Influence of Land Use and Land Cover Change on Diversity of Earthworms in Raebareli District of Indogangetic Plains, India

Tunira Bhadauria1*, K. G. Saxena2, Pradeep Kumar2, Rohit Kumar2, V. K. Chaturvedi1

1 Department of Zoology, Feroze Gandhi College, Raebareli 229001, Uttar Pradesh, India
2 School of Environmental Sciences, Jawahar Lal Nehru University, New Delhi 110067, India

Corresponding author: * tunira@gmail.com

ABSTRACT

Land use-land cover change and management practices influence earthworm species composition and abundance. The natural and agro-ecosystems under study in the Indogangetic region have a depauperate earthworm fauna. This study provides evidence that agriculture intensification and soil sodicity can severely influence earthworm diversity, in which natural and less disturbed ecosystems had lower earthworm diversity. Predominance of endemic earthworms at all sites under study could probably be explained by barriers in dispersal of exotic species and a wider distribution of native species. The change in functional guild with the change in land use could be attributed to the change in the input rates and chemical characteristic of organic matter associated with varied land management practices. The ecological group studies revealed that earthworm communities of agro-ecosystems have lower species richness, fewer ecological groups and predominance of endogeics. Epigean and anecic species are not widespread in the agriculture systems and their dependence on litter layer for survival implies that litter management practices must be implemented for their role of soil function to be important.

INTRODUCTION

Soil organisms are an integral part of agricultural and forest ecosystems and they play a critical role in maintaining soil health, ecosystem function and production. The interacting functions of soil organisms and the effects of human activities in managing land for agriculture and forest affect soil health and quality. These changes strongly influence soil faunal biodiversity by altering habitat heterogeneity and vegetation type (Dekaens et al. 2004; Eggleton et al. 2005). Poor irrigation management practices coupled with the lack of a properly designed drainage system and high rate of evaporation cause soluble salts to concentrate on the soil surface, resulting in sodic soil conditions in the vast tracts of the Indogangetic plains of semi-arid India, thus rendering these ecosystems unfit for soil faunal biodiversity and agricultural purposes. Earthworms constitute the largest part of the macrofauna in the soil and various soil management options can have a dramatic effect upon their community structure (Vazquez and Simberloff 2003; Dekaens et al. 2004). Intensive agricultural practices influence the population density, species diversity and activity of earthworms as soil organisms are largely dependant upon organic matter input, largely derived from the vegetation cover of the site (Freekmann 1994). Annual crops have lower earthworm biomass and therefore considered to be relatively unfavorable for soil macrofauna (Radford et al. 2001). Seasonal rhythm or environmental factors such as temperature, soil moisture and soil pH affect to different extents soil biological communities and their functions, and are key factor of changes in the species assemblage of below-ground communities (Miranda et al. 2007). The present study in the Indogangetic plains of semi-arid India is an effort to provide evidence that agriculture intensification and managing land for plantation and forest not only affect soil health and quality but also can severely influence the earthworm community structure and species diversity. The study also evaluates the impact of soil sodic condition and subsequent reclamation of a degraded landscape on the diversity and distribution pattern of earthworm species. The ecosystems thus identified and impacted by various factors will be compared with reference to non-impacted or less impacted ecosystems, to compare the level of loss or change in the earthworm species and the recolonization processes.

STUDY SITE

The study was carried out in Gangaganj and Bachhrawan Villages of Raebareli district, (Latitude 25° 49’ and 26° 36’ North and longitudes 80° 41’ and 81° 34’ East) state of Uttar Pradesh located in the Indogangetic plains at an altitude between 8 to 10 m with a fairly flat land and with a slope from NW to SE, the study site is covered under agroecoregion 4, a hot semi-arid ecoregion whose soils are formed through the alluvial deposits formed by the rivers comprising of Ganga, Gomti and their tributaries (Sehgal et al. 2002). Soils are loamy to sandy loam, dark grey and coarsely textured with inherently low nutrients like nitrogen and organic carbon; the soils are poorly drained with low to very low permeability and with alkalinity problems. The climate is hot and dry summer extends from May to June (max. temp. 42.2°C, min. temp. 38°C) with severe winter extending from November to February (max. temp. 25.2°C, min. temp. 7.8°C), the rainy season extends from the last week of June to October with an average annual rainfall of 60 to 100 cm. The landscape in this agro-ecological region had a mosaic of natural and human managed ecosystems (Table 1). Agriculture in the Raebareli district is a modern, intensive farming system characterized by mechanized tillage and chemical fertilizers. The chronosequence of land use classes of both natural and
man-made ecosystems were selected for the study. Based on anthropogenic disturbances the natural ecosystem identified was less impacted ecosystem represented by primary forest (PF); agro-ecosystems that can be ordered relatively to the intensity of management as: productive agro ecosystem (PAE); low productivity agroecosystem with negligible organic manure, well managed paddy-wheat crop rotation and two crops are harvested per year, addition of NP occasionally K. Field left fallow for a short period of 3-4 months.

Abandoned agricultural fallow plot

Sodic agroecosystem

Highly degraded agro ecosystem rendered unfit for crop growth due to soil sodic conditions and leading to soil fertility recovery. No fertilizer added and field is left fallow for a period of 6 months, this practice is continued for a period of 3 years.

5-year-old reclaimed agroecosystem

Sodic agroecosystem that was reclaimed 5 years back for cultivation through continuous application of gypsum or pyrite for three years, occasional grazing by cattle and collection of fire wood by local people.

Elevation

Dry deciduous thorn bush forest, thickness of litter layer < 3 cm; occasional grazing by cattle and collection of fire wood by local people.

Location of sites

Raebareli (Uttar Pradesh)

Table 1 Distinguishing features of vegetation and management practices in different land uses in Raebareli district of Indogangetic plains.

<table>
<thead>
<tr>
<th>Ecoregion</th>
<th>Indogangetic plains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of sites</td>
<td>Raebareli (Uttar Pradesh)</td>
</tr>
<tr>
<td>Elevation</td>
<td>8-10 m (asl)</td>
</tr>
<tr>
<td>Natural forest</td>
<td>Dry deciduous thorn bush forest, thickness of litter layer &lt; 3 cm; occasional grazing by cattle and collection of fire wood by local people.</td>
</tr>
<tr>
<td><em>Babunia verigata</em>, <em>Butea monosperma</em>, <em>Acacia</em> sp. <strong>Ziziphus sp., Calotropis sp., Indigofera sp., Jatropha sp., Tectona grandis</strong></td>
<td></td>
</tr>
</tbody>
</table>

Soil fertility management practices

Intensive irrigated farming

RESULTS

Statistical analysis was done following the biostatistical methods described in Zar (1974). Significant differences \( (P < 0.05) \) in physicochemical characteristics of the soil across different sampling sites were carried out using one-way ANOVA. Significant differences in the density and biomass of earthworm species across different sampling sites (interhabitat variations), and in the same site (intrahabitat variations) were tested using non-parametric one-way ANOVA \( (F\text{-test}) \), and the Newmann-Keul’s multiple range test. Significant differences \( (P < 0.05) \) in functional guild changes of earthworm species in the same site were tested using the non-parametric Mann-Whitney test \( (U\text{-test}) \). Significant differences \( (P < 0.05) \) in functional guild changes of earthworm species across different sampling sites were done using one-way ANOVA \( (F\text{-test}) \). Seasonal variations in total density and biomass of earthworm species in PF, AAFP and in AP were tested using the non-parametric Kruskal-Wallis test of variance \( (H\text{-test}) \) and New Mann Keul’s multiple range test. The correlation between soil parameters such as temperature moisture and organic matter and earthworm species was calculated as a simple correlation coefficient \( (r) \). The SYSTAT 12 software for Windows package (Systat Software Inc., San Jose, USA) was used for all statistical tests. Sample standard error was calculated as the standard error of the Mean \( (\pm S\ E) \).

RESULTS

Physico-chemical properties of soils varied significantly between different sites. Sand (%) was significantly higher \( (F = 18.4, \ P < 0.05) \) under SE whereas silt and clay content were higher under PF \( (F = 12.4, \ P < 0.05) \), all other sites had a very similar soil texture. Soil had a mildly alkaline to alkaline pH in PF, PAE and LPAE. Soil had a highly alkaline pH in the degraded SE and subsequent reclamation.
AAFP as well in 10 Yr RA (Fig. 1). In PF, soils sodic conditions representing highly degraded agro-ecosystems were devoid of any earthworm fauna; in AP, soil sodic conditions also led to a loss of total N, but improved significantly (F = 1.63, P < 0.05) in 10 Yr RA; these values were much higher in reclaimed AP than all other sites (Table 2).

Earthworm communities

The family Megascolecidae with a single genus having three species Eutychoeus incommodes, E. orientalis and E. nicholsoni in both natural and agro-ecosystems and the family Almidae represented by a single genus Glyphidrilus in 5 Yr RA and 10 Yr RA alone characterizes the PF, PAE and LPAE, AP and degraded agro-ecosystems (Table 3). Earthworm species diversity was maximum in PF and AAFP and minimum in 5 and 10 Yr RA (Fig. 1). PF had all three endemic species (E. incommodes, E. orientalis and E. nicholsoni) and conversion of PF to agro-ecosystems led to the loss of endemic E. orientalis in both PAE and LPAE. AAFP was however recolonized by all three species present in PF. Soil sodic conditions representing highly degraded agro-ecosystems were devoid of any earthworm fauna; however, subsequent reclamation of soil for agricultural purposes led to the invasion by another endemic Glyphidrilus sp. in both 5 and 10 Yr RA. AP were recolonized by E. incommodes and E. nicholsoni (Fig. 2). Endemic species had a significantly higher density (F = 8.74, P < 0.05) in AAFP as well in 10 Yr RA (F = 7.63, P < 0.05). However, in terms of biomass the endemics contributed significantly (F = 8.93, P < 0.05) more to AAFP than to PF and PAE. In 5 and 10 Yr RA the contribution by endemics in terms of biomass was very low. Exotic species were absent in all sites under study (Fig. 3).

Table 4 Total density and biomass of earthworm species across different sampling sites in Raebareli district of Indogangentic plains.

<table>
<thead>
<tr>
<th>Sampling sites</th>
<th>Density (Individuals/m²/yr)</th>
<th>Biomass (g/m²/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural forest</td>
<td>168 ± 10.2 a</td>
<td>378.9 ± 26 a</td>
</tr>
<tr>
<td>Productive agro ecosystem</td>
<td>276 ± 18.4 b</td>
<td>480.5 ± 35 b</td>
</tr>
<tr>
<td>Low productivity agro ecosystem</td>
<td>151 ± 13.4 c</td>
<td>412.5 ± 37 c</td>
</tr>
<tr>
<td>Abandonend agricultural fallow plot</td>
<td>288 ± 11.0 d</td>
<td>560.7 ± 42 d</td>
</tr>
<tr>
<td>Sodic agro ecosystem</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5-year-old reclaimed agro ecosystem</td>
<td>143 ± 14.0 c</td>
<td>144.4 ± 11 e</td>
</tr>
<tr>
<td>10-year-old reclaimed agro ecosystem</td>
<td>282 ± 23.0 d</td>
<td>225.6 ± 19 f</td>
</tr>
<tr>
<td>Acacia plantation</td>
<td>177 ± 12.0 c</td>
<td>411.3 ± 29 c</td>
</tr>
</tbody>
</table>

Numbers followed by the same letter are not significantly different (P < 0.05) between different sites. ± SE, n = 10
Intrahabitat variation

Of the three species present in PF, *E. incommodes* was the dominant species having significantly higher density ($F = 15.09, P < 0.05$) and biomass ($F = 8.73, P < 0.05$) values than the other two species. *E. nicholsoni* had significantly higher density ($F = 8.42, P < 0.05$) and biomass ($F = 7.98, P < 0.05$) values than *E. incommodes* in both PAE and LPAE. *E. orientalis* was absent under the agro-ecosystems, but was present in AAFP. *E. orientalis* had higher density ($F = 29.78, P < 0.01$) and biomass ($F = 28.71, P < 0.01$) values than *E. nicholsoni* and *E. incommodes*. *Glyphidrilus* sp. was the only species present in both 5 and 10 Yr RA. In AP, *E. incommodes* had significantly higher density ($F = 9.7, P < 0.05$) and biomass ($F = 5.42, P < 0.05$) values than *E. nicholsoni* (Table 5).

Interhabitat variation

Population density and biomass values of *E. incommodes* did not vary significantly between PF, PAE and AAFP. However, density ($F = 4.94, P < 0.05$) and biomass ($F = 4.35, P < 0.05$) values of this species declined significantly in LPAE. *E. orientalis* was absent under the agro-ecosystems, but was present in AAFP. *E. orientalis* had higher density ($F = 5.62, P < 0.05$) and biomass ($F = 3.52, P < 0.05$) values in AAFP. *E. nicholsoni* had significantly higher density ($F = 9.1, P < 0.05$) and biomass ($F = 3.52, P < 0.05$) values in LPAE. *E. nicholsoni* did not vary significantly between PAE and LPAE. *E. incommodes* had significantly higher density ($F = 9.62, P < 0.01$) and biomass ($F = 8.27, P < 0.01$) values in 10 Yr RA (*P* = 0.05) values of *Glyphidrilus* sp. were significantly higher ($P < 0.05$) in 10 Yr RA (Table 5).

Functional guild changes within same site

The study of earthworm species in a gradient of PF disturbance showed the presence of an anecic species *E. nicholsoni* and two endogeic species *E. incommodes*, *E. orientalis* in PF. Their relative abundance and biomass values changed with associated land use types within the same site, endo-
The biomass values of these species did not vary significantly in AAFP. Density (\( U = 14, P < 0.05 \)) values of endogeic species were significantly higher in 10 Yr RA than 5 Yr RA, but based on their biomass values (\( F = 8.20, P < 0.05 \)) alone, they were the dominant functional group in AP than both 5 Yr RA and 10 Yr RA (Table 6).

**Seasonal variation**

Population density of all the earthworm species varied seasonally in response to the seasonal changes in soil moisture and temperature. *E. nicholsoni* was present throughout the year in the PF, AP and in AAFP, and had significantly higher population density values in PF (\( H = 7.35, P < 0.05 \)) and in AAFP (\( H = 6.41, P < 0.05 \)) during rainy season than winter and summer (Table 7). Population density values of *E. orientalis* were significantly higher during rainy season in PF and in AAFP than the winter months, but it was absent during the summer months. *E. incommodes* showed similar seasonal pattern as *E. orientalis* with significantly higher population density values in PF (\( H = 6.21, P < 0.05 \)) and in AAFP (\( H = 6.41, P < 0.05 \)) during the rainy season, and was absent during the summer months in AP and PF (Fig. 4A-C; Fig. 5A-C). In the PAE population density values of *E. incommodes* (\( F = 10.25, P < 0.05 \)) and *E. nicholsoni* (\( F = 9.45, P < 0.05 \)) improved significantly in October subsequent to the harvest of rice crop with a decline in the wheat crop, both the species were absent in the intervening fallow period. In LPYE both *E. incommodes* and *E. nicholsoni* showed significant increase in the population density values (\( F = 8.84, P < 0.05 \)) during July, with subsequent decline in the abundance thereafter, the latter species showed a small peak of increased density values during October, as in PAE here also both the species were absent in the intervening fallow period. Population density values of *Glyphidrilus* sp. increased significantly (\( F = 7.95, P < 0.05 \)) in September and October corresponding to harvest of rice crop in 5 Yr RA, whereas in 10 Yr RA *Glyphidrilus* sp. showed a minor

### Table 5 Inter- and intrahabitat variations in density (individuals/m²/year), and biomass (g/m²/year; values in parenthesis) of earthworm species across different sampling sites in the Indogangetic plains.

<table>
<thead>
<tr>
<th>Density (biomass)</th>
<th>Natural forest</th>
<th>Productive agroecosystem</th>
<th>Low productivity agroecosystem</th>
<th>Abandoned agricultural fallow plot</th>
<th>Sodic agroecosystem</th>
<th>5-year-old reclaimed agroecosystem</th>
<th>10-year-old reclaimed agroecosystem</th>
<th>Acacia plantation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural forest</td>
<td>91 ± 4.5 a</td>
<td>36 ± 1.9 a</td>
<td>41 ± 2.3 a</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>133 ± 9.1c</td>
</tr>
<tr>
<td>Productive agroecosystem</td>
<td>75 ± 3.6 a</td>
<td>0</td>
<td>141 ± 6.2 b</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>143 ± 7.7 a</td>
<td>47 ± 3.2 a</td>
</tr>
<tr>
<td>Low productivity agroecosystem</td>
<td>45 ± 3.2 b</td>
<td>0</td>
<td>106 ± 5.6 c</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>114.4 ± 8.4 a</td>
<td>160.6 ± 10.5 b</td>
</tr>
<tr>
<td>Abandoned agricultural fallow plot</td>
<td>85 ± 6.3 a</td>
<td>89 ± 10.5 b</td>
<td>64 ± 4.4 a</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>282 ± 15.4 b</td>
<td></td>
</tr>
<tr>
<td>Sodic agroecosystem</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5-year-old reclaimed agroecosystem</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10-year-old reclaimed agroecosystem</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Acacia plantation</td>
<td>133 ± 9.1c</td>
<td>47 ± 3.2 a</td>
<td>132 ± 7.8 a</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>279.3 ± 21.5 c</td>
<td></td>
</tr>
</tbody>
</table>

Values followed by different Roman letters are significantly different (\( P < 0.05 \)) between different sampling sites.

### Table 6 Effect of management practices in different land uses on density (individuals/m²/year), and biomass values (g/m²/year) of functional categories of earthworms in the Indogangetic plains.

<table>
<thead>
<tr>
<th>Density (Anecic)</th>
<th>Biomass (Anecic)</th>
<th>Density (Endogeics)</th>
<th>Biomass (Endogeics)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural forest</td>
<td>41 ± 3.2 a</td>
<td>23 ± 11.6 a</td>
<td>127 ± 13.8 a</td>
</tr>
<tr>
<td>Productive agroecosystem</td>
<td>141 ± 1.6 b</td>
<td>323 ± 23.5 b</td>
<td>75 ± 6.3 b</td>
</tr>
<tr>
<td>Low productivity agroecosystem</td>
<td>106 ± 7.9 c</td>
<td>318 ± 27.8 b</td>
<td>45 ± 3.2 c</td>
</tr>
<tr>
<td>Abandoned agricultural fallow plot</td>
<td>64 ± 3.8 d</td>
<td>42 ± 2.9 c</td>
<td>274 ± 14.6 d</td>
</tr>
<tr>
<td>Sodic agroecosystem</td>
<td>0</td>
<td>0</td>
<td>143 ± 12.7 e</td>
</tr>
<tr>
<td>5-year-old reclaimed agroecosystem</td>
<td>0</td>
<td>0</td>
<td>282 ± 24.7 d</td>
</tr>
<tr>
<td>10-year-old reclaimed agroecosystem</td>
<td>0</td>
<td>0</td>
<td>133 ± 9.6 a</td>
</tr>
<tr>
<td>Acacia plantation</td>
<td>44 ± 5.3 a</td>
<td>132 ± 5.9 a</td>
<td>479.9 ± 13.7 c</td>
</tr>
</tbody>
</table>

Values followed by different Roman letters are significantly different (\( P < 0.05 \)) between different sampling sites.

### Table 7 Correlation coefficient for soil parameters and earthworm species across different sampling sites in the Indogangetic plains.

<table>
<thead>
<tr>
<th>Moisture (%)</th>
<th>Temperature (°C)</th>
<th>Organic matter (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. incommodes</td>
<td>0.88 *</td>
<td>0.91 *</td>
</tr>
<tr>
<td>E. orientalis</td>
<td>0.95 **</td>
<td>0.88 *</td>
</tr>
<tr>
<td>E. nicholsoni</td>
<td>0.92 **</td>
<td>0.91 *</td>
</tr>
<tr>
<td>Glyphidrilus sp</td>
<td>0.96 **</td>
<td>0.85 *</td>
</tr>
</tbody>
</table>

\( *: P < 0.05, **: P < 0.01 \)
Temperature probably still the secondary successional stage over a time absence of original species composition in AP, as compared and Knoll (2001) and Delamini and Haynes (2004). The AAFP as has also been shown through the studies of Myers loss in species richness in the agro ecosystems, AP and the habitat, which caused a shift in species composition and Community structure.

increase in the density values during July and then a major peak of increased population density values ($F = 8.73, P < 0.05$) during September-October. This species was absent during the fallow period in 5 Yr RA but was present in the wheat crop under 10 Yr RA (Fig. 6A-D; Fig. 7 A-D).

DISCUSSION

Community structure

Conversion of natural PF to other land use types altered the habitat, which caused a shift in species composition and loss in species richness in the agro ecosystems, AP and the AAFP as has also been shown through the studies of Myers and Knoll (2001) and Delamini and Haynes (2004). The absence of original species composition in AP, as compared to PF even after a period of 15-20 years suggest that this is probably still the secondary successional stage over a time scale of 15 years (Folgarail et al. 2003). Higher species diversity in the PF could be explained to availability of diverse niches here.

Endemic versus exotics

The dominance of endemic earthworm species at all the sites could probably be explained as due to their better adaptation to local soil and climate condition (Callahan et al. 2006). This contradicts the report that native species dominate the undisturbed sites and disturbance and degradations leads to invasion by the exotic species (Callahan and Brail 1999). Resistance to invasion by exotic species here could be a function of physical and chemical characteristics of the site (Hendrix et al. 2006), and the unsuitability of the habitat probably impeded the invasion by the exotic species in the ecosystems under study (Hendrix and Bohlen 2002). Extreme degradation of agriculture ecosystems due to faulty land management practices probably led to the loss of earthworms in SE, as has also been shown through the studies of Delamini and Haynes (2004). Reclamation of degraded agro ecosystems over a period of 5 years led to recolonisation by another endemic species.

Density and biomass variations

Earthworms thrive best in moist soils and for this reason the earthworm fauna is depauperate in semi arid region of the Indogangetic plains (Julka and Paliwal 2005). The mean earthworm density in the AAFP, AP and in the PF was lower (Fig. 4) than that reported for similar ecosystems in Argentina by Thomas et al. (2004) and for the agro ecosystems in Bardsey Island by Edwards (1983). However the species richness observed in the present study falls within the range of 1 to 7 as reported for cultivated soils (Haynes et al. 2003). Land use land cover change and management practices influence abundance and distribution of earthworm species (Bhadauria and Ramakrishnan 2005); land use intensification resulted in decline in the population density and biomass of earthworms probably due to alteration of habitat heterogeneity (Myers and Knoll 2001). Higher density and biomass of earthworms in the AAFP as compared to other experimental sites was probably due to large input of easily decomposable litter layer in form of root turnover which conserves moisture and improves the soil nutrient status thus supporting higher abundance of earthworms here, this pattern has been well documented by Haynes et al. (2003) and Frouze et al. (2006). Low resource diversity with high pH and low nitrogen and organic matter could probably account for lower density and biomass in 5 Yr RA and 10 Yr RA (Delamini and Haynes 2004). The improvement in
Influence of land cover change on earthworms diversity. Bhadauria et al.

the soil condition with organic matter input into the soil through the litter fall under AP could account for improved density and biomass of earthworms as compared to 5 Yr RA and 10 Yr RA (Kimbatsa et al. 2007). The overlap of *E. incommodes* in the PF, PAE and LPAE could be due to wider ecological amplitude of this species, but conversion of PF to PAE and LPAE resulted in the lower density and biomass of this species and elimination of *E. orientalis*, this could probably be linked to canopy cover differences and type of agriculture practices as earthworms are known to be more sensitive to vegetation cover changes (Haynes et al. 2003; Frouz et al. 2006). This alters the soil microclimatic condition related to disturbance regime and tillage activity and thus to decline in number or loss of some species (Altieri
Functional guild

The conversion of PF to agro ecosystems led to a shift in functional categories from endogec to anecic dominated composition; use of organic manure and higher soil moisture percentage prior to rice crop plantation probably favored the dominance of anecic species in the LPAE and PAE (Pizl 2001). Experimental studies (Butt et al. 2004) in the reclaimed plots have shown anecics to be slow colonizers of the reclaimed sites and this could probably explain the decline in the population associated with declining soil moisture and temperature conditions in winters (Delamini and Haynes 2004; Rossi and Blanchart 2005).

CONCLUSIONS

From the results so obtained it can be concluded that land use intensification strongly influences species composition according to the land management practices, thereby leading to shift in the range of species and/or local extinction. Due to wider ecological amplitude, some species show overlap between the natural and degraded ecosystems. Resistance to invasion by exotic species could be a function of physical and chemical characteristics of the site and the unsuitability of the habitat probably impeded the invasion by the exotic species in the ecosystems under study. Functional guild changes with the change in land management practices, and endogeics dominated the disturbed and degraded ecosystems. Extreme degradation of agriculture ecosystems led to the loss of earthworms however reclamation of degraded ecosystems can lead to recolonization by some earthworm species having good adaptation to low soil nutrient condition and disturbances which in turn can further enhance soil reclamation process through their activity. From these conclusions it can be inferred that by manipulating the existing earthworm fauna through suitable management techniques under disturbed and degraded ecosystems, the soil fertility can be sustained over longer period of time.

ACKNOWLEDGEMENTS

The research was financially supported by Department of Science and Technology (D.S.T), Govt. of India. Thanks are due to Dr JM Julka (Emeritus Scientist) of Zoological Survey of India, Govt. of India for taxonomic identification of the earthworm species. The authors acknowledge the help extended by the co-ordination unit of TSBF - SARNET based at JNU New Delhi for providing the necessary literature.

REFERENCES

Blanchart E, Julka 2001 JM (1997) Influence of forest disturbance on earthworm (Oligochaeta) communities in the Western Ghats (South-India). Soil Biology and Biochemistry 29, 303-306
Seasonal variation

Seasonal variation has been shown for macro faunal assemblages for temperate (Berg et al. 1998), for tropical (Rossi and Blanchart 2005) and for semiarid region (Miranda et al. 2007), similar seasonal rhythm for all the species was also observed in our studies. The increase in the population density and the biomass of all earthworm species during the rainy season could be attributed to better soil moisture and temperature condition, with subsequent decline in the population associated with declining soil moisture and temperature conditions in winters (Delamini and Haynes 2004; Rossi and Blanchart 2005).

The research was financially supported by Department of Science and Technology (D.S.T), Govt. of India. Thanks are due to Dr JM Julka (Emeritus Scientist) of Zoological Survey of India, Govt. of India for taxonomic identification of the earthworm species. The authors acknowledge the help extended by the co-ordination unit of TSBF - SARNET based at JNU New Delhi for providing the necessary literature.


Rossi JP, Blanchart E (2005) Seasonal and land use induced variation of soil macro fauna composition in the Western Ghats (Southern India). Soil Biology and Biochemistry 37, 1093-1104


