Effects of Microhabitat Characteristics on Abundance of Macroinvertebrate Soil Fauna in Ranibari Community Forest, Kathmandu, Nepal

Subash Pokhrel

T.U. Registration no: 5-2-37-1210-2013

T.U. Examination Roll no: 854/076

A Dissertation Submitted in Partial Fulfillment of the Requirement for the Award of Degree of Master of Science in Zoology with Special Paper Ecology and Environment

Submitted to

Central Department of Zoology

Institute of Science and Technology

Tribhuvan University, Kirtipur, Kathmandu,

Nepal

May 2023

DECLARATION

I hereby declare that the work presented in this thesis work entitled "**Effects of Microhabitat Characteristics on Abundance of Macroinvertebrate Soil Fauna in Ranibari Community Forest, Kathmandu, Nepal**" has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution (s).

Date: 02 May 2023

Subash Pokhrel

त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY
प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY
कीर्तिपुर, काठमाडौं, नेपाल।
Kirtipur, Kathmandu, Nepal.

०१-४३३१८९६
01-4331896
Email: info@cdztu.edu.np
URL: www.cdztu.edu.np

पत्र संख्या :-
च.नं. Ref.No.:-

Central Department of Zoology
T.U., Kirtipur

RECOMMENDATION LETTER

This is to recommend that the project work entitled **"Effects of Microhabitat Characteristics on Abundance of Macroinvertebrate Soil Fauna in Ranibari Community Forest, Kathmandu, Nepal"** has been carried out by **Subash Pokhrel** for the partial fulfillment of Master's degree of Zoology with special paper Ecology. This is his original work and has been carried out under my supervision. To the best of my knowledge, this project work has not been submitted for any other degree in any institutions.

Date: 04 May 2023

....

Dr. Laxman Khanal

Supervisor /Associate Professor

Central Department of Zoology

Tribhuvan University

Kathmandu, Nepal

त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY
प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY
कीर्तिपुर, काठमाडौं, नेपाल ।
Kirtipur, Kathmandu, Nepal.

०१-४३३१८९६
01-4331896
Email: info@cdztu.edu.np
URL: www.cdztu.edu.np

पत्र संख्या :-
च.नं. Ref.No.:-

Central Department of Zoology
T.U., Kirtipur

LETTER OF APPROVAL

On the recommendation of supervisor **Dr. Laxman Khanal** this project work submitted by Ms. Subash Pokhrel entitled **"Effects of Microhabitat Characteristics on Abundance of Macroinvertebrate Soil Fauna in Ranibari Community Forest, Kathmandu, Nepal"** is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements of Masters Degree of Zoology with special paper Ecology.

Date: 07 May 2023

……………………………

Prof. Dr. Kumar Sapkota

Head of Department

Central Department of Zoology

Tribhuvan University

Kathmandu, Nepal

त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY
प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY
कीर्तिपुर, काठमाडौं, नेपाल।
Kirtipur, Kathmandu, Nepal.

०१-४३३१८९६
01-4331896
Email: info@cdztu.edu.np
URL: www.cdztu.edu.np

पत्र संख्या :-
च.नं. Ref.No.:-

Central Department of Zoology
T.U., Kirtipur

CERTIFICATE OF ACCEPTANCE

This project work submitted by Mr. Subash Pokhrel entitled **"Effects of Microhabitat Characteristics on Abundance of Macroinvertebrate Soil Fauna in Ranibari Community Forest, Kathmandu, Nepal"** has been accepted in partial fulfillment for the requirements of Master's Degree of Zoology with special paper Ecology.

EVALUATION COMMITTEE

…………………………	…………………………
Supervisor	Head of Department
Dr. Laxman Khanal	Dr. Kumar Sapkota
Associate Professor	Professor
Central Department of Zoology	Central Department of Zoology
Tribhuvan University	Tribhuvan University
…………………………	…………………………
External Examiner	Internal Examiner
Dr. Narayan Prasad Koju	Dr. Bishnu Prasad Bhattarai

Date of Examination: 24 May 2023

ACKNOWLEDGMENT

I would like to express my sincere gratitude and grateful thanks to my supervisor Dr. Laxman Khanal, Associate Professor, Central Department of Zoology, Tribhuvan University, Kathmandu Nepal for his genuine guidance, valuable suggestion, encouragement and supervision to formulate this project work.

I am grateful to Prof. Dr. Kumar Sapkota head of department, Prof. Dr. Tej Bahadur Thapa, formal head and Department of Zoology, Tribhuvan University for his supporting role in the preparation of this project work. Further, I would like to impart my thanks to all the Professors, Associate Professors, Assistant Professors, and Teaching Assistants, Department of Zoology, Tribhuvan University, for their suggestions. I would like to thanks to members of Ranibari Forest Committee for giving me permission to conduct research.

I would like to thank non-teaching staffs of Department of Zoology, Tribhuvan University for their help, whenever required. The direct help from my classmates in this concern is highly solicited. At last, but not least I would like to thank my family members and friends for their support during this research work.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Microenvironmental characteristics like canopy cover, litter depth, soil moisture, soil organic matter, pH, nutrient content of soils are associated with the soil biodiversity. The soil faunal community are strongly affected by urban green space, community gardens and plotted lands. This study aimed to explore the association between the microenvironmental characteristics of forest ecosystem and the abundance of macroinvertebrate soil fauna (here after soil fauna) in Ranibari Community Forest, one of the biggest forest patches in the urban environment of the Kathmandu Valley. The effects of the microhabitat on the soil fauna were observed in 10 × 10 m^2 plots. Faunal sampling was done from 85 quadrates of each 1×1 m^2 to observe the richness and abundance of soil fauna. Highest number of soil fauna (n=200) were spotted under the canopy cover of *Stranvaesia nussia*. The canopy is predominately occupied by the bamboos and tree species of *Stranvaesia nussia*, *Schima wallichilli*, *Persea duthiei*. Soil physio chemical analysis was conducted to know the effects of the soil characteristics on soil fauna. The lowest canopy ranged between 65%– 85% and the most of the canopies (n=43) were in the range of 76%–80%. A total of 1011 soil fauna were observed out of which 56.4% (530) were recorded in the moist soil. The soil pH of the study area ranged from 6.2 to 8.3. Out of 85 samples tested, 59 samples had soil pH above 7. The most area in the forest was covered by the leaf litter under the canopies. About 81% (n=69) of the total studied quadrates had the presence of leaf litter and 19% (n=26) had no litter decomposed under their canopies. The pH, N, P, K of the soil also affect the abundance of the soil fauna; acidic soil condition and high nitrogen content in the soil can be toxic to the soil fauna. Clay soil had the most number of soil fauna (n=543) than loamy and sandy soil. Soil fauna abundance was higher in lower concentration of nitrogen and phosphorous and medium concentration of potassium.

1. INTRODUCTION

1.1 Background

Soil biodiversity includes the group of life that is almost hidden from surface view. The diversity and abundance of soil fauna depends upon the quality of soil and vegetation types. The microenvironmental characteristics including vegetation types with canopy cover are associated with soil biodiversity. Soil fauna are in abundance under the dense canopy areas (Sanaei et al. 2021). Diverse group of the organisms are present in the soil among which some are not visible to naked eyes. Viruses, Bacteria, fungi, algae, protozon and macro invertebrates such as terrestrial gastropods (Slugs and Snails), Oligochaeta (earthworm), spider, scorpions, beetle, millipede, centipedes, ants and termites grouped as microfauna, mesofauna and metafauna (Mueller et al. 2016). Approximately one-fourth of the total biodiversity on earth is estimated to be soil fauna including the microinvertebrates (Protozoa, Nematoda, Turbellaria, Rotifera, Tardigrada), mesoinvertebrates (smaller than 2mm eg., Collembola, Diplura, Symphylla and Palpigradi) and macroinvertebrates (larger than 2 mm) (Lavelle et al. 2006). Forest ecosystem includes the living organisms in the forest in different habitats which may be soil, grassland, watershed or others (Wei et al. 2017).

Soil fauna have a great role in the formation of the soil structure and there is a positive correlation, direct and indirect relationship between soil fauna and vegetative structure in the forest. High leaf litter decomposition also results in the increasing number of the soil fauna on the ground cover and depth (Gillison et al. 2003). Forest extends vertically upward developing canopies and downward to the lowest soil layers in which soil fauna exists (Jouquet et al. 2006). Ecological approach of canopy cover is integral component for the colonization of the soil macroinvertebrates (Reynolds et al. 2003). The soil faunal community are strongly affected by urban green space type such as sports fields, community gardens and other plotted lands, and the floral species richness is associated with the soil faunal diversity (Baruch et al. 2021). The changes in the composition of the soil fauna may result due to the less availability of the litter and nutrients and the less leaf litter tends to lower the soil fauna population in the forest dynamics (Wright et al. 2011). The richness of the soil fauna and the components of soil faunal community, may be controlled by local factors like climate, soil type, canopy cover, NPK nutrients available and pH of the soil (Mubarak & Olsen 1976). Vegetational effect, which are associated with the dynamics of the forest ecosystems are supposed to affect the abundance and diversity of the soil macroinvertebrates because they are corelated to most of environmental and soil parameters and humus profile (Bernier 1998). Organic matter and other related soil features like soil pH, moisture and nutrient availability are associated to each other to determine the relationship between soil fauna and plant succession, because it contains the lining substrate for both vegetation and soil fauna (Mordelet et al.1993). The soil faunal community are strongly affected by urban green space type such as sports fields, community gardens and other plotted lands, and the floral species richness is associated with the soil faunal diversity (Baruch et al. 2021). The abundance and biodiversity of soil fauna species varies with the vegetation dynamics (Miggie et al 1995). Moisture and sunlight are also the factors that affect the number and behavior of the macroinvertebrates on the soil. Interaction between solar radiation and forest result in the moist and dry condition of the soil and moisture and dryness is also known to be the factor that impact the abundance and distribution of the soil fauna (Salmon et al. 2008).

1.2 Objectives of the study

Major objective of the study was to identify the effect of microenvironmental characteristics of forest ecosystem on assemblage of soil fauna in Ranibari Community Forest, Kathmandu

Specific objectives were:

- To explore the abundance of soil fauna in Ranibari Community Forest
- To find the relationship between the abundance of soil fauna and microhabitat characteristics in forest ecosystem of Ranibari Community Forest.

1.3 Rationale of the study

This study confirmed the distribution and species richness of macroinvertebrates in soil and their relation with vegetation in the forest, whether the habitat studied was biologically appropriate or require other improvements in terms of biodiversity conservation. The study showed the vegetation status of the forest. The study provided the status of macroinvertebrates in soil regarding different vegetation types associated to forest and helped to analyze the relation between vegetation types and soil fauna with better conservation policy. Ranibari Community Forest can be the appropriate area to explore the status of soil fauna, and effect of forest canopies and vegetation types on those species. Soil is the structure where the biology and geology met. Hence the research work was started to know the status of vegetation types and soil fauna. Till date, there is no any research is done to determine the effect of vegetation types on the soil fauna in that forest. The biological activities of the soil fauna are highly affected by the vegetation types and soil.

2. LITERATURE REVIEW

2.1 Abundance of the soil fauna

The characteristics of the tree and the vegetation on the litter faunal community and decomposition process below their canopies (Negrete-Yankelevich et al. 2008). The abundance of soil fauna is observed among different tree species. The production of a specific quality of litter plays an important role for the development of the soil fauna under the canopies. The relation of the vegetation types and the diversity of the soil fauna has the great role in the formation of the soil structure (Gillison et al. 2003). There is highly significance with the positive correlation between the species richness of soil feeders with the vegetation types and forest canopy. The role of the soil fauna to the ecosystem services at plot and landscape level (Jouquet et al. 2006). The study showed soil fauna activities are the good indicator of soil quality. The effects of vegetation types on the soil faunal activities on the abundance of soil organisms are positively influenced by vegetation types (Kooch & Noghre 2020). Woody species in rangeland increase the soil fertility. Seasonal variation also influences the soil fauna. Brussaard (1998) studied the soil fauna with respect to the vegetations of forest. The vegetation has the great role in bio assessment of the soil fauna in ecosystem processes. The quantitative model of ecological interaction in soil is based on the faunal activity of soil. The effect of tree diversity on soil fauna and tree species traits, rather than tree species richness is the important factor for the soil faunal communities (Korboulewsky et al. 2016). The effect of tree canopy on the spatial distribution of soil nutrient was determined by Gallardo (2003) which observed the biomass of the soil faunal community in the forest ecosystem resulting the concentration of the soil humus, organic matters, minerals and NPK content higher under the trees canopies and canopies also play the useful role to maintain the optimum temperature to the soil fauna

2.2 Effects of microhabitat on the abundance of soil fauna.

The abundance and diversity of soil fauna in semi evergreen forest under the influence of dominant vegetation species which showed that the abundance of the soil fauna is higher in the soil under forest canopies (Imbert et al. 2007). Soil invertebrates, as a major part of biodiversity in forest soil (Menta 2012), play an essential role in soil ecosystems, litter decomposition processes, above-ground food webs, and plant growth in forest ecosystems (Wardle 2002; Mueller et al. 2016). The tree species influencing soil fauna should be considered an important factor in biodiversity (Komonen et al. 2015). The abundance and diversity of invertebrates relative to multiple tree species and composition groups (Schwarz et al. 2015). There is the significant different in the structural composition of the soil fauna in the natural habitat and in the places where the anthropogenic activities are performed (Koehler 1992). Soil fauna both mesofauna and macrofauna are supported to be useful ecological parameters for the functioning of the soil ecology. The soil faunal assemblage, distribution and density are highly affected by the local environmental variables like soil moisture, air, water, chemical and physical properties of the soil (Zagatto et al. 2019) . The roles of the soil fauna in the nature are most important components to increase the biodiversity due to their diverse species coverage along with the different functions in the environment roles such as soil engineers and organic decomposers (Pouyat et al. 2015). The number of macrofauna like Arachnids, Hexapoda, Insecta declines in the number due to the lower quality of the soil and resources unavailability and there is the major role of the soil fauna for the formation of the soil particles (Madej & Kozub 2014).

The dryness of the soil ultimately decreases the number of soil fauna and lowers their interactions with each other on the soil but the number of soil fauna tends to increases if the soil regains the suitable moisture (Lindberg & Bengtsson 2006). The abundance and biodiversity of the soil fauna are influenced by different type of organic matters and chemical composition of soil and layers of soil. The soil fauna depend upon the root residues for their food which increases the soil diversity (Kautz et al. 2006).The relatively more biomass in the soil result in the high number of soil fauna in the soil ecosystem (Blanchart & Julka 1997). Biomass relatively provides the good feeding mechanism for the soil fauna and also provides soil biomass which help to regulate soil moisture and temperature which are the important factors for the survival of soil fauna (Blanchart & Julka 1997). The acidic condition of the soil also decreases the abundance of the soil fauna and the soil nutrient, organic matters and other physical and chemical parameters of the soil (Wei et al. 2017). Alvey (2006) showed that the fragmentation of the natural habitat tend to decrease the richness and abundance of the soil fauna in the urban forest core, community forest, wetlands, protected areas has the numerous patch that helps to promotes their biodiversity. Nitrogen is the most required plant nutrient, which is found in various composition in soil(Rosolem et al. 2017), resulting in a very dynamic behavior. Soil nitrogen has been assessed mainly as mineral, nitrate and organic N which is stored in the soil organic matter. Despite the importance in plant nutrition and environment, the use of nitrogen as parameter for assessing soil health is subjected to factors that affect its dynamics in soil, like climatic conditions, turning inadequate the diagnosis of the real availability for plants, based on soil chemical analysis (Cantarella 2007). Phosphorus (P) is also a key nutrient for vegetation yields and soil fauna and is essential in assessments of soil quality. Along with nitrogen, P is the main nutrient that limits the vegetative yields in tropical soils, especially in highly weathered soils, where the major part of the total soil P is fixed in clay minerals and oxides. The available P in the soil solution is present as orthophosphates, but the microbial P and organic-P are also stocks that can rapidly become available. Procedures for assessment of P availability have been well established (Pankhurst et al. 1996) Soil chemical parameters have been traditionally used for assessment of potentially available nutrients for vegetations and soil fauna, and are based on worldwide well established analytical methodologies. Among them, organic matter as leaf litter, pH and available nutrients as NPK have been used to establish levels of soil health. These procedures do not fulfill the promises to help us to understand all factors associated to sustainability, especially in relation to ecological processes. Melo and Marchiori (1999) reported very good levels of chemical indicators in a different vegetative fields with different plant species but the biological indicators were far below the ones found in a native forest ecosystem.

3. MATERIALS AND METHODS

3.1 Study area

This study was carried out in the Ranibari Community Forest (Latitude 27°43ˈ44.19"–27°43ˈ58.62" N and 85°19ˈ12.85"–85°19ˈ17.64" E) which is located in north-west region of Kathmandu Valley at an elevation of around 1400m. The area of entire forest is 0.07 km^2.

Ranibari Community Forest is the one of the major areas for biodiversity and forest conservation modality. Because of day by day increasing population, the forest coverage of Kathmandu Valley is declining but some forests are protected as in situ conservation model. . The forest is reported to have total of 108 species belonging to 58 families and 92 genera of plant (Maharjan et al. 2007). The canopy is predominately occupied by the bamboos and tree species of *Stranvaesia nussia, Schima wallichilli, Persea duthiei*. .

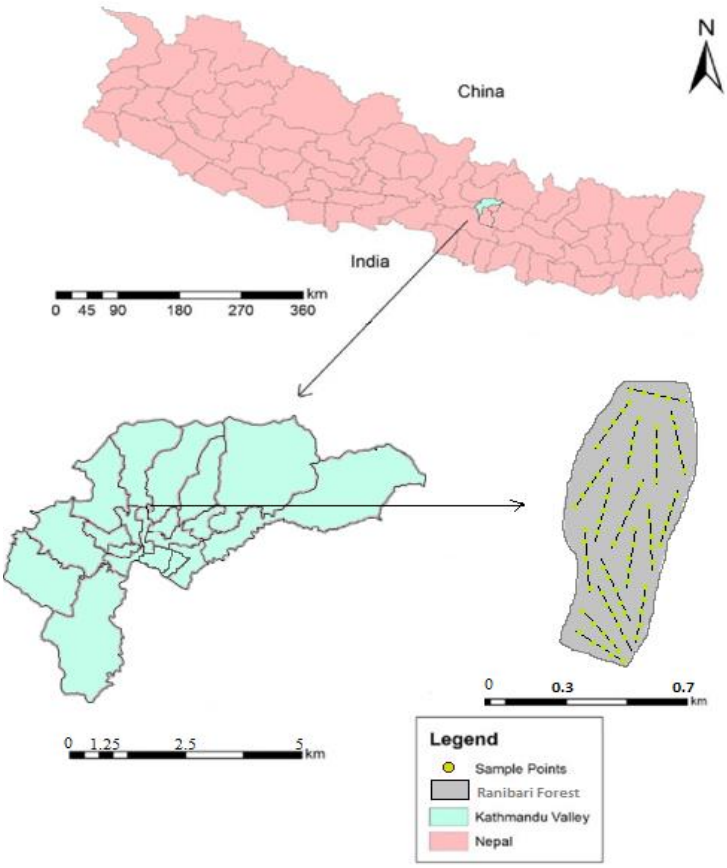


Figure 1. Map of the study area

3.2 Materials

- Measuring tape
- Scale
- Plastic bag
- Tray
- Canopy Cover Mobile App (developed by Nikhil Patel)
- GPS

The study was carried in following plants (85 individuals of following 18 species)

Table 1: Studied vegetations

Scientific Names	Common Name
Stranvaesia nussia	Indo-China jhoke berry
Celtis australis	European hackberry
Sahima wallichiania	Needle wood berry
Ziziphus incurve	Wild jujube
Bambusa vulgaris	Golden bamboo
Grevillea robusta	Silky oak
Ficus benghalansics	Indian banyan
Persea duthiei	Duthie avocado
Eucalyptus alba	Poplar gum
Ilex excels	Himalayan holly
Albizia julibrissin	Persian silk tree
Pinus roxburghii	Chir pine
Acer oblongum	Indian maple
Pyrus pashia	Wild Himalayan pear
Grenia optiva	Indian cross berry
Sapindus mukorassi	Soap-nut tree
Litsea ablonga	Round-leaved litsea
Pinus wallichiana	Himalayan white pine

3.3 Methods

To know the status of the soil fauna and its relation with the microenvironmental characteristics, the study was conducted from 10^{th} November 2022 to 10^{th} January 2023. The study was conducted to determine the effects of vegetation types and forest canopies on the diversity of soil fauna in Ranibari Community Forest. Several plots were selected regarding different tree species of *Stranvaesia nussia, Schima wallichili, Persea duthiei* and several others canopies and trees. The canopy cover was the independent variable whereas the abundance of soil fauna is the dependent variable. Faunal sampling was done from 1×1 m^2 quadrate to observe the richness and abundance (Edwards 1991).

The study area was selected preferably an area with vegetation and plant species. Seventeen transects of 30 meter keeping the distance of 10 meter were used in the plot where trees species were studied in different quadrates of 1×1 m^2. 85 vegetations of 18 different plant species were selected for study. The ground grass was removed of the plots by cutting. The ground was dug up to depth of 25cm. Faunas were spotted in the range of 10cm to 22cm. The litter and soil were removed from the plot and placed in a plastic bag. The number of soil faunas were counted and identified. The identifications of the species were done by the study of identification keys and microscopic observation. Tabulation of data was done. The canopy cover of the tree was measured by using mobile app 'Canopy capture' (developed by Nikhil Patel) to study the relationship between canopy cover and abundance of arachnids. The soil samples were collected from the different areas of the community forest by digging the sampling sites in V shaped structure and the soil samples were collected from below V shaped sites.. Total 85 samples of soil at least half kilogram of different plots was collected. pH of the soil was detected by using pH meter. The types of the soil were determined as clay, loam and sand using jar sedimentation method. The qualitative analysis of total nitrogen, potassium and phosphorous were determined.

3.4 Soil physiochemical analysis

Apparatus and chemicals used for soil analysis were:

- pH meter
- Test tubes
- Beaker
- Conical Flask
- Wash bottle
- Hydrochloric acid
- Ammonium acetate
- Potassium chloride
- Ammonium fluoride
- Calcium chloride
- EDTA

3.4.1 Methods for NPK analysis of the soil (Carolina & Acetate 1971)

Ammonium fluoride- EDTA stock solution was prepared by dissolving 135 gram of ammonium fluoride in 600 ml of deionized water and then adding 73 grams of EDTA dissolved and diluted to 1000 ml Mehlich 3 extraction solution was prepared by dissolving 200 gram ammonium nitrate in about 6000 ml of deionized water. 40 ml of the ammonium fluoride- EDTA solution was added and was mixed well (Penn et al. 2018).115 ml of concentrated glacial acetic acid and 8 ml of concentrated nitric acid were added and finally brought to 10000 ml final volume. Then the qualitative test of NPK was done using the Mehlich solution.

Test for Nitrogen

Ten ml of extraction solution was taken in test tube, where the soil sample was added. Ammonium acetate was added 2 drops. The blue color of the solution was compared through NPK calorimetry chart. Bright color showed high amount whereas dark color showed medium amount and only ring formation showed low amount of Nitrogen.

Test for Potassium

Ten ml of extraction solution was taken in test tube, where the soil sample was added. Potassium chloride was added, and left 1 minute. 5 drops of calcium chloride were added and shake for 2 minutes. The brown red coloration was compared through NPK calorimetry chart. Red color formation showed high amount whereas only ring in bottom showed medium amount and bright ring in top showed low amount of Potassium.

Test for Phosphorus

Ten ml of extraction solution was taken in test tube and 2 ml of Brays regent was added and was shacked. Some tin metals were added in solution. The purple blue coloration of solution was compared through NPK calorimetry chart. No color formation showed low amount whereas bright color showed the high amount and dark color showed the medium amount of phosphorous.

3.4.2 Method to determine the types of soil

The Mason jar sedimentation method was used to determine the soil types as clay, loam and sand. In the borosilicate glass 500 ml of water was added then the soil samples were added. The mixture was left overnight. The next day the types of soil were determined by visualizing the layers of the soil. The sandy type of soil sunk and made layer at bottom. The clay type of soil made the water remain cloudy and thin layer of dirt particles were seen in bottom. The loam soil made the high bonding layer at the top and held in rigid shape.

3.4.3 Method to determine the pH of soil

Ten mg of the soil was taken in the beaker and 50ml of water was poured. It was shacked gently for 10 seconds. The pH meter was dipped in it. The correct pH of the soil was noticed.

3.5 Data analysis

Simpson's diversity and Shannon Wiener diversity index were used to analyze the diversity of macroinvertebrates in different habitat with respect to different vegetation types. Three or more samples come from populations with the same mean and it requires the multivariant analysis method for analysis.

The following assumptions are to be considered:

- The populations have normal distributions.
- The populations have the same variance or standard deviation.

The Shapiro–Wilk test was performed to check normality of data but it showed data were not normally distributed, then after Generalized Linear Model was performed. Multivariate analysis was performed by showing Heatmap to analyze data that involved multiple variables, to determine the relation between them. It was also used to determine the effect of one variable upon another.

Simpson's Diversity Index was used to measure the diversity of species in a community.

$$D = \Sigma n_i(n_i-1) \ / \ N(N-1)$$

Denoted as D The index ranges from 0 to 1, where 0 represents no diversity (only one species present) and 1 represents infinite diversity (an infinite number of species present, each with equal abundance). A value of 1 indicates that all species in the community are equally abundant, while a value close to 0 indicates that one or a few species dominate the community

where:

n_i: The number of organisms that belong to species *i*

N: The total number of organisms

In general, a higher value of the Simpson diversity index indicates a more diverse community with a more even distribution of species. It is commonly used in ecology and conservation biology to assess the impact of environmental disturbances, habitat fragmentation, and other factors on the biodiversity of a given area.

Shannon Diversity Index was used to measure the diversity of species in a community.

Denoted as *H*, this index is calculated as:

$$H = -\Sigma p_i * ln(p_i)$$

Where, pi = The proportion of the entire community made up of species

The Shannon index ranges from 0 to ln(S), where S is the number of species in the community. A value of 0 indicates no diversity (only one species present), while a higher value indicates greater diversity and evenness of species. The maximum value of the index (ln(S)) is reached when all species are equally abundant.

The Shannon diversity index is widely used in ecology, conservation biology, and other fields to measure and compare the biodiversity of different communities or habitats. It is sensitive to changes in both species' richness and evenness, and can be used to track changes in biodiversity over time or in response to environmental disturbances.

4. RESULTS

4.1 Diversity and abundance of soil fauna in Ranibari Community Forest

During the study period a total of 1011 soil fauna belonging to 16 species were recorded in Ranibari Community Forest. Arachnids group had the highest relative frequency 39 and relative abundance 47. The lowest relative frequency was recorded in snails 0.67 and relative abundance 8.22. Simpson diversity index was 0.72 whereas Shannon diversity index was 1.5. Dominance of the species was 0.27 and the evenness was 0.64. The following species were identified:

Table 2: Identified macroinvertebrates in the **s**tud**y** **a**rea

Group	Common name	Scientific name	RF	RA
Beetles	Digging beetle	*Pterygida gracilis*	3.26	18.82
	Ground beetle	*Tetragonoderus* spp.	1.18	14.1
	Ground beetle	*Platynus kleebergi*	0.49	2.3
	Rhino beetle	*Catharsius* spp.	0.49	2.3
Snails	Tapered snail	*Gyraulus euphraticus*	0.49	5.88
	Marsh snail	*Gyraulus convexiusculus*	0.09	1.17
	Asiantramp snail	*Bradybaena similaris*	0.09	1.17
Myriapods	Red legged millipede	*Trigoniulus corallinus*	1.48	9.41
	Blue legged centipede	*Rhysida afra*	1.87	12.94
Insects		*Autocrates* spp.	14.04	16.47
	Large rose sawfly	*Cimbex americenus*	14.44	14.11
Arachnids	Widow spider	*Latrodectus* spp.	15.62	22.35
	Crab spider	*Thomisidae* spp.	23.83	24.70
Annelids	Red wiggler worm	*Eisenia foetida*	5.63	15.29
	Blue Indian worm	*Pheretima posthuma*	6.72	12.22
	Red head worm	*Lumdricus rubellus*	3.56	16.29

RF= Relative frequency; RA = Relative abundance

The most macrofauna recorded was arachnids (39%) followed by insects (29%)(Figure 2).

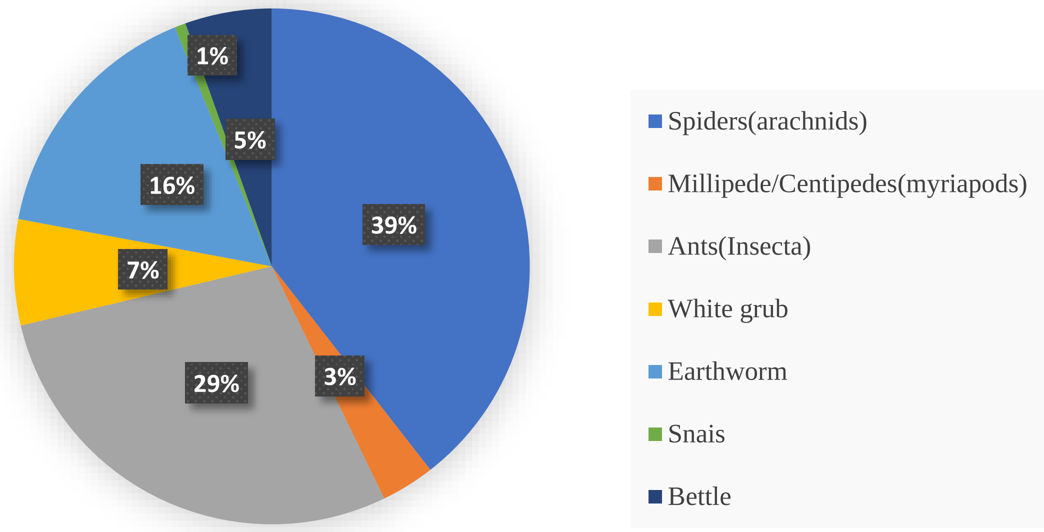


Figure 2: Abundance of soil fauna

4.2 Effects of microhabitat characteristics on abundance of soil fauna

4.2.1 Abundance of soil fauna under different vegetation types

Soil fauna such as arachnids, beetles and annelids were recorded in canopy of different vegetation (Figure 3). The plant species like *Stranvaesia nussia*, *Schima wallichilli* and *Persea duthiei* were mostly distributed in forest. Highest number of soil fauna were spotted in the canopy cover of *Stranvaesia nussia* (n=200) followed by *Celtris australis*.

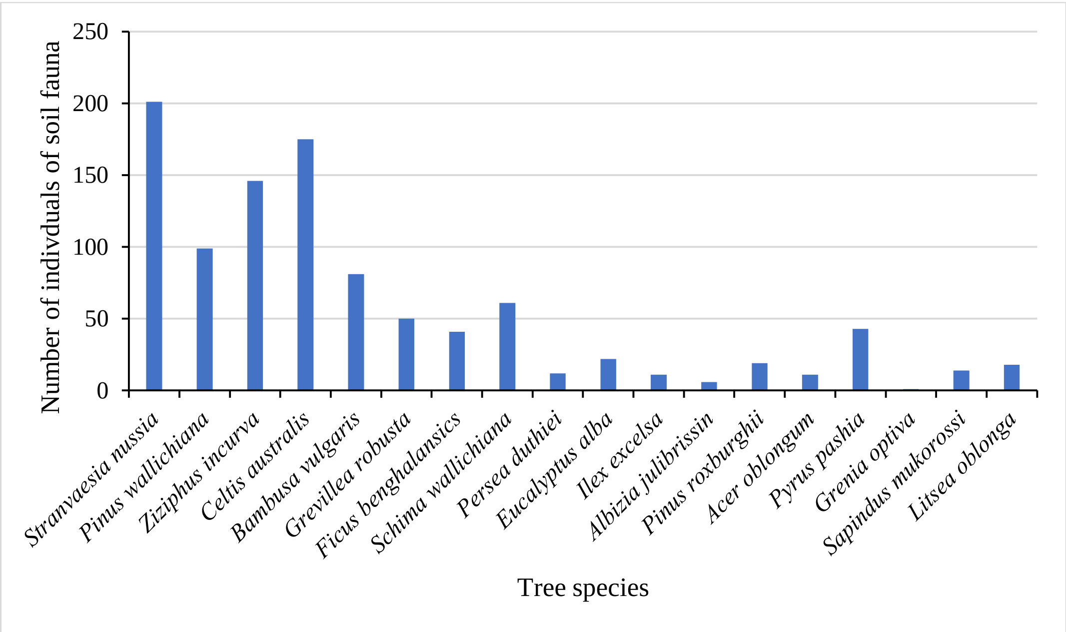


Figure 3: Abundance of soil fauna under different vegetation types

4.2.2 Abundance of soil fauna with leaf litter

Insects including the ants were mostly recorded in the leaf litter. The most area in the forest is covered by the leaf litter under the canopies. 81.1% (n=69) of the total studied vegetations has the presence of leaf litter and 18.8% (n=26) vegetations has no litter decomposed under their canopies (Figure 4).

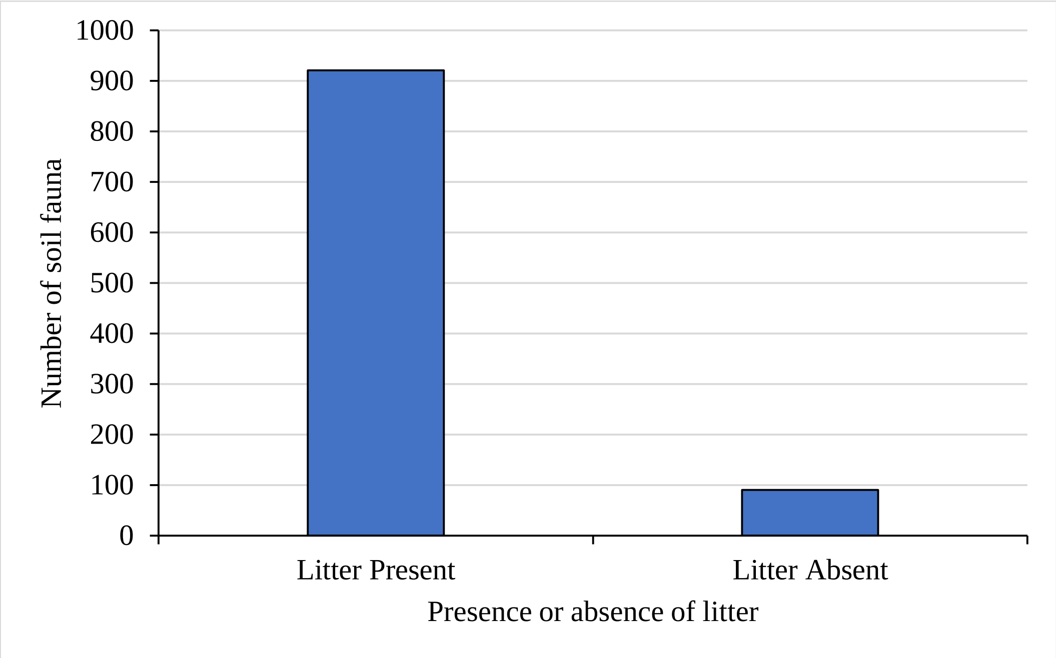


Figure 4: Abundance of soil fauna with leaf litter

4.2.3 Effects of canopy cover in abundance of soil fauna

The lowest canopy cover was found to be 65% and the highest canopy was found to be 85% (Figure 5). Most of the canopies were of the range 76% to 80% where total 440 individuals' fauna was spotted. Most of them were larvae of soil fauna (white grub), beetles and annelids. High organic matter and litter under the canopies were seen.

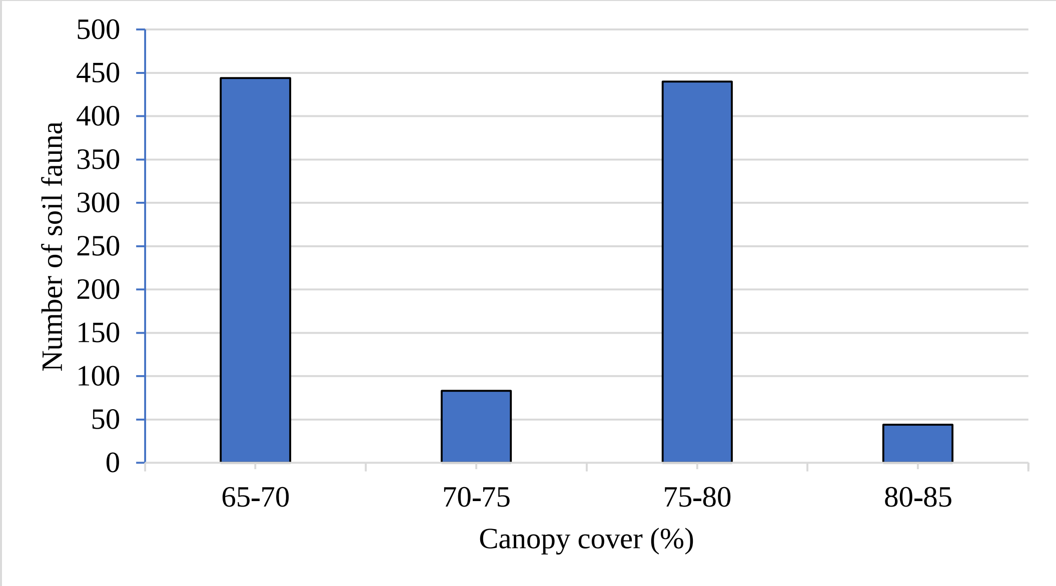


Figure 5: Abundance of soil fauna under different soil types

4.3 Abundance of soil fauna under different soil conditions

Mainly the three types of the soil were identified in the study area. The soil has its different properties on the basis of its physical and chemical characteristics.

4.3.1 Soil moisture

Soil fauna like arachnids and beetles were mostly observed in the moist soil. Most of the vegetation types were distributed on the moist soil. 56.4%(n=48),following the first table which had the total macrofauna 53(Figure 6).

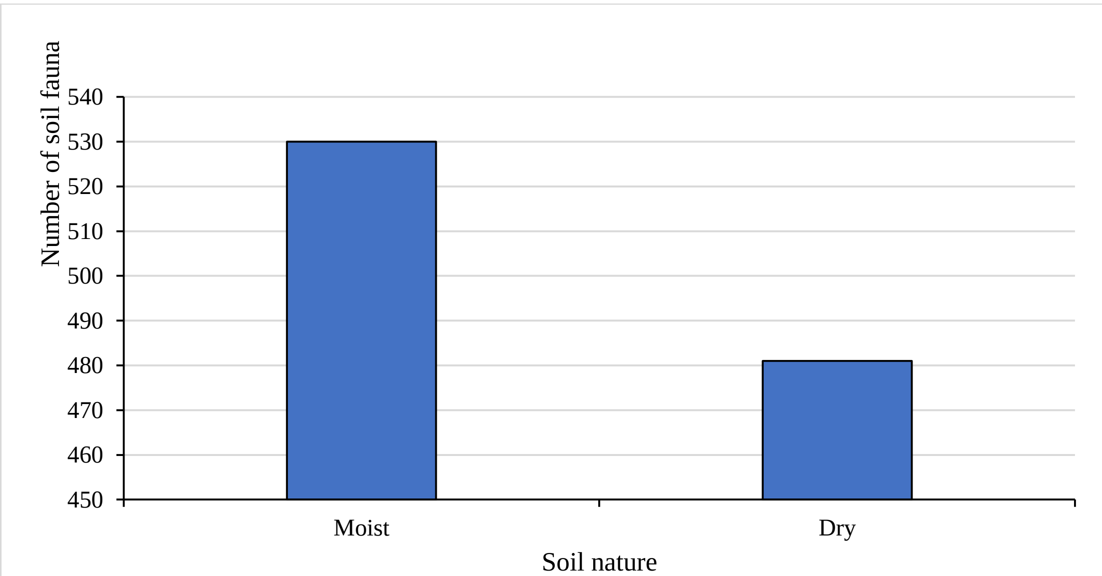


Figure 6: Abundance of soil fauna with soil moisture

4.3.2 Soil types

The most soil fauna including snails and millipede were spotted on the clay soil. (Figure7).

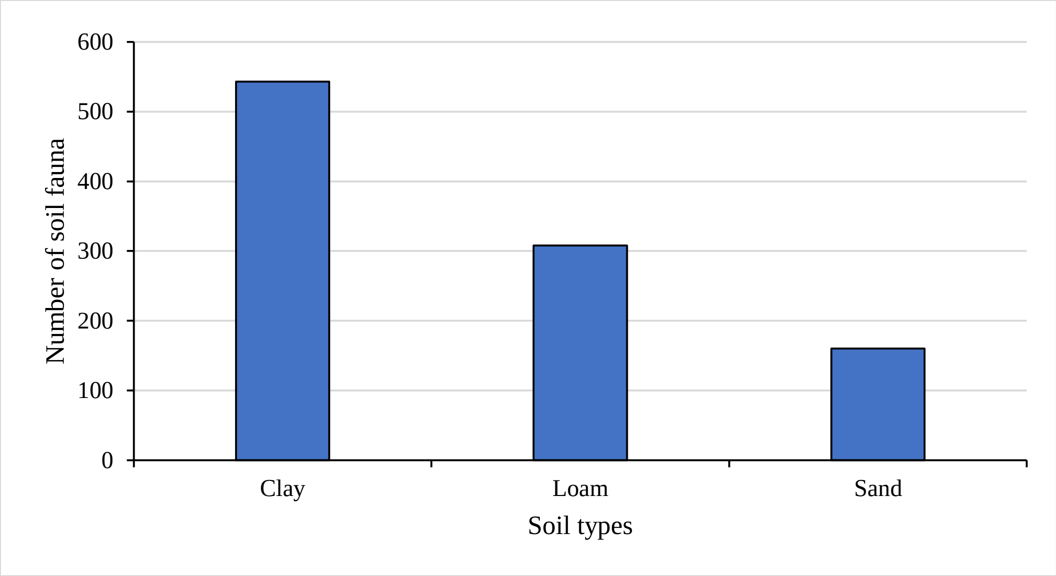


Figure 7: Abundance of soil fauna under different soil types

4.3.3 Soil pH

The soil pH of the study area ranges from 6.2 to 8.3 which is slightly acidic to basic. Most of the plots in the forest has the basic soil. Annelids and Snails were observed mostly in basic condition. Out of 85 samples tested, 59 samples have soil pH above 7(Figure 8).

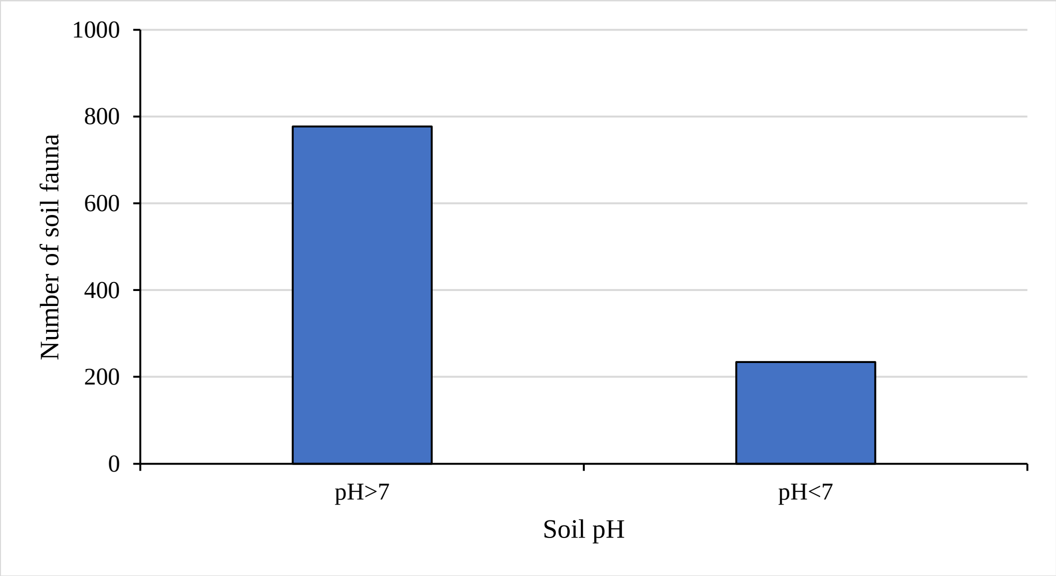


Figure 8: Abundance of soil fauna in different soil pH

4.3.4 NPK content of the soil

Low amount of the nitrogen was found in most of the soil samples. Mostly myriapods were found in this type of soil. Not any soil fauna was spotted on the soil that contain high amount of nitrogen (Figure 9).

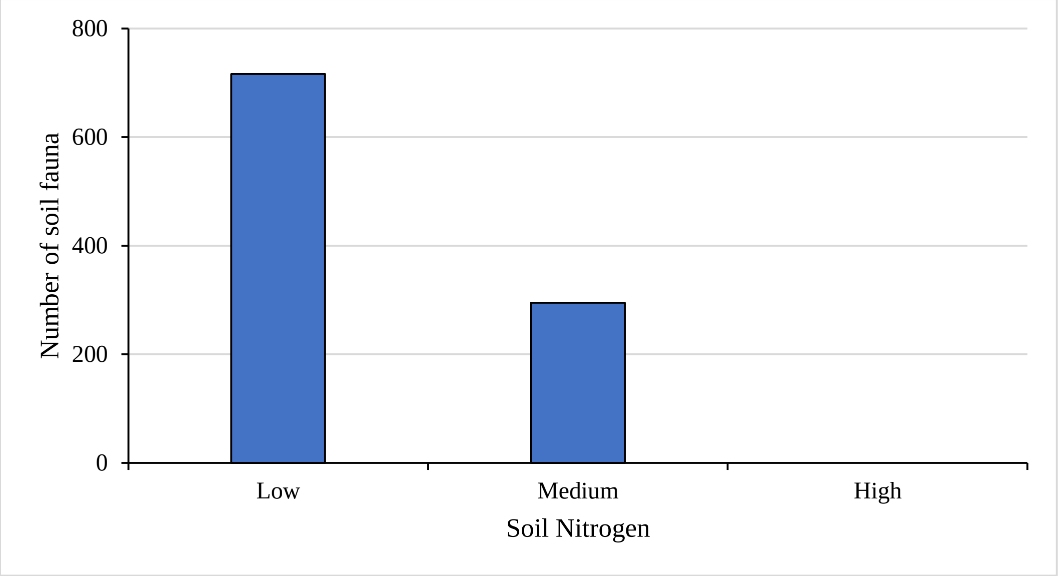


Figure 9: Abundance of soil fauna with soil Nitrogen

Mostly beetles and annelids were recorded in the soil. Soil fauna were abundant in the soil that contain low amount of phosphorous (Figure 10).

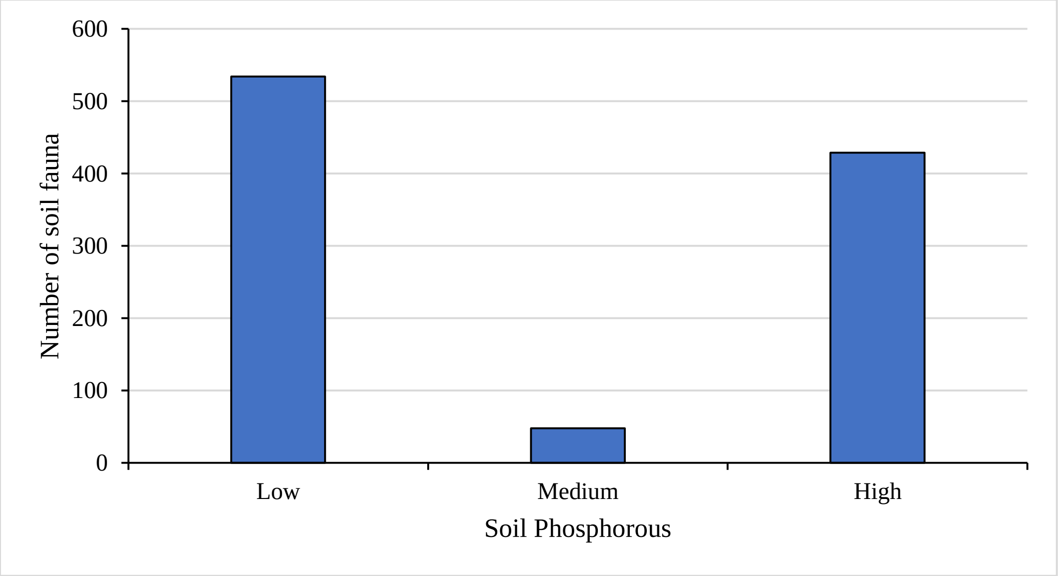


Figure 10: Abundance of soil fauna with soil Phosphorous

Soil fauna including insects, annelids and beetles were recorded in the soil that had medium amount of potassium. Soil fauna were abundant in the soil that contain medium amount of potassium(Figure 11).

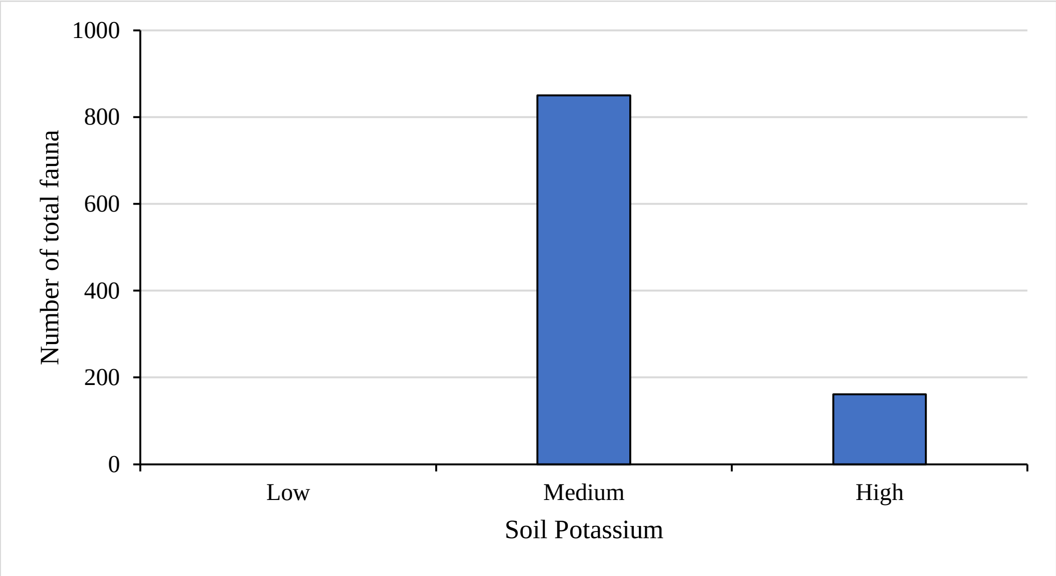


Figure 11: Abundance of soil fauna with soil Potassium

4.3.5 Microhabitat characteristics determining the abundance of soil fauna

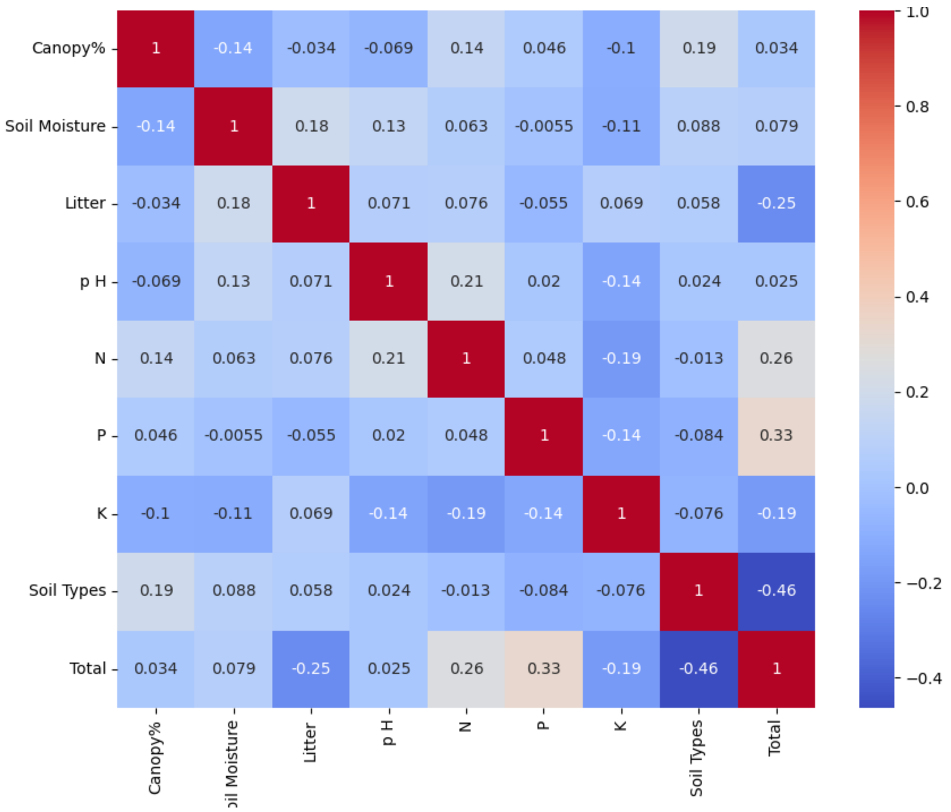


Figure 12: Heatmap showing correlation between dependent and independent variables

Table 3: Results of Generalized Linear Model

	Coefficient	Standard Error	Z	P>|z|	[0.025	0.975]
Const	9.758e+16	1.72e+08	5.67e+08	0.000	9.76e+16	9.76e+16
Canopy%	1.792e+15	1.5e+06	1.19e+09	0.000	1.79e+15	1.79e+15
Soil Moisture	3.293e+16	1.54e+07	2.14e+09	0.000	3.29e+16	3.29e+16
Litter	-6.534e+16	1.92e+07	-3.41e+09	0.000	-6.53e+16	-6.53e+16
p H	-5.915e+15	1.53e+07	-3.86e+08	0.000	-5.92e+15	-5.92e+15
N	6.14e+16	1.97e+07	3.12e+09	0.000	6.14e+16	6.14e+16
P	3.153e+16	8.5e+06	3.71e+09	0.000	3.15e+16	3.15e+16
K	-2.535e+16	1.67e+07	-1.52e+09	0.000	-2.53e+16	-2.53e+16
Soil Types	-5.962e+16	8.98e+06	-6.64e+09	0.000	-5.96e+16	-5.96e+16

Based on the above table, the coefficients and their corresponding standard errors (std err) indicate the estimated effect of each predictor variable on the response variable in a logistic regression model. The z-values and p-values (P>|z|) determine the statistical significance of each coefficient. In this case, since the p-values are all very close to zero (0.000), it suggests that all predictor variables are statistically significant. A p-value of less than 0.05 is commonly used as a threshold for statistical significance, so the extremely low p-values indicate strong evidence against the null hypothesis of no relationship between the predictor variables and the response variable.

Additionally, the confidence intervals [0.025, 0.975] provide a range of plausible values for each coefficient. Since the confidence intervals do not include zero, it further supports the conclusion that the predictor variables have a significant effect on the response variable. In summary, based on the provided table, all the predictor variables (Canopy%, Soil Moisture, Litter, pH, N, P, K, and Soil Types) are statistically significant in the logistic regression model.

5. DISCUSSION

5.1 Abundance of soil fauna

The richness of the soil fauna and the components of soil faunal community, might be controlled by local factors like soil type, canopy cover, NPK nutrients available and pH of the soil (Mubarak & Olsen 1976). Vegetational effect, which were associated with the dynamics of the forest ecosystems were supposed to affect the abundance and diversity of the soil fauna because they were corelated to most of environmental and soil parameters and humus and litter profile (Bernier 1998). Organic matter and other related soil features like soil pH, moisture and nutrient availability were associated to each other to determine the relationship between soil fauna and plant succession, because it contains the lining sub rate for both vegetation and soil fauna (Mordelet et al. 1993).

It was observed in study that changes in the composition of the soil fauna might result due to the less availability of the litter and nutrients and the less leaf litter tends to lower the soil fauna abundance in the forest dynamics (Wright et al. 2011). So, most of the species were found in the canopy of *Stranevensia nussia* due to large leaf litter decomposition and dense canopy cover tend to have more litter decomposition and have more resource's ability. In this study, abundant soil fauna was observed in the leaf litter. Also found that the most of soil fauna was observed in the leaf litter decomposition. The vegetative parameters of the forest area were also responsible for the distribution pattern of the soil fauna and the leaf litter also helped to protect the soil fauna from the unsuitable climatic conditions (Seitz et al. 2015). It was also observed that the faunal diversity of the soil habitat varied according to vegetations due to the change in the local environment conditions, forest patch structure, canopy cover and soil leaf litter and humus. Precipitation also increased the number of the soil fauna compared to the dry environment because high moisture played an important role for the survival of the soil fauna during the study.

The soil faunal community were strongly affected by forest green space type such as sports fields, community gardens and other plotted lands, and the floral species richness is associated with the soil faunal diversity (Baruch et al. 2021) Study had pointed out the changes in abundance, bio diversity of soil fauna species with the vegetations dynamics (Miggie et al.1995). Moisture and sunlight were also the factors that affect the number and behavior of the faunal community of the soil in moist and dry condition of soil. Interaction between solar radiation and ground cover of forest result in the moist and dry condition of the soil and moisture and dryness were known to be the factors that impact the abundance and distribution of the soil fauna (Salmon et al. 2008)

5.2 Effects of microhabitat on the abundance of soil fauna

There was the effects in relation between the soil fauna of particular plots and nutrient availability like NPK on the soil and canopy cover (Cade-Menons et al. 2018). By comparing earthworm numbers present in the soil under canopy, where the ant nests with the surround litter and soil showed that litter dwelling earthworms are likely to held by the sufficient amount of food for the ants (Tajik et al. 2019). Selective feeding on the leaf litter had been observed in soil fauna like millipedes (Arpin 1986). Less number of the macroinvertebrates were found in the area where there is no leaf litter because of no food availability and litter deprecation (Judos, 1990). The absences of canopy did not give soil fauna to flourish, which caused the decline in the macroinvertebrates number (Meier & Bowman 2008). It was also seen that the depth of the soil and soil quality were also the most important factors for the proper growth of native vegetation and number of soil fauna existing under the canopy (Bateman et al. 2021).

Most soil fauna were detected on the top layer of the soil because, the most interaction between macro fauna and soil environment depended upon the leaf litter decomposition or soil organic matter and nutrients (Wang et al. 2017) and the number of macroinvertebrates existing in litter and under horizon showed the great diversity of their varied group with respect to the soil. By the moving and feeding behavior, soil fauna transformed different plant debris into small and rigid aggregates, with the mineral matter, makes the holes and cavities in the soil particles and transport the leaves into the mineral horizons or with litter (Brussaard et al. 2007) which creates the movement of the matter within the litter and other food nutrients , resources and habitat which result in the wide range of the macroinvertebrates interact with each other and cohabit there and this also could explain why the more number of the earthworm and other were found during the study. The availability of the soil nutrients like potassium lead to massive number of the soil fauna (Cade-Menun et al. 2018).

Different pH values might have affected on the metabolic activities of the soil fauna, so the number of the species were found varied in different pH level of the soil. Study in community forest suggested that pH is the bio indicator of the soil acidification. Acidic soil and high nitrogen connect in the soil could be toxic to the plants and soil fauna (Yu et al. 2021). The pH, available phosphorus were higher under the tree clumps due to the greater organic matters like leaf litter below the canopies (Mordelet et al. 1993).

The number of soil fauna depended upon the amount of nitrogen, potassium, total phosphorous and other soil parameters and soil toxicity on fauna can occur due to high intake of the chemical and minerals (Koehler 1992). Plant litter decomposition accumulated the soil organic compound which also increased the number of soil fauna (Gonzalez & Seastedt 2001). There was the interlink among plant litter chemistry, Soil faunal diversity and below ground ecosystem so they depended upon each other (Meier & Bowman 2008). Potassium, Phosphorus and nitrogen limit the root allocation, tree growth and litter production in the forest (Wright et al. 2011).

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The soil fauna was mostly affected by the factors like canopy cover, N,P,K, pH, of the soil and soil moisture. Arachnids were most spotted in the studied area. The canopy of *Stranvaesia nussia* had the most abundance of the soil fauna. The soil fauna was in the more in the sampling sites where there plenty of leaf litter decomposition. Moist soil was present in the most part of the studied area which played the favorable condition for the survival of soil fauna. Acidic soil had the low tendency to support the abundance of the soil fauna. The high availability of the nitrogen decreased the abundance of the soil fauna.

6.2 Recommendation

The community forest must develop the comprehensive management plan and the strategy for planting new trees. Planting a diverse mix of native tree species can also increase the biodiversity of the forest.

REFERENCES

Arpin, P., David, J. F., Guittonneau, G. G., Kilbertus, G., Ponge, J. F., & Vannier, G. 1986. Ecology Solution **23**:89–118.

Alvey, A. A. 2006. Promoting and preserving biodiversity in the urban forest. Urban Forestry and Urban Greening **5**(4):195–201. https://doi.org/10.1016/j.ufug.2006.09.003

Baruch, Z., Liddicoat, C., Cando-Dumancela, C., Laws, M., Morelli, H., Weinstein, P., Young, J. M., & Breed, M. F. 2021. Increased plant species richness associates with greater soil bacterial diversity in urban green spaces. Environmental Research **196**:110425. https://doi.org/10.1016/j.envres.2020.110425

Bateman, A. M., Erickson, T. E., Merritt, D. J., Veneklaas, E. J., & Muñoz-Rojas, M. 2021. Native plant diversity is a stronger driver for soil quality than inorganic amendments in semi-arid post-mining rehabilitation. Geoderma **394**:115001. https://doi.org/10.1016/j.geoderma.2021.115001

Bernier, N. 1998. Earthworm feeding activity and development of the humus profile. Biology and Fertility of Soils **26**(3):215–223. https://doi.org/10.1007/s003740050370

Blanchart, E., & Julka, J. M. 1997. Influence of forest disturbance on earthworm (Oligochaeta) communities in the Western Ghats (South India). Soil Biology and Biochemistry **29**(3–4):303–306. https://doi.org/10.1016/S0038-0717(96)00094-6

Brussaard, L. 1998. Soil fauna, guilds, functional groups and ecosystem processes. Applied Soil Ecology**, 9**(1–3):123–135. https://doi.org/10.1016/S0929-1393(98)00066-3

Brussaard, L., de Ruiter, P. C., & Brown, G. G. 2007. Soil biodiversity for agricultural sustainability. Agriculture, Ecosystems and Environment **121**(3):233–244. https://doi.org/10.1016/j.agee.2006.12.013

Cade-Menun, B. J., Elkin, K. R., Liu, C. W., Bryant, R. B., Kleinman, P. J. A., &

Moore, P. A. 2018. Characterizing the phosphorus forms extracted from soil by the Mehlich III soil test. Geochemical Transactions **19**(1):1–17. https://doi.org/10.1186/s12932-018-0052-9

Carolina, N., & Acetate, A. 1971. Determination of Phosphorus, Potassium, Calcium, and Magnesium Simultaneously in soil. In: Instrumental Methods for Analysis of Soils and Plant Tissue. https://doi.org/10.2136/1971.instrumentalmethods.c6

Edwards, C. A. 1991. The assessment of populations of soil-inhabiting invertebrates. Agriculture,Ecosystems and Environment **34**(1–4):145–176. https://doi.org/10.1016/0167-8809(91)90102-4

Gallardo, A. 2003. Effect of tree canopy on the spatial distribution of soil nutrients in a Mediterranean Dehesa. Pedobiologia **47**(2):117–125. https://doi.org/10.1078/0031-4056-00175

Gillison, A. N., Jones, D. T., Susilo, F. X., & Bignell, D. E. 2003. Vegetation indicates diversity of soil macroinvertebrates: A case study with termites along a land-use intensification gradient in lowland Sumatra. Organisms Diversity and Evolution **3**(2):111–126. https://doi.org/10.1078/1439-6092-00072

Gonzalez, G., & Seastedt, R. T. 2001. Soil Fauna and Plant Litter Decomposition Ecology **82**(4):95964.http://www.esajournals.org/doi/pdf/10.1890/00129658(2001)082[0955:SFAPLD]2.0.

Jouquet, P., Dauber, J., Lagerlöf, J., Lavelle, P., & Lepage, M. 2006. Soil invertebrates as ecosystem engineers: Intended and accidental effects on soil and feedback loops. Applied Soil Ecology **32**(2):153–164. https://doi.org/10.1016/J.APSOIL.2005.07.004

Kautz, T., López-Fando, C., & Ellmer, F. 2006. Abundance and biodiversity of soil microarthropods as influenced by different types of organic manure in a long-term field experiment in Central Spain. Applied Soil Ecology **33**(3):278–285. https://doi.org/10.1016/j.apsoil.2005.10.003

Koehler, H. H. 1992. The use of soil mesofauna for the judgement of chemical impact on ecosystems. Agriculture, Ecosystems and Environment **40**(1–4):193–205.

https://doi.org/10.1016/0167-8809(92)90092-P

Kooch, Y., & Noghre, N. 2020. The effect of shrubland and grassland vegetation types on soil fauna and flora activities in a mountainous semi-arid landscape of Iran. Science of the Total Environment **703**, 135497. https://doi.org/10.1016/j.scitotenv.2019.135497

Korboulewsky, N., Perez, G., & Chauvat, M. 2016. How tree diversity affects soil fauna diversity: A review. Soil Biology and Biochemistry **94**(December):94–106. https://doi.org/10.1016/j.soilbio.2015.11.024

Lavelle, P., Decaëns, T., Aubert, M., Barot, S., Blouin, M., Bureau, F., Margerie, P., Mora, P., & Rossi, J. P. 2006. Soil invertebrates and ecosystem services. European Journal of Soil Biology **42**(SUPPL. 1). https://doi.org/10.1016/j.ejsobi.2006.10.002

Lindberg, N., & Bengtsson, J. 2006. Recovery of forest soil fauna diversity and composition after repeated summer droughts. Oikos **14**(3):494–506. https://doi.org/10.1111/j.2006.0030-1299.14396.x

Madej, G., & Kozub, M. 2014. Possibilities of using soil microarthropods, with emphasis on mites (Arachnida, Acari, Mesostigmata), in assessment of successional stages in a reclaimed coal mine dump (Pszów, S Poland). Biological Letters **51**(1):19–36. https://doi.org/10.1515/biolet-2015-0003

Maharjan, S. R., Bhuju, D. R., & Khadka, C. 2007. Plant Community Structure and Species Diversity in Ranibari Forest, Kathmandu. Nepal Journal of Science and Technology, **7**:35–44. https://doi.org/10.3126/njst.v7i0.569

Meier, C. L., & Bowman, W. D. 2008. Links between plant litter chemistry, species diversity, and below-ground ecosystem function. Proceedings of the National Academy of Sciences **105**(50):19780–19785. https://doi.org/10.1073/pnas.0805600105

Mordelet, P., Abbadie, L., & Menaut, J. C. 1993. Effects of tree clumps on soil characteristics in a humid savanna of West Africa (Lamto, Côte d'Ivoire). Plant and Soil **153**(1):103–111. https://doi.org/10.1007/BF00010549

Mubarak, A., & Olsen, R. A. 1976. An Improved Technique for Measuring Soil pH. Soil Science Society of America Journal **40**(6):880–882. https://doi.org/10.2136/sssaj1976.03615995004000060024x

Mueller, K. E., Eisenhauer, N., Reich, P. B., Hobbie, S. E., Chadwick, O. A., Chorover, J., Dobies, T., Hale, C. M., Jagodziński, A. M., Kałucka, I., Kasprowicz, M., Kieliszewska-Rokicka, B., Modrzyński, J., Roz˙en, A., Skorupski, M., Sobczyk, Ł., Stasińska, M., Trocha, L. K., Weiner, J., … Oleksyn, J. 2016. Light, earthworms, and soil resources as predictors of diversity of 10 soil invertebrate groups across monocultures of 14 tree species. Soil Biology and Biochemistry **92**:184–198. https://doi.org/10.1016/J.SOILBIO.2015.10.010

Negrete-Yankelevich, S., Fragoso, C., Newton, A. C., Russell, G., & Heal, O. W. 2008. Species-specific characteristics of trees can determine the litter macroinvertebrate community and decomposition process below their canopies. Plant and Soil 2008 307:1 **307**(1):83–97. https://doi.org/10.1007/S11104-008-9585-5

Penn, C. J., Rutter, E. B., Arnall, D. B., Camberato, J., Williams, M., & Watkins, P. 2018. A discussion on mehlich-3 phosphorus extraction from the perspective of governing chemical reactions and phases: Impact of soil pH. Agriculture (Switzerland) **8**(7):1–20. https://doi.org/10.3390/agriculture8070106

Pouyat, R. V., Szlavecz, K., Yesilonis, I. D., Groffman, P. M., & Schwarz, K. 2015. Chemical, physical, and biological characteristics of urban soils. Urban Ecosystem Ecology 0129: 119–152. https://doi.org/10.2134/agronmonogr55.c7

Reynolds, B. C., Crossley, D. A., & Hunter, M. D. 2003. Response of soil invertebrates to forest canopy inputs along a productivity gradient. Pedobiologia **47**(2):127–139. https://doi.org/10.1078/0031-4056-00176

Salmon, S., Artuso, N., Frizzera, L., & Zampedri, R. 2008. Relationships between soil fauna communities and humus forms: Response to forest dynamics and solar radiation. Soil Biology and Biochemistry **40**(7):1707–1715. https://doi.org/10.1016/j.soilbio.2008.02.007

Sanaei, A., Yuan, Z., Ali, A., Loreau, M., Mori, A. S., Reich, P. B., Jucker, T., Lin, F., Ye, J., Fang, S., Hao, Z., & Wang, X. 2021. Tree species diversity enhances plant-soil interactions in a temperate forest in northeast China. Forest Ecology and Management **491**(January). https://doi.org/10.1016/j.foreco.2021.119160

Seitz, S., Goebes, P., Zumstein, P., Assmann, T., Kühn, P., Niklaus, P. A., Schuldt, A., & Scholten, T. 2015. The influence of leaf litter diversity and soil fauna on initial soil erosion in subtropical forests. Earth Surface Processes and Landforms **40**(11):1439–1447. https://doi.org/10.1002/esp.3726

Tajik, S., Ayoubi, S., Khajehali, J., & Shataee, S. 2019. Effects of tree species composition on soil properties and invertebrates in a deciduous forest. Arabian Journal of Geosciences **12**(11). https://doi.org/10.1007/s12517-019-4532-8

Wang, Z., Hu, Y., Wang, R., Guo, S., Du, L., Zhao, M., & Yao, Z. 2017. Soil organic carbon on the fragmented Chinese Loess Plateau: Combining effects of vegetation types and topographic positions. Soil and Tillage Research **174**:1–5.

Wei, H., Liu, W., Zhang, J., & Qin, Z. 2017. Effects of simulated acid rain on soil fauna community composition and their ecological niches. Environmental Pollution **220**: 460–468. https://doi.org/10.1016/j.envpol.2016.09.088

Wright, S. J., Yavitt, J. B., Wurzburger, N., Turner, B. I., Tanner, E. V. J., Sayer, E. J., Santiago, L. S., Kaspari, M., Hedin, L. O., Harms, K. E., Garcia, M. N., & Corre, M. D. 2011. Potassium, phosphorus, or nitrogen limit root allocation, tree growth, or litter production in a lowland tropical forest. Ecology **92**(8):1616–1625. https://doi.org/10.1890/10-1558.1

Yu, K., Wang, L., Duan, Y., Zhang, M., Dong, Y., Jia, W., & Hu, F. 2021. Soil pore characteristics, morphology, and soil hydraulic conductivity following land subsidence caused by extraction of deep confined groundwater in Xi'an, China: Quantitative analysis based on X-ray micro-computed tomography. Soil and Tillage Research **211**. https://doi.org/10.1016/j.still.2021.105018

Zagatto, M. R. G., Pereira, A. P. de A., Souza, A. J. de, Pereira, R. F., Baldesin, L. F., Pereira, C. M., Lopes, R. V., & Cardoso, E. J. B. N. 2019. Interactions between mesofauna, microbiological and chemical soil attributes in pure and intercropped Eucalyptus grandis and Acacia mangium plantations. Forest Ecology and Management **433**:240–247. https://doi.org/10.1016/j.foreco.2018.11.008

ANNEX

Pterygida gracills

Bradybsena similaris

***Catharsius* spp.**

***Thomisidae* spp.**

***Gyraulus* spp**

Gyraulus convexiusculus

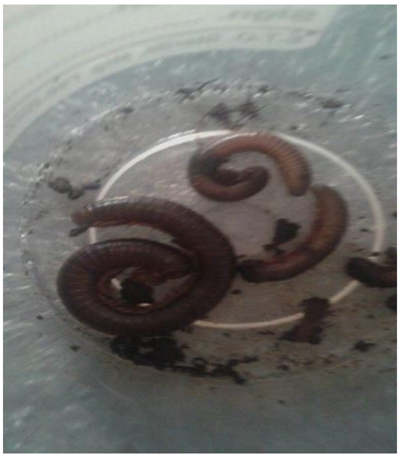
Platynus kleebergi

***Catharsius* spp.**

***Latrodectus* spp.**

Rhysida afra

***Thomisidae* spp.,**



Trigoniulus corallinus