71	0.48	0.50	0.84
Beetle grubs	0.00	4.92	2.03	3.36	4.04	3.88
Caterpillars	1.80	0.39	0.14	0.00	0.40	0.38
Thrips	3.60	1.61	2.77	0.84	4.24	1.90
Termites	0.00	0.00	0.17	0.12	0.00	0.00
Coccids	0.00	0.05	0.00	0.36	0.00	0.08
Cockroach	0.00	0.00	0.07	0.00	0.20	0.00
Spiders	1.80	0.63	0.68	1.08	1.31	1.06
P. scorpions	0.00	0.39	0.17	0.48	0.50	0.15
Millipedes	0.00	0.00	0.14	0.00	0.20	0.08
Centipedes	0.00	0.34	0.07	0.00	0.10	0.00
Symphylans	0.00	0.00	0.00	0.00	0.10	0.08
Protura	0.00	0.05	0.00	0.00	0.20	0.00

Earthworms: Component of Soil Biota

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INTRODUCTION

Earthworms play a crucial role in maintenance of soil fertility. Their abundance depends on availability of feed, adequate moisture and physical characters like soil texture, pH and electrolyte concentrations (Kale and Krishnamoorthy, 1978; Reddy and Alfred, 1978; Chauhan, 1980; Ganihar, 1996). Kale and Krishnamoorthy observed that variations in earthworm abundance in landscape is more strongly correlated to the quality of organic matter measured in terms of C/N (Ratio of Carbon to Nitrogen) and H/F (Ratio of Humic to Fulvic acids) ratios of the available organic matter than to its quantity. Senapati *et al* (1979) have shown such positive correlation to C/N ratio of soil for earthworm biomass relationships in pastures of Sambalpur, India.

Southern peninsular region of Indian subcontinent shows the highest diversity of earthworm species (Stephenson, 1923; Julka, 1993). Gates (1972) has provided the list of earthworms of S.E. Asia and of Indogangetic plains. Julka and Senapati (1987) have provided the distribution pattern of earthworms in Orissa State; Ismail *et al* (1990) in and around Chennai; Kale and Krishnamoorthy (1978) in and around Bangalore city (Radius of 15 Km at different points from center of the city). Bano and Kale (1991) have provided a list of species of earthworms of common occurrence in different geographical regions of Southern Karnataka. There is also a report on earthworms of Kendujhar district of Orissa (Patnaik *et al*, 2004), Jodhpur District of Rajasthan (Tripathi and Bhadwaj, 2004), Western ghats (Blanchart and Julka, 1997), Goa (Ganihar, 1996), Kumaon, Himalayas Kaushal *et al*, 1999; Bhadauria *et al*, 2000), Tripura (Chaudhuri and Bhattacharjee, 1999).

The representative species of the families Megascolecidae, Moniligastridae, Octochaetidae, Ocnerodrilidae, Glossoscolecidae and Almidae are found distributed in all the agroecosystems, pastures and natural forests. With intensification of agriculture and other disturbances that have led to changes in the natural habitats might have resulted in changes in species composition and abundance (Kale, 1997; Julka, 2005; Bhadauria *et al*, 2000; Curry *et al*, 2002).

More attention is laid on spatial distribution of earthworm species rather than the population fluctuations. In one of the studies, maximum size of population of three species of earthworms *Pheretima elongata* (*Polypheretima elongata*), *Lampito mauriti,* and *Pontoscolex corethrurus* was observed in September (Kale and Krishnamoorthy, 1982). Chauhan (1980) had reported similar trend for *Pheretima postuma* and *Eutyphoeus waltoni.* Dash and Patra (1997) had recorded unimodal population increase in the grasslands in September. Bhadauria and Ramakrishnan (1989) have reported maximum population size of three species of earthworms of North East India to the wet season. Kaushal and Bisht (1994) have also reported maximum density during wet seasons.

Amount of cast produced can serve as an index for assessing earthworm activity and surface castings more during rainy seasons (Gates, 1961; Dash and Patra, 1979; Roy, 1957). The nature of cast released by earthworms is species specific but it cannot be the criteria for identification of earthworms (Tembe and Dubash, 1961). Influence of seasonal variation and land use pattern was observed with respect to earthworm cast production I shifting agriculture (Bhadauria and Ramakrishnan, 1989). Just as seasonal variation is observed with regard to cast production, physico- chemical properties of castings depend on the habitat soil and with the species of earthworm (Nijhawan and Kanwar, 1952). The aggregate stability of earthworm castings may depend on the nature of available organic matter (Dutt, 1948). Earthworm castings show better nutrient status than that of the surrounding soil (Nijhawan and Kanwar, 1952; Kale and Krishnamoorthy, 1979; Bhadauria and Ramakrishnan, 1996; Ganihar, 2003; Saharan and Singh, 1988; Basak *et al,* 1990).

Species richness and abundance is an indicator to understand the fertility status of the given agroecosystem. The intensity of disturbance caused due to the existing agricultural practices can also be realized from the available data on earthworm population at the study site. The information available on the nutrient status in the castings reflects on the contribution of earthworms on biogeochemical cycle. As their activity is restricted to very short period annually to wet seasons, it is essential to fix this period of time for collection of information on earthworms and their activity. Based on these factors, an attempt has been made to study the population structure and their abundance at different agro ecosystems designated in the study area along with amount of cast production to link the same to their activity.

MATERIAL AND METHODS

The benchmark area, Koothy is situated adjacent to the northern part of Nilgiri Biosphere Resource, in Kodagu District of Karnataka State, India. Two windows that are situated just about 40 Km from benchmark area have been considered for the present investigations. Different habitats at this point of survey are coffee and cardamom plantations, which form the major component and natural forests of evergreen type is at the periphery showing varying levels of degradation. There are patches of social forestry of *Acacia auriculiformis* and grassy blanks adjoining the forests. Rain fed agriculture is practiced in valleys and paddy is the main crop cultivated during rainy season. Crops like chilly and some legumes that require less moisture form the summer crops.

An area of 25 Km ^{2} was demarcated as sampling area and two windows were identified for grid sampling. The windows were further divided into 200 M grids using Arc/Info software with GPS (Global Positioning System model - Garmin 12 channel). Different habitat types that coincided with these markings were considered for earthworm survey, which included 60 transects. Of the 60 transects considered for collection, nine were in natural forests, eight in grasslands, sixteen in coffee plantations, thirteen in cardamom plantations, eight in paddy fields and six in *Acacia* plantations. In each transect an equilateral triangle of 50 X 50 X 50 M was considered to mark the point of monolith, which was 25 X 25 X 30 cm at the centre of the triangle for collection of earthworms at different depths of 10, 20 and 30 cm.

Different stages of earthworms like clitellate (adults), aclitellate (subadults), juvenile and cocoons were collected by hand sorting for recording of the actual number present at different

depths in the monolith. Only clitellate earthworms were fixed in 4% formaldehyde solution to transport to laboratory for the purpose of identification. At the collection spot different stages of different species were segregated based on colour, extended prostomium, and their thigmotactic responses. Before marking of monolith, surface litter if any, was cleared and searched for earthworms. Surface castings at each of the point were collected and air died before weighing.

The population count was used to determine species richness, population density, and similarity in species at the study sites.

RESULTS AND DISCUSSION

Collection of earthworms in each of the chosen habitats was restricted to the monoliths that coincided along the path of the windows earmarked for observations on soil biodiversity study. As the monoliths covered at the study sites were several kilometers apart, the species composition changed in the monoliths of the same type of land use. Similarly, it is difficult to assess the actual number of species distributed in the given land use because of the collection restricted to the points along the path of the windows. One of the important observations from this survey is that *Drawida somavarapatana* is the predominant species of earthworm in all the land use s except in grasslands where it was totally absent. Because of its existence, more or less in all the monoliths of five of the land use sites, the expressed standard deviation is not more than the observed mean values (Table 1). This species has also shown higher level of percent distribution than other species of earthworms collected at different sites (Table 2). The patchy distribution of rest of the 15 species of earthworms other than *Pontoscolex corethrurus* at different habitats can be made out from high values of standard deviations to those of the observed mean values (Table 1).

According to Lee (1985), number of earthworm species in a community is the simple measure of diversity and the range may be from one to eleven species. Most commonly the consistency of species combination is between two to five. Similar trend of species composition of two to five species at the collection spots has resulted in wider standard deviation for different species inhabiting the same type of land use. In tropical conditions, many scientists from different vegetation types have reported species association of one to eleven species, included under Megascolecidae, Lumbricidae, Moniligastridae, Eudrilidae and Glossoscolecidae (Lee, 1985). In the present study, eleven species were collected in coffee and cardamom plantations but in the composition each of these systems differed in having the species of earthworms specific to individual land uses. They are *Drawida minuta, D. Kanarensis, Octochaetoides beatrix* and *Octochaetona pitnyii* in cardamom plantations and *Lampito mauritii, Megascolex curgensis, M. feliciseta* and *Curgia narayani* in coffee plantations. These species exhibit ed very low incidence of occurrence when compared to many other species in the respective study sites (Table 2).

Earthworm collections were carried out at post monsoon season immediately after the last showers monsoon showers. The prevailing moist conditions in most of the collection spots had resulted in distribution of earthworms in subsoil up to a depth of 20 cm and maximum collection was at 0-10 cm. This shows that under favourable conditions, their activity is restricted to a depth of 20 cm (Table 3).

The Similarity index of species between the different land uses has shown that species composition of natural forest is closer to that of coffee plantation also has species more similar to those of paddy fields, *Acacia* and cardamom plantations. The least similarity is observed in species composition of grassland to any other experimental site (Table 4). *Pontoscolex corethrurus* was found distributed at all the sites with lowest density in grassland. Another sites its density was next to *D. somavarapatana* (Table 1). It is clear that coffee plantations have congenial conditions for earthworms found in different habitats. This may be due to rich diversity in tree populations that provide necessary shade to coffee shrubs. Regular litter fall from these trees and of coffee is adding to leaf mulch on soil surface. The shade and litter cover minimizes the sudden moisture loss from soil surface and moisture is one of the crucial factors for earthworm activity. Rapid loss of moisture due to evaporation in grasslands might have led to occurrence of very low level of earthworm species and their density, though there will be regular contribution of organic matter due to death decay of grasses. *Acacia* plantations are developed in denuded lands. *Acacia* litter being hard for fast degradation, adding up of humus to soil is a slow process. Low moisture and organic matter contents might have resulted in decline in earthworm species diversity in these plantations, though these two ecosystems are adjacent to coffee or cardamom plantations.

Detail information on age structure of field population of tropical earthworm is of *Millsonia anamola* (Megascolecidae). Of the five levels of cohorts of the field populations, half the populations were in six to eight months age class (sub adults and adults) and 25% were juveniles. This is the report on the findings of Lavelle provided by Lee (1985). The population structure of three species of earthworms *Pheretima elongata (Polypheretima elongata), Lampito mauritii* and *Pontoscolex corethrurus,* carried out from Nov. 1978 to Dec. 1979 in a farmyard garden in Bangalore (Karnataka, India) has shown that these earthworms have peak populations during the months of Sept. - October. Adults and juveniles outnumbered sub adults (earthworms who have attained the size of adults but aclitellate) in case of *Polypheretima elongata.* Population of sub adults was three to four times that of juveniles and adults in *Pontoscolex corethrurus.* These levels were maintained all through the year except for two to three months that had totally dry. *Lampito mauritii* with two peaks of high density of population had high level of sub adults in June and was adults and juveniles in September. Thus definite pattern in population structure was observed I these earthworms (Kale and Krishnamorthy, 1982). Earthworms collected at the benchmark area has shown a definite pattern in the population structure and values are expressed in Table 5 as the ratio of occurrence of three age groups, considering the smallest number of individuals for particular species as one and the rest as its multiples. In majority of cases adults outnumber the other two stages and in very few cases all the three stages remained equal in number.

Presence of cocoons at study sites suggests that production of cocoons of majority of species of earthworms coincides with onset of post monsoon period. Dash and Senapati (1980, 1982) have reported the required temperature of > 20°C and soil moisture of > 7% for Indian Megascolecoids. Lavelle (1978) in studies carried out on some African earthworms has linked the peak production time of earthworms to commencement of dry spell at the end of each wet seasons. Similar trend in cocoon production can be predicted to some of the species at the study site. Cocoons that are produced at this time of the year may pass through the adverse situations and hatch when temperature or soil moisture is favourable (Table 6).

In many studies surface castings in Indian soils have been quantified (Roy, 1957; Patel and Patel, 1959; Dubash and Ganti, 1963; Dash and Patra, 1977). The cast production is not continuous throughout the year and ceases during summer months under dry conditions. Surface casting in *Acacia* plantation and in grassland was found only in one monolith each and was absent in other monoliths that had turned dry. There was no difference in weights of recovered castings in coffee and cardamom plantations. It remained same with paddy field and natural forest (Table 7).

The patchy distribution of earthworms, their size variations among the species and within the species of different stages poses the problem for assessing the quantitative abundance. They may even be missed as they may move away due to disturbance caused during digging. The counts taken for field populations may be mostly underestimates. Reinecke and Ljungström (1969) have given an estimate of 72/M² for earthworm population density in South African pasture. In the present study population density for certain major species approximates this range and rear species in the same habitats have expressed low density. Lavelle (1978) had adopted other methods like washing and sieving along with hand sorting for field level population studies. According to him the larger sized earthworms can be hand sorted and do not require any corrections and washing and sieving is needed when very small sized populations are present. The present study site did not have any earthworm weighing about one mille gram, as was found in case of studies of Lavelle (1978). Very deep burrowing earthworms were also not found in these sites except for *Drawida grandis,* which was not encountered at the points of collection, but were found in spots outside the path of windows. Some species like *Dichogaster curgensis* were also lost during collection, though hey were found in some of these land uses, In general, hand sorting method and selection of season for understanding of biodiversity of earthworm fauna was found to be appropriate at the bench mark area of Northern Nilgiri Biosphere.

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Table 1: Earthworm species density (No./m²) at different land use types during Nov.2004 in window 1 of Nilgiri biosphere (0- 30 cm). Values are Mean ± S.D of observed populations.

Family/species	NF	GL	AC	CP	CoP	PF
Moniligasridae						
Drawida fakir Conjn.	30.0 ± 62.4	22.0 ± 24.0	40.0 ± 48.0	42.0 ± 62.4	94.0 ± 92.8	----
D. kanarensis Steph.	-----	-----	----	16.0 ± 38.4	--------	----
D. minuta (A.G.Bourne)	------	------	-----	15.0 ± 38.4	-------	----
D. modesta Rao	34.0 ± 62.4	-----	------	56.0 ± 100.8	51.0 ± 48	40.0 ± 44.8
D. pellucida (A. G. Bourne)	------	64.0 ± 57.6	-----	37.0 ± 91.2	71.0 ± 96.0	------
D.somavarapatana Rao	148.0 ± 62.4	-----	136.0 ± 64.0	254.0 ± 192.0	213.0 ± 192.0	96.0 ± 70.4
Megascolecidae						
Lampito mauriti (Kinb.)	20.0 ± 38.4	------	------	------	75.0 ± 112.0	------
Megascolex curgensis (Mich.)	-------	------	64.0 ± 43.2	------	71.0 ± 80.0	64.0 ± 40.0
M. feliciseta Steph.	-----	------	------	-----	41.0 ± 64.0	------
Metaphire houlleti (E. Perr.)	20.0 ± 38.8	------	------	14.0 ± 30.4	93.0 ± 84.8	78.0 ± 57.6
Megascolex sp.	------	-----	------	------	--------	34.0 ± 36.8
Octochaetidae						
Octochaetoides beatrix Bedd.	-------	------	------	11.0 ± 24.0	--------	------
Octochaetona castellanus Steph	48.0 ± 52.8	12.0 ± 24.0	24.0 ± 24.4	14.0 ± 27.2	54.0 ± 96.0	56.0 ± 49.6
O. pitnyii Mich.	------	-------	------	11.0 ± 24.0	-------	------
Ramiella pallida	-------	28.0 ± 23.0	-------	--------	-------	20.0 ± 1.2
Ocnerodrillidae						
Curgia narayani Mich.	18.0 ± 28.8	-------	30.0 ± 22.0	-------	76.0 ± 80.0	20.0 ± 27.2
Glossoscolecidae						
Pontoscolex corethrurus (Fr.Mill)	93.0 ± 100.8	52.0 ± 46.0	104.0 ± 83.2	85.0 ± 112.0	112.0 ± 160.0	92.0 ± 68.8

Note: NF – Natural forests, CoP – Coffee plantations, CP – Cardamom plantations, PF – Paddy fields, AP – Acacia plantations, GL – Grasslands

Table 2: Percentage distribution of earthworm species in different land use types

Family/species	NF	GL	AP	CP	CoP	PF
Moniligæridae						
Drawida fakir Conjn.	7.58	12.36	10.05	7.57	9.88	-
D. kanarensis Steph.	-	-	-	2.88	-	-
D. minuta (A.G.Bourne)	-	-	-	2.7	-	-
D. modesta Rao	8.31	-	--	10.09	5.36	8.33
D. pellucida (A. G. Bourne)	-	33.95	-	6.66	7.46	-
D.somavarap D.somavarapatana Rao	36.18	-	34.17	45.76	22.39	20.00
Megascolecidae						
Lampito mauritii Kinb)	-	-	-	-	7.88	-
Megascolex curgensis (Mich.)	-	-	16.08	-	7.46	13.33
M. feliciseta Steph.	-	-	-	-	4.31	-
Metaphire houlleti (E. Perr.)	4.89	-	-	2.52	9.77	16.25
Megascolex sp.	-	-	-	-	-	7.08
Octochaetidae						
Octochaetoides beatrix Bedd	-	-	-	1.98	-	-
O.castellanus Steph	11.74	6.74	6.03	2.52	5.67	11.66
O. pitnyii Mich.	-	-	-	1.98	-	-
Ramiella pallida	-	15.73	-	-	-	-
Ocnerodrillidae						
Curgia narayani Mich.	4.40	-	7.53	-	7.99	4.16
Glossoscolecidae						
Pontoscolex corethrurus (Fr.Mill)	22.7	29.21	26.13	-	11.77	19.16

Note: NF – Natural forests, CoP – Coffee plantations, CP – Cardamom plantations, PF – Paddy fields, AP – Acacia plantations, GL – Grasslands

Table 3. Population abundance of species of earthworms in different land use types at different depths in Nov. 2004 (No./m²)

Species	NF			GL			AP			CP			CoP			PF		
	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
D. fakir	66	15	7	18	4	0	30	10	0	25	19	2	111	23	2	-	-	-
D. kanarensis	-	-	-	-	-	-	-	-	-	8	4	4	-	-	-	-	-	-
D. minuta	-	-	-	-	-	-	-	-	-	9	4	1	-	-	-	-	-	-
D. modesta	36	8	1	-	-	-	-	-	-	21	20	10	56	9	6	25	10	5
D. pellucida	-	-	-	45	19	0	110	26	0	22	11	4	67	7	5	-	-	-
D. somavarapatana	198	32	8	-	-	-	45	10	9	122	78	55	318	56	2	55	35	11
L. mauritii	43	12	2	-	-	-	-	-	-	-	-	-	95	35	9	-	-	-
M. curgensis	-	-	-	-	-	-	-	-	-	-	-	-	109	26	5	40	20	4
M. feliciseta	-	-	-	-	-	-	-	-	-	-	-	-	39	2	10	-	-	-
Metaphire houlluti	87	9	0	-	-	-	-	-	-	10	3	2	161	35	1	66	12	0
Megascolex sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	9	0
O. beatrix	-	-	-	-	-	-	-	-	-	11	0	0	-	-	-	-	-	-
O. pitnyii	-	-	-	-	-	-	-	-	-	6	5	3	-	-	-	45	11	0
O. castellanus	51	6	0	9	3	0	16	6	2	10	2	4	46	22	8	-	-	-
R. pallida	-	-	-	19	9	0	-	-	-	-	-	-	-	-	-	-	-	-
C. narayani	21	5	3	-	-	-	20	9	0	-	-	-	86	45	13	15	5	0
P. corethrurus	21	5	3	35	14	3	75	20	9	50	30	10	198	68	10	62	15	7

Note: NF – Natural forests, CoP – Coffee plantations, CP – Cardamom plantations, PF – Paddy fields, AP – Acacia plantations, GL – Grasslands

Table 4. Earthworm species similarity index between different land use types

Land use types	GL	AP	CP	CoP	PF
NF	0.31	0.43	0.42	0.73	0.62
GL	-	0. 54	0.50	0.50	0.31
AP	-	-	0.47	0.71	0.71
CP	-	-	-	0.63	0.52
CoP	-	-	-	-	0.73

Note: NF – Natural forests, CoP – Coffee plantations, CP – Cardamom plantations, PF – Paddy fields, AP – Acacia plantations, GL – Grasslands

Table 5: The ratio of clitellate (C), Aclitellate(AC) and juveniles (J) in different land use types during November 2004

Species	NF			GL			AP			CP			CoP			PF		
	C	AC	J	C	AC	J	C	AC	J	C	AC	J	C	AC	J	C	AC	J
D. fakir	2	2	1	3	1	1	1	1	1	2	1	1	1	1	1	-	-	-
D. kanarensis	-	-	-	3	3	1	-	-	-	1	1	1	-	-	-	-	-	-
D. minuta	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-
D. modesta	2	2	1	-	-	-	-	-	-	2	2	1	2	1	1	2	1	1
D. pellucida	-	-	-	2	2	1	-	-	-	1	1	1	2	3	1	-	-	-
D. somavarapatana	3	1	1	-	-	-	6	2	1	2	1	1	3	1	1	3	1	1
L. mauritii	18	10	1	-	-	-	-	-	-	-	-	-	2	1	1	-	-	-
M. curgensis	-	-	-	-	-	-	2	1	1	-	-	-	2	1	1	3	1	1
M. feliciseta	-	-	-	-	-	-	-	-	-	-	-	-	2	1	1	-	-	-
Megascolex sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2	1
M. houlluti	3	2	1	-	-	-	-	-	-	3	1	1	1	1	2	2	1	1
O. beatrix	-	-	-	-	-	-	-	-	-	2	1	1	-	-	-	-	-	-
O. castellanus	1	1	1	3	2	1	2	1	1	2	1	1	1	1	1	1	1	1
O. pitnyii	-	-	-	-	-	-	-	-	-	2	1	1	-	-	-	-	-	-
R. pallida	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-
C. narayani	12	2	1	-	-	-	3	1	1	-	-	-	1	1	1	3	1	1
P. corethrurus	4	2	1	2	2	1	2	1	1	6	1	1	1	1	2	2	2	1

Note: NF – Natural forests, CoP – Coffee plantations, CP – Cardamom plantations, PF – Paddy fields, AP – Acacia plantations, GL – Grasslands

Table 6: Total number of earthworm cocoons collected (0-30 cm) at different habitats in Nov.2004

Land use type	Cocoons no./ M^2 (mean ± S.D)
Natural forests	196. 0 ± 150.0
Grasslands	90.0 ± 64.0
Acacia plantations	106.0 ± 80.0
Cardamom plantations	134.0 ± 86.0
Coffee plantations	223.0 ± 117.0
Paddy fields	192.0 ± 104.0

Table 7: Earthworm castings recovered during sampling of earthworm population at different land uses in Nov 2004

Land use types	Castings Kg/M^2
Natural forests	11. 2 ± 0.46
Grasslands	0.8*
Acacia plantations	2.4*
Cardamom plantations	16. 8 ± 1.00
Coffee plantations	17. 2 ± 0.53
Paddy fields	13. 6 ± 1.00

* Surface castings could be recovered only from single monoliths at each of these sites.

Bench Mark Area Description: Socio-Economic Dimensions of Koothy village, Coorg District, Karnataka

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INTRODUCTION

Below ground biodiversity (BGBD) comprises a wide range of soil fauna and flora such as soil microorganisms, earth worms, termites and others which perform many essential ecosystem functions in addition to providing a plethora of services to the society. BGBD and its functions are significantly influenced by human interventions. This study deals with a benchmark survey undertaken in the study area along with other components of the project. The overall objective of the benchmark survey is to document farmers' present status of agricultural activities, their land holdings, livestock, economics of major crops/activities, resource inventory, their present farming practices related to BGBD and their awareness about BGBD.

METHODOLOGY

Study area:

The study village Koothy (Somwarpet taluk of Kodagu district) has about 160 farm families. A random sample of 60 farmers was chosen for the socio-economic characterization. Sample respondent farmers were post classified into small, medium and large farmer categories based on their landholding. A farmer with a landholding of less than 2 ha was considered as small farmer, farmers with farm size of between 2 ha and 4 ha were treated as medium farmers and those farmers who had land holdings more than 4 ha were reckoned as large farmers. This classification provides distribution of farmers according to their land holdings which indirectly indicate the status of the farm economy of the region.

A structured schedule was developed for the socioeconomic survey. It was pretested before undertaking the benchmark survey by administering the schedule to a set of selected farmers in the study village. The schedule covered various aspects pertaining to general information about the family, land holdings, crops cultivated, livestock and other asset particulars, economics of important crops of the region, farmers' awareness about BGBD practices, adoption of BGBD practices and other relevant information pertaining to the farms. Data pertained to the crop year 2003-04. Personal data of individual farmers were collected through personal interviews with selected farmers and general information about the village and general agricultural practices of the village were collected from group interviews. Group interviews comprised mostly elders and knowledgeable persons in the village. Secondary data on the study region including study site (KoothY village),

Somwarpet taluk and Coorg district were collected for the recent year from relevant government offices of the Somwarpet taluk and village panchayat.

Analysis of Data

General features of the study Area (Benchmark Area)

Land use pattern in the study area

RESULTS

The data were analyzed using several statistical measures such as measures of central tendency (mea etc), chi-square test etc. Chi-square test was used to ascertain whether the awareness and knowledge about bio-diversity conservation are associated with the type of farmer

The area of the Koothy village is about 962 ha. As indicated in Table 1, agriculture accounts for about 68% of the total village area of the village compared to 19% area under forests.

In Koothy village more than 90 per cent of the population is directly dependent on agriculture for their livelihoods.

Table 1: Land Use Pattern (ha)

	Koothy	
	Area	**Percent**
Agril.	650	67.56
Forest	180	18.74
Fallow land[a]	na	Na
Current fallows[aa]	48	4.97
Uncultivable land	84	8.73
Geo- Area	962	100.00

Source: Village Panchayat office

[a] Lands which are fallow for more than five years

[aa] Lands which are fallow at present

Distribution of land holdings (number and area)

The study region comprises mostly marginal and small farmers who constitute more than 40 per cent. However, with respect to lands owned by these groups, although they form the bulk in terms of number, the total area owned by these groups was lowest. On the contrary, large farmers who formed only about 12 per cent in the study area owned disproportionately more area which signifies inequity in the distribution of land holdings in the study region.

Table 2. Distribution of land holdings

Type of household	No.	Percent	Percent area owned
Small farmer	87	43.50	10.28
Medium farmers	74	37.00	69.54
Large farmers	25	12.50	20.17
Agril Labourers	14	7.00	0.00
Total	200	100.00	100.00

Source: Village Panchayat Office, Koothy

Livestock status

Livestock in the study village largely comprises cows (23.23%), buffaloes (10.97%) and poultry (51.77%) (Table 3). In the study area, animal husbandry was not a major economic activity. Though there is no paucity of fodder, only about six per cent of respondents in the village own cattle. Farmers of the village buy milk and milk products from nearby town. The high level of humidity and low milk yield are the important reasons for lower preference for livestock activities in the study region.

Table 3: Livestock population in the study area (Census 2003)

Particulars	Koothy village	
	Numbers	Percent
Buffaloes	136	10.97
Sheep	0	0.00
Goat	9	0.73
Pig	38	3.06
Poultry	642	51.77
Dog	127	10.24
Horse	0	0.00
Total	1240	100.00

Source: Village panchayat office

Cropping pattern in the study area

Major crops of the district are paddy and horticultural crops including plantation crops like coffee, cardamom, pepper and ginger. Paddy, the staple food crop, occupies about 24% of net cropped area of the village (table 4). Horticultural crops like chillies, and ginger occupy significant area especially during summer season. The study region is home for plantation crops like coffee, cardamom, pepper etc.

Table 4: Area under major field crops (ha) (net cropped area)

Crop	Hectares	Per cent
Paddy	173.15	19.81
Vegetables, pusles etc (under paddy lands in summer)	35.00	
Coffee	542. 34	62.16
Cardamom	147.46	16.84
Coffee + Cardamom	10.42	1.19
Total area	873.37	100.00

Source: Village panchayat office, Koothy

Fertilizer consumption in the study area

Fertilizer usage in the study region is very high because of dominance of plantation crops which require higher doses of nutrients. Hence, the fertilizer consumption in the study region is very high at 90 tons for the year 2003-04 as reported by the local village panchayat (government) office. Average fertilizer consumption in the Somwarpet taluk that includes Koothy village works out to 156 kg of N, 122 kg of P and 143 kg of K per ha.

Socio-Economic Features of Sample respondents

Education level of the sample farmers

The education level of the respondents influences the magnitude of the adoption of recommended agricultural management practices and ability to venture into self-initiatives towards innovations. About 90 per cent of respondents were literates. The mean education level of both respondents who had awareness about BGBD (FBGBD) and respondents who did not had any awareness about BGBD (FNBGBD) was found more or less the same. Farmers were classified in to two groups-those having awareness about BGBD and those who did not. If a farmer was able to recognize at least some common soil organisms including soil microbes, he was grouped under awareness category otherwise in the other category.

Age of the respondents

Of the total sample respondents of 60, 31 respondents were aged below 30 years, 13 were aged between 31 to 40 years and 16 were above 40 years of age constituting 51.66, 21.66 and 26.66 per cent, respectively.

3.2.3: Occupation pattern

About one third of families were engaged in the agricultural wage labour, in addition to their involvement in cultivation of their own fields. Coffee and cardamom plantations provide work to a very large number of men and women especially during coffee picking season.

It is found that the average annual income of the FBGBD was higher than those of FNBGBD. The annual income of FBGBD respondents was Rs./- 61589 (aware of BGBD) and Rs./-54304 (not aware of BGBD) from both farm and non-farm sources.

Table 6. Average household income of respondents

Average income of the respondents (Rs per household)	
Farmers who are aware of BGBD	61,589.00 (25703.19)*
Farmers who do not have awareness of BGBD	54,304.00 (32528.00)*

**** Std dev.***

Family Size

The details on the family size of the sample respondents are presented in Table 7. In general, family size increased with an increase in the size of land holding.

Table 7: Average family size of sample farmers

Sl. No.	**Particulars**	**Category of farmers**		
		Small[1]	**Medium[2]**	**Large[3]**
1	Adult male	2.1	3.1	4.2
2	Adult female	2.0	2	4
3	Children	1.7	2.2	2.8

1 Farmers having lands upto 2ha
2 Farmers having lands between 2 and 4 ha
3 Farmers having lands more than 4 ha

Land holding

The details of land holding and average farm size of different categories of farmers in the study area are presented in the Table 8. A perusal of Table 8 reveals that 25 farmers were small farmers, 17 farmers fall under medium category and remaining 18 farmers were large farmers. The average size of land holding of small farmers was 0.9 ha while that of medium and large farmers it was 1.5 and 4.35 ha, respectively.

Table 8: Land holdings of the sample respondents

Category	No. of farmers	Per cent	Average Acreage (ha)
Small	25	41.66	0.9
Medium	17	28.33	1.5
Large	18	30.00	4.35
Average			2.11

Cropping pattern

Paddy is the staple food crop of the population of the region, hence, in kharif, paddy is the major crop grown. After the harvest of paddy, farmers take up either chilly or ginger in the months of February and March from residual moisture available in the soil. Coffee and Cardamum are the major plantation crops, both in terms of area and income of farmers. Pepper is also of considerable importance though grown by only about five per cent of the farmers. Exclusive orange or pineapple gardens are not seen in the village, for it is a common practice for the coffee planters to grow oranges or pineapple inter-mixed with coffee in their estates. More than half (68.33%) of the farmers owned coffee plantations. About 48 per cent of the farmers owned cardamom plantations. About 13 per cent of farmers owned both coffee and cardamom plantations in the study area (Table 9).

Table 9. Cropping pattern of respondent farmers

Crop	No. of farmers	Per cent of total farmers in the village
Paddy	54	90.00
Vegetables & spices	51	85.00
Coffee	41	68.33
Cardamom	29	48.33
Pepper	3	5.00
Coffee + Cardamom	8	13.33

Economics of coffee, cardamom and paddy production

Coffee and cardamom are the major plantation and commercial crops grown in the study region. Paddy, chilies and ginger are important annual crops grown in khariff and summer months. As a prelude to study the economics of coffee and cardamom, their establishment and investment were analyzed across different types of farmers. Initial capital investment needed for the establishment along with input requirement for coffee is provided in table 10.

Table 10. Establishment Cost of Coffee Per ha (Rs.)

	1st year	2nd year	Total	Per cent
Planting material	8477.93		8477.93	26.27
FYM	2580.00		2580.00	7.99
Fertilizer	4600.68	6723.89	11324.57	35.08
Pesticide		1548.56	1548.56	4.80
Labour	4963.94	3382.74	8346.68	25.86
Total	**20622.55**	**11655.19**	**32277.74**	**100.00**

The initial capital investment on coffee worked out to Rs. 32277.74 per ha. The major cost was fertilizer, which formed out 35.08 per cent for the first two years of establishment. Planting material and labour accounted for 26.27 and 25.86 per cent respectively. Coffee starts yielding berries from 4th year and economic yields from coffee are obtained from sixth year onwards.

A summary of economics of coffee production (arabica variety) is given in table 11. It is evident from the table that total fixed costs in the production of coffee works out to Rs. 15285.77 per ha. However, the cost per ha was highest among small farmers (Rs.17186.27) followed by medium (Rs.15726.21) and large farms (13371.97). Interestingly small farmers incurred highest proportion of variable costs in the total costs at 57.70 and it was lowest in the case of large farmers at 45.61 of total costs. It could be mainly because of economies of scale among large farms. The gross income realized per ha was highest among small farms (Rs.30823.62) followed by medium farms (28251.23) and large farms (Rs.27993.08). However, large farmers realized highest amount of net income of Rs. 14621.11. Perhaps this might be due to higher scale economies, which translated into higher net income although small farmers realized higher gross income.

Table 12. Economics of coffee production (per ha)

INPUTS	SMALL		MEDIUM		LARGE		Overall	
Variable costs	**Rs.**	**%**	**Rs.**	**%**	**Rs.**	**%**	**Rs.**	**%**
Fertilizer	3513.53	20.44	3826.51	24.33	2573.93	19.25	3236.14	21.17
Pesticide	722.96	4.21	721.50	4.59	722.40	5.40	723.37	4.73
Labour	4625.55	26.91	3410.20	21.68	2142.41	16.20	3399.02	22.24
Transportation	71.69	0.42	61.20	0.39	60.20	0.45	64.92	0.42
Total cash costs	8933.73	51.98	8019.41	50.99	5498.94	41.12	7423.45	48.56
Interest on cash costs	981.92	5.71	882.12	5.61	604.88	4.52	816.57	5.34
Total variable costs	9916.46	57.70	8901.56	56.60	6103.81	45.65	8240.03	53.91
Fixed costs								
Amortized cost of establishment	3526.45	20.52	3526.45	22.42	3526.45	26.37	3526.45	23.07
Rental value of land	3082.36	17.94	2825.12	17.96	2799.31	20.93	2902.74	19.00
Land revenue	60.00	0.35	60.00	0.38	60.00	0.45	60.00	0.39
Depreciation	601.00	3.50	413.08	2.63	882.40	6.60	556.55	3.64
Total fixed costs	7269.81	42.30	6824.65	43.40	7268.16	54.35	7045.74	46.09
Total costs	17186.27	100.00	15726.21	100.00	13371.97	100.00	15285.77	100.00
Yield (qtls/ha) per year	6.16		5.65		5.60		5.81	
Gross returns	30823.62		28251.23		27993.08		29027.43	
Net returns	13637.35		12525.02		14621.11		13741.66	
Net returns per farm	8727.90		17159.28		48103.44		15665.49	

Cardamom is another important perennial crop in the study region. The average establishment cost per ha was about Rs. 28684.00 (table 13). Costs of planting material costs accounted for highest proposition of 80.95 percent followed by expensed on labour, which was 9.69 per cent. Costs and returns from cardamom production are summarized in table 14. Variable costs were highest among small farmers accounting for 50.30 per cent. But in the case of medium and large farmers it formed less than 50 per cent. On an average, per ha cost of production of cardamom was highest among small farmers (Rs.10956.27) followed by medium and large farmers. However, the gross income obtained by all farmers was by and large was less than potential income. This is attributed to low yields realized by all farmers. The average yield obtained by farmers was 51.30 kg per ha as against the normal yield of about 150. In the case of large farmers the average yield was just 48 kg, which could be due to erratic rainfall, and inadequate care bestowed by farmers as opined by them.

Table 13. Establishment costs of cardamom (Rs./ha)

Inputs	Quantity	Costs (Rs)	Per cent
Planting material (no)	11610	23220.00	80.95
Fertilizer (kg)	229.34	2201.60	7.68
Pesticide (liters)	2.58	481.60	1.68
Labour (man days)	55.62	2780.66	9.69
Total		28683.86	100.00

Table 14. Economics of cardamom production (per ha)

Inputs	**Small**		**Medium**		**Large**		**Overall**	
Variable costs	Rs.	**%**	Rs.	**%**	Rs.	**%**	Rs.	**%**
Fertilizer	960.00	8.76	1100.00	11.37	1650.00	17.85	1236.00	13.16
Pesticide	702.24	6.41	725.62	7.43	446.16	4.83	582.40	6.20
Labour	3303.05	30.15	2334.43	23.90	1261.57	13.65	1876.72	19.98
Total cash costs	4965.29	45.32	3170.65	42.70	3357.73	36.33	3695.12	39.35
Interest variable costs	546.19	4.99	348.70	4.70	369.35	4.00	406.46	4.33
Total variable costs	5511.47	50.30	3518.76	47.40	3727.08	40.32	4101.58	43.68
Fixed costs								
Amortized cost	3133.80	28.60	3133.80	32.09	3133.80	33.90	3133.80	33.37
Rental value of land	1650.00	15.06	1530.00	15.67	1440.00	15.58	1539.00	16.39
Land revenue	60.00	0.55	60.00	0.61	60.00	0.65	60.00	0.64
Depreciation	601.00	5.49	413.08	4.23	882.40	9.55	556.55	5.92
Total fixed costs	5444.80	49.70	5136.88	52.60	5516.20	59.68	5289.20	56.32
Total costs	10956.27	100.00	9765.64	100.00	9243.28	100.00	9390.78	100.00
Returns								
Yield (kgs/ha)	55.00		51.00		48.00		51.30	
Gross returns	16500.00		15300.00		14400.00		15390.00	
Net returns	5543.73		5534.36		5156.72		5999.22	
Net returns per farm	3381.67		8744.29		24185.12		10738.60	

Paddy is the staple food crop of the region occupying low lying areas where during khariff season adequate water is available for the crop. The economics of paddy crop production is summarized in table 15. It was observed that large farmers were more efficient in the production of paddy crop as they could produce paddy at much cheaper

costs than small and medium farmers. The mean cost per ha among large farmers was Rs.14822.51, where as among small and medium farmers it was Rs.16893.35 and Rs.16216.20, respectively. Among several components of variable costs, labour cost was the major cost accounting for 28.79, 28.15 and 22.59 respectively among small, medium and large farmers. Bullock labour is another major cost in paddy production accounting for 15.32, 15.05 and 15.77, respectively among the three farm categories. The mean yield obtained per ha was 33.71, 30.65 and 28.90 respectively for small, medium and large farms, which translated into a gross income of Rs.23597.00, Rs.21455.00 and Rs. 20230.00. The net income was Rs. 6703.75, 5238.80 and 5407.49, respectively among, small, medium and large farmers. However, per farm income was highest among large farmers as their average paddy area was higher than those of small and medium.

Table 15. Economics of Paddy production (per ha)

Inputs	**Small**		**Medium**		**Large**		**Overall**	
Variable costs	Rs.	**%**	Rs.	**%**	Rs.	**%**	Rs.	**%**
Seeds	543.53	3.22	538.70	3.32	495.38	3.34	525.88	3.30
FYM	2588.18	15.32	2580.18	15.91	2529.53	17.07	2565.96	16.12
Fertilizer	2484.64	14.71	2472.87	15.25	2476.80	16.71	2478.11	15.57
Bullock pair days	2588.20	15.32	2441.01	15.05	2337.48	15.77	2455.56	15.43
Labour	4863.79	28.79	4565.15	28.15	3347.86	22.59	4258.93	26.76
Total costs	13068.32	77.36	12597.93	77.69	11187.60	75.48	12294.94	77.26
Interest on variable costs	1437.52	8.51	1385.77	8.55	1230.64	8.30	1352.44	8.50
Total variable costs	14505.83	85.87	13983.71	86.23	12418.24	83.78	13647.38	85.76
Fixed costs								
Rental value of land	1726.42	10.22	1759.41	10.85	1461.87	9.86	1649.28	10.36
Land revenue	60.00	0.36	60.00	0.37	60.00	0.40	60.00	0.38
Depreciation	601.00	3.56	413.08	2.55	882.40	5.95	556.55	3.50
Total fixed costs	2387.42	14.13	2232.49	13.77	2404.27	16.22	2265.83	14.24
Total costs	16893.35	100.00	16216.20	100.00	14822.51	100.00	15913.21	100.00
Returns								
Yield (qtls/ha)	33.71		30.65		28.90		31.08	
Gross returns	23597.00		21455.00		20230.00		21756.00	
Net returns	6703.75		5238.80		5407.49		5842.79	
Net returns per farm	2681.50		2462.23		4974.89		8939.46	

Awareness about BGBD practices among respondent farmers

It is surprising to note that only 45 per cent (Table 16) of the respondents had some knowledge and awareness about BGBD and their uses. Remaining 55 per cent of respondents were totally unaware of below ground flora and fauna. The low awareness about BGBD among farmers could largely be attributed to lack of sensitizing/extension programs on the part of the developmental departments on BGBD programs. Farmers had

awareness about different types of soil organisms including microbes, earthworms, insects, etc. But they do not have much knowledge about nitrogen fixing bacteria and other nutrient-supplying organisms in the soil. However, a training program on compost making conducted by the district agricultural training school has given some opportunity to a few farmers to learn some new ideas and information about BGBD. The program was conducted in the agricultural school of the district for about three weeks. In the training program farmers were exposed to new technologies and were given practical hands on training on some of the practices including vermi-compost making. Farmers who received this training responded positively on BGBD especially about vermi-compost and earthworms. The data presented in Table 17 reveal farmers awareness about benefits, functions and services from BGBD. It is clear that awareness level is not that high although some farmers had awareness about some of the commonly known benefits from BGBD. Table 18 reveals awareness of farmers about specific BGBD components. Large farmers possess a higher degree of awareness about the BGBD as compared to the other two groups of farmers. Perhaps this could be due to higher education level and exposure to mass media and other knowledge sources thereby higher awareness about BGBD.

Table 16: Awareness about BGBD –

	No. farmers	Per cent
Aware of BGBD	27	45
Not aware of BGBD	33	55

Table 17: Awareness about benefits, functions/services of BGBD

Benefits/ Function/Harm	**Percent**
Higher nutrient availability	31.66
Faster decomposition of OM	10.00
Improves soil health	21.66
Degradation	1.66
Higher moisture levels	41.66
Helps in Biomass production	11.66

Farmers defined soil health in terms of fertility status, yield potential, soil aggregation and other properties. Degradation has been indicated in terms of soil erosion, loss of nutrients, Stalinization of soil etc. Biomass production in terms of accumulation of organic matter in the soil.

Table 18: Awareness about Specific BGBD components (in percent)

Group	**Small farmers**	**Medium farmers**	**Large farmers**
Rhizobium	16.00	35.29	44.44
Earth worms	36.00	29.41	38.88
Azotobacter	16.00	35.29	44.44
Termites	32.00	11.76	55.55

Chi-square value = 8.991 NS

The Chi-square test revealed that the awareness about the bio-diversity conservation methods is independent of the size of the land holding.

Common BGBD practices adopted by farmers

Common BGBD practices followed by farmers in the study region were compost making and application of farm yard manure (FYM), green leaf manure and dried leaves collected from the forest to the soil. Compost making refers to storing of farm wastes including dung in the deep pits (about 5-6 feet and allowing it for decomposition mostly in anerobic condition for quite a long time normally 2-3 months. Farm yard manure is also collection of farm wastes including dung but stored in either open spaces or in heaps. Green leaf manure refers to incorporation of fresh green leaf cut from the trees into the soil. This is a common practice in paddy cultivation in south India including Coorg district. Incorporation of weeds into the soil is another practice commonly followed by the farmers. Ploughing back paddy crop stubbles and residues to the soil is a major BGBD practice followed by all farmers in the study region. Table 19 reveals that majority (91.66%) of farmers in both categories produced FYM on their farms. Only about 8 per cent of farmers purchased FYM to manure their fields. The farmers in the study area purchased FYM from the neighboring/known farmers in their own village or from the neighboring villages at a price of 930 Rs./- per ton.

Table 19: Use of farm yard manure

Category	Own production	Purchased	Total
Aware of BGBD	24 (88.88)	3 (11.11)	27
Not aware of BGBD	31 (93.94)	2 (6.06)	33
Total	55 (91.66)	5 (8.33)	60

Figures in the parentheses indicate percent of farmers reporting the practice

Reasons for non-adoption of BGBD practices

A BGBD practice is defined as any farm activity that improves soil fertility, organic matter, and beneficial soil fauna. These practices directly or indirectly aid in rising soil fauna including microorganisms. Adding FYM, compost manure, green leaf manure, soil amendments, vermicompost, and ploughing back weeds, crop residues are some of the examples of BGBD practices. Farmers' reasons for non-adoption of BGBD practices were elicited and they are presented in Table 20. Farmers expressed many reasons for the non-adoption of BGBD practices. The important ones are lack of awareness about BGBD, which was expressed by about 57 per cent of respondents. Unawareness about benefits from BGBD was another important reason for the non-adoption (47 %) followed by lack of technical expertise (20 %), non-availability of inputs locally and difficulty in the adoption of BGBD practices (10 %).

Table 20: Reasons for non-adoption of BGBD practices

Reasons	Aware of BGBD	Unaware of BGBD	Total
Lack of awareness	17	17	34 (56.66)
Unaware of benefits	14	14	28 (46.66)
Lack of technical expertise	5	7	12 (20.00)
Inputs not available locally	5	5	10 (16.66)
Difficulty in adoption	5	1	6 (10.00)

CONCLUSION

The study region is agrarian in character and represents a wide range of agroecosystems, which are congenial for studies on BGBD. The benchmark survey revealed that almost entire population of the study area is dependent on agriculture and related activities. The major source of income for the farmers is plantation crops and paddy is the staple food crop of the region. Livestock enterprises are not important enterprises due to climatic factors. Most of the farmers in the study are small farmers with average holding of 2 ha. In general farmers have awareness about the BGBD; they are unable to identify specific species and their roles. Common BGBD practices adopted by the farmers were application of farm yare manure, addition of green leaf manure and crop stubbles to the cropland, incorporation of dried leaves in to the soil etc. Important reasons for non-adoption of BGBD practices by farmers' were lack of awareness about BGBD, unawareness about benefits from BGBD, lack of technical expertise, non-availability of inputs locally and difficulty in the adoption of BGBD practices.

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