Microarthropod population dynamics in a subtropical deciduous forest of the Eastern-Ghat hill range in India in response to variation in edaphic factors

Pratik Acharya
Odisha University of Agriculture and Technology College of Basic Science and Humanities
Suryasikha Samal (suryasikha.777@gmail.com)
Orissa University of Agriculture and Technology https://orcid.org/0000-0001-7301-3249
C.S.K. Mishra
Odisha University of Agriculture and Technology College of Basic Science and Humanities

Research

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Abstract

Background: Soil microarthropods are considered as major groups of soil fauna which facilitate the decomposition of organics in soil. In forests, the sustenance of nutrient pool is dependent on the density and diversity of these animals. Edaphic factors of habitat play vital role in species distribution of any region. Any changes in population structure of microarthropod may affect the ecosystem adversely. This study reports the seasonal variation of microarthropod population of the orders Collembola, Acari and Hymenoptera in five sampling zones, degraded (DF), dense mixed (DMF), open mixed (OMF), bamboo (BF) and wet land (WL) in a subtropical deciduous forest (Chandaka-Dampara) of Eastern India.

Results: Seven species of Collembola and four species each of Acari and Hymenoptera were identified. Ecological indices did not show noticeable species diversity in different sampling zones of the forest. Heatmap analysis indicated high relative abundance of Collembola in WL irrespective of season. The abundance of Acari was high in OMF and DF, Hymenoptera in DMF and OMF for dry and wet season respectively. Wet season indicated significantly higher microarthropod population irrespective of species. The correlation colour matrix and principal component analysis (PCA) showed significant positive correlation of arthropod population with soil moisture and organic carbon. Significant population variation in the animal population were observed between dry and wet seasons.

Conclusion: The forest floor was dominated by Collembola order of microarthropod species irrespective of sampling zone and season. Soil moisture and carbon contents in different seasons were found to be most sensitive growth regulators of microarthropod populations In Chandaka forest of Eastern India.

1.0 Background

Microarthropods play a key role in the soil ecosystem and are specifically considered important for the degradation of organics and sustaining the nutrient pool. They have been reported to influence organic matter mineralization and pedogenesis (Basset et al., 2003; Cakır & Makineci, 2018). They aerate and mix the soil in addition to their functional roles in regulating the population size of other soil organisms (Esnowo *et al.*, 2014). Soil microbes facilitate the metabolism of low molecular weight compounds, where as particulate organic matters get fragmented by microarthropods for subsequent microbial exoenzyme action (Soong and Nielsen, 2016). Cole et al. (2004) observed in a microcosm experiment that nutrient release from a mixture of soil and plant litter increased with increasing density of microarthropods. Soil microarthropods can also be considered useful bioindicators of soil conditions (Menta et al., 2017).

Esnowo *et al.* (2014) indicated that community structure, abundance and diversity of soil arthropods are influenced by the availability of organic matter, substrate quality and concentration of macro and micronutrients. Various groups of soil arthropods play distinct roles in ecosystem engineering and changes in their species distribution or community structure are likely to affect soil vital ecological functions and services (Birkhofer et al., 2011; Meloni et al., 2020).

In forest ecosystems the organisms indicating the richness and diversity of other species are the invertebrate soil fauna including the arthropods (Wiedema, 2007; Cakir and Makineci, 2015). They are useful for effective monitoring of important changes affecting the quality of the sites. It is feasible to determine the population size of thee animals from small samples using the proportionate and statistical methods (Nakamura *et al*., 2003; Fu-Sheng *et al*., 2007; Sridhar *et al*., 2013; Duyar, 2018).

Reports are available on the adverse impact of changing vegetation and physico-chemical conditions of soil on the biota (Rey et al., 2011; Mayor et al., 2013). The edaphic factors provide heterogeneous conditions for the distribution and abundance of soil fauna. Seasonal variations may also influence the distribution and diversity of soil fauna including microarthropods (Liu et al., 2013; Meloni et al., 2020).

Although some basic studies have been done on the belowground arthropods of forests (Begum et al., 2014; Cakır and Makineci, 2018; Abbas and Parwez, 2020), the information on species distribution pattern in relation to the different climate and edaphic factors have been less investigated in subtropical forests. Therefore, the aim of this study was to evaluate the impact of certain important soil physicochemical parameters of diverse zones in a subtropical deciduous forest in eastern India on the density and diversity of microarthropods, Collembola,Acari and Hymenoptera.

2.0 Materials And Methods

2.1 Description of study area and sampling

Chandaka-Dampara forest is situated between 85°34’42”E to 85°49’27” E longitude and 20°12’29” N to 20°26’18”N latitudes covering an area of 193.35 sq km in the Easternghat hill range of the state of Odisha, India (Fig. 1). The map has been extracted from the official website (https://chandakawildlife.in/Map.htm) of Chandaka-Dampara forest. The temperature of this area varies from 42 °C In Summer to 11 °C in Winter with average annual rainfall is 1500 mm.

The soil was sampled from the forest in dry (January to March) and wet (July to October) seasons. Sampling was repeated three times in a month in each season at an interval of 10 days from 5 different zones, degraded forest (DF), dense mixed forest (DMF), open mixed forest (OMF), wetland (WL) and bamboo forest (BF). A 3500 m^2 area was demarcated in each zone. Each area was then subdivided into 12 sub plots (each measuring 12 m x 24 m) to ensure the total coverage. Soil samples were collected at random from each subplot (12 subplots x 3 replicates = 36 samples) with 20 cmx20 cmx30 cm dimensions. The samples represent soil cores 5 cm in diameter and 5 cm depth. Soil and litter dwelling microarthropods were extracted using modified Berlese-Tullgren funnels equipped with 25 W bulbs (Coleman et al., 2004). The extraction process continued for 4 days till the soil was completely dry. Arthropods extracted from each sample were preserved in 70% ethanol, later sorted, identified and counted under stereoscopic microscope (Magnus S5) to orders and genus as per Dindal (1990).

2.2 Soil analysis

Soil texture (sand, silt and clay) was analyzed with the help of a Bouycos hydrometer (Gee and Bauder, 1986). Soil temperature (up to 10 cm depth) was measured with the help of digital soil thermometer (Spectrum Tech-6300, USA), percent moisture by moisture meter (Lutron, PMS-714, Taiwan) and soil pH by digital pH meter (Elico). The organic carbon (OC) was estimated by rapid titration method as per Walkey and Black (1934), nitrogen (N) as per Hach et al. (1987), potassium (K) as per Jackson (1973) and phosphorous (P) following the method of Olsen et al. (1954).

2.3 Ecological indices

The ecological indices were calculated after sampling and segregation of microarthropods. Shannon's diversity index (SDI) ($H = -\sum pi \ln pi$) where pi = relative abundance of the species, estimated by pi = pi = ni ⁄ N; Margalef's richness Index ($R = N-1 / \ln(n)$), where N- Total number of species and n- total number of observed individuals and evenness ($J = H' / \ln S$) were calculated in each sampling area in each season (Shannon,1949; Margalef, 1968; Pielou, 1975).

2.4 Statistical analysis

The data have been presented as mean ± SD. One way ANOVA and Turkey's multiple test (alpha = 0.05, 0.01level) were conducted to determine the significance of variation in data between sampling regions. Paired t-test of the data was conducted to analyse the variation in parameters between seasons at 0.05 level of significance. Matrix analysis and principal component analysis (PCA) were done to find out the correlation between arthropod population and soil physicochemical parammeters. The distribution of the animal species in relation to soil parameters were visualized using XL-STAT 3D plot irrespective of species and sampling zones. The Heat map was constructed to study the relative abundance of arthropod orders in different sampling regions and seasons. Both arthropod orders and sampling zones were clustered independently using ascendant hierarchical clustering based on Euclidian distances. The data matrix's rows and columns were then permuted according to corresponding clusterings reflecting data in the permuted matrix. All the statistical analysis and graphs were done by XL-STAT and Graph Pad Prism 8 software package (GraphPad Software, Inc., La Jolla, CA).

3.0 Results

3.1 Soil physico chemical paramerers

Soil in the forest was of Alfisol type. The physicochemical analysis results of the soil have been presented in Table-1. Texture analysis indicated that sand percentage ranged from 38.57 ± 2.8% to 47.57 ± 0.9%; silt from 24.10 ± 2.9% to 37.50 ± 1.7% and clay from 21.87 ± 1.8% to 37.33 ± 1.7% irrespective of seasons and sampling zones. The variation in textural components between sampling zones were statistically significant ($p < 0.05$) irrespective of season. Significant variation in percent sand ($p < 0.05$) was also observed between seasons.

Dry season					
	DF	WL	OMF	DMF	BF
Sand***	47.57±0.9	40.13±1.6	40.63±0.4	43.33±0.47	43.60±2.4
Silt**	27.30±3.0	23.17±2.08	37.50±1.7	31.93±5.0	31.40±5.4
Clay***	25.80±1.5	36.70±1.8	21.87±1.8	24.73±4.8	25.67±2.0
Temp	34.87±2.5	31.40±3.0	34.27±1.5	32.83±0.4	34.83±2.04
Moisture**	14.97±1.4	24.93±3.05	18.77±5.8	24.77±2.2	26.40±0.3
pH	8.50±0.5	8.45±0.69	8.59±0.3	8.31±0.4	8.30±0.5
OC*	0.13±0.03	0.22±0.07	0.18±0.01	0.29±0.009	0.24±0.05
N	0.07±0.02	0.07±0.02	0.06±0.02	0.07±0.02	0.08±0.01
P	0.02±0.001	0.02±0.01	0.03±0.002	0.03±0.002	0.03±0.001
K	0.01±0.008	0.12±0.001	0.01±0.003	0.01±0.004	0.02±0.007
Wet season					
	DF	WL	OMF	DMF	BF
Sand*	46.47±1.15	38.57±2.8	39.97±0.77	41.33±1.2	42.80±3.6
Silt*	27.37±3.5	24.10±2.9	36.83±2.2	27.50±5.8	27.40±3.6
Clay*	26.17±2.4	37.33±1.7	23.20±1.6	31.17±5.4	29.80±5.5
Temp**	31.67±2.1	28.07±1.6	29.63±2.4	30.60±0.6	24.98±1.3
Moisture***	39.67±2.43	44.57±2.3	36.17±5.1	30.43±1.5	30.93±0.5
pH	8.63±1.2	8.77±1.1	9.29±1.4	8.74±1.1	8.73±1.0
OC	0.44±0.11	0.39±0.1	0.31±0.004	0.30±0.05	0.34±0.05
N	0.08±0.02	0.08±0.01	0.07±0.01	0.08±0.02	0.08±0.008
P	0.02±0.01	0.03±0.01	0.02±0.005	0.04±0.002	0.03±0.001
K	0.02±0.001	0.12±0.01	0.01±0.003	0.02±0.002	0.02±0.006

Table 1: Physicochemical parameters in different seasons and zones of Chandaka Dampara forest. DF-degraded forest, WL-wetland, OMF-open mixed forest, DMF-dense mixed forest, BF- bamboo forest Variation between different regions was statistically at * (p<0.001) , ** (p<0.01), *(p<0.05) levels**

The mean soil temperature varied from 31.40 ± 3.0˚C to 34.87 ± 2.5˚C in dry season and 24.98 ± 1.3˚C to31.67 ± 2.1˚C in wet season. In wet season, significant variation ($p < 0.01$) in temperature was found between different zones. The variation in soil temperature was also found to be significant between seasons ($p < 0.05$).The overall average soil temperature was higher in dry relative to wet season.

Percent moisture widely varied between sampling zones in different seasons. It was found to be the highest (44.57 ± 2.3%) in WL of wet season and lowest (14.97 ± 1.4%) in DF of dry season. In general, percent soil moisture was higher in wet season compared to dry season and the variation was found to be significant ($p < 0.05$). The variation in soil moisture between zones was statistically significant ($p < 0.01$) irrespective of seasons.

The mean soil pH ranged between 8.30 ± 0.5 to 9.29 ± 1.4 irrespective of seasons and zones. Percent organic carbon (OC%) ranged between 0.13 ± 0.03% to 0.29 ± 0.009% in dry season and 0.31 ± 0.004% to 0.44 ± 0.11% in wet season. The variation in OC% was statistically significant ($p < 0.05$) in dry season. Student's t-test indicated significant variation in OC% ($p < 0.05$) between seasons. The present study indicated that OC% was higher in wet season compared to dry season. Percent nitrogen (N%) ranged between 0.06 ± 0.02% to 0.08 ± 0.01%. The seasonal variation in N% was found to be significant ($p < 0.05$). Soil phosphorus percentage(P%) varied between 0.02 ± 0.001% to 0.04 ± 0.002% and percent soil potassium (K%) ranged between 0.01 ± 0.008% to 0.12 ± 0.01%.

3.2 Microarthropod population density

A total of 6,717 adult individuals of soil microarthropods belonging to 3 orders (Collembola, Hymenoptera and Acarina) were identified, which were common in all sampling zones. Colllembola included *Axelsonia sp., Lepidocyrtus sp., Cyphoderus sp., Lepidocyrtus sp., Sinella sp., Labella sp.* and *Isotoma sp*. Hymenopterans identified were *Anochetus sp., Hypoponera sp., Cerapachys sp.* and *Plagiolepis sp.*. Acari included *Scheloribates sp., Xylobates sp., Galumna sp.* and *Lamellobates sp.* The population of Collembola was observed to be the highest relative to other microarthropods in the forest soil. In general the population density of arthropods was higher in wet season relative to dry season. Highest mean population of arthropods (1082 ± 5.12) was observed from BF in wet season and the lowest (293.67 ± 3.89) from OMF in dry season (Fig. 2). The variation of species populations between different zones and seasons was significant ($p < 0.05$).

Microarthropod diversity, richness and evenness could be understood from various ecological indices. The Shannon's diversity index (H) was found to be the highest (2.68) in OMF of wet season and minimum (2.60) in WL of dry season. Margalef's richness index (R) was maximum (2.46) in OMF of dry season and minimum in BF (2.0) of wet season. Maximum (0.983) value of Pielous evenness index (J) was recorded from DMF of both dry and wet season and minimum (0.961) from WL of dry season (Table 2).

Ecological indices	Dry season					Wet season				
	DF	WL	OMF	DMF	BF	DF	WL	OMF	DMF	BF
H	2.61	2.6	2.64	2.66	2.63	2.62	2.64	2.68	2.66	2.65
R	2.38	2.29	2.46	2.3	2.29	2.11	2.01	2.08	2.02	2
J	0.966	0.961	0.976	0.983	0.973	0.968	0.976	0.991	0.983	0.98

Table 2: Ecological indices of species in different sampling zones in both dry and wet seasons. H- Shannon Weiner diversity index, R- Margalef's richness index, J- Pielous evenness index. DF-degraded forest, WL-wetland, OMF-open mixed forest, DMF-dense mixed forest, BF-bamboo forest

The relative abundance of order, Collembola, Hymenoptera and Acari in different zones and seasons have been presented in the Heat map (Fig. 3). Similarly orders were characterized by homogeneous color horizontal rectangles and zones by homogeneous color vertical rectangles along the map. The intersection area expressed the clusters of order in a particular sampling zone. Collembola indicated high relative abundance in all zones irrespective of seasons. In dry season, Collembola indicated similar abundance in OMF and DMF, Hymenoptera in DF and WL, Acari in WL, DMF and BF zones. In wet season, identical abundance was observed for Hymenoptera in DF, DMF, Collembola in OMF, BF, Acari in BL, WL and DMF zones.

The microarthropod populations indicated significant positive correlation with OC% ($r = 0.81$, $p < 0.05$), moisture %($r = 0.74$, $p < 0.05$) and negative correlation with temperature ($r =-0.52$, $p < 0.05$). The correlation between parameters have been depicted in colour matrix and PCA plot (Fig. 4). In the the PCA plot, 11 variables were reduced to a few principal components. Two components were extracted and those two components accounted for 88.5% of the total variance. The scree plot creates the graph taking the eigen value against the component number. From the third component on, it was observed that the line was almost flat indicating that each successive component accounted for smaller amounts of the total variance. In general, those principal components were retained whose eigen values were greater than 1. Components with an eigen value of less than 1 account for less variance than did the original variable (which had a variance of 1), and so were of little use. The small angle between variables indicated positive correlation and wide aangles indicated negative orrelation (Fig. 4b,c). The correlated soil physicochemical parameters (OC%, moisture% and temperature) were taken in 3 different axis to visualize the distribution of microarthropod species irrespective of season and sampling zones. The 3D plot indicated species abundance in colour gradient and the average maximum number of species were found in optimum 30.3 ˚C temp, 42% moisture, 0.56 OC% (Fig. 5).

4.0 Discussion

The importance of climatic factors, changes in soil temperature, moisture, pore size distribution, organic matter and nutrient content on the distribution of soil microarthropods in forests have been reported by various authors (Sharma and Parwez, 2017; Cakır and Makineci, 2018). Ghosh and Roy (2005) observed positive correlation between higher organic content in soil and distribution of microarthropods. This was likely due to the availability of the sufficient amount of litter on the top soil which served as a source of organic matter on which the arthropods feed on. This finding corroborates the results obtained in this study indicating that organic carbon is a vital player for determining the density and abundance of microarthropods. Bhagawati et al. (2018) reported significant positive correlation between organic carbon and soil moisture with the population of Collembola in diffrent seasons. They also described soil moisture as the important eadaphic factor for sustaining high microarthropod population. A negative correlation between abundance of Collembola and soil temperature was observed by Kardol et al. (2011) during Winter which is in agreement with the results of this study. However, the results of the present study indicated negative correlation between soil temperature and microarthropod population which contradicts the findings of these authors who reported positive significant correlation between soil temperature and abundance of Acari in wet season .

Ojala and and Huhta (2001) reported that in a spruce forest of Finland, the Collembola had significantly higher population density with respect to other dominant groups. Esenowo et al. (2014) reported the abundance and diversity of soil arthropods in farm land of different geographical regions in Nigeria and found that Hymenoptera were the dominant taxa and Blattoidia, the least abundant. The differences in the arthropod population between study sites have been attributed to the density of vegetation, organic matter and soil moisture.

In the present study, Collembola was found to be the most abundant group relative to other groups. These findings are identical to those of Ojala and Huhta (2001) and may be attributed to the superior adaptation and favourable environmental conditions in the forest which provided a suitable niche for these groups of microarthropods. The significantly higher population of animals in the wet season relative to dry season observed in the present study is in agreement with the earlier reports of Badejo et al. (1997) and Chitrapati (2002) who observed the maximum soil arthropod population in the rainy season with decreasing trend with the onset of Winter. Guru *et al.* (1998) had earlier reported a positive but non significant correlation between soil moisture and arthropod population. Palacios-Vargas et al. (2007) in a dry forest ecosystem in western Mexico have correlated the seasonal variation in precipitation, temperature, along with litter fall with the population of Collembola and Mesostigmata densities. In another study, Bayartogtokh et al. (2016) determined the population density of surface active and soil inhabiting arthropods in a boreal forest of Eastern Kazakhstan and found positive correlation between soil moisture content and arthropod population. The results of the present study are more or less similar to these earlier observations and the also with the findings of Sharma and Parwez (2017), who reported that mites belonging to the order Acarina were the most abundant in a semi arid agroforestry soil within a temperature range of 18 °C to 33 °C and moisture range of 26–34%.

Conclusion

Soil moisture and OC% seemed to be the limiting factors determining the population of microarthropods in the Chandaka-Dampara forest which was evident from the significant variation of the faunal population between wet and dry seasons. It was also evident that the soil composition and quality favoured the Collembola most, relative to other two arthropod orders. The ecological indices did not show significant variation between sampling zones indicating that the microarthropods do not exhibit high species diversity in this forest although they indicated significant variation in their populations between zones. The probable causes of the relatively low species diversity of the arthropods in the forest needs to be further investigated. The results of the present study however will help to visualize the dynamics of soil microarthropod community in this subtropical deciduous forest on a long term basis and provide information for the future conservation measures.

List Of Abbreviations

DF- degraded forest

OMF- open mixed present

DMF- dense mixed forest

BF- bamboo forest

WL- wetland

PCA- principal component analysis

OC- organic carbon

N- nitrogen

P- phosphorous

K- potassium

Sp.- species

Declarations

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Ethics approval (include appropriate approvals or waivers): Not applicable

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Authors' contributions: Pratik Acharya has carried out the experiments, Suryasikha Samal has done the graphical presentation and statistical analysis. C.S.K Mishra has designed and supervised the experiments.

Availability of data and material (data transparency): Not applicable

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Figures

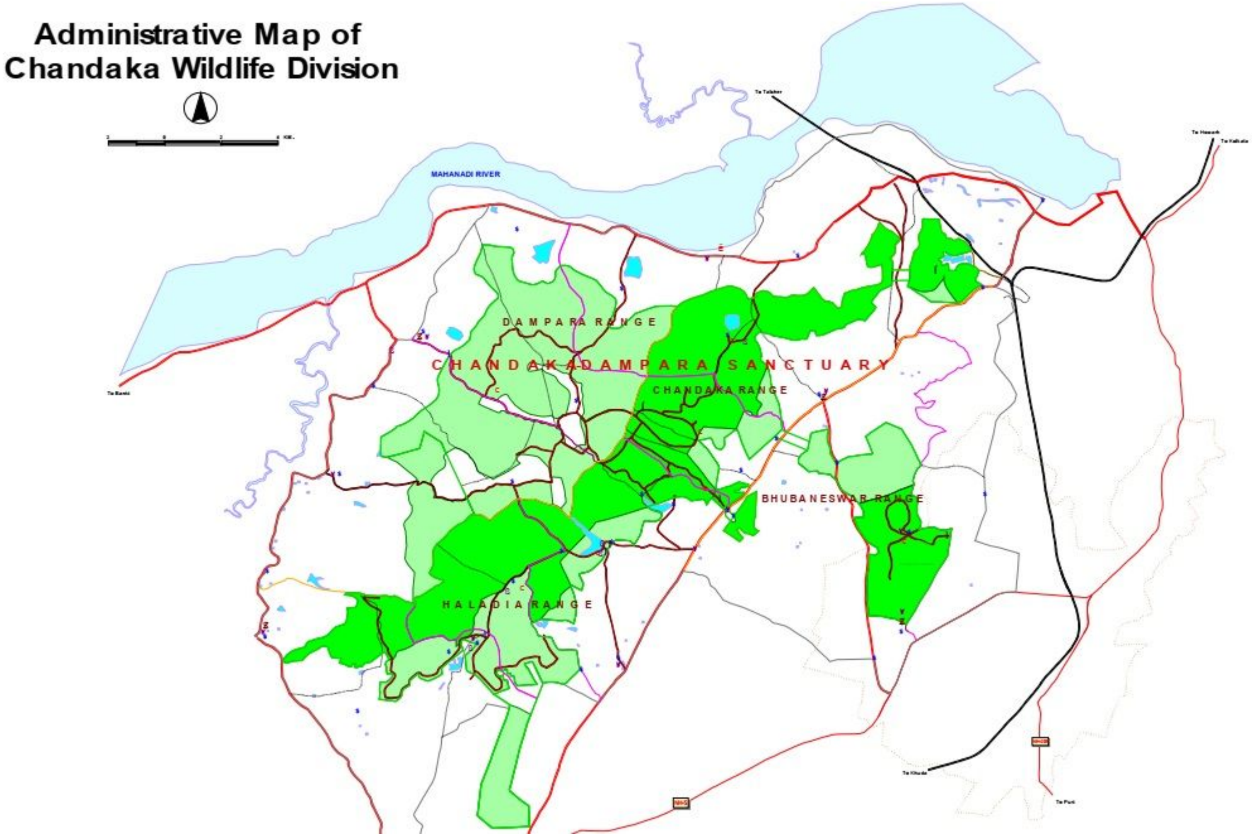
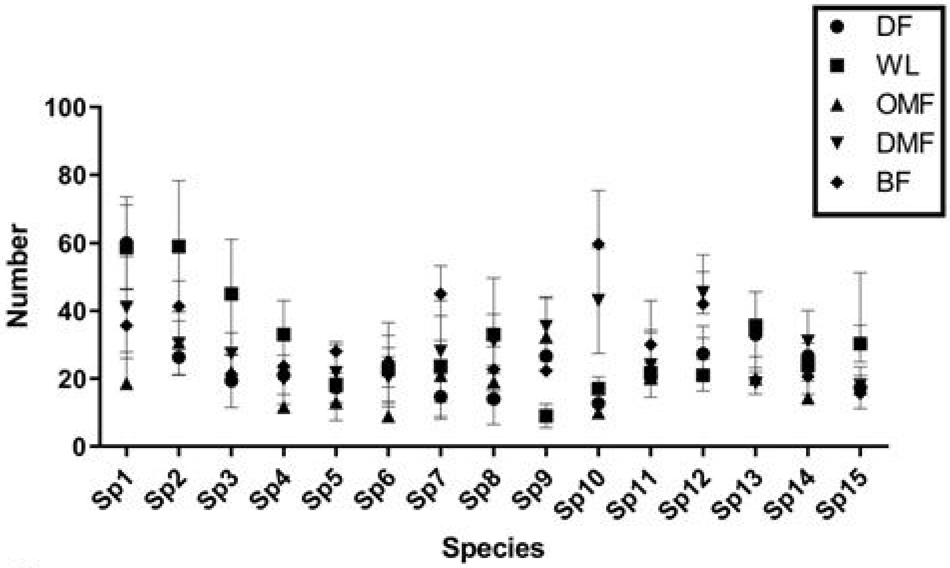
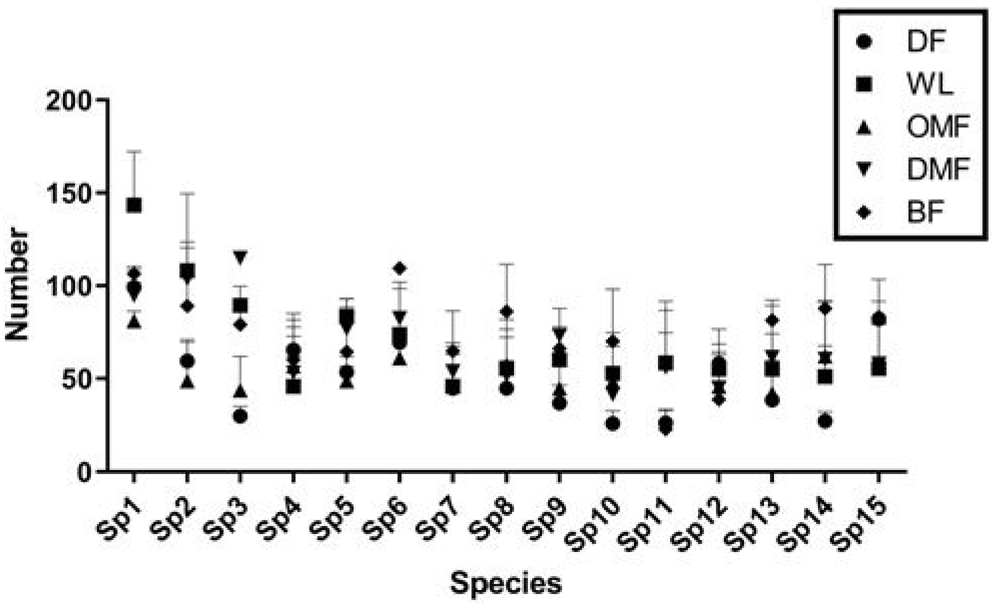


Figure 1

The forest cover map of Chandaka-Dampara forest



a



b

Figure 2

Soil microarthropods in different seasons and zones of Chandaka Dampara forest. a) dry season, b) wet season. DF-degraded forest, WL-wetland, OMF-open mixed forest, DMF-dense mixed forest, BF- bamboo forest. Sp1- Axelsonia sp., Sp2-Lepidocyrtus sp., Sp3- Cyphoderus sp., Sp4-Lepidocyrtus sp., Sp5-Sinella sp., Sp6-Labella sp., Sp7- Isotoma spp, Sp8- Anochetus sp.,Sp9- Hypoponera sp., Sp10-Cerapachys sp. , Sp11- Plagiolepis sp., Sp12- Scheloribates sp., Sp13- Xylobates sp., Sp14- Galumna sp. and Sp15- Lamellobates sp.

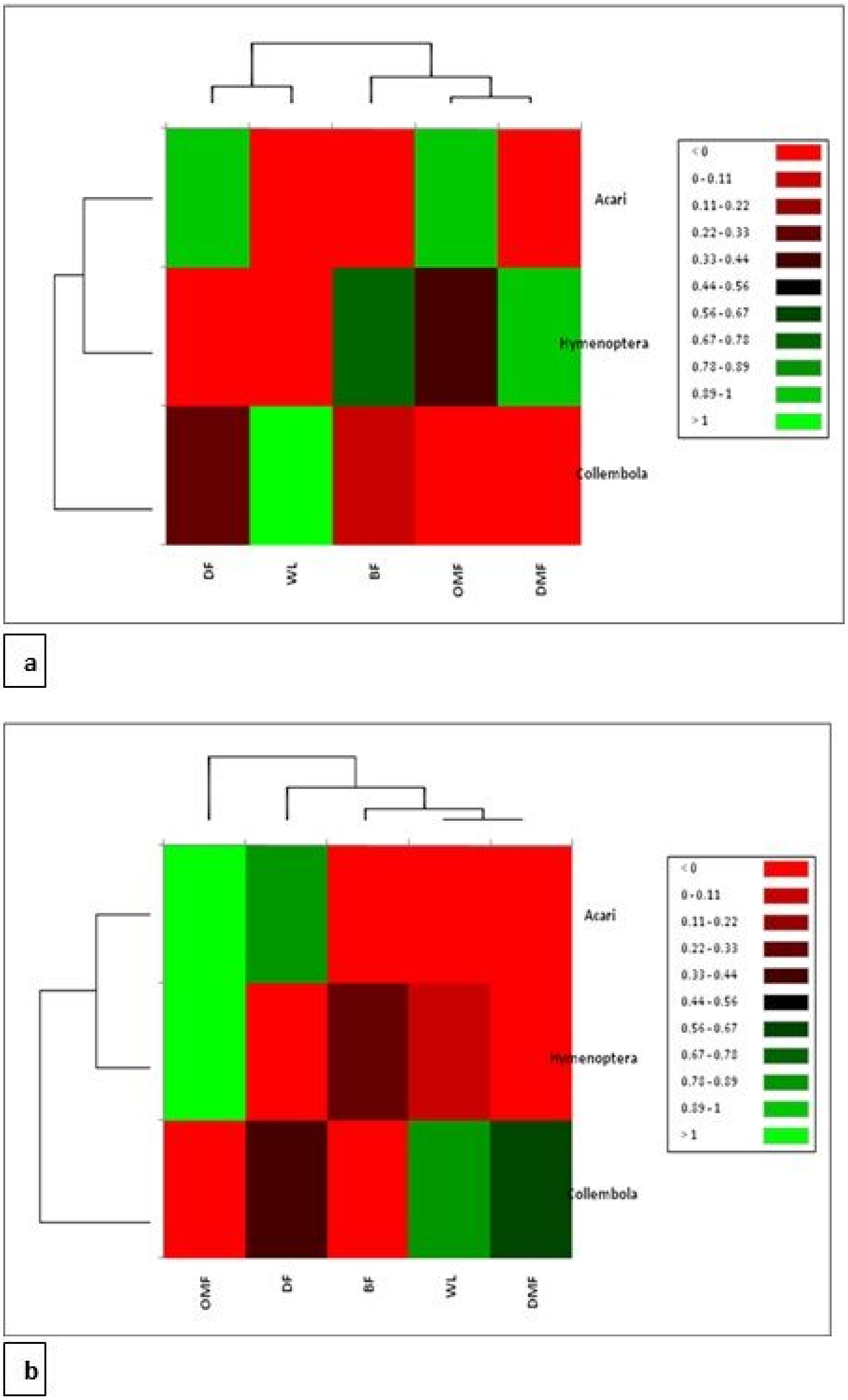


Figure 3

Heat map showing relative abundance of microarthropods for each order in different sampling zones and seasons. a) dry season, b) wet season. DF-degraded forest, WL-wetland, OMF-open mixed forest, DMF-dense mixed forest, BF- bamboo forest

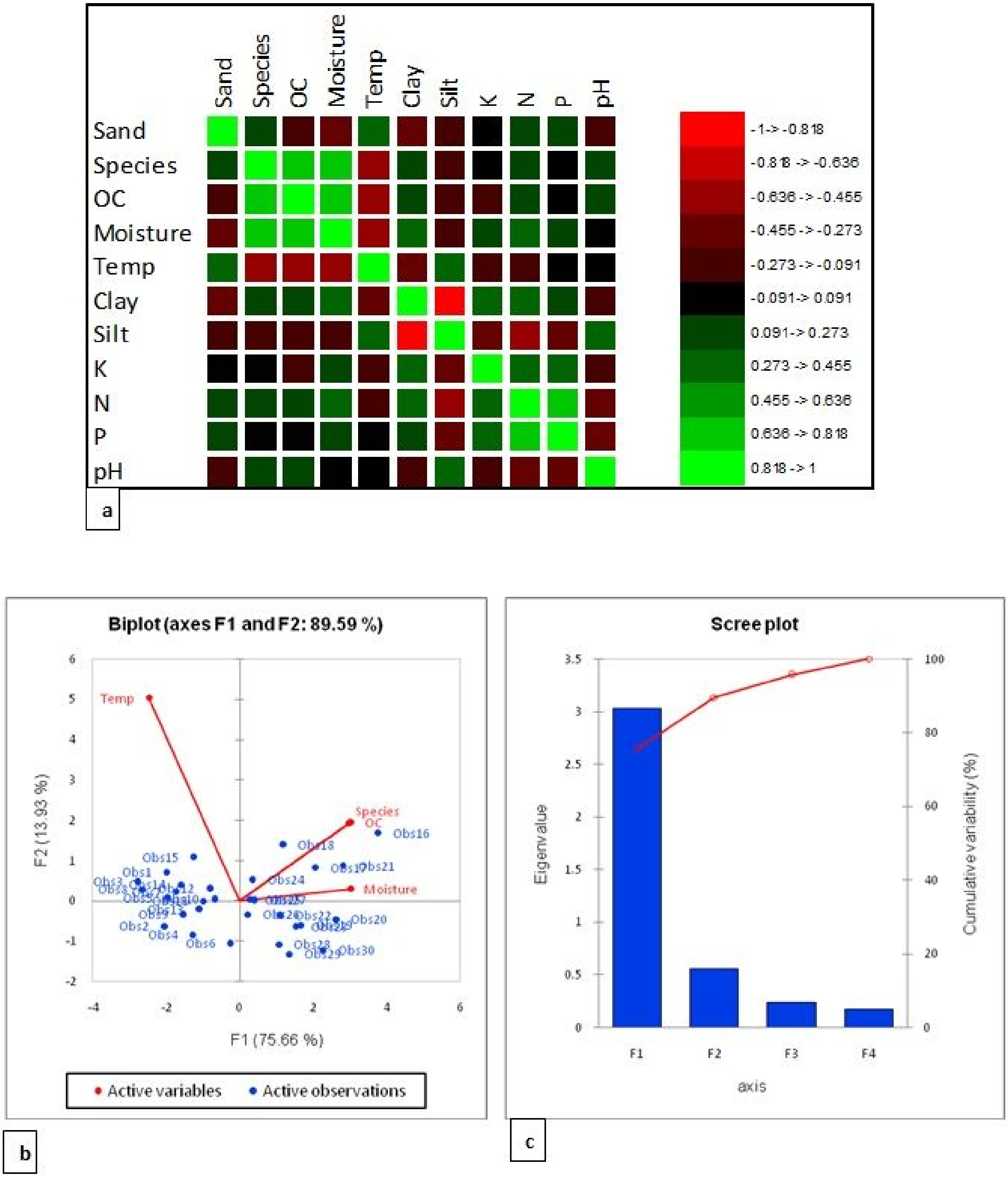


Figure 4

Correlation colour matrix and PCA analysis between soil physicochemical parameters and microarthropods. a) correlation colour matrix, b) biplot, c)scree plot. The wide angles between parameters indicated negative correlation and narrow angles indicated positive correlation.

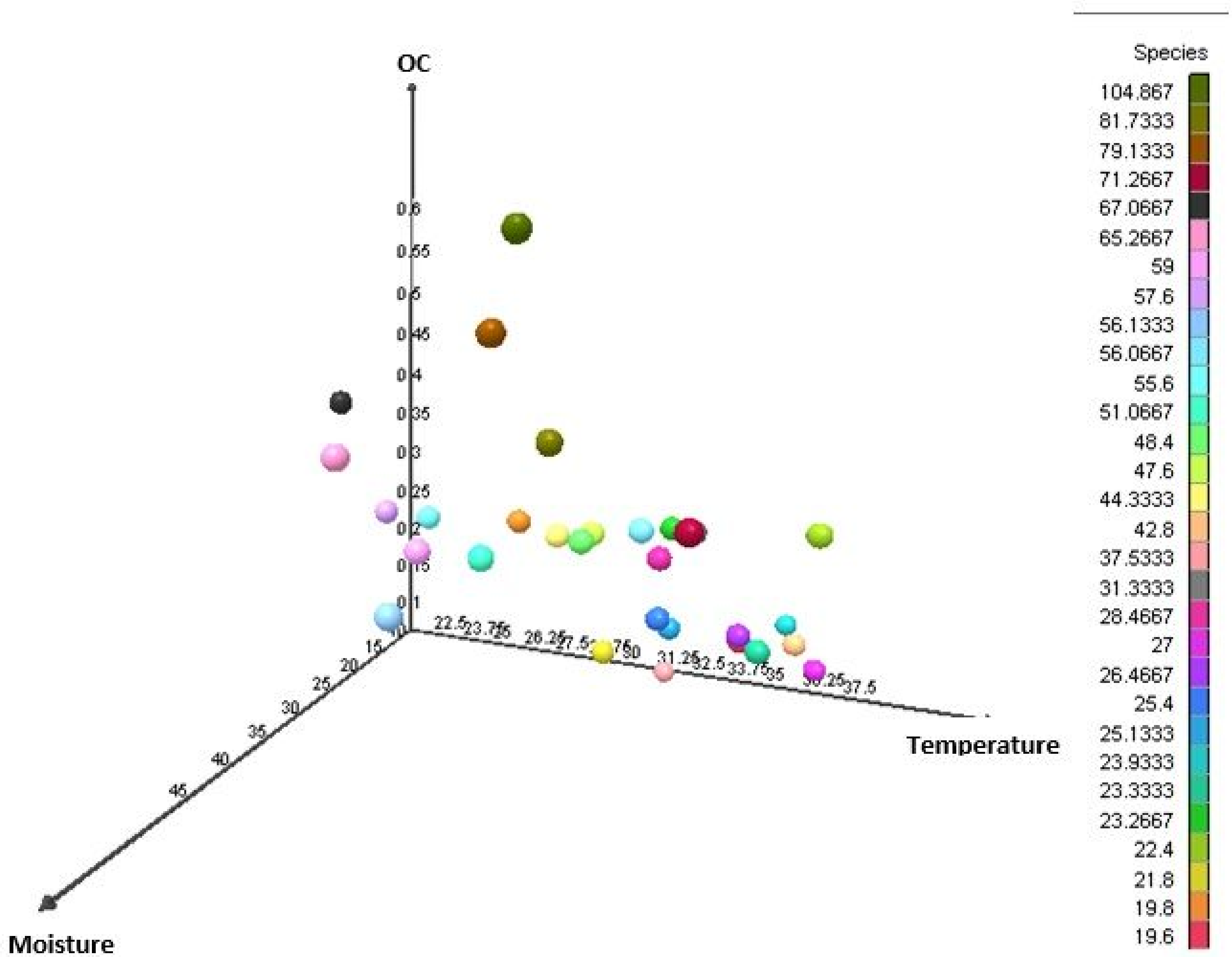


Figure 5

Visualisation 3D-plot of species and soil parameters interaction. Microarthropods are distributed between three axes of soil physicochemical parameters irrespective of zones and seasons. X axis- Temperature, Y axis – Moisture and Z axis- Organic carbon (OC).