Landuse transformation and loss of belowground biodiversity- An analysis

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Introduction

Kerala is still a land of agriculture. In earlier period, rural people in the State were mainly depending on the agriculture, especially paddy cultivation. However, in the recent years the agriculture land has been going through tremendous transformations due to sprawls in agriculturalisation, industrialization and globalization (Thampi, 1995). While increase in the area under cash crops helped to increase farm income, changes in the cropping pattern in favour of perennial crops have an immediate and direct impact on the employment of rural a people and in the staple food security in the State (Panikar, 1980). Several efforts have been made to analyze the root causes and consequences of transformation of food crop based systems to cash crop based systems of the State (Kannan and Pushpangadan, 1988; Narayanan, 1995; Baiju and Chandrashekara, 2007). Such studies also highlighted the need of more site-specific studies which would help to identify strategies, policy interventions and programmes for reviving the rural landscape of Kerala that was once dominated by paddy fields. Thus, though information on the impact of landuse transformation on the socio-economic and cultural aspects of rural Kerala are available, its impact on biodiversity in general, belowground biodiversity in particular are lacking. In this paper, attempt has been made to test a hypothesis that in a micro- watershed of Chaliyar River in the Kerala part of Nilgiri Biosphere Reserve, transformation of paddy fields into different cropping systems resulted in the loss of soil microflora and faunal diversity.

Materials and Methods

The study area was located in Vazhikkadavu Panchayat (76^0 19' to 76^0 23' E longitude and 11^0 23' to 11^0 25' N latitude), Malappuram District. Here, an area of 2.6 x 1.4 km in the Karakkode micro-watershed was selected for detail studies. The area was divided into 200 m x 200 m grids and the grid intersection points were marked using a Geographical Positioning System. Out of the 72 grid intersection points, 24 points which fell in land cover types other than agriculture/forestry were excluded. In the remaining 48 points that were sampled, four were paddy fields while twenty five points were agroecosystems/ agroforestry systems that had once been paddy fields (Figure 1 and Table 1).

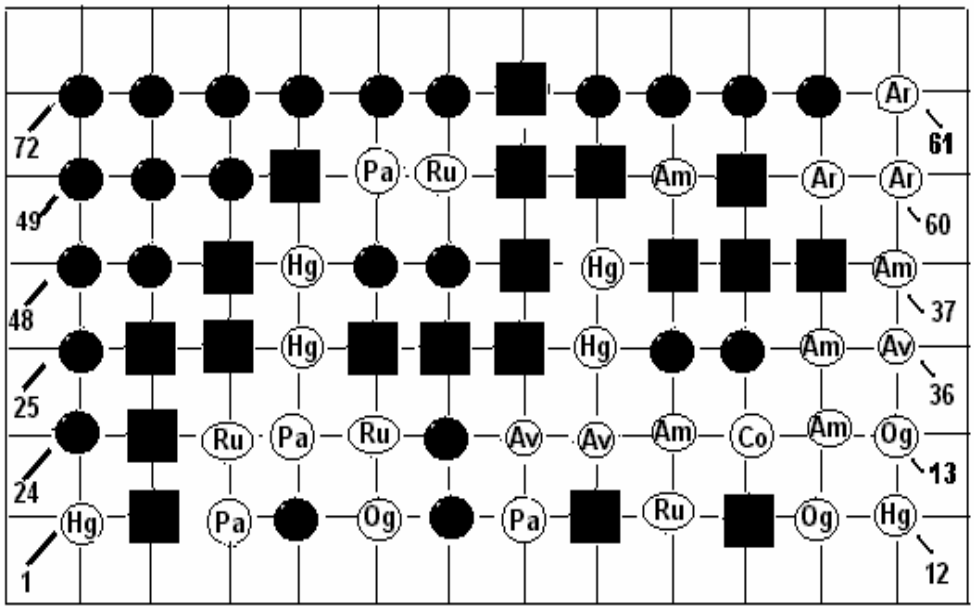

Figure 1. Paddy fields and landuse systems derived from paddy fields in the Kerala part of Nilgiri Biosphere Reserve.

Pa: Paddy fields, **Hg**: polyculture homegarden, **Og**: Polyculture farm, Av: Arecanut with annual crops, **Am**: Arecanut with perennial crops, **Ar:** Arecanut plantation, Co: Coconut plantation, **Ru**: Rubber plantation, ● Non sample points, ■ Landuse systems derived from other than paddy fields.

Composition and diversity of belowground organisms

Soil fauna

For the sampling of soil fauna, protocols suggested by TSBF were followed (Swift and Bignell, 2001). A Transect of 40 x 5 m in size was marked in each landuse system, which was divided into 4 sections, each of 10 x 5 m dimension. The monoliths, each of 25 x 25 x 30cm in dimension, for sampling faunal elements were marked in each section (a total of 4 in each landuse). The monolith was delimited by removing soil around the monolith area. Macrofaunal elements were hand sorted at site and preserved in alcohol.

Table 1. Characteristics of paddy fields and landuse types transformed from paddy fields in the Kerala part of the Nilgiri Biosphere Reserve

Land Use Type	Characteristic features of landuse systems
1. Paddy fields	Paddy cultivation from June-December. Vegetable cultivation or leaving the field fallow from January to May
2. Tree based systems	Tree crops are dominant. The system may be monoculture or polyculture
2.1. Polyculture homegardens	Land cultivated around the farmer's dwelling place with annual, biennial and tree crops, mostly integrated with animal husbandry.
2.2. Polyculture farm	Land cultivated away from the farmer's dwelling place with annual, biennial and tree crops, sometimes integrated with animal husbandry.
2.3. Plantations of a tree crop with some other associated crops (annual, biennial or perennial)	Area is dominated by one tree species, along with some annual/perennial crops.
	2.3.1.Arecanut plantation integrated with cultivation of some annual crops
	2.3.2.Arecanut plantation integrated with cultivation perennial crops
2.4. Monoculture plantations	Mono-specific tree plantations.
	2.4.1. Arecanut plantation
	2.4.2. Coconut plantation
	C2.4.3. Rubber plantation

Soil samples were brought to the laboratory for the extraction of microfauna. Tullgren Funnel Extraction method was followed. The funnels containing soil was illuminated with an electric bulb of 60W. Organisms like mites, collembola etc., that move away from the light source were collected in the beaker containing alcohol, placed below the tail end of the funnel.

Nematode extraction was carried out by water migration technique. Twenty gram of soil was placed over a filter paper above wire gauze with the soil just touching the water column. This unit was kept undisturbed overnight and the nematodes that migrate from soil to water were collected. Thus the number of nematodes per unit volume of soil was obtained.

All organisms were preserved in 5% formalin. Soil invertebrates were then grouped into larger divisions, i.e., earthworms, Coleoptera (beetles), Isoptera (termites), Hymenoptera (ants, wasps etc.), Dermaptera (earwigs), Orthoptera (hoppers, crickets, mole crickets), Hemiptera (bugs, coccides, cicadas etc.), Isopoda (woodlice), Chilopods (centipeds), Diplopods (millipeds), Decapoda (crabs) and Arachnida (spiders), other macrofauna invertebrates. Density of each of these major groups were determined. Frequency of distribution of each group of organism in the study plots of each landuse type was calculated as the number plots where the individuals of that group of organisms recorded divided by the total number of plots studied. Similarity index value for a given landuse system and paddy fields was calculated using the following formula:

$$\text{Similarity index value} = 2C/ (A+ B)$$

Where, A=number of groups of soil fauna recorded in paddy fields, B= number of groups of soil fauna recorded in a given landuse system derived from paddy fields, C= number of groups of soil fauna common in paddy fields and the given landuse system

Shannon - Weiner index of diversity (H) (Shannon and Weiner,1963) was calculated using the formula given below:

$$H= - \sum(n_i/N) * \ln (n_i/N)$$

Where, n_i = density (individuals m^{-2}) of a group of soil fauna and N= total density of soil fauna.

Arbuscular mycorrhizal (AM) fungi

In each selected crop land, a plot (40 x 20 m) was laid and divided into 5 equal blocks. From each block, 12 soil cores (0-20 cm) were obtained and all samples from a crop land were mixed together to get a composite sample. The samples were air dried for 24 hrs in shade, sieved through 2 mm sieve and were stored at 4°C till they were analysed for spore abundance.

Isolation of AM spores was done following wet sieving and decanting technique (Gerdemann and Nicolson, 1963). To start with, 10 g of the soil samples was suspended in water and stirred thoroughly. The soil suspension was allowed to stand undisturbed for one minute and then passed through 750, 500, 250, 100 and 45 um sieves arranged one below the other in the same order. The contents from the last three sieves were filtered through filter papers and the filtrate observed under a stereoscope and spores of fungi enumerated from each soil sample. Percentage frequency distribution of each AM fungal species in the study plots of each landuse type was calculated as the number plots where the individuals of the species were recorded divided by the total number of plots studied. Similarity index value for a given landuse system and paddy fields were calculated using the following formula:

$$\text{Similarity index value} = 2C/(A+B)$$

Where, A=number of species recorded in paddy fields, B= number of species recorded in a given landuse system derived from paddy fields, C= number of species common in paddy fields and the given landuse system

Species diversity index (H) of AM fungal species diversity was determined for each land use system using the formula

$$H = -\sum(n_i/N) * \ln (n_i/N)$$

Where, $n_{i\ =}$ density (number of spores in 10 gm of soil) of the i^{th} species and N= density of all species.

Statistical Analysis

The data with respect to species diversity index value of a given group of soil organism (soil fauna and AM fungi) in different land use systems were subjected to one-way ANOVA using Statistica software. If the difference in the species diversity index value between different landuse systems were significant, means were compared using LSD-test.

Results and Discussion

In the study plots, a total 84 species of AM fungi were recorded (Table 2). However, the number of species recorded in different landuse systems ranged from 42-60 with more than 50% of the species showing uniform distribution in a given landuse system (Table 3). Out of the 48 species recorded in paddy fields, 23 to 37 species were also observed in other landuse systems which were derived from paddy fields. Similarity index value obtained for paddy fields and each landuse systems derived from it indicated very low similarity between areca dominant systems and the paddy field (Table 3). Species diversity index value for AM fungi in paddy fields was 3.1213 ± 0.3390 (Figure 2), which is not significantly different from the values recorded for other landuse systems. The above results clearly indicate that though there is loss of some AM fungal species due to landuse change, species diversity value did not change. This could be attributed to the addition of some other AM fungal species after the transformation of paddy fields into other landuse systems.

During the study period, a total 18 groups of soil fauna were recorded (Table 4) of which 6 to 14 groups were observed in each landuse systems. Out of 8 soil faunal groups recorded in paddy fields, 4 to 7 were also reported from other landuse systems. As in the case of micro-flora, in a given landuse system frequency of distribution was more (>50%) for

majority of the faunal groups. Similarity index value obtained for paddy fields and a given landuse system was less than 0.83, with least value in the case of areca dominant systems (Table 5). Group diversity index value of soil fauna obtained for paddy fields was 1.2906 ± 0.1097 (Figure 3) which was not significantly different from those obtained for polyculture homegardens, areca dominant systems, coconut and rubber plantations. This result can be attributed to the fact that in these landuse systems some of the groups of soil fauna which were recorded in paddy field showed decreased dominance or complete replacement by other faunal groups. However, in the case of areca mixed with annual crops and polyculture farmlands, soil faunal diversity value was significantly less that that in the paddy fields due to over dominance of earthworms.

The present study is an indicator of the fact that the transformation of paddy fields into other landuse systems leads to change in the composition of AM fungal species and soil faunal groups. The study also demonstrated the fact that the landuse transformation contributed for the appearance several new AM fungal species. However, unlike the aboveground plant composition change, which is mainly triggered by the farmer's activities, belowground floral composition change appears to be a slow process, as even 5 to 25 yr after transformation of paddy fields, some of the AM fungi are common to both paddy fields and landuse systems derived from them. It may be pointed out here that the sampling pattern, frequency of sampling, seasonality etc., even for a group of organisms may be different in different landuse system. Thus, there is a scope for a systematic study by adopting landuse-specific standard methods, for analyzing the links between belowground species composition and diversity change in response to landuse transformation.

Table 2. Species of AM fungi and their spore abundance (spores per 10 g of soil) in paddy field and landuse systems derived for paddy field in the Kerala part of NBR.

AM fungi	Pa	Av	Am	Hg	Og	Ar	Co	Ru
Acaulospora appendicula	0.7 ± 0.9	3.3 ± 1.2	0.8 ± 0.8	3.2 ± 3.9	1.7 ± 0.6	0	2 ± 0	3 ± 1.2
A. bireticulata	1.7 ± 0.9	2 ± 1.7	1.6 ± 0.5	5 ± 1.5	2.7 ± 3.1	1.3 ± 0.6	2 ± 0	1 ± 0
A. denticulata	1 ± 0.8	2 ± 0	0.6 ± 0.5	1.6 ± 1.1	1 ± 0	1 ± 1	1 ± 0	3.25 ± 2.6
A. dilatata	0.7 ± 0.5	3.3 ± 1.2	1 ± 1	1.4 ± 1.7	0	1 ± 0	0	0.75 ± 1
A. elegans	0	1 ± 0	0.8 ± 0.4	0.4 ± 0.9	1.3 ± 0.6	1 ± 0	1 ± 0	0
A. lacunosa	2.7 ± 2.5	1.3 ± 0.6	1.4 ± 0.9	0.6 ± 0.5	0	2 ± 0	1 ± 1.4	2 ± 1.4
A. laevis	0	2.3 ± 1.5	0.2 ± 0.4	0	1 ± 0	0.3 ± 0.6	1.5 ± 0.7	1.75 ± 0.5
A. longula	1 ± 0.8	1 ± 0	2.2 ± 0.4	0.8 ± 0.8	0.7 ± 0.6	3 ± 1	0.5 ± 0.7	0.5 ± 1
A. mellea	2.3 ± 1.7	3 ± 2.6	1.4 ± 0.5	1.8 ± 1.1	0.7 ± 0.6	2 ± 0	0	0
A. morrowae	0	1 ± 0	0.2 ± 0.4	0	1.3 ± 0.6	0	1.5 ± 0.7	1 ± 0
A. myriocarpa	0.7 ± 0.9	2 ± 1.7	1.4 ± 0.5	0.6 ± 0.5	0	1.3 ± 0.6	0	1 ± 1.2
A. rehmii	0	0.7 ± 0.6	0	0.2 ± 0.4	1.3 ± 1.2	0	2 ± 0	0
A. rugosa	0.7 ± 0.5	1 ± 0	1.4 ± 0.9	4.4 ± 3	2 ± 2	1 ± 0	0	0
A. scrobiculata	6 ± 5.4	1.3 ± 2.3	0.2 ± 0.4	0	0	0	4 ± 0	3.5 ± 1.3
A. spinosa	0	1 ± 0	0.8 ± 0.4	0.8 ± 0.8	1 ± 0	1 ± 0	2 ± 1.4	1 ± 0
A. tuberculata	0.7 ± 0.9	0	0	0.8 ± 1.1	0	0	0	1.75 ± 0.5
Acaulospora sp.1	0	1.3 ± 0.6	1 ± 0.7	0.8 ± 0.8	1.3 ± 0.6	1 ± 1	1.5 ± 0.7	1 ± 0
Acaulospora sp.2	0	0.7 ± 0.6	0	0	0	0	1 ± 0	0
Acaulospora sp.3	0.3 ± 0.5	2 ± 0	0.4 ± 0.9	3.8 ± 1.3	1.3 ± 0.6	0	0	1.75 ± 1.3
Acaulospora sp.4	1 ± 1.4	0.7 ± 1.2	0.4 ± 0.5	0	0	0.7 ± 1.2	1 ± 1.4	0
Acaulospora sp.5	0	0.7 ± 0.6	0.4 ± 0.9	1.2 ± 1.6	1.3 ± 1.2	0	1.5 ± 2.1	1 ± 1.2
Acaulospora sp.6	0	1 ± 0	0.6 ± 0.9	0.4 ± 0.9	0	0.3 ± 0.6	0	0
Gigaspora albida	0.7 ± 0.9	0	0.8 ± 0.8	0.4 ± 0.9	0.7 ± 0.6	0.7 ± 1.2	2 ± 0	0.25 ± 0.5
G. decipiens	0	1 ± 0	0.4 ± 0.9	1.2 ± 1.1	1.3 ± 0.6	0	0	0.75 ± 1.5
G. gigantea	0	0	0.6 ± 0.5	0	0	0.3 ± 0.6	1 ± 1.4	0
Glomus albidum	0	0	0	0.6 ± 0.9	0	0	0.5 ± 0.7	0.75 ± 1
G. aggregatum	3 ± 1.4	3.3 ± 1.2	2.6 ± 1.8	2.6 ± 0.9	1.7 ± 1.5	4.3 ± 2.1	0	0
G. ambisporum	2 ± 0.8	0	0	1.6 ± 0.9	1.7 ± 0.6	0	1 ± 1.4	0
G. botryoides	0	0.7 ± 0.6	0.6 ± 0.9	0	0	0	0	0.5 ± 0.6
G. canadense	0	2 ± 0	0.8 ± 0.8	1.6 ± 0.5	2 ± 0	1.3 ± 1.2	3 ± 0	0
G. citricolum	1 ± 0.8	0	0	0.6 ± 0	0	0	2 ± 0	1 ± 0
G. claroideum	0	2.7 ± 1.2	0	0.4 ± 0.9	0.3 ± 0.6	1.3 ± 1.2	0	0
G. clarum	2.3 ± 0.9	2 ± 0	1 ± 0.7	2.2 ± 0.4	2 ± 0	0	0.5 ± 0.7	1 ± 0
G. constrictum	0	0	0	0	0	0.7 ± 1.2	2 ± 2.8	0
G. convolutum	0	0.7 ± 0.6	0	0.6 ± 1.3	0	0	0	0.75 ± 1
G. delhiense	0.7 ± 0.9	2 ± 0	1.2 ± 1.1	0.6 ± 0.5	0	2 ± 0	1.5 ± 0.7	0
G. diaphanum	0	2 ± 0	1.4 ± 1.1	1 ± 0	1.7 ± 0.6	2 ± 0	0	0
G. etunicatum	1.7 ± 1.2	0	0.2 ± 0.4	0	0	0	0	1 ± 0
G. fasciculatum	1.7 ± 0.5	2 ± 1.7	0	4.2 ± 1.6	3.7 ± 3.2	0.7 ± 1.2	1 ± 0	0
G. fragile	0	0	0.4 ± 0.5	0	0	0.3 ± 0.6	2 ± 0	0.5 ± 1
G. geosporum	0.7 ± 0.5	0.7 ± 0.6	1 ± 1	1.8 ± 1.6	1.3 ± 0.6	0	0	2 ± 1.2

Pa: Paddy fields, **Hg**: polyculture homegarden, **Og**: Polyculture farm, **Av**: Arecanut with annual crops, **Am**: Arecanut with perennial crops, **Ar:** Arecanut plantation, **Co**: Coconut plantation, **Ru**: Rubber plantation

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Table 2 (cont'd) . Species of AM fungi and their spore abundance (spores per 10 g of soil) in paddy field and landuse systems derived for paddy field in the Kerala part of NBR.

AM fungi	Pa	Av	Am	Hg	Og	Ar	Co	Ru
G. halonatum	0	0	0.8 ± 0.8	0.4 ± 0.9	0	0	1 ± 0	0
G. heterosporum	1.3 ± 0.5	1 ± 0	0	1 ± 0	1 ± 0	0.3 ± 0.6	0	0.5 ± 1
G. hoi	0	1.3 ± 2.3	0	0	0	0.7 ± 1.2	2 ± 0	0
G. intraradices	3.3 ± 0.9	1 ± 0	0.6 ± 0.5	2.4 ± 2.5	2 ± 0	0.3 ± 0.6	0	2.75 ± 1.5
G. invermaium	0	0	0	0.4 ± 0.9	0	0	0.5 ± 0.7	0
G. leptotichum	0	1 ± 0	0.6 ± 0.5	0	0	0	0.5 ± 0.7	0.25 ± 0.5
G. macrocarpum	0.7 ± 0.5	0	0	2 ± 0	2 ± 0	0	2 ± 0	0
G. maculosum	7 ± 4.6	1.3 ± 0.6	1.6 ± 1.5	9.6 ± 4.2	4.7 ± 5	4 ± 2	4.5 ± 2.1	5.5 ± 3
G. monosporum	0	1.3 ± 2.3	0	0	0	0	0	0
G. mosseae	1.7 ± 1.2	0	0	2 ± 0	2 ± 0	0	1 ± 0	3.5 ± 1.7
G. multicaule	0.7 ± 0.5	1.3 ± 0.6	1.4 ± 1.1	1.2 ± 1.1	0.7 ± 0.6	2.7 ± 0.6	2 ± 0	2.5 ± 1
G. multisubstensum	0	0	0.4 ± 0.9	0	0	0.7 ± 1.2	0	0
G. occultum	0	1.3 ± 0.6	0.8 ± 1.1	0.8 ± 1.8	2 ± 0	0	0	2 ± 0
G. pallidum	0.7 ± 0.9	1.3 ± 2.3	0	1.2 ± 1.1	0.7 ± 0.6	0	2 ± 1.4	0
G. pansihalos	0	0	0.2 ± 0.4	0.8 ± 1.8	0	0	0	2 ± 0
G. pulvinatum	0	2 ± 0	1.2 ± 0.8	1.2 ± 1.1	2 ± 0	2 ± 0	2 ± 0	0
G. pustulatum	1.3 ± 0.9	0	0.4 ± 0.5	0.2 ± 0.4	0	0	0	2.5 ± 0.6
G. radiatum	0	1 ± 0	0.4 ± 0.9	0.8 ± 1.1	1 ± 0	0	2 ± 0	2.5 ± 1
G. reticulatum	0.7 ± 0.9	0	0.8 ± 0.8	0.8 ± 1.8	0.3 ± 0.6	1 ± 1	0	1.25 ± 0.5
G. scintillans	0	1.7 ± 2.1	0.2 ± 0.4	1.2 ± 1.1	0.3 ± 0.6	0	0.5 ± 0.7	1.5 ± 1
G. segmentatum	0.3 ± 0.5	0	0	0	0.3 ± 0.6	0	1 ± 0	0
Glomus sp. 1	1 ± 0	1 ± 0	0.8 ± 0.4	1 ± 1.2	0	1 ± 0	3 ± 1.4	1 ± 0
Glomus sp. 2	1.3 ± 0.5	0	0	0	0.7 ± 0.6	0	3 ± 1.4	1 ± 0
Glomus sp. 3	1.3 ± 0.5	1 ± 0	1.6 ± 0.9	0.4 ± 0.9	0	0	2 ± 0	1 ± 0
Glomus sp. 4	1.7 ± 0.5	0.7 ± 0.6	0	1 ± 1.2	0	1 ± 1	3 ± 0	1 ± 0
Glomus sp. 5	1.3 ± 0.5	0	0.8 ± 0.8	0	0.7 ± 0.6	0	3.5 ± 0.7	1 ± 0
Glomus sp. 6	0.7 ± 0.5	1 ± 0	0.4 ± 0.9	2.2 ± 1.5	0	0	4 ± 0	1 ± 0
Glomus sp. 7	0.7 ± 0.5	0	0.4 ± 0.5	0	1 ± 0	0	1 ± 0	0
Glomus sp. 8	1 ± 0.8	0.7 ± 1.2	0	0	0	0	0	0.5 ± 0.6
Glomus sp. 9	1 ± 0.8	1.3 ± 0.6	1.8 ± 1.5	4.4 ± 4.6	0.7 ± 0.6	1 ± 1	0	0.5 ± 0.6
Glomus sp.10	0.7 ± 0.5	0	0	0.6 ± 1.3	0	0	2 ± 0	0.25 ± 0.5
Glomus sp.11	0.7 ± 0.5	0	0	0	1 ± 0	0	0	0.5 ± 0.6
Glomus sp.12	0.7 ± 0.5	1.3 ± 0.6	0.8 ± 0.4	2 ± 2.8	0	0	1.5 ± 0.7	0.25 ± 0.5
Glomus sp.13	0	0.7 ± 1.2	0	0.4 ± 0.9	1 ± 1	1 ± 1	0	1.5 ± 1.9
Glomus sp.14	0.3 ± 0.5	0.7 ± 0.6	0	0	0	0	2 ± 0	0.5 ± 1
Glomus sp.15	0	2 ± 0	0.6 ± 0.5	1.2 ± 1.1	2 ± 0	0.3 ± 0.6	0	0
Glomus sp.16	0.3 ± 0.5	0	0	0	0	0	0	0.25 ± 0.5
Glomus sp.17	0.7 ± 0.9	0	0.6 ± 0.9	0.6 ± 0.5	1 ± 0	1 ± 1	1 ± 1.4	1.5 ± 1.3
Glomus sp.18	0	1.3 ± 0.6	0	0	0	0	0.5 ± 0.7	0
Glomus sp.19	0.3 ± 0.5	0.7 ± 1.2	0	0.4 ± 0.9	1 ± 0	0.3 ± 0.6	0	0.5 ± 0.6
Glomus sp.20	0	0	0.6 ± 0.5	0.6 ± 0.5	0.3 ± 0.6	0	0.5 ± 0.7	1 ± 0.8
Glomus *sp. 21*	0	1 ± 0	0.2 ± 0.4	0	0	0.3 ± 0.6	0.5 ± 0.7	0
Glomus sp. 22	0	1 ± 0	0.2 ± 0.4	1.4 ± 1.5	1 ± 0	0.3 ± 0.6	1 ± 0	0.5 ± 0.6
Total	65 ± 25.9	82 ± 28	46 ± 8.8	89± 14.8	64 ± 1.7	49 ± 16.5	90 ± 3.5	73 ± 6.8

Table 3. Basic information on AM fungal species distribution in paddy fields and landuse systems derived for paddy fields in the Kerala part of NBR.

	Pa	Av	Am	Hg	Og	Ar	Co	Ru
Number of species encountered								
	48	58	56	60	48	42	54	55
Number of species belonging to different frequency distribution (%) categories								
1-25%	0	0	14	16	0	0	0	0
25-50%	14	8	8	4	5	17	0	10
50-75%	21	9	15	22	16	9	17	12
75-100%	13	41	19	18	27	16	38	33
Number of species common with paddy fields								
		31	31	37	29	23	31	37
Similarity index value between paddy field and the landuse system								
		0.58 49	0.59 62	0.68 52	0.60 42	0.51 11	0.60 19	0.71 84

Pa: Paddy fields, **Hg**: polyculture homegarden, **Og**: Polyculture farm, **Av**: Arecanut with annual crops, **Am**: Arecanut with perennial crops, **Ar:** Arecanut plantation, **Co**: Coconut plantation, **Ru**: Rubber plantation

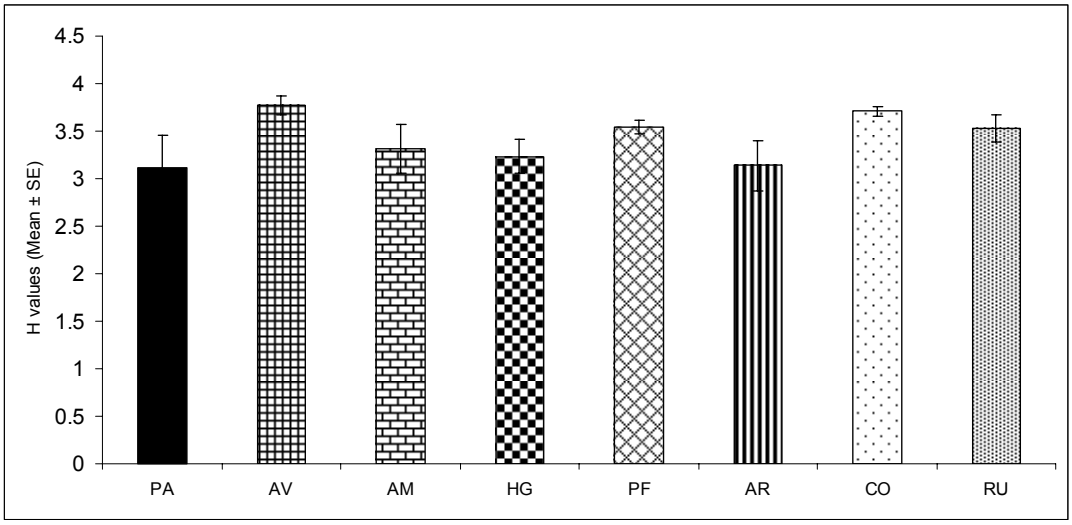

Figure 2. Species diversity index value (H, mean ± SE) of AM fungi in paddy field and landuse systems derived from paddy fields in the Kerala part of NBR.

PA: Paddy fields, **AV**: Arecanut with annual crops, **AM**: Arecanut with perennial crops, **HG**: polyculture homegarden, PF: Polyculture farm, **AR:** Arecanut plantation, **CO**: Coconut plantation, **RU**: Rubber plantation

Table 4. Groups of soil fauna and their density (individuals m^{-2}) in paddy field and landuse systems derived for paddy field in the Kerala part of NBR.

Groups	Pa	Av	Am	Hg	Og	Ar	Co	Ru
Coleoptera (Beetles)	44 ± 10	0	4 ± 1	0	16 ± 8	0	16 ± 17	21 ± 15
Isopoda	0	7 ± 2	4 ± 2	0	0	0	2 ± 3	3 ± 3
Hymenoptera (Ants)	44 ± 23	3 ± 1	34 ± 11	10 ± 4	9 ± 4	261 ± 247	36 ± 3	18 ± 12
Dermoptera	2 ± 2	3 ± 1	0	3 ± 1	0	0	1 ± 1	18 ± 16
Orthoptera	2 ± 2	3 ± 1	0	3 ± 1	0	0	5 ± 7	1 ± 1
Hemiptera	0	6 ± 1	0	0	0	0	0	1 ± 1
Isoptera (Termites)	35 ± 15	44 ± 31	122 ± 53	76 ± 27	88 ± 61	336 ± 170	99 ± 27	268 ± 263
Chaelopoda	0	2 ± 2	0	0	4 ± 3	3 ± 1		9 ± 3
Diplura	0	11 ± 4	6 ± 4	8 ± 2	0	3 ± 1	3 ± 4	11 ± 10
Decapoda	0	0	0	0	0	6 ± 4	0	0
Arachinida	4 ± 4	0	0	8 ± 2	0	7 ± 4	3 ± 7	13 ± 8
Blattidae	0	0	0	0	0	0	0	1 ± 2
Thysonura	0	0	0	0	0	0	0	0
Earthworm	125 ± 96	278 ± 53	156 ± 24	129 ± 9	192 ± 20	153 ± 49	252 ± 156	350 ± 173
Nematode	0	3 ± 1	9 ± 5	0	0	1 ± 1	7 ± 1	2 ± 2
Enchyttaeia	0	0	0	0	0	0	0	0
Molluscs	0	0	0	0	0	0	0	1 ± 2
Other organisms	0	0	0	0	5 ± 2	0	0	0
Total	256 ± 111	359 ± 86	335 ± 95	236 ± 46	314 ± 97	770 ± 471	426 ± 156	717 ± 463

Pa: Paddy fields, **Av**: Arecanut with annual crops, **Am**: Arecanut with perennial crops, **Hg**: polyculture homegarden, **Og**: Polyculture farm, **Ar:** Arecanut plantation, **Co**: Coconut plantation, **Ru**: Rubber plantation

Table 5. Basic information on distribution of soil faunal groups in paddy fields and landuse systems derived for paddy field in the Kerala part of NBR.

	Pa	Av	Am	Hg	Og	Ar	Co	Ru
Number of groups encountered								
	8	10	7	7	6	8	8	14
Number of groups belonging to different frequency distribution (%) categories								
1-25%	0	0	0	0	0	0	0	0
25-50%	1	0	0	0	0	0	0	2
50-75%	3	0	0	0	1	1	5	4
75-100%	4	10	7	7	5	7	5	8
Number of groups common with paddy fields								
		6	4	6	5	4	7	7
Similarity index value between paddy field and the landuse system								
		0.6667	0.5333	0.8000	0.7143	0.5000	0.7778	0.6364

Pa: Paddy fields, **Av**: Arecanut with annual crops, **Am**: Arecanut with perennial crops, **Hg**: polyculture homegarden, **Og**: Polyculture farm, **Ar:** Arecanut plantation, **Co**: Coconut plantation, **Ru**: Rubber plantation