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Land uses and its impact on community structure of soil collembola

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Abstract
In this study community structure of collembola and their seasonal abundance was evaluated along a land use intensification gradient (from the agriculture land to the natural grass cover) in a central Indian semiarid landscape. The collembola community was dominated by few abundant species, generally Isotomidae. Total abundance was highest under agriculture land use, but species diversity was more in natural grassland, silvipasture and the cultivated pasture systems.

Keywords: Arable land use, Collembola, Community structure, Grassland, Pasture, Perennial land use, Seasonal abundance, Silvipasture, Soil ecosystem

Abbreviations: AL: Arable land; **BL:** Bare land; **CP:** Cultivated pasture; **GL:** Grassland; **SP:** Silvipasture; **TP:** Open Tree Cover

Introduction

The Bundelkhand region of central India is characterized as hot semi-arid and the agrarian economy is largely livestock based. The exhausting natural grazing lands and forest are not able to meet the fodder and fuel wood requirements of the locals. The availability of crop residue is also limited (cropping period is 90-150 days a year) in this region. To meet out the demand of fodder and fuel wood, a number of improved production systems have been developed by research organization and are promoted by various developmental agencies on wastelands in this region. It is possible that the introduction of such production systems and/or the plant species may affect the soil ecosystem which may in turn influence soil biological community structure.

Soil collembola and mites constitute about 72 to 97 per cent of the total arthropod fauna of Indian soil. The collembolans due to their sedentary life reflect the local conditions of a specific habitat. The stable communities of collembola are generally associated with undisturbed natural ecosystems, while they fluctuate in anthropogenic ecosystems. The changes in their organization influence the soil fertility and productivity (Warren and Zou, 2002). They act in response to the soil physical and chemical changes, like organic matter removal (Battigelli *et al*., 2004), moisture (Wiwatwitaya and Takeda, 2005), soil pH (Ponge, 2000), vegetation pattern (Driessen and Greenslade, 2004), land uses like agriculture (Miyazawa *et al*., 2002; Roy and Bano, 2007) and forests (Yang *et al*., 2002). This study examines whether or not the introduced land uses influence diversity and dynamics of collembola in this region.

Materials and Methods

The study sites were located on red alfisol at Jhansi ($25^0$27ô N latitude and $78^0$35ôE longitude and about 275 m above mean sea level). Four perennial land uses were selected in this study; grassland (*Cenchrus ciliaris* linn, *Heteropogon contortus* (L.) Beaur. and Schult, *Panicum maximum* and bushes of *Zizyphus* sp.), Cultivated pasture (*Cenchrus ciliaris* along with legume *Stylosanthes hamata*), Open tree cover of *Albizia amara* (400 trees/ ha), no ground vegetation except some seasonal weeds in rainy season, silvipasture system (consisted of five tree species *viz*., *Azadirachta indica*, *Acacia nilotica*, *Leucaena luecocephala*, *Zizyphus* sp., *Dalbergia sissoo* and pasture stand of Guinea grass, Tri specific hybrid and legume *Stylosanthes hamata*. The arable land was for about ten months under fodder crop cultivation (cowpea + maize-Lucerne) with recommended agronomical practices. Nearby the experimental fields, a bare plot without vegetation was maintained for comparison.

The climate of this region is semi arid with temperature ranging from 39^0C in May to 5^0C in January and average rainfall of 650mm which is erratic in nature with long dry spells. The texture of the soil is sandy clay loam to sandy clay. The soil is almost neutral with 38.6 per cent water holding capacity. Soil nutrient status is in low to medium range.

Soil samples were collected at monthly interval from each of the site (up to 15cm depth) using a Cylindrical Core Sampler (diameter 5 cm). Berlese-Tullgren funnel method was used for extraction of Collembola and its identification was done as per key of Christiansen (1990).

Diversity indices were calculated by using Bio Dap3 software. The species association was calculated using cluster analysis based on the Pearson index using SPSS10 window version. To analyze the relation between collembolan and habitat diversity cluster analyses was performed for untransformed data based on average linkage between groups using squared Euclidian distance.

Results and Discussion

Community structure

A total of 2438 individuals were isolated from 432 samples taken from six land uses. Collembolans were represented by 14 taxa belonging to 5 families. *Brachystomella* (72%) was the most frequent taxa while *Folsomia candida* (33%) was the most dominant taxa (Table 1). The interspecies association based on Pearson correlation showed significant positive co-occurrence between *Folsomides purvulus* and *Folsomia candida* and between *Sminthurus parvulus* and Brachystomella (Fig. 1).

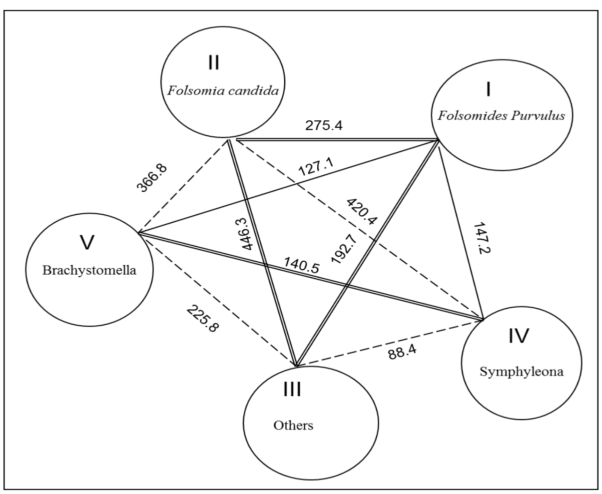

Fig 1. Positive association of common species of collembola based on Pearsonõs correlation the Euclidean distance between the clusters are shown (Double lines indicate the significant association at 1%, lighter lines indicate significance at 5% and broken lines for non-significant association)

In this study an impact of land uses was observed on the community structure of collembola (Fig. 2). When compared across the system, *Folsomides purvulus* (46%) and *Folsomia candida* (68%) were the dominant in arable land use whereas *Sminthurus parvulus* (35%) and *Brachystomella* sp. (34%) were dominant in natural grassland. This dominance pattern is more evident within systems. *Folsomia candida* occupied fifty four percent of the population in arable land use while *Brachystomella* was the dominant species of other systems (41% in bare land situation, 30% in natural grassland, 43% in cultivated pasture land, 36% in *Albizia amara* plantation and 32% in silvipasture land use).

Highest number of species was recorded in natural grassland (11 species) and six species were found in bare land situation. The diversity was low in arable (8 species) and bare land (6 species) situation in comparison to natural vegetation and the perennial systems validated by the various diversity indices (Table 2).

Based on the dominance-diversity relationship, a clear bearing of different land uses on the community structure of collembola was recognized. The slope of the regression line of grassland, silvipasture and open tree cover use are log series fit signifying mature community in which most of the species were intermediate in abundance indicative of balanced ecosystem (Fig. 3). Whereas the geometric series fits to the cultivated pasture land, bare land and arable land situations, suggesting low species richness and high dominance of few species. However the slopes of curve indicate that the resources were utilized by the collembola efficiently in all the systems. Though the species composition of cultivated pasture was almost similar to the natural grassland, but the average build up was less. This may be attributed to the age of the pasture (4 years of establishment). The recovery of adapted species in land uses depends on the time and the proximity of possible sources of immigration. The re-establishment of species in this land use is still under process and may become at par with the passage of time. The cluster analysis was carried out to separate the samples as a function of species, showing an initial division of arable land from the perennial land uses (Fig. 4), also hold up the above result.

Seasonal abundance

The highest average population of soil collembola was recorded in arable land use (71.40 x $10^2/m^2$) followed by grassland (47.51 x $10^2/m^2$), silvipasture (21.70 x $10^2/m^2$), cultivated pasture land (17.67 x $10^2/m^2$) and open tree cover area (11.66 X $10^2/m^2$). Lowest population was found in bare land situation (2.40 x $10^2/m^2$). The peak population built up was observed during rainy season and lowest was found during summer months in all the systems (Table 3).

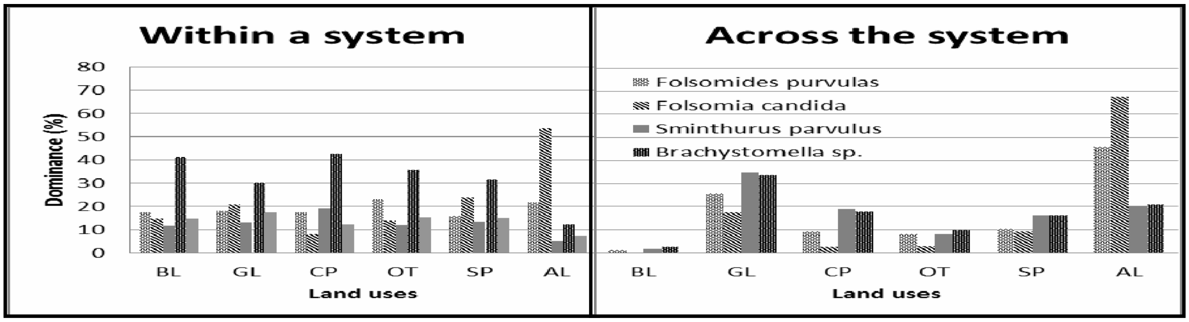

Fig 2. Dominance pattern of collembola within and across the land uses

Similar type of seasonal dynamics was reported in *Hardwickia binata* Roy *et al.* (2003a), *Acacia tortilis* (Roy *et al.*, 2003b), *Albizia amara* (Roy *et al.*, 2005) based silvipasture systems. Roy and Roy (2006) have analyzed spatial distribution and seasonal abundance of soil mites and collembola in grassland and *Leucaena* plantation and reported seasonal variation in abundance in these systems. Ponge *et al.*, (2003) reported that the collembola population was not significantly reduced in cereal crops in spite of heavy disturbances by deep ploughing, pesticides and absence of plant cover over a large part of the year when compared with the hay meadows. They reasoned that due to the vertical distribution of collembolan population following annual ploughing and burying of crop residues have synchronized their population dynamics with the cycle of changes. Many other studies reported an impoverished community of collembola in the agriculture sites and a clear separation of collembola taxonomic spectrum between agriculture site and other land uses (Sousa *et al.*, 2002; Tripathi *et al.*, 2005).

In this study, it may be concluded that the community differs between low land disturbances (natural grass cover) to high disturbances (high input arable land use), but there was no negative impact of the land uses on the community structure of collembola.

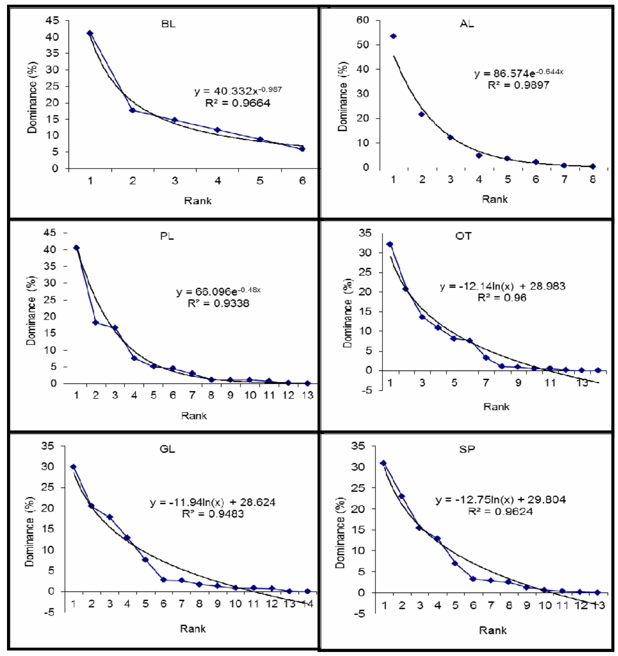

Fig 3. Community rank abundance of collembola in different land uses

(BL= Bare land, GL = Natural Grassland, CP = Cultivated pasture, OT = Open tree cover, SP = Silvipasture, AL = Arable land)

Table 1. Dominance and frequency of collembola across the production systems

Family	Genera	Dominance (%)	Frequency (%)
Isotomidae	*Folsomides purvulus*	9.6	29.7
	Folsomia candida	32.9	44.4
	Proisotoma minuta	10.0	30.0
	Isotomurus sp.	0.6	9.0
	Isotomina thermophila	0.5	10.4
Neauridae	*Brachystomella* sp.	24.9	72.2
Poduridae	*Sensiphorura* sp.	2.7	4.2
Entomobryidae	*Lepidocrytus* sp.	2.1	22.2
	Orchesella sp.	1.8	15.3
	Entomobrya sp.	0.9	8.3
	Seira sp.	0.0	1.4
Sminthuridae	*Neosminthurus* sp.	1.8	8.3
	Sminthurus parvulus	10.3	34.7
	Sphaerida biniserrata	1.9	6.9

Table 2. Diversity indices of collembola associated with different land uses

Indices	BL	GL	CP	OT	SP	AL
Number of species	6	11	10	8	10	8
Margalef	1.85	2.70	2.44	2.04	2.51	1.79
E	0.93	0.91	0.88	0.82	0.89	0.95
Hó	1.67	2.18	2.03	1.7	2.06	1.97
Simpsonõs Index	0.15	0.11	0.14	0.2	0.13	0.13
1 / Simpsonõs Index	6.56	8.82	7.22	5.11	7.78	7.75
Mean Abundance (10^2/ m^2)	2.4	47.51	17.67	11.66	21.7	71.4

(BL= Bare land, GL = Grassland, CP = Cultivated pasture, TP = Open Tree Cover, SP = Silvipasture, AL = Arable land)

Table 3. Seasonal population built up of soil inhabiting collembola (10^2/ m^2) in various systems

Months	BL	GL	CP	OT	SP	AL	SE ±
Jan	4.24	93.32	55.99	10.18	9.33	82.29	6.65
Feb	-	5.09	6.79	8.48	17.82	78.9	4.94
Mar	1.7	9.33	5.09	2.55	8.48	-	0.63
Apr	-	2.55	2.55	3.39	2.55	-	0.24
May	-	-	1.7	0.85	-	5.09	0.33
Jun	-	-	-	-	-	-	na
Jul	10.18	13.57	24.6	33.09	6.79	353.76	22.6
Aug	5.94	282.5	43.27	38.18	137.43	111.98	16.78
Sep	-	100.1	23.75	21.21	44.96	99.26	7.06
Oct	-	27.15	21.21	6.79	6.79	35.63	2.31
Nov	5.09	32.24	23.75	9.33	21.21	31.39	1.87
Dec	1.7	4.24	3.39	5.94	5.09	58.54	3.69
SE±	0.27	6.81	1.49	1.05	3.21	8.14	

(BL= Bare land, GL = Grassland, CP = Cultivated pasture, TP = Open Tree Cover, SP = Silvipasture, AL = Arable land)

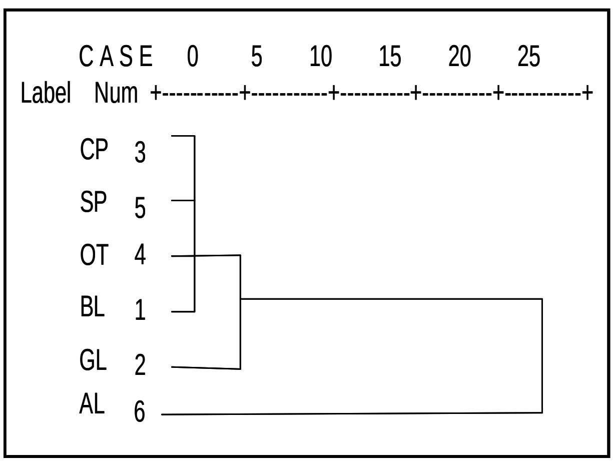

Fig 4. Land use assessment based on similarity of collembolan communities (BL= Bare land, GL = Natural Grassland, CP = Cultivated pasture, OT = Open tree cover, SP = Silvipasture, AL = Arable land)

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