International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 5, No. 2, p. 114-123, 2014

RESEARCH PAPER OPEN ACCESS

Seasonal dynamics and land use effect on soil microarthropod communities in the Mid-hills of Nepal

Farida Begum[1, 2*], **Roshan Man Bajracharya**[2], **Bishal Kumar Sitaula**[3], **Subodh Sharma**[2], **Shaukat Ali**[1], **Haibat Ali**[1]

[1] *Department of Environmental Sciences, Karakoram International University, Gilgit Baltistan, Pakistan*

[2] *Department of Environmental Sciences and Engineering, School of Science, Kathmandu University, Dhulikhel, Kavre, Nepal*

[3] *University of Life Sciences, Ǻs, Norway*

Article published on August 30, 2014

Key words: Biological indicators, soil organic carbon, soil biological quality, microarthropods, moisture.

Abstract

The study addressed the influence of seasons and land use on soil microarthropod communities. Soil fauna were grouped into three categories, i.e., Collembola (20%), Acari (59%) and other microarthropods (21%). The densities of total microarthropod, Collembola, and Acari were highly significant with seasons. Shannon Index and QBS-ar were also significant with seasons while with the land use change density of Collembola and Shannon Index were weakly significant. Highest average densities of Collembola (60%), Acari (54%), other microarthropods (55%) and QBS-ar were observed in the forest as compared to agriculture. Pearson's correlation indicated that bulk density, soil temperature and pH were significantly negatively correlated with biological indicators except Shannon Wiener Index. Most of the investigated biological indicators were positively correlated among each other. Seasons had greater influence on biological indicators than the land use change. This research indicated that soil microarthropods appear to be consistent and potentially a good indicator for assessing the impact of land use practice and seasons on soil quality. However long term research is required to fully understand the impact of different agricultural practices and seasons on soil faunal abundance, diversity and community structure for the conservation of soil biota as well as assessment of soil quality.

* **Corresponding Author:** Farida Begum ✉ farida.shams@kiu.edu.pk

Introduction

Soil is one of the most essential and diverse natural habitat of biodiversity on earth. Soil fauna constitute 23% of the total diversity of living organisms (Decaens *et al.*, 2006). Among soil biota microarthropods are considered to be one of the very important biotic components of soil ecosystem being actively involved in decomposition, nutrient cycling, changing the soil structure, improving soil fertility, and, thus influencing the overall soil health or quality. These ecosystem services are important for the sustainable functioning of our planet. However soil fauna has not received much attention from soil ecologists despite their important ecological role. In many ecosystems the influence of seasons and land use change has not been addressed adequately. As micro- arthropods live in the soil, and are sensitive, as well as, dependent on its ecological conditions, and respond to disturbance of soil structure, they could be good biological indicators of soil conditions. Biological indicators of soil quality have the capacity to integrate across a range of factors that might affect soil health (Webster *et al.*, 2001).

According to the published data, soil micro arthropods are considered to be indicators of the state of soil conditions or health (Gardi *et al.*, 2002, Lavella *et al.*, 2006, Lee *et al.*, 2009, Parisi *et al.*, 2003 and 2005 , Paolo *et al.*, 2010 and Rombke *et al.*, 2006). In soil ecosystems, the status of soil biota at local and regional scales is influenced by different driving forces, such as forestry, agriculture, urbanization and seasonal fluctuation. These forces causes changes in land use ,soil moisture, temperature, bulk density, SOC and other physio-chemical factor which directly or indirectly affect density and diversity pattern of soil biota . Many soft bodies animal such as Collembola and Enchytraeids are sensitive to desiccation during dry condition (Didden, 1993, Verhoef, 1980). Temperature fluctuation during different seasons commonly induces vertical movement of soil animals in the soil profile (Didden, 1993, Luxton, 1981). To avoid drought conditions soil biota move vertically deeper into the soil or redistribute to moisture patches (Didden, 1993, Verhoef, 1983). Seasonal differences in the abundance of soil arthropods have been studied by various workers (Badejo, 1990; Badejo, and Straalen, 1993, Lasebiken, 1974 and Usher, 1975). Their findings reported that microarthropods undergo enormous fluctuations in densities, due to changes in microenvironment and thus water is a primary abiotic factor influencing population size (Badejo, 1990). However, the mechanism of the population dynamics of microarthropods in the soil ecosystem is complex, often without a sole environmental factor that can explain the variation of micro arthropods population (Miyazawa *et al.*, 2002).

Modern agricultural practices, such as, use of heavy machinery for tillage operation, chemical fertilizers, and pesticides, have led to severe impacts on the soil ecosystem. Among these impacts the reduction in soil biodiversity and degradation of soil quality are often viewed as major threats for the future (Solbrig, 1991). Conversion of natural vegetation into agro ecosystems and agriculture intensification, have profound impact on soil communities because they involve changes within the primary determinants of soil biodiversity, e.g., vegetation and microclimate (Decaens and Jimenez, 2001, Wall *et al.*, 2001). Land use change and agricultural intensification generate severe habitat degradation or destruction for soil biota (Decaens *et al.*, 2006). Intensified agri-farming deteriorates the soil key processes and resulting negative impact on soil, hydrological processes, detoxification, gas exchange, structure and recycling of organic matter (Rana *et al.*, 2010).

Agricultural intensification, cultivation of marginal lands, and intensive use of the forests have been identified as the factors that lead to soil fertility problems in the middle mountains of Nepal, that might have direct or indirect effects on the soil biota. Land use change is rapid in the developing countries, especially in the Hindu Kush Himalayan (HKH) region due to biophysical and socioeconomic factors (Upadhyay, 2006). Therefore, it is imperative that ecologist develop sound methods for monitoring, assessing and managing ecological integrity, and evaluating temporal changes in habitat structure, function and composition in response to natural factors, human activity or management practices (Paolo, 2010). Studies to determine the seasonal dynamics and land use influence on soil microarthropods in the Nepal Himalaya are very few. Little has been documented about the relationship between soil fauna and their abiotic environment.

Thus, the objectives of our study were: to evaluate the influence of land use practice and seasonal variations on soil faunal densities, diversities and biological soil quality index i.e. QBS-ar; and to investigate the relationship among soil biological and phyico-chemical indicators.

Materials and methods

Study Area

The study was carried out at Khasre village N 27° 41’ and E 085° 32’ under VDC Nayagaun about 9-10 km away from Nagarkot a famous tourist destination of Bhktapur district of Nepal (Figure 1). The climate of the area is subtropical monsoon with an annual average rainfall of 2105mm (1995-2005 data was taken from climatological record of Nepal), most of the rainfall (80%) occurring from May to September. The average maximum air temperature was 19.96°C and minimum 10.43°C during the period of 1995-2006. Two sites agriculture and forest land were selected for the main study, as it was considered that they would show the two extreme of the fauna. Dominated forest species were *Castanopsis indica*, *Gaultheria fragrantissma*, *Alnus nepalensis*, *Eupetorium odinophorium*, *Schima wallichi*, Eucalyptus species, *Prunus cerosoides* and *Listea monopotella*. Their major crops are Rice, wheat, maize, and among vegetables Cauliflower, mustard, Potato, cabbage etc. and usually grows two crops annually.

The site is on a North-West slope and both agriculture and forest soils were on back-slope positions of the landscape. The bedrock underlying the agricultural land consisted of quartzite and schist and parent material was colluvial deposits, while in the forest bedrock type was schist, phyllite and sand stone and the parent materials was made up of weather rock. The texture of the soil was loam for both land use type.

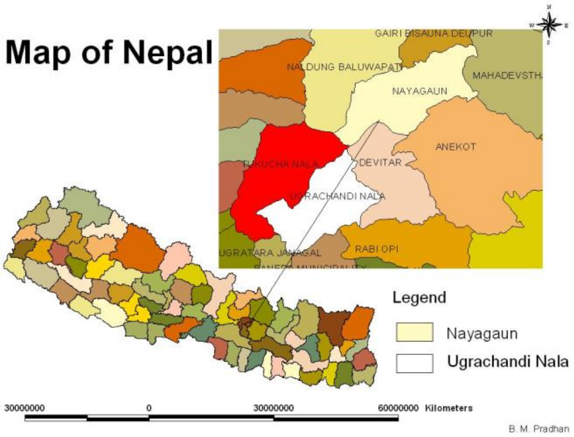

Fig. 1. Map of Nepal indicating study area, Bhktapur district, VDC Nayagaun.

Soil morphological characteristics at the study sites

The morphological characteristics of the land use system are presented in Table 1. The soil depth under different land use systems varied considerably. The deepest soil profile was observed in cultivated soil. The variations in soil depth under different land use systems was attributed to the variation in relief and slope, which influences soil formation and development through its effects on runoff and erosion/deposition processes. However, the B horizon was well developed in both land use systems. Similarly, there were colour variations among the surface soil horizons of different land use types. There were very dark grayish brown colours of surface horizon of the forest land as compared to brown in agriculture soils, which may be due to differences in organic matter contents.

There also were differences in soil structure among the different land use systems. Agriculture soils had moderate medium granular sub-angular blocky structure, while forest land had weak medium granular to weak fine sub-angular blocky structure in the surface horizon (Table 1).

Sampling design

The study was conducted during April (pre-monsoon) and October (post-monsoon) 2009 and January (winter) 2010 under two different land use practices in the mid-hills of central Nepal. During the first sampling five replicate soil samples were taken randomly from each land use type using a quadrate size 10*10*10 cm, but in subsequent seasons six replicates were taken from each land use practice. An extra set of soil samples from the top 10cm were taken for physiochemical properties. Extraction of soil fauna was performed using Modified Berlese-Tullgren Funnel (Coleman *et al.*, 2004).

Once the extraction was completed, the organisms were observed under stereomicroscope at low magnification 20-40X and identified to the order or family level as appropriate. Soil Biological Quality index was determined, namely, QBS-ar developed by (Parisi *et al.*, 2003). The diversity of soil organisms was also determined using Shannon Index, (H') also known as the Shannon-Wiener Index.

Field soil profile examination was done for each land use system and profile descriptions and horizon designations were determined according to USDA soil taxonomy .Soil colour were determined using the Munsell Soil Color Charts.

Soil physio-chemical analyses

Standard procedures were used for measuring soil moisture, temperature, bulk density, pH, texture and soil organic carbon as detailed in (Begum *et al.*, 2010)

Statistical Analysis

Two-way analysis of variance (ANOVA) was used to evaluate the influence of land use practice and seasonal variation on densities and diversity of soil microarhtropods and QBS-ar index. Tukey test was used for multiple comparisons of means. Pearson's correlation analysis was performed to evaluate the relationship among soil biological and physico-chemical indicators. The statistical analyses were performed using the software SPSS 15.0 for Windows (SPSS Inc. 1989-2006).

Results and discussions

Influence of land use and seasons on microarthropod density and diversity and Pearson's correlation coefficients

Microarthropods from samples were grouped into the following categories: a) Collembola b) Acarina c) other microarthropods. The latter group included Diptera larvae and adults, microcoleoptera adults and larvae, Pauropoda, Chilopoda, Diplopoda, Aranea, Hymenoptera (formacidae), Symphylla, Pseudoscorpion and was designated as "other microarthropods". The total microarthropods population consisted of 59% Acarina, 20% Collembola and 21% other microarthropods groups (Figure 2). This was in agreement to the work of Fijita and Fujiyama (2000) but contrasted with the work of Reddy (1984) and Adeniyi (2009), in which collembolans was observed to be the most abundant taxa.

Table 1. Selected morphological characteristic of investigated soils under different land use system.

Land use	Depth(cm)	Horizon	Colour	Structure*	Consistency**	Roots***
Agriculture	0-16	Ap	10YR 4/3	MMGSB	fri fi	M vf f
	16-28	BA	10YR 4/3	WMSB	fri	F f
	28-50	Bw	10YR 4/4	WMSB	fri	-
	50^+	Bc	10YR 4/4	WMSB	-	-
Forest	0-8	A	10YR 3/2	WMGSB	fri	M f m
	8-32	Bw	10YR 4/4	WMSB	vfri	M f m
	32^+	Bc	10YR 4/3	WMSB	vfri	C f c

structure*: mmgsb = moderate medium granular subangular blocky, wmsb= weak medium subangulr blocky, wmgsb = weak moderate granular subagular blocky

consistency **: fri fi = friable fine, vfri = very friable

roots***: m vf f = many very fine, fine, f f = few fine, m f m = many fine medium,

c f c = common fine coarse.

Population density of total microarthropods, Collembola and Acari varied highly significantly with respect to seasons ($p<0.00$) (Table 4). Similar results were obtained by Begum *et al.*, (2011). The average population densities of total microarthropods, Collembola, other microarthropods were higher in the winter followed by post-monsoon and lowest in the pre-monsoon season (Table 3). Interaction between seasons and land use for population density was significant ($p<0.031$) indicating a varied response of microarthropods to seasonal change under different land uses. Seasonal fluctuation of total microarthropods population ranged from 5980 per m^2 in April (pre-monsoon), 19500 per m^2 in October (post-monsoon) and 42850 per m^2 in January (winter). Highest average densities of Collembola (60%), Acari (54%), other microarthropods (55%) and higher QBS-ar were observed in the forest as compared to agricultural land.

Table 2. Physical and chemical properties (Means and ±standard variation) in different land use and seasons at the investigated sites.

Soil properties	*Pre-monsoon (April)*		*Post-monsoon (October)*		*Winter (January)*	
	Agriculture	Forest	Agriculture	Forest	Agriculture	Forest
Bulk density(g/m^3)	1.07 (±0.04)	0.75 (±0.10)	1.27 (±0.05)	0.84 (±0.12)	0.65 (±0.34)	0.79 (±0.28)
Organic carbon (%)	2.93 (±0.41)	4.11 (±0.43)	2.49 (±0.23)	4.31 (±0.48)	2.75 (±0.43)	2.9 (±0.61)
Temperature (^{o}C)	21 (±0.79	34 (±11.06)	17 (±0.10)	15.98 (±1.07)	8.7 (±1.65)	10.15 (±1.25)
Moisture (%)	17.5 (±4.19)	34 (±11)	28.8 (±6.29)	39.48 (±6.29)	18.5 (±4.4)	22.9 (±6.43)
pH	5.6 (±0.29)	4.97 (±0.4)	5.5 (±0.34)	5.28 (±0.28)	4.86 (±0.19)	4.68 (±0.48)

Among the soil microarthropod groups Collembola and Acari are the most often studied group, due to their high abundance and diversity, important role in key biological processes such as, catalyzing organic matter decomposition and central role in the soil food web, making them suitable organisms for use as bioindicators of changes in soil quality, especially due to land use practice and pollution (Rombke, 2006). Collembola density was weakly significantly different according to land use ($p<0.1$). Average population density of Collembola was higher in forest land use as compared to agricultural soils in all the seasons (Table 3). Mite density did not significantly vary with the land use, however, the interaction between land use and seasons was highly significant ($p<0.028$) for Acari suggesting that their response to seasonal changes differed markedly according to land use. Such differences may be due to disturbances caused by soil tillage and planting/harvesting activities on agricultural land.

Table 3. Average densities ($100 * m^{-2}$± Std. deviation) of different soil micro arthropods and QBS-ar in different seasons and land use system.

	Pre-monsoon (April)		*Post-monsoon (October)*		*Winter (January)*	
Soil biota	Agriculture	Forest	Agriculture	Forest	Agriculture	Forest
Total microarthropods	51 (±35)	68(±19)	70 (±35)	321(±236)	462 (±172)	399 (±163.8)
Collembola	18.6 (±5.9)	21 (±7)	21 (±16.9)	65 (±36.8)	81(±37)	93(±60)
Acari	12.6 (±9.7)	26 .4(±11)	27 (±17.9)	197 (±156)	341(±111)	286 (±131)
Other microarthropods	20(±22.16)	20.8(±15)	22 (±10)	59 (±43)	38 (±24)	19 (±10)
QBS-ar	62.8 (±12)	62.8(±12)	178 (±20)	97(±20)	101.6(±35)	101.6(±17.7)
Shannon Index	1.16 (±0.26)	1.08 (±0.26)	1.58 (±0.59)	1.04 (±0.33)	0.35 (±0.056)	0.36 (±0.099)

Low densities and diversities of total microarthropods, Collembola, and Mites during the pre-monsoon month of April was probably due to low soil moisture content, higher temperature and recent tillage operations in agricultural plots. The decrease in microarthropod populations caused by tillage practices can be attributed to the destruction of microhabitat, changes in temperature, humidity, and pore size distribution, and decrease in organic matter content (Heisler and Kaiser, 1995, Loring, 1981, Perdue and Crossley, 1989). Further, environmental factors, such as water and nutrient contents, are important factors affecting the populations of soil microarthropods (Klironomos, 1995 and Tadeka, 1987). We observed during sampling that after crop harvest during the post monsoon period farmers left crop residues (roots, stems and weeds in the agriculture fields), which helped to maintain the habitat as well as served as a source of food, hence favoring higher density of microarthropods during the winter seasons. The increase in microarthropod population was also likely caused by inputs of various forms of organic matter such as manure, sewage sludge, green manure and crop residues (Alssiuty, 2000, Axelsen, 2000, Primental and Warneke, 1989 and Vreeken-Buijis, 1998).

Table 4. Two way Analysis of Variance (ANOVA) of biological indicators with respect to seasons and land use.

	Total microarthropods	*Acari*	*Collembola*	*Other Microarhtropods*	*QBS-ar*	*Shannon Wiener Index*
Seasons	19.335***	26.141***	10.961***	1.272^{ns}	11.948***	29.426***
Land use	1.768^{ns}	1.588^{ns}	2.626*	.352^{ns}	.806^{ns}	3.298*
Seasons and Land use	3.926*	4.066**	1.149^{ns}	2.717*	.605^{ns}	2.429*

Note. ***, **,*, indicate significant at $p<0.01$, $p<0.05$, $p<0.1$ and ns non significant respectively.

Comparing both land use systems, mean population densities of total micro arthropods, Collembola and Acari were highest in the forest (Table 3). This could be attributed to higher organic content (from litter) and moisture, and slightly lower temperature and bulk density in forest soils compared to agricultural land (Table 2). According to Begum *et al.* (2011) these differences are likely relate to microhabitat, and the differences could reflect the soil abiotic factors such as differences in temperature, soil moisture, bulk density, changes in food sources and SOC. Pearson's correlation showed a significant negative correlation of bulk density ($p<0.05$), soil temperature ($p<0.01$) and pH ($p<0.01$) with population densities of total microarthropods, Collembola and Acari. Total microarthropods density was positively significantly correlated ($p<0.01$) with QBS-ar index, densities of Collembola, Acari and other micro arthropods, however, it was negatively correlated with Shannon Index.

In case of other the microarthropods group and Acari, average population densities were higher in the forest during pre-monsoon and post monsoon, but during the winter they were higher in agricultural land, especially the density of predatory mite. Haarlove, (1960) and Block, (1966) also found higher population densities of mites during the winter. The reason for winter season the population densities increasing could be due to crop residues, in particular, many fine roots partially or completely decomposed as observed during soil sampling. Hishi *et al.*, (2008) found that greater quantities of fine roots appeared to promote the abundance of microarthropod communities, including predatory mites, through increasing hyphal growth. Other reasons could be that agricultural soils get direct and more sunlight during the day time, thus, soil temperatures might be more favorable than forest soils for the microarthropods. Despite lower winter average soil temperatures in agricultural land as compared to forest during our sampling, the time of sampling may have been crucial, since agricultural fields were sampled in the morning, while forest soils were sampled in the afternoon.

Shannon Wiener Index was strongly differed significantly with seasons ($p<0.00$) and land use

($p<0.08$). Average Shannon Index was highest during post-monsoon followed by pre-monsoon and lowest during the winter (Table 3). While comparing land use, the average index was highest for agriculture. This index was positively correlated ($p<0.05$) with bulk density, temperature, pH, moisture and SOC, but negatively correlated ($p<0.01$) with the total population densities of micro- arthropods, Collembola, Acari and QBS-ar Index ($p<0.05$).

Table 5. Ecomorphological Index (EMI) for the microarthropods occurring at investigated sites.

Microarthropods group	*Pre-monsoon (April)*		*Post-monsoon (October)*		Winter (January)	
	Agriculture	Forest	Agriculture	Forest	Agriculture	Forest
Collembola	20	20	20	20	20	20
Acari	20	20	20	20	20	20
Diptera larva	10	10	10	10	10	10
Diptera adult	1	1	1	1	1	1
Coleoptera larva	10	10	10	10	10	10
Coleoptera adult	6	10	10	15	5	10
Diplopoda	-	5	-	20	-	-
Chilopoda	-	-	-	10	20	20
Symphylla	-	20	-	20	20	20
Protura	-	-	-	20	20	20
Diplura	-	-	20	20	20	20
Pauropoda	-	-	20	-	-	-
Pseudoscorpions	-	-	-	-	20	-
Aranea	-	-	5	-	5	-
Formacidae	5	5	5	5	-	5
Holometabolus larva	-	-	10	-	-	10
Lepidoptera larva	-	-	-	-	-	10
Lepidoptera adult	-	-	-	-	1	1
Blatteria	-		5	-	-	5
Gryllidae	-	20	-	-	-	-
Orthoptera	1	-	-		1	-
Hemiptera	1	-	-	1	1	1
Homoptera	1	-	-	-	-	-
Thysanoptera	-	1	-	-	1	-
Pscoptera	-	1	-	1	-	-
QBS-ar	75	123	136	173	175	183

Spatial and temporal variability of soil biological as well as physico-chemical properties affects soil performance, ecosystem services and processes, and, therefore, the crop productivity. Hence, understanding changes in soil biological indicators is important to minimize the environmental degradation and enhance the sustainability of agro ecosystems.

Influence of land use and seasons on soil biological quality index QBS-ar and Pearson's correlation coefficients

The biological soil quality was evaluated by using the QBS-ar index proposed by Parisi *et al.* (2003) as it is easy to use and accessible to non-specialists because it does not require complex taxonomic identification. Adaptation to the edaphic environment is taken into consideration without classification to the species level, resulting in lower cost and labour (Paolo *et al.*, 2010). QBS-ar varied highly significantly ($p<0.00$) according to seasons but not significantly different with land use. Similar findings were reported in our earlier studies Begum *et al.*, (2011). Average QBS-ar values were highest under forest land use systems as compared to agriculture, while with the seasons it was highest in winter followed by post-monsoon and lowest during the pre-monsoon (Table 3). Soil pH, bulk density and temperature were significantly negatively correlated with soil biological quality index (QBS-ar). This result is consistent with our earlier finding Begum *et al.* (2010, and 2011). The index was slightly positively correlated with soil moisture and organic carbon, but not significant statistically. This result was again consistent with our previous findings Begum *et al.* (2010, and 2011). QBS-ar was positively significantly correlated with densities of total microarthropods ($p<0.00$), Collembola ($p<0.00$), Acari ($p<0.00$) and other micorarthropods ($p<0.001$), but negatively correlated with Shannon Wiener index ($p<0.03$). Begum *et al.* (2011) reported a positive correlation among QBS-ar with total density of microarthropods and Shannon Wiener Index.

In the soil under study, microarthropods fauna were well differentiated as shown by the data reported in Table 5. Some important groups such as puaropods, chilopods, psuedoscorpions, Blatteria and Gryllidae were present only in some of the soil samples.

Conclusion

On the basis of the density, diversity of microarthropods and soil biological quality index, QBS-ar, a high soil quality could be attributed to forest soils of the investigated area. When compared across the seasons, soil biological quality was highest in the winter, followed by post-monsoon and lowest during the pre-monsoon. The seasonal variations in soil microarthropod population groups were largely due to climatic fluctuations. Spatial and temporal variability of soil biological as well as physico-chemical properties affected soil performance, ecosystem services and processes, and hence, the crop productivity. Understanding changes in soil biological indicators is, therefore, important to minimize the environmental degradation and improve the productivity and sustainability of agro ecosystems in the Nepal mid-hills. Therefore, there is a need to investigate spatial and temporal variability of the dynamics soil attributes to refine the agricultural management practices for sustainable management of agro ecosystem. Long-term monitoring is required to fully understand the impact of different agricultural practices and seasons on soil faunal abundance, diversity and community structure for the conservation of soil biota, as well as, for assessment of soil quality.

Acknowledgements

This research was supported by the HIMUNET (NUFU) project Norway. Technical and financial support provided by this project was highly acknowledged. I would also thank the Aquatic Ecology Centre, Kathmandu University for assistance and logistical support both in the field and lab.

References

Adeniyi AS. 2009. Diversity and abundance of soil mesofuana of soil mesofuana and microbial population in South-Western Nigeria. African Journal of plant sciences **3,** 210-216.

AlssiutyAIM,KhalilMA, Abdul-LatiefHM.2000. Effect of dry sludge application ion soil microarthropods communities in reclaimed desert ecosystem. Pedobiologia **44,** 567-578.

AxelsenJA, KristensenKT. 2000. Collembola and Mites in plot fertilized with different types of green manure. Pedobiologia **44,** 556-566.

BadejoMA. 1990. Seasonal abundance of soil mites (Acarina) in two contrasting Environment. Biotropica **22,** 382-390.

Badejo MA,Van-StraalenNM. 1993. Seasonal abundance of springtail (Collembola) in two contrasting environment. Biotropica **25,** 222-228.

Begum F, BajracharyaRM,SharmaS,SitaulaBK.2010. Influence of slope aspect on soil physic-chemical and biological properties in the mid hill of central Nepal. International Journal of sustainable development and world ecology **17,** 438- 443.

Begum F, BajracharyaRM,Sharma S,SitaulaBK.2011. Assessment of soil quality using micro arthropods communities under different land use system-A case study in the mid hill of central Nepal. Journal of life science **5,** 66-73.

BlockW.1966. Seasonal fluctuation and distribution of mite population in MoorlandSoils,with a note on Biomass. Journal of Animal Ecology **35,**487-503.

ColemanDA,CrossleyJR,HendrixPF.2004. Fundamentals of soil ecology. Elsevier USA.

DecaensT, JimenezJJ. 2002. Earthworm communities under agriculture intensification gradient in Columbia. Plant Soil **240,** 133-143.

Decaens T,Jimenez JJ,GioiaC, MeaseyGJ, LavelleP. 2006. The value of soil animals for conservation biology. European Journal of Soil Biology **42,** S23-S38.

Didden WAM. 1993. Ecology of terrestrial Enchytraeidae. Pedobiologia **37,** 2-29.

Fujita M, Fujiyama S. 2000. Soil Mesofauna in Two Microenvironments of No-tillage Organic Farming Field. Edaphologia **66,** 11-20.

Gardi C, Tomaselli M, Parisi V, Petraglia A, Santini C.2002. Soil quality indicators and biodiversity in northern Italian permanent grasslands. European Journal of Soil Biology **38,** 103-110.

HaarlovN. 1960. Microarthropods from Danish soils, Ecology, Phenology. Oikos. Acta oecologica Scandinavica, Supplementum **3,** 1-176.

Heisler C, Kaiser EA. 1995. Influence of agricultural traffic and crop management on Collembolan and microbial biomass in arable soil. Bio. Fertil. Soil **19,** 159-165.

Hishi T, Fujimaki R, Mc Gonigle TP, Takeda H. 2008. Relationship among roots, fungal hyphae and soil micro arthropods among different soil microhabitats in temperate coniferous forest of Chamaecyparis obtuse. European Journal of soil Biology **44,** 473-477.

Klironomos JN, Kendrick B. 1995. Relationship among micro arthropods, fungi, and their environment. Plant Soil **170,** 183-197.

Lasebikan BA. 1974. A preliminary communication on micro arthropods from tropical in Nigeria. Pedobiologia **14,** 402-411.

Lavelle P, Decaen T, Aubert M, Barot S, Blouin M, Bureau F, Margerie P, Mora P, Rossi JP. 2006. Soil invertebrates and ecosystem services. European Journal of Soil Biology **42,** S3-S15.

Lee YF, Kuo YM, Lu S.S, Chen DY, Jean HJ, Chao JT.2009. Trampling, Litter removal and variation in the composition and relative abundance of soil arthropods in the sub tropical hardwood forest. Zoological studies **48**, 62-173.

Loring SJ, Snider RJ, Robertson LS. 1981. The effects of three tillage practices on collembolan and Acarina populations. Pedobiologia **22,** 172-184.

Luxton M. 1981. Studies on the orbatid mites of Danish beech wood soil, V. Vertical Distribution. Pedobiologia **21,** 365-386.

Miyazawa K, Tsuji H, Yamagata M, Nakano H, Nakamoto T. 2002. The Effects of Cropping systems and Fallow managements on Microarthropod Populations. Plant Prod. Science **5,** 257-265.

Perdue JC, Crossley AJ. 1989. Seasonal abundance of soil mites (Acari) in experimental agro ecosystem: effects of drought in no-tillage and conventional tillage. Soil Tillage Research **15,** 117-124.

Parisi V, Menta C, Gardi C, Jacomin C. 2003. Evaluation of soil quality and biodiversity in Italy: the biological quality of soil index (QBS) approach. Meeting on Soil Erosion and Biodiversity Indicators, Rome, Italy, OECD, Paris.

Parisi V, Menta C, Gardi C, Jacomini C, Mozzanica E.2005. Micro arthropods communities as tool to assess soil quality and biodiversity: a new approach in Italy. Agric. Ecosys. and Environment **105,** 323-333.

Paolo AG, Raffaella B, Danio A, Attilo DR, Ettore C. 2010. Assessment of soil quality index based on micro arthropods in corn cultivation in Northern Italy. Ecological Indicators **10,** 129-135.

Primentel D, Warneke A.1989. Ecological effects of manure, sewage sludge and other organic waste on arthropod populations. Agric. Zool. Rev. **3**, 1-30.

Reddy MV. 1984. Seasonal Fluctuation of different edaphic microarhtropods population densities in relation to soil moisture and temperature in Pine, Pinus kesiya Royle Plantation Ecosystem. International Journal of Biometeorology **28,** 55-59.

Rana N, Rana SA, Khan HA, Sohail A. 2010. Assessment of possible threats to soil macro-invertebrate diversity in wheat fields from high input farming. Int. J. Agric. Biology**12,** 801–808.

Rombke J, Sousa JP, Schouten T, Riepert F. 2006. Monitoring of soil organisms: a set of standardized field methods proposed by ISO. European Journal of Soil Biology **42**, S61-S64.

Solbrig OT. 1991. From Genes to Ecosystems: A Research Agenda for Biodiversity, IUBS–SCOPE–UNESCO. Monograph series.124 pages.

Tadeka H. 1987. Dynamics and maintenance of Collembolan community structure in a forest soil System. Research Population Ecology **29,** 291-346.

Upadhyay TP. 2006. Land-Use Changes and Forest/Soil Degradation Effects on Carbon Sequestration at Watershed Level in Nepal: An Interdisciplinary Systems Analysis Using Bio-Economic Modeling. Norwegian University of Life Sciences, Department of Ecology and Natural Resource Management, Ås.

Usher MB. 1975. Seasonal and vertical distribution of population of soil arthropods: Criptostimata. Pedobiologia **15,** 364-374.

Verhoef H, Witteveen J.1980.Water balance in Collembola and its relation to habitat selection; cuticular water loss and water uptake. Journal of Insect Physiology **26,** 201-208.

Verhoef H & Van Selm AJ. 1983. Distribution and population dynamics of Collembola in relation to soil moisture. Holarctic Ecology **6,** 387-394.

Vreeken-Buijs MJ, Hassink J, Brussard L. 1998. Relationships on soil microarthropods biomass with organic matter and pore size distribution in soil under different land use. Soil Biol. Biochem **30**, 97-106.

Wall DH, Adans GA, Parsons AN. 2001. Soil Biodiversity, in: F. S. CHAPIN, O. E. Sala., E.huber-Sannwald (Eds.), Global Biodiversity in a changing Environment, Springer Verlag, New York 47-82.

Webster EA, Hopkin DW, Chudek JA, Haslam SFI, Simek M, Picek T. 2001. The relationship between microbial carbon and resource quality of soil carbon. Journal of Environmental quality **30,** 147-150.