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Impact of landuse transformation on arbuscular mycorrhizal fungal diversity in the Kerala part of Nilgiri Biosphere Reserve, India

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ABSTRACT:

The study was conducted to analyze the effect of transformation of paddy fields into perennial crop dominant landuse systems on diversity, distribution and abundance of arbuscular mycorrhizal fungi (AM fungi). When the basal area of tree and palm community in different landuse systems derived from paddy fields did not differ significantly, density was low in coconut and rubber plantation. Among different landuse systems, polyculture homegarden showed significantly high value for tree species diversity index (2.31). Polyculture homegardens also differ from paddy field and other landuse systems studied with significantly more AM fungal spore abundance in the soil. Even though significantly low spore abundance in the soil was recorded, percentage of root colonization value was significantly more in the roots collected from arecanut mixed with perennial cropping system. In the present study, fifty six AM fungi species were recovered from paddy field and landuse systems derived from it. About 55%-74% of AM fungal species were found to be common in paddy fields and a given landuse system derived from it. AM fungal species diversity index values did not vary among landuse systems, with exceptions being in paddy fields and polyculture farms, where significantly low values were recorded. These findings highlight the fact that due to landuse transformation, aboveground plant species composition changed drastically while the changes in AM fungal species composition and spore abundance remained a slow process.

Keywords:
Aboveground plant diversity, AM fungal diversity, AM fungal spore abundance, Landuse transformation, Mycorrhizal root colonization, Paddy fields, Perennial cropping systems.

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INTRODUCTION

In tropical countries, due to socioeconomic and cultural changes, several landuse systems are being transformed into some other landuse systems. For instance, in rural Kerala agricultural land has been going through transformation due to sprawls in agriculturisation, industrialization and globalization (Thampi 1995). Despite the fact that increase in area under cash crops help to increase farm income, changes in cropping pattern which favour perennial crops that have immediate and direct impact on the staple food security of 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 system of the State (Kannan and Pushpangadan 1988; Narayanan 1995 Baiju and Chandrashekara 2007). Such studies also highlighted the need for 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 socioeconomic and cultural aspects of rural Kerala is available on biodiversity in general, belowground biodiversity in particular is lacking.

Among belowground biota, Arbuscular Mycorrhizal fungi (AM fungi) which form obligate, mutualistic, symbiotic relationship with the roots of trees and crop plants facilitate host plant nutrient uptake. Similarly, AM fungi can also enhance tolerance or resistance to root pathogens or abiotic stress, such as drought and metal toxicities. In addition, AM fungi may play a vital role in the formation of stable soil aggregates, building up a macroporous structure of soil that allows penetration of water and air and prevents erosion (Miller and Jastrow 1992; Smith and Read 1997; Meharg and Cairney 2000; Borowicz 2001). Quite a few efforts have been made in the tropical region to characterize the diversity of AM fungi and also their role in managing soil health (Mohankumar and Mahadevan 1987; Ragupathy *et al*., 1990; Sengupta and Chaudhuri 1990; Muthukumar and Udaiyan 2000; Dhar and Mridha 2007; Shi *et al*., 2007). It is reported that landuse and land management can influence the diversity and effectiveness of AM fungi (Strzemska 1975; Ocampo and Hayman 1980; Mulligan *et al*., 1985). According to Giller (1996), in an ecosystem landuse change can bring more changes in belowground biodiversity than in aboveground biodiversity. However, detailed studies on changes in density, distribution and diversity of AM fungi are due to the transformation of landuse systems which were once dominated by annual crops to those dominated by perennial crops are lacking. In the present study, we examined abundance, diversity and distribution pattern of AM fungi in landuse systems derived from paddy fields in comparison with paddy fields in the Kerala part of Nilgiri Biosphere Reserve.

MATERIALS AND METHODS

Study area

The study was conducted in Vazhikadavu Panchayat (a Panchayat is a group of villages which constitute the basic unit of rural administration. Each Panchayat generally covers between two and twenty villages, depending on the size of the villages), Malappuram District, Kerala located between 76°19’ to 76°23’ E longitude and 11°23’ to 11°25’ N latitude. Here, an area of 2.6 x 1.4 km 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, 23 points represented land cover types other than agriculture/forestry and another 20 points represented landuses that were not derived from paddy fields. In the remaining 29 points, four were paddy fields while 25 points were agroecosystems/agroforestry systems that were once as paddy fields (Figure 1). Salient characters of paddy fields and landuse systems

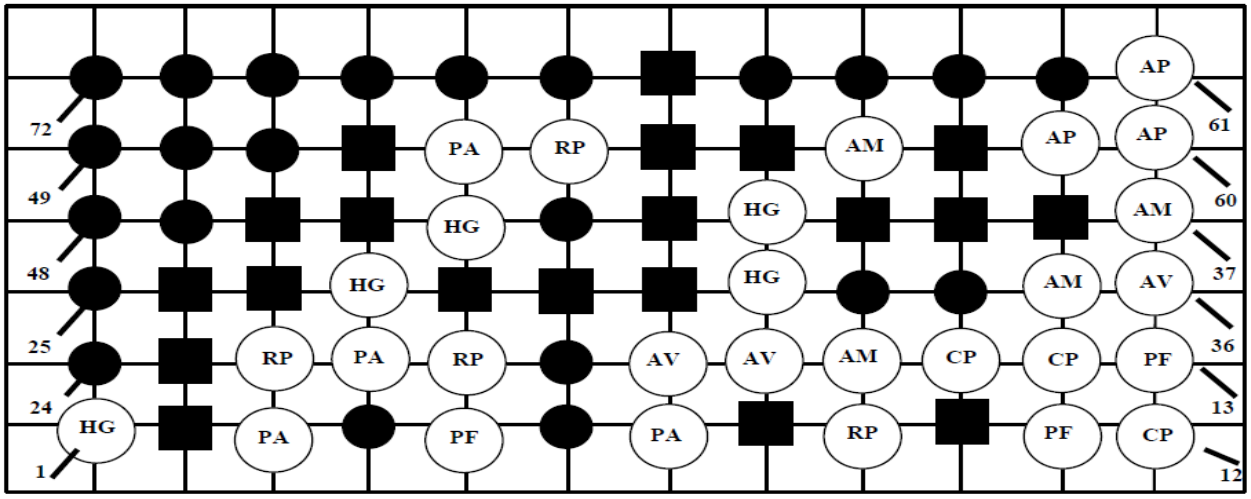

Figure 1. Paddy fields and landuse systems derived from paddy fields in the Kerala part of Nilgiri Biosphere Reserve.

■ **Non sample point**
● **Landuse systems derived from other than paddy field**
○ **Agroecosystems/agroforestry systems derived from paddy field**
(AM: arecanut mixed with perennial crops, **AP:** arecanut plantation**, AV:**arecanut mixed with annual crops, **CO:** coconut plantation**, HG:** homegardens **PA:** paddy field, **PF:** polyculture farm and **RP:** rubber plantation).

derived from paddy fields are given in Table 1. Age since the transformation of paddy fields into other type of croplands ranges from 5 to 25 years.

Climate

The climate in the study area is typically monsoonic with annual rainfall varying from 1621mm to 3271 mm (mean over 1990-2008: 2312mm). More than 65% of annual rainfall is drawn from the southwest monsoon during June- August period. The northeast monsoon, which sets in October and lasts till the end of November, accounts for much less rainfall (hardly 25% of annual rainfall). The mean annual maximum and minimum temperatures are 35°C and 15°C respectively. Soils are acidic (pH 5.6- 6.2) and gravelly clay loam. In general, soils are poor in total nitrogen (0.05-1.2%), available phosphorous (7.4-14.0 ppm), exchangeable potassium (0.15- 0.23 Cmol (+)/kg) and organic carbon (1.0-2.0%) (Chandrashekara *et al*., 2008).

Phytosociological analysis

For each landuse type derived from paddy fields, three plots were selected. In each plot, twelve quadrats, each of 10 m X 10 m size were marked. All trees and palms present in each quadrat were identified, counted and the Gbh (girth measured at 1.37 m above the ground level) was recorded. To estimate the density and basal area of shrub community, four sub-quadrats, each of 5 m x 5 m of size, nested in each of the quadrats laid for tree enumeration were used. On the other hand, for estimating herb density, four sub-quadrats, each of 1 m x 1 m, nested in each of the quadrats laid for tree enumeration were used. Since herb density was more and measurement of girth of individual plant of herbs, particularly of trailing herbs were tedious and time consuming, their biomass was estimated. All herbs within each sub-quadrat were uprooted, sorted into different species and weighed after air drying for getting constant weight. Species diversity index values were calculated separately for tree, shrub and herb communities using the following equation (Shannon and Wiener 1963):

$$H = -\Sigma(ni/N) \times \ln (ni/N)$$

Where, n_i= Density of a species and N= Density of all species

Leaf area index (LAI) is an important parameter to understand the canopy cover of landuse systems. The LAI of landuse systems derived from paddy fields were analyzed after the south-west monsoon (September-October) using canopy analyzer (LI COR, USA).

Composition and diversity of AM fungi

Sampling technique

In each of the four plots selected for a given landuse type, a quadrat (40 x 20m) was laid and divided into five equal blocks. From each block, 12 soil cores (0-20cm) were obtained and all samples from a given plot 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 until they were analyzed for spore abundance.

Enumeration of AM fungi

Isolation of AM spores was done using wet sieving and decanting technique (Gerdemann and Nicolson 1963). To start with, 10 g of the soil samples were 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 µm 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 was observed under a stereoscope and spores of fungi enumerated from each soil sample.

Percent colonization of AM fungi

Feeder roots (1cm long) collected from the soil sample were stained using the method of Philips and Hayman (1970) and colonization by AM fungi was assessed. A total of 100 root pieces were examined from each soil sample collected from different landuse systems. Root bits showing vesicles/arbuscules were considered as being colonized by AM fungi. The percent of mycorrhizal colonization was computed using the following formula:

% AM colonization = (Total number of root bits positive for AM colonization/ total number of bits observed for AM colonization) x 100.

Estimation of infective propagules of AM fungi

Infective propagules in the soil consist of 1) spores, 2) dead roots with AM colonization and 3) network of AM fungi. Estimation of the number of infective propagules would indicate the capability of mycorrhization of each type of soil (Porter, 1979). The procedure employed for estimating the number of infective propagules was as follows. 30 g of the test soil taken in a polythene bag was added with 270 g of sterilized sand soil mixture (1:1). This mixture was shaken thoroughly to get 10^{-1} dilution. From this

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 (PA)	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 farm (PF)	Land cultivated away from the farmer's dwelling place with annual, biennial and tree crops, sometimes integrated with animal husbandry.
2.2.Polyculture homegardens (HG)	Land cultivated around the farmer's dwelling place with annual, biennial and tree crops, mostly 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 annual crops (AV)
	2.3.2. Arecanut plantation integrated with cultivation of some perennial crops (AM)
2.4. Monoculture plantations	Mono-specific tree plantations.
	2.4.1. Coconut plantation (CP)
	2.4.2. Rubber plantation (RP)
	2.4.3. Arecanut plantation (AP)

dilution, 30 g of soil was transferred to another polythene bag and added with 270 g of sterilized sand soil mixture (1:1) to get 10^{-2} dilution. This procedure was repeated to get dilutions of 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6}. Each dilution was replicated for five times. Seeds of sorghum were sown in the polythene bags and the plants were maintained for six weeks in the glass house. Presence or absence of colonization was determined by staining technique (Philips and Hayman 1970). MPN number was determined referring to MPN table (Fischer and Yates 1963).

Estimation of diversity of AM fungi

Trap plant method was used to estimate the diversity of AM fungi in different landuse systems. In this method, 400 g of test soil was mixed with 400 g of sterilized sand; soil mixture (1:1 ratio) was taken in pots and seeds of sorghum, maize/cow pea were sown. The plants were maintained in the glass house by periodic watering up to a period of three months after which the soil in each pot was wet sieved and the spores are observed under a compound microscope. Identification of the spores was done using the Manual for the identification of AM fungi by Schenck and Perez (1990) and INVAM website by Joe Morton. Species diversity index (H') of AM fungal species was determined for each land use system using the formula

$$H' = - \Sigma(n_i/N) \times \ln (n_i/N)$$

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

Frequency distribution of individuals AM fungal species in a given landuse type was calculated as the number of plots (in that landuse type) where the species was encountered divided by total number of plots in that landuse type.

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

Statistical Analysis

The significance of differences between paddy fields and landuse systems derived from paddy fields for each parameter such as number of AM fungal spores, percent colonization of AM fungi in roots, number of infective propagules in soil, species diversity index value of AM fungi were tested separately by Analysis of Variance (ANOVA). Differences were deemed to be significant when $P<0.05$ according to Least Significant Difference (LSD) test. Similarly, significance of

Table 2. Density and basal area of tree and shrub community and density and biomass of herb community in different landuse systems derived from paddy field in the Kerala part of Nilgiri Biosphere Reserve. Values are Mean ±SE. In a column, means with same alphabet in the superscript are not significantly different at 5% level.

Landuse systems	Trees		Shrubs		Herbs	
	Density (individual ha^{-1})	Basal area (m^2 ha^{-1})	Density (individual ha^{-1})	Basal area (cm^2 ha^{-1})	Density (individual ha^{-1})	Biomass (gm m^{-2})
PF	954±224[a]	13.7±4.3[a]	609±299[a]	350±180[a]	78±11[a]	676±86[a]
HG	885±316[a]	12.1±5.7[a]	469±115[a]	298±83[a]	56±16[a]	782±70[a]
AV	1058±293[a]	14.4±4.6[a]	610±250[a]	857±387[b]	411±345[c]	1450±743[b]
AM	928±367[a]	19.6±12.2[a]	3619±1029[b]	1044±309[b]	149±65[b]	2222±623[c]
CP	200±50[b]	18.8±10.9[a]	2919±1918[b]	2345±1635[c]	87±33[a]	1433±499[b]
RP	433±62[c]	10.5±3.0[a]	684±397[a]	1161±749[ab]	122±41[b]	1082±283[ab]
AP	956±294[a]	12.1±4.7[a]	4223±664[b]	4484±476[c]	127±15[b]	2414±377[c]

PF: Polyculture farms, **HG**: Polyculture homegardens, **AM**: Arecanut with perennials, **AV**: Arecanut with annuals, **CP**: Coconut plantations, **RP**: Rubber plantations and **AP**: Arecanut plantations.

differences among different landuse systems derived from paddy fields for each parameter such as plant density, basal area/biomass (in case of herbs) and species diversity index value were tested separately using ANOVA and LSD test.

RESULTS AND DISCUSSION

Phytosociological analysis

In landuse systems transformed from paddy fields, density of trees and palms ranged from 200-1058 individuals ha^{-1} with significantly low density in coconut plantation followed by rubber plantation (Table 2). Trees and palm density in other landuse systems such as polyculture farmlands, homegardens, arecanut with annual crops, arecanut mixed with perennial crops and monoculture of arecanut did not differ significantly ($P>0.05$). The wide variation noticed here between coconut plantation, rubber plantation and other croplands in terms of tree and palm density can be attributed to factors like composition and space requirement of different crop species. However, mean basal area of tree and palm components among different landuse systems did not vary significantly. It is reported that in fully established homegardens the mean basal area of tree component can vary from 31 to 63 m^2ha^{-1}, depending upon the species composition (Sankar and Chandrashekara 2002; Das and Das 2005). The estimated low basal area in homegardens and polyculture farms of the present study area is thus an indication of young age of these landuse systems.

Density and basal cover/biomass of understorey components (herbs and shrubs) seem to be primarily determined by management practices adopted by the farmers. For instance, due to regular weeding in polyculture farms, homegardens and rubber plantations low values for parameters like density and basal area (biomass in case of herbs) were recorded. Since majority of shrub species recorded from arecanut and coconut based cropping systems have multi-purpose values, high density and basal cover of the understorey community is maintained.

Among different landuse systems, homegardens are species rich with mean tree species diversity index value of 2.31 followed by polyculture farmlands (Table 3). These may be attributed to the cultivation of several multipurpose trees apart from dominant cash crops like coconut and arecanut. A positive correlation between tree basal area and tree species diversity in homegardens and polyculture farms were observed. The packages of practice given by the Rubber Board stipulate that no trees other than rubber shall be managed or grown in rubber plantation. Since the farmers are adopting this package of practice so that they get subsidies and other benefits from the Rubber Board, the

Table 3. Shannon-Weiner Species diversity index and leaf area index of plant communities in different landuse systems derived from paddy field in the Kerala part of Nilgiri Biosphere Reserve. Values are Mean ±SE. In a column, means with same alphabet in the superscript are not significantly different at 5% level.

Landuse systems	Tree species diversity	Shrub species diversity	Herb species diversity	Leaf area index (LAI)
PF	1.43 ± 0.09^{c}	1.92 ± 0.26^{ab}	3.14 ± 0.93^{a}	2.50 ± 0.25^{b}
HG	2.31 ± 0.12^{d}	2.26 ± 0.11^{b}	3.69 ± 0.45^{a}	3.19 ± 0.23^{c}
AV	0.87 ± 0.26^{b}	1.94 ± 0.23^{a}	3.38 ± 0.72^{a}	1.59 ± 0.04^{a}
AM	0.94 ± 0.39^{b}	2.11 ± 0.09^{b}	2.53 ± 0.98^{a}	3.26 ± 0.11^{c}
CP	0.63 ± 0.06^{b}	1.90 ± 0.32^{a}	3.37 ± 0.99^{a}	2.11 ± 0.32^{b}
RP	0.16 ± 0.04^{a}	2.46 ± 0.07^{c}	3.29 ± 1.01^{a}	4.35 ± 0.06^{d}
AP	0.46 ± 0.25^{b}	1.50 ± 0.45^{a}	3.23 ± 1.22^{a}	1.25 ± 0.44^{a}

PF: Polyculture farms, **HG**: Polyculture homegardens, **AM**: Arecanut with perennials, **AV**: Arecanut with annuals, **CP**: Coconut plantations, **RP**: Rubber plantations and **AP**: Arecanut plantations.

lowest tree diversity index value was recorded for rubber plantations. Generally species diversity index values recorded for herb and shrub communities in different landuse systems were not significantly different (Table 3). This can be attributed to weeding and other management practices adopted in these plots.

LAI value ranged from 1.25 - 4.35 with higher value in rubber plantation (Table 3). In arecanut based cropping system, space maintained between plants is more and crown area per palm is also less. Thus, LAI value obtained for this cropping system was lesser than that in other systems.

Composition and diversity of Arbuscular Mycorrhizal fungi

The mean AM fungal spore density in paddy fields and landuse system derived from paddy fields ranged from 50-67 spores per 10g of soil (Table 4). These values are within in the range of AM fungal spore density reported for natural forests of South India (Visalakshi 1997). Comparison of paddy fields and other landuse systems for AM fungal spore density revealed that the values are not significantly different ($P>0.05$); exception being in polyculture homegardens and arecanut mixed with perennial cropping system. The AM fungal spore density in polyculture homegardens was more than that in paddy fields ($P<0.05$). On the other hand, significantly low spore density was recorded for arecanut mixed with perennial cropping system ($P<0.05$).

It is also interesting to note that in arecanut mixed with perennial cropping system percentage of root colonization value of AM fungi was significantly more than that in paddy fields ($P<0.05$; Table 5). Therefore, it can be concluded that due to intensive management adopted in arecanut mixed with perennial cropping system spore abundance may be decreased. On the other hand, when favourable conditions are available, AM fungal species may propagate well as we observed in root colonization studies conducted by collecting roots from the arecanut mixed with perennial cropping system.

According to Oehl *et al*., (2003) the AM root colonization in the trap cultures established from different field sites can exhibit the pattern similar to spore abundance in different agroecosystems. However, in the present study correlation between percentage

Table 4. Spore density (number of spores per 10 g of soil) of AM fungi in soils of paddy field and landuse systems derived from paddy fields in the Kerala part of Nilgiri Biosphere Reserve. Values are Mean ±SE. In a column, means with same alphabet in the superscript are not significantly different at 5% level.

Landuse systems	Number of spores per 10 g of soil
Paddy fields	50 ± 7^{bc}
Polyculture farms	50 ± 5^{bc}
Polyculture homegardens	67 ± 3^{d}
Arecanut mixed with annual crops	61 ± 3^{cd}
Arecanut mixed with perennial crops	35 ± 1^{a}
Coconut plantations	56 ± 6^{cd}
Rubber plantations	56 ± 3^{cd}
Arecanut plantations	41 ± 1^{ab}

Table 5. Percentage colonization and number of infective propagules of AM fungi in soils of paddy fields and landuse systems derived from paddy fields in the Kerala part of Nilgiri Biosphere Reserve. In a column, means with same alphabet in the superscript are not significantly different at 5% level.

Landuse systems	% of colonization of AM fungi in roots	Number of infective propagules per g of soil
Paddy fields	47 ± 6^{a}	73 ± 23^{b}
Polyculture farms	52 ± 6^{a}	121 ± 34^{a}
Polyculture homegardens	66 ± 11^{a}	133 ± 32^{a}
Arecanut mixed with annual crops	56 ± 4^{a}	183 ± 43^{a}
Arecanut mixed with perennial crops	81 ± 8^{b}	170 ± 45^{a}
Coconut plantations	55 ± 7^{a}	123 ± 44^{a}
Rubber plantations	46 ± 15^{a}	132 ± 85^{a}
Arecanut plantations	66 ± 6^{a}	163 ± 40^{a}

Table 6. Mean spore abundance (spores per 10 g of soil) of AM fungi in paddy field and landuse systems derived for paddy field in the Kerala part of Nilgiri Biosphere Reserve.

AM fungi	PA	PF	HG	AV	AM	CP	RP	AP
Acaulospora appendicula	0.7	1.7	3.2	3.3	0.8	2.0	3.0	-
Acaulospora bireticulata	1.7	2.7	5.0	2.0	1.6	2.0	1.0	1.3
Acaulospora denticulata	1.0	1.0	1.6	2.0	0.6	1.0	3.3	1.0
Acaulospora dilatata	0.7	-	1.4	3.3	1.0	-	0.8	1.0
Acaulospora elegans	-	1.3	0.4	1.0	0.8	1.0	-	1.0
Acaulospora lacunose	2.7	-	0.6	1.3	1.4	1.0	2.0	2.0
Acaulospora laevis	-	1.0	-	2.3	0.2	1.5	1.8	0.3
Acaulospora longula	1.0	0.7	0.8	1.0	2.2	0.5	0.5	3.0
Acaulospora mellea	2.3	0.7	1.8	3.0	1.4	-	-	2.0
Acaulospora morrowae	-	1.3	-	1.0	0.5	1.5	1.0	-
Acaulospora myriocarpa	0.7	-	0.6	2.0	1.4	-	1.0	1.3
Acaulospora rehmii	-	1.3	0.2	0.7	-	2.0	-	-
Acaulospora rugosa	0.7	2.0	4.4	1.0	1.4	-	-	1.0
Acaulospora scrobiculata	6.0	-	-	1.3	0.2	4.0	3.5	-
Acaulospora spinosa	-	1.0	0.8	1.0	0.8	2.0	1.0	1.0
Acaulospora tuberculata	0.7	-	0.8	-	-	-	1.8	-
Gigaspora albida	0.7	0.7	0.4	-	0.8	2.0	0.3	0.7
Gigaspora decipiens	-	1.3	1.2	1.0	0.4	-	0.8	-
Gigaspora gigantean	-	-	-	-	0.6	1.1	-	0.3
Glomus albidum	-	-	0.6	-	-	0.5	0.8	-
Glomus aggregatum	3.0	1.7	2.6	3.3	2.6	-	-	4.3
Glomus ambisporum	2.0	1.7	1.6	-	-	1.0	-	-
Glomus botryoides	-	-	-	0.7	0.6	-	0.5	-
Glomus canadense	-	2.0	1.6	2.0	0.8	3.0	-	1.3
Glomus citricolum	1.0	-	0.6	-	-	2.0	1.0	-
Glomus claroideum	-	0.3	0.4	2.7	-	-	-	1.3
Glomus clarum	2.3	2.0	2.2	2.0	1.0	0.5	1.0	-
Glomus constrictum	-	-	-	-	-	2.0	-	0.7
Glomus convolutum	-	-	0.6	0.7	-	-	0.8	-
Glomus delhiense	0.7	-	0.6	2.0	1.2	1.5	-	2.0
Glomus diaphanum	-	1.7	1.0	2.0	1.4	-	-	2.0
Glomus etunicatum	1.7	-	-	-	0.2	-	1.0	-
Glomus fasciculatum	1.7	3.7	4.2	2.0	-	1.0	-	0.7
Glomus fragile	-	-	-	-	0.4	2.0	0.5	0.3
Glomus geosporum	0.7	1.3	1.8	0.7	1.0	-	2.0	-
Glomus halonatum	-	-	0.4	-	0.8	1.0	-	-
Glomus heterosporum	1.3	1.0	1.0	1.0	-	-	0.5	0.3
Glomus hoi	-	-	-	1.3	-	2.0	-	1.7
Glomus intraradices	3.3	2.0	2.4	1.0	0.6	-	2.8	0.3
Glomus invermaium	-	-	0.4	-	-	0.5	-	-
Glomus leptotichum	-	-	-	1.0	0.6	0.5	0.3	-
Glomus macrocarpum	0.7	2.0	2.0	-	-	2.0	-	-
Glomus maculosum	7.0	4.7	9.6	1.3	1.6	4.5	5.5	4.0
Glomus monosporum	-	-	-	1.3	-	-	-	-
Glomus mosseae	1.7	2.0	2.0	-	-	1.0	3.5	-
Glomus multicaule	0.7	0.7	1.2	1.3	1.4	2.0	2.5	2.7
Glomus multisubstensum	-	-	-	-	0.4	-	-	0.7
Glomus occultum	-	2.0	0.8	1.3	0.8	-	2.0	-
Glomus pallidum	0.7	0.7	1.2	1.3	-	2.0	-	-

Glomus pansihalos	-	-	0.8	-	0.2	-	2.0	-
Glomus pulvinatum	-	2.0	1.2	2.0	1.2	2.0	-	2.0
Glomus pustulatum	1.3	-	0.2	-	0.4	-	2.5	-
Glomus radiatum	-	1.0	0.8	1.0	0.4	2.0	2.5	-
Glomus reticulatum	0.7	0.3	0.8	-	0.8	-	1.3	1.0
Glomus scintillans	-	0.3	1.2	1.7	0.2	0.5	1.5	-
Glomus segmentatum	0.3	0.3	-	-	-	1.0	-	-

PF: Polyculture farms, **HG**: Polyculture homegardens, **AM**: Arecanut with perennials, **AV**: Arecanut with annuals, **CP**: Coconut plantations, **RP**: Rubber plantations and **AP**: Arecanut plantations.

colonization of AM fungi in roots and number of infective propagules per gram of soil is not significant ($r = 0.61$; $P>0.05$). At the same time, the values obtained for number of propagules per g of soil in different landuse systems are not significantly different (Table 5; $P>0.05$). This pattern observed for number of infective propagules can be attributed to the fact that a short period (about two months in this case) of trap culturing may not allow most of the species to sporulate. Thus, further studies by prolonging the trap culture period may show the actual relationships between percentage colonization and number of infective propagules in each landuse system.

Fifty six species belonging to three genera namely, *Acaulospora, Gigaspora* and *Glomus* were recovered from the soils of paddy fields and landuse systems derived from it (Table 6). *Glomus* and *Acaulospora* showed dominance in the present study with 37 and 16 species respectively. The preponderance of these two genera in Indian soils reported by several authors (Thapar and Khan 1985; Ragupathy and Mahadevan 1993; Muthukumar and Udaiyan 2000; Mohanan 2003) can be linked to acidic nature of the soil the landuse systems studied. It may also be pointed out here that the genus *Glomus* is of rare occurrence in Western Australia due to high soil pH (Porter *et al*., 1987). As in the present study, rare occurrence of *Gigaspora* in Indian soil has been reported elsewhere (Ragupathy and Mahadevan 1993; Sankaran *et al*., 1993; Muthukumar and Udaiyan 2000; Mohanan 2003). It is interesting to note that six out of 30 AM fungal species recorded from the natural forests of Kerala (Chandrashekara *et al*., 2008), were also recorded from paddy fields.

Table 7. Species diversity index of AM fungi of paddy fields and landuse systems derived from paddy field in the Kerala part of Nilgiri Biosphere Reserve. Values are Mean ±SE. In a column, means with same alphabet in the superscript are not significantly different at 5% level.

Landuse systems	Species diversity
Paddy fields	2.10 ± 0.07^{a}
Polyculture farms	2.13 ± 0.01^{a}
Homegardens	2.88 ± 0.08^{b}
Arecanut mixed with perennial crops	2.86 ± 0.05^{b}
Arecanut mixed with annual crops	2.67 ± 0.15^{b}
Coconut plantations	2.71 ± 0.16^{b}
Rubber plantations	2.83 ± 0.15^{b}
Arecanut plantations	2.56 ± 0.15^{b}

Comparison of AM fungal species composition in different landuse systems in the study area indicated that there are a few 'generalist' species and also 'highly specialist' species. For instance, species like *Acaulospora bireticulata*, *A. denticulata*, *A. longula*, *Glomus maculosum* and *G. multicaule* can be regarded as 'generalist' species as they are found in all landuse systems in the present study. On the other hand, *Glomus monosporum* can be considered as a 'highly specialist' species due to its occurrence only in soils of arecanut mixed with annual crops.

Out of 30 species recorded from paddy fields seven species namely *Acaulospora lacunose*, *A. mellea*, *A. scrobiculata*, *Glomus aggregatum*, *G. clarum*, *G. intraradices* and *G. maculosum* are contributing to more than 50% of total spore abundance. However, when these species are present in other landuse systems, their spore abundance was lesser than that in paddy fields.

Thus, due to landuse change the dominance of above mentioned species seems to decrease and at the same time contribution to total spore abundance by the constituent species becomes uniform. These two changes lead to comparatively high species diversity index value in majority of the landuse systems derived from paddy fields (Table 7).

Similarity index value estimated for paddy field and landuse systems derived from it ranged from 0.55-0.74 with following order : homegardens (0.74)> polyculture fams (0.66)> rubber plantations (0.63)> arecanut mixed with perennial crops (0.61)> arecanut with annual crops (0.59)> arecanut plantation (0.58)> coconut plantation (0.55). Thus, it is clear that transformation of paddy fields into different landuse systems did not alter drastically the AM fungal species composition. The present study also revealed that changes in the aboveground plant species composition is drastic, as it is mainly triggered by farmers' activities. On the other hand, changes in the AM fungal species composition and spore abundance due to landuse change appear to be a slow process.

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