Original research paper

Abundance and diversity of soil arthropods in major plantation crops under different farming practices

ABSTRACT

Agriculture is the main source of greenhouse gas emission~~s~~. It is therefore vital to understand the role of the agricultural soil communities in maintaining the soil economic value for agriculture. Soil arthropods play a vital role in soil systems, through ~~in~~ decomposition, nutrient cycling and regulation of microbial communities. The study examining ~~on~~the effects of farming practices (~~*viz.*~~ Natural farming, Organic farming and Inorganic farming) on the abundance and diversity of soil arthropods in major plantation crops (Arecanut, Coconut, Coffee) was conducted~~studied~~ underdifferent zones : ~~*i.e.*~~ Hilly, Central Dry and Transition zone of Chikkamagaluru, Karnataka from August 2023 to May 2024. Soil arthropods belonging to 12 different orders were collected under 5 classes *viz.*,Entognatha, Arachnida, Insecta, Symphlan and Chilopoda. The highest number~~s~~ of individuals was observed in natural farming practice (1256) followed by organic farming(825) and least in inorganic farming(397). The h~~H~~ighest number of soil arthropodswas ~~in the agro-ecological zones~~recorded innatural farming practice (31.90 individuals per 400g of soil)~~in~~ within thecoconut ecosystem followed by organic farming practice ~~with~~ (12.39) and lowest in inorganic farming practices with 5.39 individuals per 400g of soil in arecanut and coffee ecosystem respectively.Shannon W~~w~~einer diversity index shows highest diversity (2.13)~~species richness~~in natural farming system ~~with 2.13~~. Whereas, the lowest diversity was recorded in ~~under~~~~I~~Inorganic farming practices (~~Shannon-Wiener:~~ 0.69). The abundance and diversity showed a significant difference between different farming practices *i.e.* natural, organic and inorganic farming practices in different zones. Natural farming practices followed by organic farming ~~generally~~supported higher diversity indices and abundance of soil fauna compared to inorganic farming practices.

Keywords:Arthropods; Abundance; Diversity; Natural; Organic; Inorganic; farming system; zones

INTRODUCTION

Comment [L1]: These two sentences do not link with each other. Either you highlight the role of soil communities in mitigating greenhouse gas emission or simply remove the first sentence and make second sentence more strong.

Comment [L2]: Do not use short forms

Comment [L3]: Where is this data in this manuscript? Please write the correct data or if you hvaen't included it, put it somewhere.

Comment [L4]: Couldn't see this data anywhere except in abstract

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Comment [L6]: Shannon-Weiner diversity index represents diversity not species richness

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Soil arthropods, ~~which include~~encompassing classes such as Crustacea, Arachnida, Myriapoda, and Insecta, are crucial components of soil ecosystems. These organisms are characterized by ~~features like~~ chitinous exoskeletons, segmentation and jointed appendages, enabling them to perform vital ecological functions. They contribute significantly to organic matter translocation, decomposition, nutrient cycling, and soil structure formation, all of which are essential for maintaining soil quality and health. Diverse arthropod communities are linked to enhance ecosystem stability and resilience to disturbances, making their assessment important for effective habitat management and conservation strategies (Menta and Remelli, 2020; Nahmani*et al.*, 2005). As integral members of soil food webs, these arthropods serve as valuable indicators of soil biological activity, influencing factors such as hydrology, aeration and nutrient dynamics.

However, intensive agricultural practices pose significant threats to soil arthropod diversity and overall soil health. The conversion of natural habitats to agricultural land leads to drastic changes in ~~soil~~ biological and chemical properties of soil, often resulting in biodiversity loss. These changes can negatively impact soil fauna abundance and activity due to altered temperature, moisture levels and organic matter availability (Edwards, 2004). Conventional farming methods, which heavily rely on chemical fertilizers and pesticides, disrupt natural ecosystem processes, further degrading soil quality. The widespread application of pesticides, while beneficial for crop production, has detrimental side effects, killing not only pests but also beneficial insects and other soil invertebrates, leading to environmental imbalances.

In contrast, organic and natural farming systems prioritize the enhancement of soil health and biodiversity by focusing on the management of soil organic matter and utilizing natural nutrient sources. These practices emphasize reduced soil disturbance, avoidance of synthetic chemicals, and the promotion of biodiversity through diverse planting and natural pest management strategies. Research has shown that conservation farming systems support greater arthropod abundance compared to conventional methods (Hole *et al.*, 2005). Monitoring soil arthropod diversity is critical for assessing soil stability and ensuring sustainable agricultural practices. ~~With increasing global concern over the impacts of modern farming on soil biological activity, biodiversity, and water quality, embracing these sustainable approaches is essential for the long-term health of agro-ecosystems and the environment (Rossi *et al.*, 2006).~~In this context,~~With this background~~ thepresent study was

Comment [L7]: Provide citation

Comment [L8]: Add citation

Comment [L9]: Kindly add citation

Comment [L10]: Add citation

Comment [L11]: Monitoring itself is not a sustainable approach. Rather it's an assessment tool so this sentence doesnot align with the focus of the study

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conducted~~on~~to assess theabundance and diversity of various soil arthropods under different farming practices in major plantation crops.

MATERIALS AND METHODS

Study area

The ~~soil fauna~~ study was conducted in three major plantation crop ecosystems~~such as~~ coconut, arecanut and coffee - across~~in~~ three different zones *viz.*, hill zone (13.13°N, 75.64°E), Transition Zone (13.71°N, 75.81°E) and central dry zone (13.54°N, 76.00°E) taluks of Chikkamagaluru district. ~~The s~~Soil samples were collected from ~~plantations of~~ farmers' plantations~~fields~~that had been practicing ~~for > 5 yearsunderdifferent farming practices~~ as ~~*viz.*,~~natural farming, organic farming and inorganic farming for over five years.~~during *kharif*, *Rabi* and summer season of 2023 – 2024.To know the diversity of arthropods~~the soil samples were randomly drawn from ~~natural, organic and inorganic plantations of~~ coconut, arecanut, and coffee ~~farming systems~~plantationsacross all three farming systems from August 2023 to May 2024.

Sampling site

Natural farming: ~~This~~ The research area ~~is~~ had a good composition of weed mulch with grasses and herbs. The practice ~~followed with~~involved the application of Jeevamritha 200 litre per acre at monthly intervals.

Organic farming: This ~~sampling~~ site ~~were~~ practiced ~~with~~ theaddition of farm yard manure/ organic manure to the soil at 2 tonnes per acre. The plantations were free from weed mulches.

Inorganic farming: The plantations were applied with inorganic fertilizers @2 splits per year and fertilizers used ~~are~~ wereurea, DAP, potash and complex form. The plots were free from weeds and no mulching practices followed.

Sampling procedure

The samples were drawn near the root zone within the radius of 45 cm from the plant. The surface litter and weeds were removed carefully from the sampling spot before sampling.~~.~~S~~s~~oil was collected by using circular core sampler measuring 12 cm diameter and 10 cm height. The core sampler was placed on the soil surface and pressed downward to a depth of 10 cm in the sampling spot. Soil sample weighing 400 g was collected in three spots randomlyfrom each plot and were immediately transferred to aluminium cans and closed with lid. Labelling~~labels were placed~~was doneon ~~into~~ each can and ~~closed with lid and~~ brought to the laboratory for further analysis.

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Extraction technique of Soil arthropods and processing

The soil fauna was separated from soil sample using Tullgren funnel which consistedof a funnel with meshscreen,a glass vial~~s~~ and a light source. The glass vial~~s~~was ~~were~~filled with 10 ml of 75 percentethyl alcohol. The vials was~~were~~ periodically checked to keep the alcohol at desired levels. The collected soil sampleswere placedover the meshfixed across wide end of each funnel. The electric bulbs were fixed at the top of the funnel setup thatserved as the source of light and heat energy. Light source of Berlese funnel was switched-on for48 hours to generate heat thatled the micro-arthropods to move down passing through sieve ofthe funneland get collected in glass vials.The arthropods collected were sorted using a stereo binocular microscope (35x magnification)and~~. Taxonomic groups sorted~~ were identified up to order level following taxonomic keys.

Comment [L12]: Write either Berlese or Tullgren funnel or you can write any one name in bracket where these words appear first so that reader can understand both mean the same funnel

Data Analysis

The r~~R~~ecorded data onthe total number of individual~~s of all~~ arthropod~~s~~ speciesobserved~~, which appeared at the time of observation~~ in each sample~~s~~were subjected to analysis of variance using~~with~~ square root transformation (√X+0.5). The a~~A~~bundance of arthropods was compared among farming practices ~~under~~ acrossdifferent zonesand~~as well as across~~ seasons using DMRT.

Shannon- Wiener Diversity index

Diversity index were computed using PAST prog (Hammer *et al.*, 2001).

The abundance and diversity of insect communitywere computed ~~was commuted~~ usingShannon's diversity index (H),~~that~~which accounts~~ed~~for both abundance and evenness of thespecies.

$$H = -\sum pi\ (\ln pi)$$

Where, H represents the index of species diversity in a given locality

Pi is the proportion of"i^{th}"species in total sample and

ln = Natural logarithm.

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Relative abundance wasdetermined using the following equation

$$RA\ (\%) = \frac{Ts}{Tp} \times 100$$

Where RA = denotes the species relative abundance (%)

Ts = total number of individuals of a species in a given area

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Tp = total population of all species in the area

RESULTS AND DISCUSSION

Abundance of soil arthropods across various farming practices

During the study period, natural farming practices exhibited the highest ~~total~~ abundance~~,with~~ (1256individuals)~~ individuals~~ followed by organic f~~r~~arming practices ~~with~~(825 individuals) and lowest in i~~I~~norganic f~~F~~arming~~with~~ (397 individuals). Highest individuals were recorded in classEntognatha followed by Arachnida, Insecta, Symphylaand least was recorded in class Chilopoda. The majority of soil arthropods~~main groups~~in these class belong to orders: Diplura, Coleoptera, Hemiptera, Blattodea, Dermaptera, Diptera, Hymenoptera,Entomobryomorpha, and Scutegeromorpha and sub orders:Mesostigmata, Cryptostigmata~~Entomobryomorpha,Diplura~~, ~~Mesostigmata, Cryptostigmata~~, ~~Coleoptera, Hemiptera, Blattodea, Dermaptera, Diptera, Hymenoptera, and Scutegeromorphawith the majority of soil arthropods.~~ (Table 1).~~Recently~~ T~~t~~hese findings ~~are supported by~~are similar to that of Deepika*et al.* (2020)~~,where theywho~~recorded a higher population of soil arthropods (1987 individuals) in an~~the~~ agricultural ecosystem,~~of which most individuals recorded are~~ with most individuals from Class Entognatha, Order Acarina, and Order Entomobryomorpha.~~Also~~ Ojija (2016) also reported 1,719 arthropods across 63 species in grassland and woodland ecosystems.C~~c~~ompared totheir findings~~thier study,~~ our study exhibited more abundance in natural farming followed by organic farming, which might be due to the availability of rich organic carbon, mulching practices and arthropods friendly soil and climatic conditions.~~They also observed that undisturbed habitat host more soil relative abundance than organic and inorganic practices.~~

Relative abundance of soil arthropods

A significant variation in the number of soil arthropodswas observedamong~~between~~ different farming practices.~~were observedwhere~~ Entognatha, Acarina, I~~i~~nsecta, Symphyla and Chilopoda~~which~~were~~was~~ most abundant in Natural farming (55.18%, 56.18%, 49.28%, 18.84% and 11.24% respectively), followed by Organic farming (33.11%, 34.98%, 32.13%, 31.88% and 40.45% respectively) andthe least relative abundance was observed in Inorganic farming (19.38%, 15.77%, 11.50%, 18.84% and 11.24% respectively) (Table 2).These findings align with Pahari *et al.* (2007) who reported ~~thatAcari constituted~~ 47.04% of Acari,

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followed by Collembola (38.68%), while the ~~with~~ other groups showed~~ing~~ significantly lower dominance.

Abundance and diversity of soil arthropodsacross various zones

Soil arthropod abundance varied significantly across different farming practices in various zones. In hill zone, natural farming plantations of arecanut and coffee showed the highest arthropod populations, averaging 26.70 and 20.00 per 400 g of soil, respectively. Organic farming practices recorded ~~with~~ 17.23 and 15.09 individuals, while inorganic farming had the lowest numbers (8.15 ~~for arecanut~~, 11.00 ~~for coconut~~, and 6.76 ~~for~~ for arecanut, coconut andcoffee respectively). Similar trend was observed among farming practices in transition zone and dry zone. Overall, natural farming consistently supported the highest mean values of soil arthropods across all crops, while inorganic practices ~~yielded~~ resultedthe lowest abundance and diversity, highlighting the significant differences in arthropod populations linked to farming methods across zones (Table 3). In contrast to our findingsHole *et al.* (2005) found that most groups exhibited greater abundance or biomass under conservation systems than under conventional-tillage systems because the former cause less disturbance to their habitats, maintaining the structures that serve as shelter.Organic farming practices performed better than inorganic practices, indicating that they support higher soil arthropod populations than conventional chemical inputs. Inorganic farming practices were associated with the lowest soil arthropod counts, reflecting the negative impact of chemical inputs on soil health.

In plantation crops, the species diversity ~~indices~~ of soil arthropods recorded ~~a~~ significant differences across farming practices and zones.The highest diversity was noticed in the Natural farming practices in the Hill Zone(H = 2.13) in coffee followed by arecanut (H = 2.02). While, ~~in~~Organic farming practices also recorded maximum diversity in the Hill Zone (H = 1.97) in arecanut.~~Least~~ Least diversity~~species richness~~ was found ~~supported~~in~~I~~Inorganic farming practices (H= 0.69)in transition zone(Table 3). The lower evennessmight be~~is~~ due to the enormous difference in relative abundance from one order to another order.These results ~~are in~~support the findings of ~~from~~Gkisakis*et al.* (2014) who ~~also~~ observedsoil arthropods~~,~~ in conventional, organic and integrated olive orchards - whereHilly orchards showed significantly higher seasonal ~~tota~~l arthropod diversity and evenness. Selected habitats in this study was relatively undisturbed compared to organic and inorganic farming

Comment [L13]: In this case, provide reasons for the differences among various zones not only the farming practices. Also, provide citation while reasoning.

Comment [L14]: H denotes diversity not species richness

Comment [L15]: You havenot calculated evenness anywhere. Diversity and evenness are completely different

Comment [L16]: Is this correct?

Comment [L17]: This reason might not justify the finding. Find another suitable reason along with the citation.

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CONCLUSION

The ~~population abundance and diversity of~~ soil dwelling arthropods in natural farming practices ~~generally~~showed~~supported~~ higher diversity indices and abundance~~of soil fauna~~, followed by organic farming practices and least ~~soil arthropods~~ were recorded in inorganic farming practices. The present study is the first time effort to investigate the abundance and diversity of soil arthropods in different farming practices. The information generated by this study would be partial base line of soil living arthropods groups. The practices with natural and organic farming showed increased soil fertility, which is due to addition of large amounts of organic residue inputs, which in turn increase the biological activity of soil arthropods due to the mulching practices followed. It~~And~~ alsoprovided a more balanced and nutrient - rich environment compared to inorganic approaches, potentially leading to better crop performance and soil health.

Comment [L18]: Conclusion needs thorough revision. Please go through it carefully.

Comment [L19]: Abundance denotes the number of individuals or population. No need to write 'population abundance'.

Comment [L20]: repeated

Comment [L21]: is it so? Please check other articles too. I guess there have been some researches done in different farming practices

Comment [L22]: its not clear. Do you want to say that, This study will serve as a baseline for understanding soil-dwelling arthropods?

Comment [L23]: I don't think that your study showed this so better not to put this in conclusion

Comment [L24]: Is it what you have been trying to say through your research? Is it the importance of soil arhtopods or farming ptactice?

Comment [L25]: Add citation in the mentioned places and add references accordingly

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Table 1. Abundance of Soil arthropods ~~as influenced by~~across different farming practices

Class	Order	Abundance (Number of individuals)		
		Natural farming	Organic farming	Inorganic farming

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Entognatha	Collembola	Entomobryomorpha	201	145	64
		Poduromorpha	30	12	9
	Diplura		122	89	71
Arachnida	Mesostigmata		158	135	58
	Cryptostigmata		170	98	47
Insecta	Coleopteran		48	37	14
	Hemiptera		32	18	6
	Blattodea		22	15	6
	Dermaptera		39	21	15
	Diptera		80	39	11
	Hymenoptera		137	74	21
Symphyla	Symphylan		170	110	65
Chilopoda	Scutegeromorpha		47	32	10
Total			**1256**	**825**	**397**

Comment [L26]: Cryptostigmata and mesostigmata are the suborders of different orders under subclass Acari. Go through it thoroughly

Table 2. Relative abundance of soil arthropods ~~as influenced by~~across different farming practices

Class	**Natural farming (RA %)**	**Organic farming (RA %)**	**Inorganic farming (RA %)**
Entognatha	55.18	33.11	19.38
Arachnida	49.25	34.98	15.77
Insecta	56.38	32.13	11.50
Symphyla	49.28	31.88	18.84
Chilopoda	52.81	40.45	11.24

Note: RA – relative abundance

Table 3: Abundance and diversity of soil arthropods in plantation crops under different farmingpractices

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Note: Figures in parentheses are √X+0.5 transformed values. Means followed by the same letter do not differ significantly by DMRT (P = 0.05)

H° □ Shannon – weiner diversity index

Crops	Farming practices	Hill zone		Transition zone		Central Dry zone	
		Abundance	**H°**	**Abundance**	**H°**	**Abundance**	**H°**
Arecanut	Natural	26.70 (5.21[a])	1.81	21.15 (4.65[a])	2.02	17.84 (4.28[a])	1.69
	Organic	17.23 (4.21[b])	1.97	12.0 (3.53[b])	1.72	7.96 (2.90[b])	1.61
	Inorganic	8.15 (2.94[d])	0.69	5.85 (2.51[d])	0.81	3.50 (2.00[d])	0.90
*Coconut	Natural	-	-	22.44 (4.78[a])	1.91	18.93 (4.40[a])	1.77
	Organic	-	-	9.00 (3.08[c])	1.71	6.67 (2.67[bc])	1.68
	Inorganic	11.0 (3.39[cd])	0.78	6.29 (2.60[c])	0.85	4.58 (2.25[cd])	0.81
**Coffee	Natural	20.0 (4.52[b])	2.13	16.00 (4.06[a])	1.86	-	-
	Organic	15.09 (3.9[c])	1.79	12.63 (3.62[b])	1.75	7.18 (2.77[bc])	1.58
	Inorganic	6.76 (2.69[e])	0.85	5.4 (2.42[cd])	0.91	4.03 (2.12[bc])	0.72
S.Em±		0.12		0.10		0.1	
CD at 5%		0.38		0.31		0.30	

* Coconut plantation observed only in inorganic plantation. In hill zone non-availability of plantation with organic and natural farming practice.

** Coffee plantation observed only in organic and inorganic plantation. In central dry zone Non availability of plantation with natural farming practice

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