Tropical and Subtropical Agroecosystems, 11 (2009): 415- 422

Tropical and Subtropical Agroecosystems

COLLEMBOLA RICHNESS AND DIVERSITY ALONG A LAND-USE INTENSITY GRADIENT IN TAITA, KENYA

[RIQUEZA Y DIVERSIDAD DE COLLEMBOLA EN UN GRADIENTE DE USO DEL SUELO Y FACTORES ABIOTICOS EN TAITA, KENIA]

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SUMMARY

Soil Collembola communities were sampled along a gradient of land use intensification in Taita-Taveta, Wundanyi division, Coast Province during the wet season (October-November 2007) and dry season (February- March 2008). This gradient ranged from Natural undisturbed land use to intensively cultivated (disturbed) horticulture fields. The eight land use types (LUTs) were stands of (1) *Pinus patula*, (2) *Cypress lusitanica*, (3) Indigenous forest, (4) Fallow, (5) *Pennisetum purpureum*, (6) horticulture fields, (7) *Coffea africana* and (8) *Zea mays* intercropped with *Phaseolus vulgaris*. The dynamic behavioural modified Berlesse funnel technique was used for collembolan extraction from soil. Collembola were identified to genus level. 11462 individuals per m² were identified from 30 genera. Generally, low Collembolan population were recorded in the wet season of 2007 with density of 2618 individuals per m² compared to density of 8844 individuals per m² in the dry season of 2008 sampled in all the land use types (LUUs). The highest Collembolan population was recorded in *Cypress lusitanica* with a density of 3781 individuals per m² and lowest in *Zea mays* intercropped with *Phaseolus vulgaris* with a density of 198 individuals per m². A total of 30 genera in 11 families were recorded. The genus *Cryptopygus* was the most commonly sampled followed by *Thalassaphorura*, *Parisotoma*, *Lepidocyrtus* and *Folsomides* (37.2%, 17.7%, 8.5%, 6.1% and 5.5%) respectively. Land use type like *Pinus patula*, *Cypress lusitanica*, and *Pennisetum purpureum* had high carbon, nitrogen and acidity, supported high numbers and diverse Collembolan assemblages. The results show that both density and diversity of soil the Collembolan communities were higher in undisturbed sites than in disturbed land use types. In conclusion the Collembolan communities are negatively impacted by land use intensification.

Key words: Collembola, land use types, agricultural intensification

INTRODUCTION

The status of biodiversity in terrestrial environment is influenced by forces that cause change in land-use, land fragmentation, agricultural intensification, urbanization, afforestation and re-forestation (Sousa *et al*., 2004). Soil organisms are important components of agroecosystems and they are of great importance in nutrient turnover and soil structure. (Hendrix *et al*., 1990). Among the mesofauna, soil Collembola were chosen in the present as a study group due to their known influence in the soil systems in terms of feeding relations, decomposition of organic material and their ability to respond to a wide range of disturbance forces.

Generally, despite their environmental importance, basic information on the occurrence, diversity patterns induced by land use intensification and ecology is lacking (Andre *et al*., 1994, Ponge *et al*., 2003). Inventories on above-ground biodiversity have been documented in Taita, Kenya, but, none exists for below ground organisms (Moreira *et al*., 2006). The purpose of the current study was to (i) to determine the abundance and diversity of soil Collembola in different land use types (ii) determine the effect of soil parameters on the abundance of the soil Collembola.

MATERIAL AND METHODS

Study sites, experimental design and sampling

The study was conducted in Taita-Taveta district in Coast Province during the wet and dry season of

October 2007 and February 2008 respectively. Taita-Taveta, bench mark sites are in Taita district, Werugha location of Wundanyi division along valley bottoms of Werugha and Ngangao forest, of Taita hills. The hills are in isolated location and comparatively stable conditions containing unique assemblages of fauna and flora with high levels of endemism (Mwanyumba and Mwangombe, 1999). The International conservation has identified the area as top–ten biodiversity hotspots in the world (Clark and Pellika, 2005). Due to increased land pressure, the forest area is under serious threat from land fragmentation as well as intensive agricultural farming in its environment leading to loss of biodiversity. Hence, the urgent need to document the status of soil fauna before it gets lost.

The sites lie approximately along longitude 0 38 ° 15´E and 0 3° 20´S. Soils are deep, well drained dark brown and vary from sandy clay loam to clay. They are mainly Haplic Acrisol, Chromic Luvisols, Regosols and Eutric Canisols. A total of eight land use types located using GPS systems (Swift and Bignell, 2000) were sampled in the study site.

The land use types (LUTs) comprised of (1) *Pinus patula* (Pinaceae), (2) *Cypressus lusitanica* (Cupressaceae), (3) indeginous forest predominated by *Strombosia scheffleri* (Olacaceae), *Dicralonepsis usambarica* (Thymelaceae) and *Oxyanthus speciosa* (Rubiaceae), (4) fallow predominated by *Lantana camara* (Verbebaceae) and *Sporobolus pyramidalis* (Poaceae), (5) napier grass *Pennisetum purpureum* (Poaceae), (6) Horticulture fields predominated by (*Brassica oleraceae*) (Brassicaceae), (7) *Coffea arabica* (Rubiaceae) and (8) *Zea mays* (Poaceae) intercropped with *Phaseolus vulgaris* (Fabaceae).

The land use types in the study site range from undisturbed forest land use types to disturbed agricultural land use types. The sampling points in each area representing a land use type were established at fixed intervals of 200 m apart along a transect. At the sampling point in each land use type, twelve sub-samples were collected from different points and composed into three samples (Figure 1). There were four replications in each land use type. At each sampling point, Collembola were sampled by taking a soil core of 5 cm diameter and at a depth of 5 cm including the organic horizon. Collembola were extracted using dynamic behavioral modified Berlese funnel and were identified to the genus.

Data analysis

Data collected were averaged per sampling point and later per land use types. The means for the land use types, with respect to the chosen attributes, were compared, using the analysis of variance (ANOVA). Pair-wise comparison of the means were performed after the ANOVA using Fisher test criterion. Prior to analysis, data were normalised using log transformation. The biodiversity descriptions estimated include genera abundance, Shanon and Rényi index. Principal Component Analysis (PCA) was later conducted to deal with dimensionality and visualise the interrelations between the variables. Relationship between biodiversity and descriptors, soil chemical parameters and land use type were explored using Principal Component Analysis.

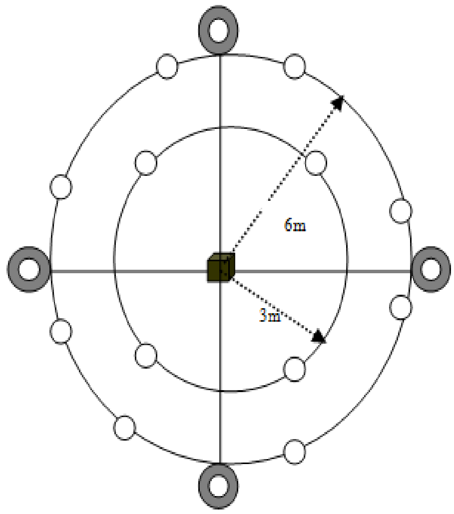

Fig. 1. Lay out of a sampling point in the site. The sampling point in the middle of the circles shows the location of the monolith where other data on below ground biodiversity were collected. The lighter circles outside the monolith show the points at which core samples of both mites and Collembola were sampled**.**

RESULTS

Eight thousand six hundred and thirty eight of soil dwelling Collembolan individuals were identified and grouped into eleven families and thirty genera. The family Isotomidae was the most frequently sampled, with a cumulative frequency of 61.6% followed by the family Onychiuridae 19.2%. The genera occurrence was as follows *Cryptopygus* (37.7%), *Thalassaphorura* (*17.7%*), *Parisotoma* (8.5%), *Lepidocytus* (6.1%), *Folsomides* (5.5%), *Isotomiella* (3.8%), *Folsomia* (3.5%), *Hypogastrura* (3.4%), *Ceratophysella* (3.2%), *Folsomina* (3.1%), the rest of the genera had a frequency of less than 3% (Table 1). Nine of the eleven families sampled belonged to the sub-class Arthropleona while, the rest belonged to the Sub-class Symphypleona.

Table 1: Frequency of occurrence of soil dwelling Collembola in different land use types during the wet and dry seasons (2007-2008) in Taita, Kenya.

Genera	No of Collembola	Frecuency
Cryptopygus	3210	37.2
Thalassaphorura	1525	17.7
Parisotoma	732	8.5
Lepidocyrtus	531	6.1
Folsomide	475	5.5
Isotomiella	324	3.8
Folsomia	306	3.5
Hypogastrur	296	3.4
Ceratophysella	275	3.2
Folsomina	272	3.1
Oncopodura	131	1.5
Tullbergia	118	1.4
Tomocerus	75	0.9
Cyphoderus	70	0.8
Psuedosinella	69	0.8
Coecobrya	62	0.7
Entomobrya	44	0.5
Odontella	43	0.5
Heteromurus	16	0.2
Pseudachorutes	14	0.2
Seira	12	0.1
Sminthurus	9	0.1
Sminthurinus	8	0.1
Brachystomella	6	0.1
Onychiurus	6	0.1
Xynella	2	0.0
Protaphorura	2	0.0
Subisotoma	2	0.0
Kalaphorura	2	0.0
Sinella	1	0.0
Total	**8638**	**100**

The eight land uses were not significantly different in terms of mean densities in year 2007 wet season p=0.547, though in napier LUT a high mean density of 4911.54 individuals (m²) was recorded while, the lowest mean density of 987.26 individuals (m²) was recorded in land use under maize (Table 2). There were difference in mean richness and mean Shannon in LUTs between pine and maize (p=0.013), pine and horticulture (p=0.013), pine and maize (p=0.038) though generally there was no difference in mean richness (p=0.215) and mean Shannon (p= 0.378). The highest mean densities were recorded in napier followed by pine (Table 2). The eight LUTs showed significant differences in their mean density in the dry season of year 2008 (p<0.001). At that time the highest density recorded was in cypress 26709.12 individuals (m²) and the lowest in maize 538.86 individuals (m²) (Table 3). The mean richness and mean Shannon did not show significant difference between each pair of the land uses (p=0.126 and p=140) respectively though, there was difference in mean richness between the following LUTs; pine and maize (p=0.003), pine and coffee (p=0.032), indigenous forest and maize(p=0.007), pine and maize (p=0.008), napier and maize (p=0.038), horticulture and maize (p=0.037) (Table 3). The results indicate that the genera *Cryptopygus, Folsomides, Hypogastrura, Ceratophysella and Lepidocyrtus* were found in all LUTs while, *Xynella, Subisotoma, Kalaphorura, Protaphorura, Onychiurus, Seira, Brachystomella* and *Sinella* were found in specific LUTs (Table 4).

Table 2. Effect of land use on density (m²), richness and diversity of Collembola in the wet season (2007) in Taita, Kenya

LUT	Density	Richness	Mean Shannon
Napier	4911.54 ±4295.84a	5.33 ±1.86a	1.42 ±0.35a
Pine	4734.60 ±1846.23a	7.25 ±0.63ab	1.57 ±0.15ab
Cypress	3301.48 ±725.68a	4.75 ±0.63ab	1.23 ±0.14ab
Fallow	3025.47 ±178.44a	5.25 ±1.1.70ab	1.19 ±0.41ab
Indigenous	2558.38 ±1349.30a	4.75 ±1.11ab	1.23 ±0.22ab
Coffee	2091.29 ±992.87a	4.25 ±1.03ab	0.97 ±0.22ab
Horticulture	1125.26 ±824.41a	3.00 ±0.83b	0.82 ±0.27ab
Maize	538.86 ±308.83a	3.00 ±1.08b	0.76 ±0.29b
F-value	0.866	1.504	1.132
Df	7.23	7.23	7.23
P-value	0.547	0.215	0.378

Means in the same column followed by the same lower case letter are not significantly different (Fisher test, p≤0.05), LUT = Land Use Type

The diversity profiles of the soil dwelling Collembola in the eight LUTs show that fallow, indigenous forests, cypress and pine exhibited the highest diversity, followed by horticulture, then napier with the least diversity realized in maize (Fig. 2a,b). Forest ecosystems highest diversity with least recorded in agro-based ecosystem *Cryptopygus, Thalassaphorura, Parisotoma, Lepidocyrtus, Folsomia, Coecobrya, Xynella, Cyphoderus, Sinella, odontella, Folsomides, Pseudosinella,* while, *Subisotoma, Tullbergia, Protaphorura, oncopodura* were common in agro-based ecosystems.

Table 3. Effect of land use on density (m²), richness and diversity of Collembola in the dry season (2008) in Taita, Kenya

LUT	Density	Richness	Mean Shannon
Cypress	26709.12 ±3291.66a	4.000 ±0.408a	0.9630 ±0.005a
Pine	21231.14 ±5075.80a	5.750 ±0.946ab	1.3192 ±0.163a
Napier	10884.64 ±8025.31b	4.667 ±1.202abc	1.2010 ±0.154a
Fallow	6942.67 ±1877.87bc	4.250 ±0.250abc	1.1140 ±0.039a
Indigenous	4129.51 ±495.61bc	4.750 ±0.479abc	1.3327 ±0.088ab
Horticulture	2038.21 ±1065.38bc	4.000 ±0.913abc	1.1643 ±0.266ab
Coffee	1061.15 ±361.72c	3.500 ±0.645bc	1.0860 ±0.179ab
Maize	987.26 ±316.99c	2.500 ±0.645c	0.6480 ±0.231b
F-value	9.912	1.849	1.782
Df	7,23	7,23	7,23
P-value	0.001	0.126	0.140

Means in the same column followed by the same lower case letter are not significantly different (Fisher test, $p \leq 0.05$), LUT = Land Use Type

Soils in forest LUTs were acidic and had high carbon and nitrogen levels while, cultivated LUTs had a high pH, low acidity, carbon and nitrogen levels. High soil Collembola populations were recorded in undisturbed land use like Pine, indigenous forest, Cypress and less disturbed LUTs like fallow where there was high acidity, shade, moisture and humus (organic matter) Figure 3a,b and 4a,b.

DISCUSSION

The biota resident in the upper 0-5cm depth of the soil reflected the current land use practice in Taita. The high abundance of soil Collembola in the undisturbed land use type (forests and fallow) recorded, corroborates with other studies by Filser *et al*., 1995; Salamon *et al*., 2004; Sousa *et al*., 2005 that, abundance of epiedaphic Collembola is influenced by site properties which include quality of litter, land management practice and abiotic parameters. Though, soil Collembola were found in all LUT sampled, higher numbers were found in forest/undisturbed/less disturbed/stable land uses. Plant and plant diversity, abiotic parameters of the organic horizons of the soil determine functioning of below ground ecosystems (van Noordwijk and Swift, 1999). Probably, microhabitat configuration, especially in terms of shade, moisture conditions, and /or organic matter quantity and quality influenced survival of Collembola. Though, the organic matter quality was not determined, the present results indicate that plant community, stability of LUT and nature of the organic matter influence abundance and richness of Collembola as shown by the high numbers recorded in LUTs under pine, cypress, napier and few numbers recorded in LUTs under coffee, horticulture and maize based. Thick litter layer, shade/plant cover/absence of tillage in pine, cypress and indigenous forest land uses may have provided micro-climatic factors inclusive of increased nutrient availability facilitating soil species coexistence through either resource partitioning or increased physical niche (Bardget *et al*., 2005). Thus, the high densities recorded in the land uses in the two sites in both seasons.

Filser *et al*., (2002), working in arable landscape of Southern Germany, found that the highest abundance of certain Collembola taxa like; *Protaphorura armata*, *Isotoma viridis* and *Isotoma fucicolus* was in wet grassland and arable land where green manure and high organic matter was high. This may be attributed to increased microbial biomass, high nutrient content hence reducing competition and allowing resource partitioning. Similarly, Lageröf and Andrén (1991) and Mäder *et al*., (1997), found that arthropod taxa are generally high at high weed biomass, high organic input or organic farming. The high numbers recorded in napier land use may be attributed to less disturbance, accumulation of organic matter from drying leaves and the application of animal manure in the plots to replenish depleted nutrients. Though, effect of soil moulding, compaction and application of pesticides were not evaluated, previous studies carried by Heisler and Kaisser, 1995, Sousa *et al*., 2005 showed that abundance reduces with increase in frequency cycle of disturbance and coarse scale environmental heterogeneity arising from land use can influence diversity. The disturbance may create additional niche space, refuges and passive dispersal of soil fauna. Hence, the genera richness realised in the present study.

Collembola have a free running life cycles usually requiring at least two years per generation. Among other environmental factors temperature influence the rate of Collembola development (S□mme, 1999). On this study our finding of significant difference in the dry season and high abundance during the season is surprising: hypothesising a seasonal life cycle development. In the current study a higher Collembola abundance was recorded in the dry season of 2008 than in the wet season of 2007. There was extensive dry spell in 2006 and early 2007 while, during the study period there were light and sporadic rains realised during the wet season. The extensive dry season coupled with high temperatures may have caused high mortality of Collembola or influenced their temporal vertical migration hence the low Collembolan abundance preceding during the wet season. In the dry season of 2008 a higher population was recorded, this may be due to species regeneration rate in the late wet season and availability of food resource from organic matter resulting from the dry plant residuals. The current study has found that the family *Isotomidae* was the most predominant in all land uses. Launga-Reyrel and Deconchat, 1999 reported a similar pattern for coppice forests in France. The dominant *Isotomidae* represented a high reproductive rate, temperature tolerance and adaptive ability. These adaptive features of Collembola may explain why some genera were able to colonise different land uses and the numbers were high even during the dry season.

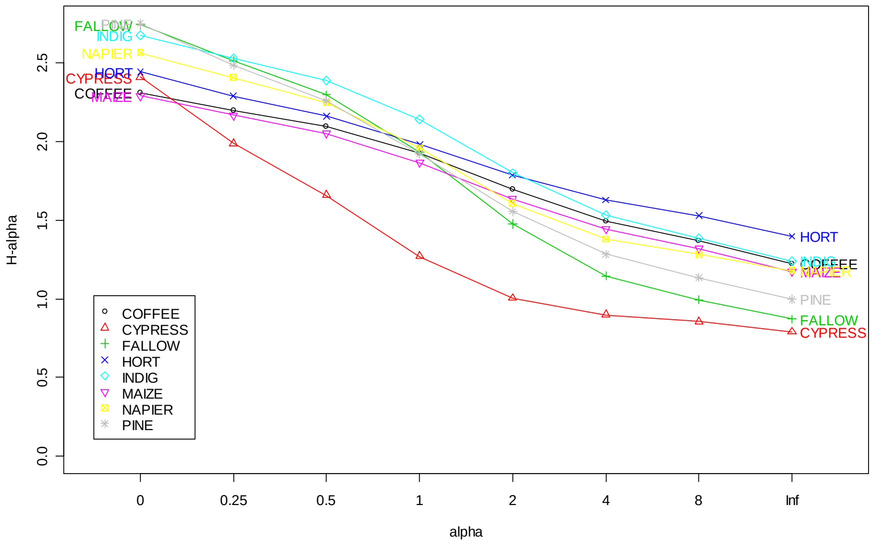

Figure 2a: The diversity of Collembolans in different land use types in Taita (Rényi diversity profiles)

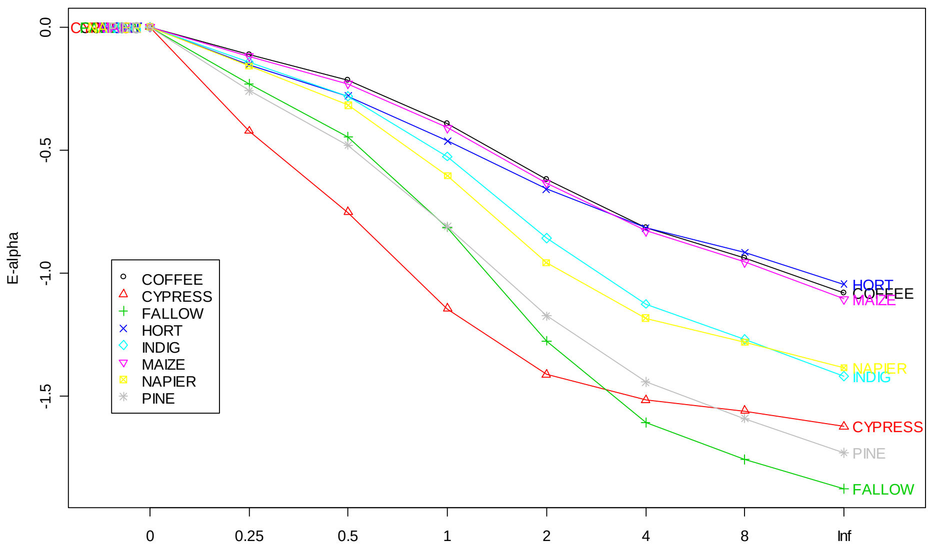

Figure 2b: The evenness profiles of Collembolans in different land use types in Taita (Rényi evenness profile)

Table 4:List of Collembolan individuals per genera found in the study site in Taita, Kenya in the different land use type during the wet season (October-November 2007) and dry season (February- March 2008).

	Land		Use		Type			
Taxa	Coffee	Cypress	Fallow	Horticulture	Indigenous	Maize	Napier	Pine
Cryptopygus	36	1268	403	57	178	44	340	884
Folsomides	5	82	103	57	21	31	126	50
Folsomina	0	20	35	2	76	0	29	110
Parisotoma	15	0	91	22	34	4	54	512
Isotomiella	0	0	13	0	29	0	12	270
Folsomia	85	0	0	15	17	19	42	128
Subisotoma	0	0	0	0	2	0	0	0
Xynella	0	2	0	0	0	0	0	0
Hypogastrura	16	73	9	52	57	12	45	32
Ceratophysella	17	3	1	46	109	0	28	71
Tullbergia	49	0	20	2	16	17	14	0
Kalaphorura	2	0	0	0	0	0	0	0
Protaphorura	0	0	0	0	0	2	0	0
Thalassaphorura	0	1132	43	12	12	9	317	0
Onychiurus	0	0	0	0	6	0	0	0
Lepidocyrtus	12	127	118	16	34	2	15	207
Pseudosinella	0	3	1	0	0	0	0	65
Coecobrya	0	47	0	0	0	0	0	15
Seira	0	0	0	0	12	0	0	0
Entomobrya	7	0	20	0	0	0	0	17
Heteromurus	0	0	14	2	0	0	0	0
Sinella	0	1	0	0	0	0	0	0
Tomocerus	0	3	33	0	12	0	0	27
Odontella	0	0	10	0	0	0	22	11
Oncopodura	53	0	7	2	0	6	62	1
Sminthurus	0	0	7	0	0	2	0	0
Sminthurinus	0	0	7	1	0	0	0	0
Pseudachorates	0	0	0	0	0	0	0	14
Cyphoderus	0	66	0	0	0	0	0	4
Brachystomella	0	0	0	0	6	0	0	0

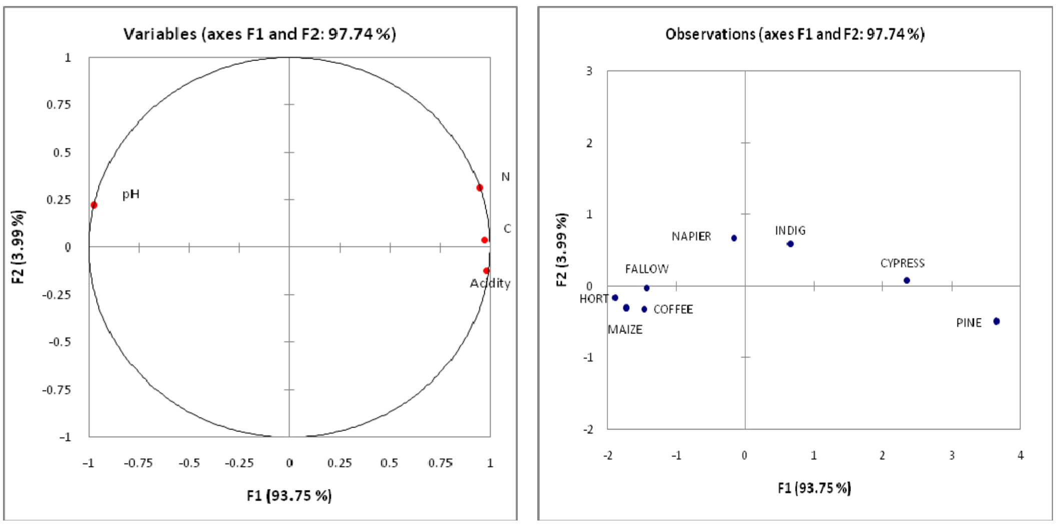

Figure 3a and 3b: Principle Component Analysis representing soil chemical parameter descriptors and land-use metrics.

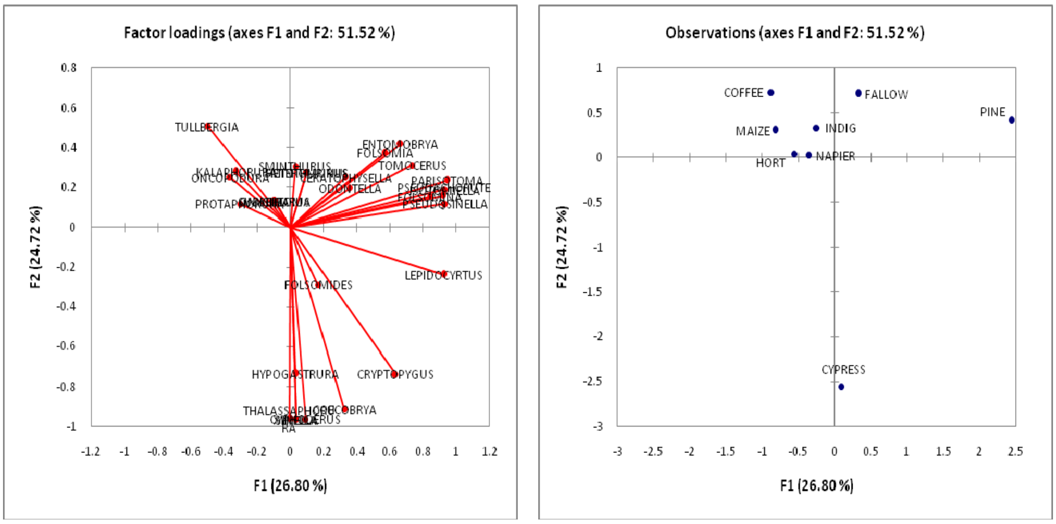

Figure 4a and 4b: Principal Component Analysis representing biodiversity descriptors and land-use metrics

The relationship between species and soil factors lying behind the difference in Collembola community between land uses is quite visible in the out come of Principal Component Analysis in the study (Fig 4 a, b). The distributions of the genera correlate with land use and soil parameters. Changes in soil chemistry (soil acidity associated factors) influence species composition of most soil animal communities (Ponge, 1993), but, effect is primarily on species in permanent contact with organic matter (Ponge, 1993). Collembola communities respond to changes in soil chemistry namely soil pH, microclimatic and microhabitat conditions like moisture, humus type and amount and quality of litter (Coffin and Urban, 1993, Ponge, 2000, Chagnon *et al*., 2000, Loranger *et al*., 2001, Pflug and Wolters, 2001, Hasegawa, 2002). The high number of Collembola collected from the land uses with high acidity, carbon and nitrogen like pine and cypress revealed their effect in influencing diversity and density.

In conclusion, this study has provided baseline information on the abundance and diversity of Collembola in Taita, Kenya. The study also reveals that Collembolans are highly influenced by physical-chemical changes of the soil and they can be suitable indicators of land use intensity gradient. However, more studies on their resilience in degraded tropical habitats are needed in order to establish viable conservation strategies.

Acknowledgement

Special thanks to Dr. Sheila Okoth, the Below Ground Project Coordinator in Kenya for her enviable support throughout the study period. We sincerely thank Dr. Arne Fjellberg and Prof. Louis Deharveng for assisting in the systematic of Collembola. Special thanks are also extended to Dr. Peter Wachira, Mr. Crispus Maribie Wambugu and Mr Josek Mugendi for their technical support.

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Submitted October 07, 2009– Accepted January 14, 2010
Revised received