Tropical Ecology
https://doi.org/10.1007/s42965-022-00277-3

International Society
for Tropical Ecology

RESEARCH ARTICLE

Soil-litter arthropod communities under pasture land use in southern Rwanda

Venuste Nsengimana[1,2] · **Christella S. Iradukunda**[2] · **Jean de Dieu Nsenganeza**[2] · **Josué William Mberwa**[2] · **Wouter Dekoninck**[3]

Received: 4 August 2021 / Revised: 21 July 2022 / Accepted: 30 August 2022

Abstract

Land use change caused by human activities is the main driver of biodiversity loss and changes in ecosystem functioning. However, less is known about how the conversion of a natural to pasture land favour the biological diversity of soil-litter arthropods to advance effective conservation plans and management systems. To fill the gap, this study focussed on soil-litter arthropod communities under a pasture land use in southern Rwanda. Data have been collected using pitfall traps and hand collection between April and June 2021. Sampled specimens of soil-litter arthropods have been identified to order and family levels by using dichotomous keys. Further, the species name was given when the identification key was available, while the morphological description was provided in absence of the identification keys. Results indicated a total of 3013 individuals of soil-litter arthropods grouped into 3 classes, 13 orders, 46 families and 87 morpho-species. Coleoptera showed a high number of families, while higher abundance and the number of morpho-species were found for ants (Hymenoptera: Formicidae). Higher abundance of sampled soil-litter arthropods is a sign that the studied area offers suitable habitat for soil-litter arthropods. However, less abundance found for some groups of soil-litter arthropods might be influenced by the used sampling techniques which were not appropriate for them. We recommend surveys using multiple sampling techniques to maximize chances of capturing a wide range of soil-litter arthropods.

Keywords Abundance · Arachnida · Diplopoda · Diversity · Insecta

Introduction

Soil-litter arthropods represent an important component of soil biodiversity. They play an important role in maintaining soil quality and providing ecosystem services (Menta and Remelli 2020). Arthropod communities perform a variety of important roles in ecosystem functioning (Cole et al. 2016). For example, saprophagous arthropods such as millipedes (Diplopoda), woodlice (Isopoda), and earwigs (Dermaptera) are litter transformers (Wardle et al. 2006), while ecosystem engineers such as termites (Isoptera), and ants (Hymenoptera: Formicidae) can affect patterns of soil formation (Jouquet et al. 2006). Further, some arthropods play key roles in litter decomposition (Lavelle 1996; Culliney 2013; Cassani et al. 2021; Illig et al. 2008) and nitrogen mineralization (Cenkseven et al. 2017) that enrich soil in nutrients. They further have an influence on soil structures and porosity formation, which in turn affect soil hydrological processes (Lavelle 1996) and facilitate soil aeration (Neira et al. 2015).

Like for all types of biodiversity, soil-litter arthropods and their ecosystem functions are affected by land use change (Sala et al. 2000). Agriculture is the most identified component in this regard and contributes to the biodiversity loss through forest clearing (Czimczik et al. 2005), habitat fragmentation (Alroy 2017), increasing number of predators (Bain et al. 2020), use of pesticides (Römbke et al. 2017), and chemical fertilizers (Yeshaneh 2015). Different studies on effects of land use change on soil-litter arthropods (Schindler et al. 2011; Vasconcelos and Bruna 2012; Cole

Venuste Nsengimana
venusteok@gmail.com

1 Department of Mathematics, Science and Physical Education, College of Education, University of Rwanda, Kigali, Rwanda

2 Centre of Excellence in Biodiversity and Natural Resource Management (CoEB), College of Science and Technology, University of Rwanda, Kigali, Rwanda

3 Royal Belgian Institute of Natural Sciences (Scientific Heritage Service), Brussels, Belgium

Published online: 19 September 2022

et al. 2016; Steinwandter et al. 2017; Srivastava et al. 2019; Menta et al. 2020) have indicated that soil-litter arthropods adapt differently to land use change either by the increase or the decrease in species richness and species diversity. These are also associated to changes in essential ecological functions provided by each species.

Few studies have been conducted in pasture land use to assess its effects on soil-litter arthropods (Newbold et al. 2014). It was found that pasture lands reduce the abundance and richness of termites (Isoptera), due to the lack of trees and bushes, and food . Depending on the studied area, absence and presence of termites can be compared to other groups of soil-litter arthropods to assess the level of environmental disturbance (Carrijo et al. 2009; Pribadi et al. 2011; Viana et al. 2014). On the other side, a study on the use of insect diversity to examine the influence of grazing history on ant assemblages in rehabilitated lands, showed little differences between ant diversity and abundance in rehabilitated and non-rehabilitated pasture lands (Erskine et al. 2012). However, less is known about the effects of pasture land use on soil-litter arthropods other than termites and ants. Hence further studies are needed to fill the gaps.

In Rwanda, recent studies indicated that native and natural forests are inhabited by a comprehensive community of soil-litter arthropods whereas exotic, coffee, and banana plantations demonstrate a less extensive soil-litter arthropod community sometimes dominated by non-native species (Nsengimana et al. 2021). The pasture land use occupies around 0.47 million of hectares of the total surface area of the country (RoR [Republic of Rwanda] 2009) and it is mainly used for feeding cows. However, knowledge on the effects of pasture land use on biodiversity, particularly soil-litter arthropods is almost completely lacking. The main purpose of this study was to provide new information on the diversity and abundance of soil-litter arthropods in one of the pasture lands located at Rubona agricultural research station, in Southern Rwanda. Specific objectives consisted of (1) sampling and identifying soil-litter arthropods to order and family levels, and (2) to study the structure of the communities of soil-litter arthropods based on the used sampling techniques.

Material and methods

Study site

The study was conducted in Rubona Agricultural research station located in the southern Province of Rwanda at 2°29´S and 29°46´E, at an altitude of 1750 m above the sea level (Fig. 1; Nsengimana et al. 2021). The mean annual temperature of the area is 20.2 °C and the mean annual rainfall is 1400 mm distributed into two rainy seasons: season A from September to January and season B from February to May (Mukuralinda et al. 2010). The area is also dominated by two dry seasons: a short dry season from January to February and a long dry season from June to September. Data were collected between April and June 2021 (end of the rainy period–starting of the dry season) in the pasture land dominated by *Hyparrhenia* grasses while the soil is mainly covered by the leaf-litter and different types of shrubs. The soil of the area is mainly Oxic Tropudalf (Birasa et al. 1990), considered to be acidic (Mukuralinda et al. 2010).

Experimental design, sampling, and identification of soil-litter arthropods

Soil-litter arthropods have been sampled in 8 transects, each transect having 5 sampling points totaling 40 sampling points (Fig. 1). They have been collected using pitfall traps, each trap having 6 cm in diameter and 10 cm in depth. Each trap was set after removing the leaf-litter layer and maintained in place for 24 h to maximize chances of collecting soil-litter arthropods (Nsengimana et al. 2021). Further, arthropods have been collected in a 1m^2 quadrat, 6 cm soil-depth, after removing and checking litter arthropods from the above ground litter (Hill 2011). Targeted soil-litter arthropods were pulled-out of the soil with sharp-pointed forceps and fingers (Martin 1997). Collected specimens have been put into entomological plastic bottles containing 20 ml of 75% ethanol (Nsengimana et al. 2021) taken to the Centre of Excellence in Biodiversity and Natural Resource Management, College of Science and Technology, University of Rwanda. There, samples have been morphologically identified under the microscope, and separated to order and family levels by using dichotomous keys in the literature (Delvare and Aberlenc 1989; Picker et al. 2004; Mignon et al. 2016; Fisher and Bolton 2016).

For each individual specimen, the species name was provided when the identification key was available. Otherwise, the morphospecies description was provided. Further, geographic coordinates of each sampling point were collected using a Garmin ETrex 10 outdoor handled Global positioning system (GPS). Finally, geographic coordinates were used to generate the map of sampled points using QGIS 3.18.3 and shapefiles from the Centre of Geographic Information System (CGIS) based at the College of Science and Technology, University of Rwanda.

Data analysis

The mean abundance and standard error of soil-litter arthropods were calculated in Excel 365 per sampling type, and it was later used to calculate the species diversity in the Paleontological Statistics (PAST) 4.0 software. Bar charts indicating the mean abundance and standard errors of the

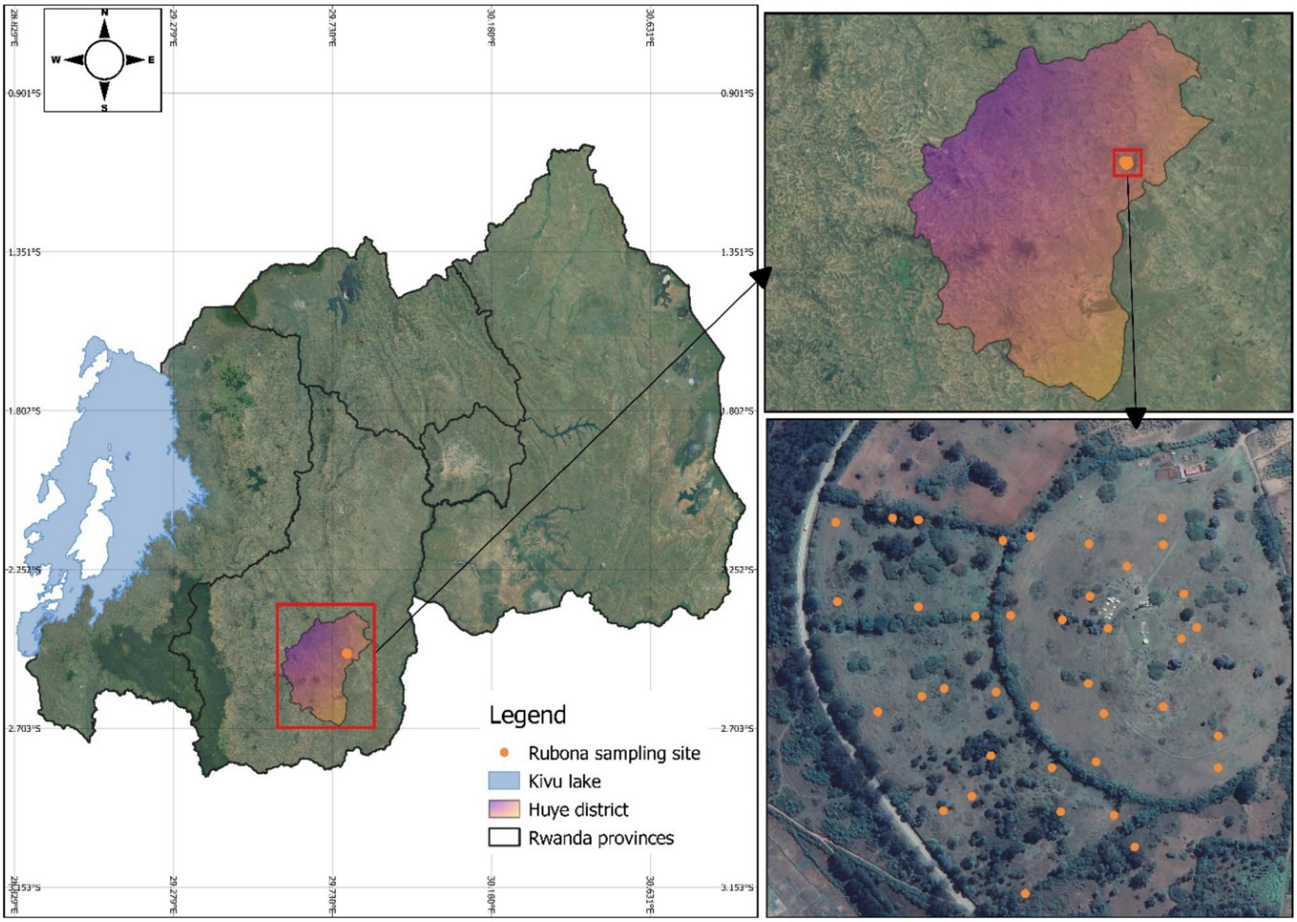

Fig. 1 Location of Rubona Agricultural Research Station and the sampling points (Adapted from CGIS shapefiles and GPS data collected on the field)

families of soil-litter arthropods have been produced by considering the families having more than 10 individual specimens. The family of Formicidae was not considered in this regard due to the highest mean-abundance and standard error. Significance was indicated by the letters based on *P* values. Further, significant differences were calculated between the mean abundance of the families of soil-litter arthropods per sampling type by using one-way ANOVA for several sample tests. In this regard, families having less than 5 individuals were excluded from the analysis to avoid biases. Further, the abundance of the individuals making the families of soil litter arthropods based on the sampling type was ordinated in non-metric multidimensional scaling (NMDS) following the Bray–Curtis similarity indices (Taguchi and Oono 2005; Gold et al. 2014) which were further used to perform the analysis of similarities (ANOSIM) to test for significant differences in the composition of the families of soil-litter arthropods (Kouakou et al. 2018). Finally, a similarity percentage analysis (SIMPER) was calculated to determine the families that contributed most to the similarity in the families of soil-litter arthropods (Clarke 1993).

Results

Soil-litter arthropods have been mainly sampled by pitfall traps (55.1%) compared to hand collection (44.9%). However, there is no significant difference between sample medians considering the pitfall traps and hand sampling techniques (ANOVA: $F = 0.02$, $df = 0.82$, $P > 0.05$). A total of 3013 individuals of soil-litter arthropods distributed into 3 classes, 13 orders, 46 families and 87 morphospecies were

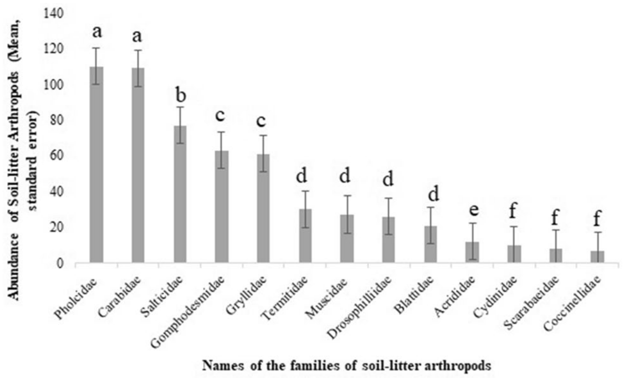

Fig. 2 Abundance of soil-litter arthropods (mean, standard error). Only the families having more than 10 individual specimens have been included in the analysis. The family of Formicidae has been also excluded due to the high abundance compared to the abundance of other families of soil-litter arthropods. The letters represent the *P* values (a > b > c > d > e > f, $P < 0.05$)

identified in this study (Appendix 1). Sampled soil-litter arthropods were dominated by the class Insecta (91.7%) with 11 orders and 44 families compared to Arachnida (6.2%) with 1 order and 2 families, and Diplopoda (2.1%) with 1 order and 1 family. The class Insecta was further dominated by the order Hymenoptera (78.4%), almost exclusively the family of Formicidae (78.3%). Coleoptera had the highest number of families namely Attelabidae, Carabidae, Chrysomelidae, Coccinellidae, Curculionidae, Erotylidae, Meloidae, Scarabaeidae, Scydmaenidae, Staphylinidae, and Tenebrionidae compared to other orders.

The overall diversity (H´) of sampled soil-litter arthropods was 1.12 while the evenness (E´) was 0.06. In this regard, soil-litter arthropods sampled by using hand collection had higher diversity (H´ = 1.095, E´ = 0.08) than those sampled by using pitfall sampling technique (H´ = 1.042, E´ = 0.09). The family of Formicidae had higher species diversity compared to other identified families (H´ = 1.8, E´ = 0.4). The NMDS and ANOSIM analysis based on

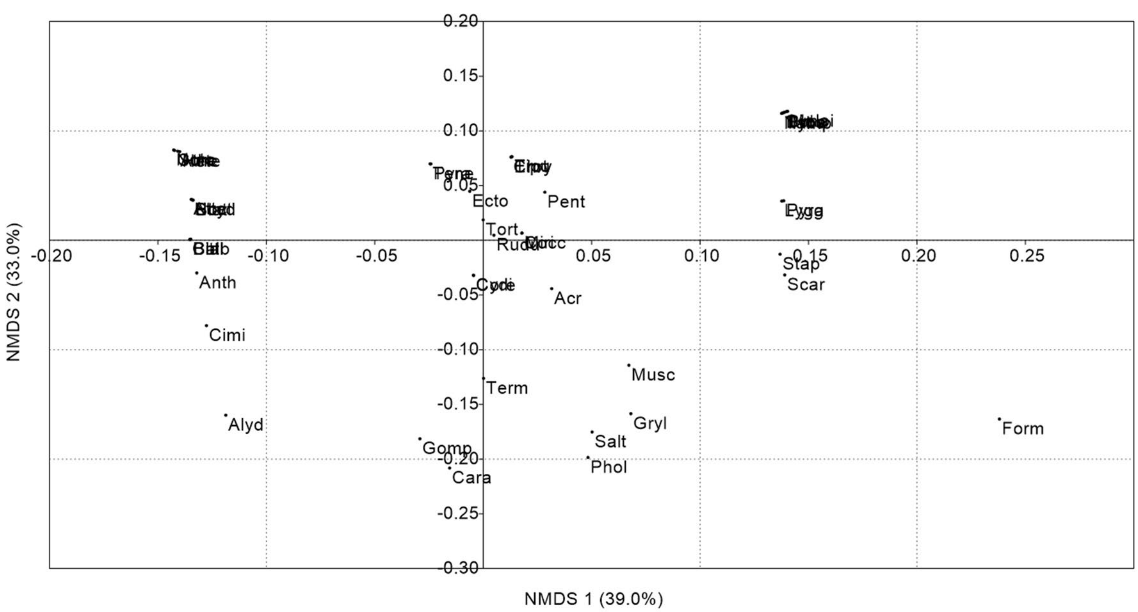

Fig. 3 Non-metric multidimensional scaling (NMDS) based on the Bray–Curtis similarity index between the families of soil-litter arthropods (Acri: Acrididae, Alyd: Alydidae, Anth: Anthophoridae, Athe: Athericidae, Atte: Attelabidae, Bitt: Bittacidae, Blab: Blaberidae, Blat: Blattidae, Call: Calliphoridae, Cara: Carabidae, Chry: Chrysomelidae, Cimi: Cimicidae, Cocc: Coccinellidae, Core: Coreidae, Curc: Curculionidae, Cydi: Cydinidae, Dros: Drosophiliidae, Erot: Erotylidae, Form: Formicidae, Gomp: Gomphodesmidae, Gryl: Grylidae, Hete: Heteronemiidae, Lima: Limacodidae, Meloi: Meloidae, Miri: Miridae, Musc: Muscidae, Noct: Noctuidae, Noto: Notonectidae, Nymp: Nymphalidae, Pent: Pentatomidae, Phol: Pholicidae, Pul: Pulicidae, Pyra: Pyralidae, Pyrg: Pyrgomorphidae, Rudu: Reduviidae, Salt: Salticidae, Scar: Scarabaeidae, Scyd: Scydmaenidae, Stap: Staphylinidae, Taba: Tabanidae, Tene: Tenebrionidae, Term: Termitidae, Tipu: Tipulidae, Tort: Tortricidae, Ecto: Ectobiidae, Lyga: Lygaeidae)

Bray–Curtis similarity indices between sampling techniques indicated differences in similarities of the families of soil-litter arthropods (NMDS: Stress = 0.20, $Axis_1 = 0.39$, $Axis_2 = 0.33$, $P < 0.05$, Fig. 2, ANOSIM: $R = 0.39$, $P < 0.05$). Further, the SIMPER analysis showed that the families of Formicidae, Pholcidae, Carabidae, Salticidae contributed to more than 87.6% of the total similarity between the identified families of soil-litter arthropods. More details on classes, orders, families, and morpho-species description of sampled and identified soil-litter arthropods are summarized in the Appendix 1 (Fig 3).

Discussion

Ants (Hymenoptera: Formicidae) were more abundant and had higher number of morphospecies than all other families found in this study. High abundance of ants was also found in another study which showed that ants are abundant and ubiquitous due to their ability to adapt to different land uses (Apolinário et al. 2019). These are the reasons why they have been used as biological indicators of land use change (Andersen et al. 2002; Nsengimana et al. 2018). Another study indicated the abundance and ubiquity of ants to be essential for ecosystem functioning (Mauda et al. 2018). Ants contribute to pollination (Wielgoss et al. 2014), soil mixing, nutrient transport, soil aeration (Henri et al. 2015), leaf-litter decomposition, enhancement of carbon flux, provision of habitat for other microorganisms (del Toro et al. 2012), facilitate seed dispersal (Christianini and Oliveira 2010), and help in pest control (Henri et al. 2015). Further, ants modify ecosystems (Andersen and Majer 2004), and hence have an influence on soil formation (Lobry De Bruyn 1999; del Toro et al. 2012). By modifying and regulating the distribution of leaf-litter resources (Jones et al. 1994), ants can also alter the composition of invertebrate assemblages (Munyai and Foord 2012). However, this was not explored in this study.

Further, sampled soil-litter arthropods were dominated by the class Araneae (Arachnida) with the families of Salticidae and Pholcidae. High abundance of Araneae was also found in another study conducted in agricultural land use systems in subtropical environments (Rosa et al. 2018). The same study highlighted also high abundance in native forests, and *Eucalyptus* plantations, whereas in cows pasture lands, there was a slight decrease in abundance. In addition, the same study indicated the families of Pholcidae and Salticidae to be more driven by the land use systems with higher abundance in the areas with less anthropogenic intervention. However, these contrast a bit the findings of this study. Nevertheless, there might be other environmental factors that contribute to the abundance of Araneae in the studied area such as the number of cows in pasture land.

After Formicidae, Coleoptera is the second abundant arthropod group and had the highest number of families dominated by carabid beetles (Coleoptera: Carabidae). A study on impacts of different land use patterns on carabid beetle diversity and species assemblages in South Korea indicated that carabid beetles are mainly influenced by litter, tree cover, shrub cover and slope of the area (Do et al. 2012). We conclude that higher diversity and abundance of carabids found in this study was mainly linked to the leaf-litter covering the soil and shrubs heterogeneity (Virić Gašparić et al. 2017) that were mainly abundant and highly distributed in studied area.

Another group of soil-litter arthropods with higher abundance in this study belongs to the order Orthoptera, with one family of Gryllidae. A study conducted on the effects of grassland management on Orthoptera diversity and abundance indicated that the species richness and abundance of Orthoptera are mainly influenced by extensive grazing in pasture lands resulting in a greater environmental heterogeneity and increase in cricket diversity and abundance (Weiss et al. 2013). Further, most cricket species have well-developed hindwings and stridulatory apparatus for acoustic communication (Szinwelski et al. 2012). A study has indicated that members of this family of Gryllidae prefer open areas that facilitated flight and allow the spread of the sound (Padgham 2004). Abundance and diversity of crickets Gryllidae in this study might be associated to the open pasture land with Hyparrhenia grasses and scattered shrubs.

Muscidae and Athericidae are most representative of Diptera group, both Muscidae and Athericidae are ectoparasites, attracted by feces from cattle and complete the life cycles by deriving blood meals from grazing animals (Scasta et al. 2012). Despite this general characteristic, a study indicated that some species such as *Stomoxys calcitrans* (Family: Muscidae) are stable fly depending on the accumulation of animal manure as substrate for larval development (Cook 2020). Another study indicated that the developmental stages of the larvae of Athericidae family takes places in water (Madsen 2012). High abundance of individuals making these families might be a sign of difference in preference of the area for the larvae development for the species belonging to Muscidae and Athericidae families. However, less is known about how the mature individuals belonging to these families are driven by the pasture land use, hence more studies are needed.

Another group of high abundance and low species diversity is the order Hemiptera with two families: Coreidae and Ruduviidae having more than one species. A study conducted on effects of grazing, vegetation structure and landscape complexity on grassland leafhoppers indicated that the vegetation structure is the most important factor influencing species richness, composition, and abundance of Hemiptera insects (Korösi et al. 2012). The distribution of the vegetation can provide suitable habitat and more resource for feeding hemipterans, and provide suitable sites for oviposition, resting and overwintering (Jones et al. 1994). High abundance in this study might be associated to *Hyparrhenia* grasses and shrubs that dominate the studied area.

This study indicated also that the order Blattodea with two families: Blaberidae and Blattidae had more than one species. A recent study indicated that individuals under this order are restricted to natural areas particularly in tropical regions, as they exhibit intolerance to low humidity and extreme temperature, which also restricts the number of potential habitats in equatorial regions (Schapheer et al. 2017). Because data have been collected during the transition between rainy and dry periods in Rwanda, we assume that the environmental conditions imposed by the studied pasture land controlled the abundance of individual species of Blattodea families.

Besides Blattodea, families under the orders Polydesmida, Lepidoptera and Isoptera showed low abundance, even though some families showed more than one species. Studies have indicated the abundance of these arthropods to be mainly controlled by the environmental conditions of the studied area. For example, the individuals under the order Polydesmida prefer a habitat rich in decaying wood and leaf-litter (Tóth and Hornung 2020), while those belonging to the order Lepidoptera prefer woodland with high plant heterogeneity (Nilsson et al. 2013). Further, low abundance of order Isoptera might be associated to less trees, bushes, and leaf-litter and consequently the lack of food and suitable habitat (Carrijo et al. 2009). As the studied area was mainly covered by the leaf-litter and different types of shrubs, low abundance could be associated to the used sampling techniques which might be inappropriate for these arthropods.

Further, Mecoptera, Phasmatodea and Siphonaptera were scarcely represented. Recent study indicated that Mecoptera prefer a soil with high soil moisture (Ghiglieno et al. 2020), Phasmatodea prefer a habitat with high plant heterogeneity that allow camouflage (Simon et al. 2019), while Siphonaptera are obligate ectoparasites depending on terrestrial vertebrates (van der Mescht et al. 2016). As the sampling was done during the transition between the rain and dry periods, the leaf-litter started to become dry and hence not favorable for Mecoptera. On the contrary, Phasmatodea could be abundant as the area was dominated by different types of shrubs, while Siphonaptera could take advantages of cattle in the area. In this regard, low abundance of Mecoptera and Siphonaptera might be associated to the sampling techniques which were not suitable for the orders.

Conclusion and recommendation

Findings of this study indicated that the pasture land use is inhabited by a wide range of leaf-litter arthropods. However, less abundance and species diversity found for some groups of soil-litter arthropods might be influenced by the used sampling techniques which were not appropriate for them. We recommend further studies focusing on the relationships between soil-litter arthropods and soil properties in pasture lands. Also, surveys using multiple sampling techniques and comparing the diversity and abundance of soil-litter arthropods in other pasture land uses as well as other ecological regions in Rwanda can gain useful information.

Appendix 1

See Table 1

Table 1 Class, order, family, common name, species name/morphospecies, abundance and functional group of sampled soil-litter arthropods

N0	Class	Order	Family	Species name or morphospecies description	Abundance
1	Arachnida	Araneae	Pholcidae	Spherical body shape with long legs, longer than the body, presence of 2 eyes on the central part of the front of the body	110
2	Arachnida	Araneae	Salticidae	Brown with black margin on the abdomen; presence of the visible pair of eyes in the center of the face, while small eyes are located on the dorsal surface of the cephalothorax	77
3	Diplopoda	Polydesmida	Gomphodesmidae	Cylindrical body shape with the presence of paranota	21
4	Diplopoda	Polydesmida	Gomphodesmidae	Presence of two pairs of jointed legs on almost all body segments	42
5	Insecta	Orthoptera	Acrididae	Probably *Leptacris* sp. (Chopard, 1921)	11
6	Insecta	Orthoptera	Acrididae	Looks like *Paracinema* sp. (Thunberg, 1815)	1
7	Insecta	Hemiptera	Alydidae	Close to *Hypselopus* sp. (Burmeister, 1835)	2
8	Insecta	Hymenoptera	Anthophoridae	Medium-sized and black body with punctured cuticle; face, eyes and parts of thorax covered with white hairs	1
9	Insecta	Diptera	Athericidae	*Atherix adamastor* (Stuckenberg, 1960)	2
10	Insecta	Diptera	Athericidae	*Trichacantha atranupta* Stuckenberg, 1955	1
11	Insecta	Coleoptera	Attelabidae	Small and stout square elytra, which do not cover the last segment of abdomen	4
12	Insecta	Mecoptera	Bittacidae	Medium sized with full developed wings of around 40 mm long	1
13	Insecta	Blattodea	Blaberidae	*Oxyhaloa deusta* (Thunberg, 1784)	1
14	Insecta	Blattodea	Blaberidae	Shiny black to reddish-brown colour with presence of wings	2
15	Insecta	Blattodea	Blattidae	*Deropeltis erythrocephala* (Fabricius, 1781)	10
16	Insecta	Blattodea	Blattidae	*Periplaneta americana (Linnaeus, 1758)*	8
17	Insecta	Blattodea	Blattidae	*Pseudoderopeltis sp.(Stål, 1856)*	3
18	Insecta	Diptera	Calliphoridae	*Chrysomya chloropyga* (Wiedemann, 1818)	1
19	Insecta	Coleoptera	Carabidae	*Atractonotus mulsanti* (Perroud, 1847)	4
20	Insecta	Coleoptera	Carabidae	*Craspedophorus bonvouloirii* (Chaudoir, 1862)	1
21	Insecta	Coleoptera	Carabidae	*Graphipterus lineolatus* (Boheman, 1848)	1
22	Insecta	Coleoptera	Carabidae	Head and pronotum finely sculptured last 7 segments of antenna	93
23	Insecta	Coleoptera	Carabidae	Irregular protonum sculptured somewhat flattened on top, hexagonal in outline	10
24	Insecta	Coleoptera	Chrysomelidae	lema trilinea: moderately elongate, with elytra wider than pronotum	1
25	Insecta	Coleoptera	Chrysomelidae	*Morphologically similar to Plagiodera caffra* sp. (Chevrolat, 1836)	1
26	Insecta	Coleoptera	Chrysomelidae	*Sonchia* sp. (Weise, 1902)	1
27	Insecta	Hemiptera	Cimicidae	Small, apricot-coloured, wingless, with circular body and flattened extensions of prothorax behind the eyes	1
28	Insecta	Coleoptera	Coccinellidae	Black with around 10 symmetrically placed yellow patches on each elytron	7
29	Insecta	Hemiptera	Coreidae	*Homoeocerus* sp. (Stål, 1866)	1
30	Insecta	Hemiptera	Coreidae	*Similar to Leptoglossus*sp. (Fabricius, 1781)	3
31	Insecta	Hemiptera	Coreidae	Small body, uniformly light, with bulbous eyes; 2 white spots on hemelytra and black tips to antennae	1
32	Insecta	Coleoptera	Curculionidae	Small, moderatelly stout body with short, thick snout about equal in length to remainder of head	1
33	Insecta	Hemiptera	Cydinidae	Medium sized, shiny, and dark-brown oval body size with spiny hind legs	10
34	Insecta	Diptera	Drosophiliidae	Small body with yellow grey colour and bright red eyes	26
35	Insecta	Blattodea	Ectobiidae	*Blattella germanica* (Linnaeus, 1767)	5
36	Insecta	Coleoptera	Erotylidae	Oval body, typically shiny, patterned in red, yellow, and black	3
37	Insecta	Hymenoptera	Formicidae	*Anoplolepis* sp. (Smith, 1858)	4
38	Insecta	Hymenoptera	Formicidae	*Camponotus fulvopilosus* (De Geer, 1778)	167
39	Insecta	Hymenoptera	Formicidae	*Camponotus maculatus* (Fabricius, 1782)	63
40	Insecta	Hymenoptera	Formicidae	*Carebara vidua* (Smith, 1858)	1
41	Insecta	Hymenoptera	Formicidae	*Crematogaster* sp. (Emery, 1895*)*	864
42	Insecta	Hymenoptera	Formicidae	*Dorylus* sp. (Linnaeus, 1764)	13
43	Insecta	Hymenoptera	Formicidae	*Lepisiota* sp. (Mayr, 1862)	2
44	Insecta	Hymenoptera	Formicidae	*Linepithema* sp. (Mayr, 1868)	13

Table 1 (continued)

N0	Class	Order	Family	Species name or morphospecies description	Abundance
45	Insecta	Hymenoptera	Formicidae	*Messor* sp. (Mayr, 1862)	311
46	Insecta	Hymenoptera	Formicidae	*Myrmicaria natalensis* (Smith, 1858)	76
47	Insecta	Hymenoptera	Formicidae	*Oecophylla longinoda (Latreille, 1802)*	171
48	Insecta	Hymenoptera	Formicidae	*Paltothyreus tarsata* (Fabricius, 1798)	54
49	Insecta	Hymenoptera	Formicidae	*Plectroctena mandibularis* (Smith, 1858)	1
50	Insecta	Hymenoptera	Formicidae	*Solenopsis* sp. (Mayr, 1865)	574
51	Insecta	Hymenoptera	Formicidae	*Streblognathus* sp. (Smith, 1858)	41
52	Insecta	Hymenoptera	Formicidae	*Tetramorium*sp. (Mayr, 1865)	5
53	Insecta	Hymenoptera	Formicidae	*Tetraponera* sp. (Jerdon, 1851)	1
54	Insecta	Orthoptera	Gryllidae	*Gryllus bimaculatus* (De Geer, 1773)	61
55	Insecta	Phasmatodea	Heteronemiidae	*Carausius morosus* small species 80–100 cm (Sinéty, 1901)	1
56	Insecta	Lepidoptera	Limacodidae	Short-winged and hairy-bodied with reduced mouth parts	1
57	Insecta	Hemiptera	Lygaeidae	Large body with parallel-sided, dark brown colour, with thin cream marginal stripe	2
58	Insecta	Coleoptera	Meloidae	*Lydomorphus* sp. (Fairmaire, 1882)	1
59	Insecta	Hemiptera	Miridae	Small body with dark brown, with orange heart-shaped mark in middle of thorax	7
60	Insecta	Diptera	Muscidae	*Musca domestica* (Linnaeus, 1758)	21
61	Insecta	Diptera	Muscidae	*Stomoxys calcitrans (Linnaeus, 1758)*	6
62	Insecta	Lepidoptera	Noctuidae	*Brithys crini* (Fabricius, 1775)	2
63	Insecta	Hemiptera	Notonectidae	Medium, parallel-sided, and slender body with triangular orange scutellum	1
64	Insecta	Lepidoptera	Nymphalidae	*Cynthia cardui* (Linnaeus, 1758)	1
65	Insecta	Hemiptera	Pentatomidae	Small, shield-shaped, and tan body; maroon wings and thorax, and large pale-yellow scutellum	4
66	Insecta	Siphonaptera	Pulicidae	*Ctenocephalides felis* (Bouche, 1835)	1
67	Insecta	Lepidoptera	Pyralidae	*Cactoblastis cactorum* (Berg, 1885)	3
68	Insecta	Orthoptera	Pyrgomorphidae	*Zonocerus elegans* (Thunberg, 1815)	3
69	Insecta	Hemiptera	Reduviidae	Large, hefty, and dull black with bright orange bands on legs, and an orange spot on wings	1
70	Insecta	Hemiptera	Reduviidae	*Reduvius tarsatus* (Germar, 1837)	6
71	Insecta	Coleoptera	Scarabaeidae	*Diplognatha gagates* (Forster, 1771)	3
72	Insecta	Coleoptera	Scarabaeidae	*Anachalcos convexus* Boheman, 1857	1
73	Insecta	Coleoptera	Scarabaeidae	*Catharsius tricornutus* (Degeer, 1778)	2
74	Insecta	Coleoptera	Scarabaeidae	*Cyphonistes vallatus* (Wiedemann, 1823)	2
75	Insecta	Coleoptera	Scarabaeidae	*Cyphonistes vallatus* (Wiedemann, 1823)	2
76	Insecta	Coleoptera	Scarabaeidae	*Heteronychus arator* (Fabricius, 1775)	2
77	Insecta	Coleoptera	Scydmaenidae	Black to reddish brown, ant-like with globular abdomen and constriction between pronotum and elytra	2
78	Insecta	Coleoptera	Staphylinidae	Black with medium body size; short elytra that covers half of the abdomen segment	5
79	Insecta	Diptera	Tabanidae	*Tabanus* sp. (Macquart, 1834)	1
80	Insecta	Coleoptera	Tenebrionidae	*Gonocephalum simplex* (Fabricius, 1801)	2
81	Insecta	Coleoptera	Tenebrionidae	*Metallonotus* sp. (Gerstaecker, 1855)	1
82	Insecta	Isoptera	Termitidae	*Macrotermes natalensis* (Haviland, 1898)	10
83	Insecta	Isoptera	Termitidae	*Microhodotermes viator* (Latreille, 1804)	11
84	Insecta	Isoptera	Termitidae	*Odontotermes badius* (Haviland, 1898)	9
85	Insecta	Diptera	Tipulidae	Medium sized body with polished jet black and yellow body; thin palps that are longer than antennae	3
86	Insecta	Lepidoptera	Tortricidae	*Chrysanthemoides monilifera* (Linnaeus, 1753)	1
87	Insecta	Lepidoptera	Tortricidae	Small body with distinctive, very broad, almost rectangular, wings and with short hair fringes at ends of typically dull brown wings	5

Acknowledgements The authors thank the Rwanda Agriculture Board (RAB), Rubona station for the authorization to sample the pasture land located at Rubona Agricultural Research Station. The Centre of Excellence in Biodiversity and Natural Resource Management (CoEB) based in the College of Science and Technology, University of Rwanda is thanked for the assistance during the identification of soil-litter arthropods and data analysis. Also Mr. Thacien Hagenimana, researcher fellow to the CoEB is acknowledged for the assistance to analyze GIS data and making the sampling point map.

Author contributions VN designed the study, analyzed the data, supported in field data collection, identification of soil litter arthropods, and wrote the manuscript; CSI and JdDN contributed to the research design, collected data, and identified soil-litter arthropods to species level; JWM proof read the manuscript; WD verified the identification and proofread the manuscript.

Funding This research was funded by the Global Taxonomy Initiative (GTI) within the framework of Capacities for Biodiversity and Sustainable Development (CEBioS). The CEBioS is based at the Royal Belgian Institute of Natural Science (RBINS), Brussels, Belgium.

References

Alroy J (2017) Effects of habitat disturbance on tropical forest biodiversity. Proc Natl Acad Sci USA 114(23):6056–6061. https://doi.org/10.1073/pnas.1611855114

Andersen AN, Majer JD (2004) Ants show the way down under: invertebrates as bioindicators in land management. Front Ecol Environ 2(6):291–298. https://doi.org/10.1890/1540-9295(2004)002[0292:ASTWDU]2.0.CO;2

Andersen AN, Hoffmann BD, Müller WJ, Griffiths AD (2002) Using ants as bioindicators in land management: simplifying assessment of ant community responses. J Appl Ecol 39(1):8–17. https://doi.org/10.1046/j.1365-2664.2002.00704.x

Apolinário LCMH, Almeida AA, Queiroz JM, Vargas AB, Almeida FS (2019) Diversity and guilds of ants in different land-use systems in Rio de Janeiro state. Brazil Floresta e Ambiente 26(4):e2017115. https://doi.org/10.1590/2179-8087.115217

Bain GC, MacDonald MA, Hamer R, Gardiner R, Johnson CN, Jones ME (2020) Changing bird communities of an agricultural landscape: declines in arboreal foragers, increases in large species. Royal Society Open Sci 7(3):200076. https://doi.org/10.1098/rsos.200076

Birasa EC, Bizimana I, Bouchaert W, Chapelle J, Deflandre A, Gallez A, Maesshal GET, Vercruysse J (1990) Description systhetique dessols. CPR, MINAGRI, Kigali

Carrijo TF, Brandão D, de Oliveira DE, Costa DA, Santos T (2009) Effects of pasture implantation on the termite (Isoptera) fauna in the central Brazilian Savanna (Cerrado). J Insect Conserv 13:575–581. https://doi.org/10.1007/s10841-008-9205-y

Cassani MT, Sabatté ML, Rubín MAR, Sfeir AJ, Massobrio MJ (2021) Litter decomposition by soil fauna: effect of land use in agroecosystems. Heliyon 7(10):e08127. https://doi.org/10.1016/j.heliyon.2021.e08127

Cenkseven S, Kizildag N, Kocak B, Sagliker AH, Darici C (2017) Soil organic matter mineralization under different temperatures and moisture conditions in Kizildağ plateau. Turkey. Sains Malaysiana 46(5):763–771

Christianini A, Oliveira PS (2010) Birds and ants provide complementary seed dispersal in a Neotropical Savanna. J Ecol 98(3):573–582. https://doi.org/10.1111/j.1365-2745.2010.01653.x

Clarke KR (1993) Non-parametric multivariate analyses of changes in community structure. Aust J Ecol 18:117–143. https://doi.org/10.1111/j.1442-9993.1993.tb00438.x

Cole RJ, Karen DH, Rakan AZ, Wickey P, Townsend AR (2016) Leaf litter arthropod responses to tropical forest restoration leaf litter arthropod responses to tropical forest restoration. Ecol Evol 6(15):5158–5168. https://doi.org/10.1002/ece3.2220

Cook D (2020) A historical review of management options used against the stable fly (diptera: muscidae). Insects 11(5):313. https://doi.org/10.3390/insects11050313

Culliney TW (2013) Role of arthropods in maintaining soil fertility. Agriculture 3(4):629–659. https://doi.org/10.3390/agriculture3040629

Czimczik CI, Mund M, Detlef SE, Wirth C (2005) Effects of reforestation, deforestation, and afforestation on carbon storage. In: Griffiths H, and Jarvis PG: The Carbon Balance of Forest Biome. https://doi.org/10.4324/9780203501344-15

del Toro I, Ribbons RR, Pelini SLP (2012) The little things that run the world revisited: a review of ant-mediated ecosystem services and disservices (hymenoptera: formicidae). Myrmecological News 17:133–146

Delvare G, Henri-Pierre Aberlenc HP (1989) *Les Insectes d'afrique et Ameriques Tropicale. Clés Pour La Reconnaissance des Familles*. Centre de Coopération Internationale en Recherche Agronomique pour le Dévelopment. MontPellier, France

Do Y, Lineman MJM, Joo GJ (2012) Impacts of different land-use patterns on the carabid beetle diversity and species assemblages in South Korea. Ekoloji 84:9–17. https://doi.org/10.5053/ekoloji.2012.842

Erskine PD, Williams ER, Mulligan DR, Erskine PD, Plowman KP (2012) Using insect diversity for determining land restoration development: examining the influence of grazing history on ant assemblages in rehabilitated pasture agriculture, ecosystems and environment. Agric Ecosyst Environ 163:54–60. https://doi.org/10.1016/j.agee.2012.02.017

Fisher BL, Barry B (2016) Ants of Africa and Madagascar: a guide to the Genera. University of California Press, Oakland, California, USA

Ghiglieno I, Simonetto A, Orlando F, Donna P, Tonni M, Valenti L, Gilioli G (2020) Response of the arthropod community to soil characteristics and management in the franciacorta viticultural area (Lombardy, Italy). Agronomy 10(5):740. https://doi.org/10.3390/agronomy10050740

Gold PB, Kivlighan DM, Patton MJ (2014) Non-metric multidimensional scaling profile analysis of non-growth change in groups: a demonstration. Small Group Research 45(3):235–265. https://doi.org/10.1177/1046496414528050

Henri DC, Owen J, Tsiattalos JO, Thébault E, Seymour CL, van Veen FJF (2015) Natural vegetation benefits synergistic control of the three main insect and pathogen pests of a fruit crop in southern Africa. J Appl Ecol 52:1092–1101

Hill JG (2011) Sifting soil and leaf litter to collect Arthropods. Missisipi State University

Illig J, Schatz H, Scheu S, Maraun M (2008) Decomposition and colonization by micro-arthropods of two litter types in a tropical montane rain forest in southern Ecuador. J Trop Ecol 24(2):157–167. https://doi.org/10.1017/S0266467407004750

Jones CG, Lawton JH, Shachak M (1994) Organisms as ecosystem engineers. Oikos 69(3):373. https://doi.org/10.2307/3545850

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. Appl Soil Ecol 32(2):153–164. https://doi.org/10.1016/j.apsoil.2005.07.004

Korösi A, Batáry P, Orosz A, Rédei D, Báldi A (2012) Effects of grazing, vegetation structure and landscape complexity on grassland leafhoppers (hemiptera: auchenorrhyncha) and true bugs (hemiptera: heteroptera) in Hungary. Insect Conserv Divers 5(1):57–66. https://doi.org/10.1111/j.1752-4598.2011.00153.x

Kouakou LMM, Dekoninck W, Kone M, Delsinne T, Yeo K, Ouattara K, Konate S (2018) Diversity and distribution of introduced and potentially invasive ant species from the three main ecoregions of Côte d'Ivoire (West Africa). Belg J Zool 148(1):83–103

Lavelle P (1996) Diversity of Soil Fauna and Ecosystem Function. Biol Int 33:3–16

Lobry De Bruyn LA (1999) Ants as bioindicators of soil function in rural environments. Agric Ecosyst Environ 74(1–3):425–441. https://doi.org/10.1016/S0167-8809(99)00047-X

Madsen BL (2012) Biological studies on adult water snipe Fly, *Atherix Ibis* (Fabricius, 1798) (diptera: athericidae): old myths and new facts. Aquatic Insects 34(SUPPL. 1):91–102. https://doi.org/10.1080/01650424.2012.643031

Martin JEH (1977) Collecting, preparing and preserving insects, mites and spiders. Ottowa, Canada

Mauda E, Grant SJ, Colleen LS, Thinandavha CM, Foord SH (2018) Changes in land use alter ant diversity, assemblage composition and dominant functional groups in African Savannas. Biodivers Conserv 27(4):947–965. https://doi.org/10.1007/s10531-017-1474-x

Menta C, Remelli S (2020) Soil health and arthropods: from complex system to worthwhile investigation. Insects 11(1):54. https://doi.org/10.3390/insects11010054

Menta C, Delia FC, Fondón CL, Staffilani F, Remelli S (2020) Soil arthropod responses in agroecosystem: implications of different management and cropping systems. Agronomy 10(7):982. https://doi.org/10.3390/agronomy10070982

Mignon J, Haubruge E, Francis, (2016) Clé d'identification Des Principales Familles d'insectes d'Europe. Les Presses Agronomiques de Gembloux, Gembloux, Belgique

Mukuralinda A, Tenywa JS, Verchot L, Obua J, Nabahungu NL, Chianu JN (2010) Phosphorus uptake and maize response to organic and inorganic fertilizer inputs in rubona. Southern Province of Rwanda. Agrofores Syst 80(2):211–221. https://doi.org/10.1007/s10457-010-9324-9

Munyai TC, Foord SH (2012) Ants on a mountain: spatial, environmental and habitat associations along an altitudinal transect in a centre of endemism. J Insect Conserv 16(5):677–695. https://doi.org/10.1007/s10841-011-9449-9

Neira J, Ortiz M, Morales L, Acevedo E (2015) Oxygen diffusion in soils: understanding the factors and processes needed for modelling. Chilean J Agri Res 75:35–44. https://doi.org/10.4067/S0718-58392015000500005

Newbold T, Scott A, Stapp P, Levensailor KE, Derner JD, Lauenroth WK (2014) Community responses of arthropods to a range of traditional and manipulated grazing in shortgrass steppe. Environ Entomol 43(3):556–568. https://doi.org/10.1603/EN12333

Nilsson SG, Franzén M, Pettersson LB (2013) Land-use changes, farm management, and the decline of butterflies associated with semi-natural grasslands in southern Sweden. Nature Conservation 6:31–48. https://doi.org/10.3897/natureconservation.6.5205

Nsengimana V, Kaplin AB, Francis F, Kouakou MML, Dekoninck W, Nsabimana D (2018) Use of soil and litter ants (hymenoptera: formicidae) as biological indicators of soil quality under different land uses in southern Rwanda. Environ Entomol 47(6):1394–1401. https://doi.org/10.1093/ee/nvy144

Nsengimana V, Kaplin AB, Nsabimana D, Dekoninck W, Francis F (2021) Diversity and abundance of soil-litter arthropods and their relationships with soil physicochemical properties under different land uses in Rwanda. Biodiversity 22(1–2):41–52. https://doi.org/10.1080/14888386.2021.1905064

Padgham M (2004) Reverberation and frequency attenuation in forests—implications for acoustic communication in animals. J Acoustical Soc Am 115(1):402–410. https://doi.org/10.1121/1.1629304

Picker M, Griffiths C, Weaving A (2004) *Field Guide to Insects of South Africa by Charles Griffiths*. Penguin Random House, South Africa

Pribadi T, Rika R, Harahap IS (2011) Termites community as environmental bioindicators in highlands: a case study in eastern slopes of Mount Slamet. Central Java. Biodiversitas 12(3):235–240

Römbke J, Schmelz MR, Pélosi C (2017) Effects of organic pesticides on enchytraeids (Oligochaeta) in agroecosystems: laboratory and higher-tier tests. Front Environ Sci 5:20. https://doi.org/10.3389/fenvs.2017.00020

Rosa MG, Santos JCP, Brescovit AD, Mafra AL (2018) Spiders (Arachnida: Araneae) in agricultural land use systems in subtropical environments. Rev Bras Ciênc Solo 42:e0160576. https://doi.org/10.1590/18069657rbcs20160576

Sala OE, Chapin FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sanwald E et al (2000) Global biodiversity scenarios for the year 2100. Science 287(5459):1770–1774. https://doi.org/10.1126/science.287.5459.1770

Scasta JD, Engle DM, Talley JL, Weir JR, Stansberry JC, Fuhlendorf SD, Harr RN (2012) Pyric-herbivory to manage horn flies (diptera: muscidae) on cattle. Southwestern Entomologist 37(3):325–334. https://doi.org/10.3958/059.037.0308

Schapheer C, Lopez-Uribe MM, Vera A, Villagra CA (2017) Distribution, habitat use and plant associations of *Moluchia Brevipennis* (Saussure, 1864) (blattodea: ectobiidae): an endemic cockroach from chilean mediterranean matorral biome. Revista Brasileira De Entomologia 61(2):114–122. https://doi.org/10.1016/j.rbe.2017.02.001

Schindler BY, Griffith AB, Jones KN (2011) Factors influencing arthropod diversity on green roofs. Cities and the Environment. 4(1):1–22

Simon S, Letsch H, Bank S, Buckley TR, Donath A, Liu S, Machida R, Meusemann K, Misof B, Podsiadlowski L, Zhou X, Wipfler B, Bradler S (2019) Old world and new world phasmatodea: phylogenomics resolve the evolutionary history of stick and leaf insects. Front Ecol Evol 7:345. https://doi.org/10.3389/fevo.2019.00345

Srivastava R, Mohapatra M, Latare A (2019) Impact of land use changes on soil quality and species diversity in the vindhyan dry tropical region of india. J Trop Ecol 36(2):72–79. https://doi.org/10.1017/S0266467419000385

Steinwandter M, Schlick-Steiner BC, Seeber GUH, Steiner FM, Seeber J (2017) Effects of alpine land-use changes: soil macrofauna community revisited. Ecol Evol 7(14):5389–5399. https://doi.org/10.1002/ece3.3043

Szinwelski N, Rosa CS, Schoereder JH, Mews CM, Sperber CF (2012) Effects of forest regeneration on crickets: evaluating environmental drivers in a 300-year chronosequence. Int J Zool 2012:1–13. https://doi.org/10.1155/2012/793419

Taguchi YH, Oono Y (2005) Relational patterns of gene expression via non-metric multidimensional scaling analysis. Bioinformatics 21(6):730–740. https://doi.org/10.1093/bioinformatics/bti067

Tóth Z, Hornung E (2020) Taxonomic and functional response of millipedes (diplopoda) to urban soil disturbance in a metropolitan area. Insects 11(1):25. https://doi.org/10.3390/insects11010025

van der Mescht L, le Roux PC, Conrad AM, Morgan JR, Sonja M (2016) The Influence of life history characteristics on flea (siphonaptera) species distribution models. Parasit Vectors 9:178. https://doi.org/10.1186/s13071-016-1466-9

Vasconcelos HL, Bruna EM (2012) Arthropod responses to the experimental isolation of amazonian forest fragments. Sociedade Brasileira De Zoologia 29(6):515–530

Viana AB, Souza VB, Reis YT, Marques-Costa AP (2014) Termite assemblages in dry tropical forests of northeastern brazil: Are termites bioindicators of environmental disturbances? Sociobiology 61(3):324–31

Virić G, Drmić HZ, Čačija M, Graša Z, Petrak I, Bažok R, Lemic D (2017) Impact of environmental conditions and agro-technical factors on ground beetle populations in arable crops. Appl Ecol Environ Res 15(3):697–711

Wardle DA, Yeates GW, Barker GM, Bonner KI (2006) The influence of plant litter diversity on decomposer abundance and diversity. Soil Biol Biochem 38(5):1052–1062. https://doi.org/10.1016/j.soilbio.2005.09.003

Weiss N, Zucchi H, Hochkirch A (2013) The effects of grassland management and aspect on orthoptera diversity and abundance: site conditions are as important as management. Biodivers Conserv 22(10):2167–2178. https://doi.org/10.1007/s10531-012-0398-8

Wielgoss A, Tscharntke T, Rumede A, Fiala B, Seidel H, Shahabuddin S, Clough Y (2014) Interaction complexity matters: disentangling services and disservices of ant communities driving yield in tropical agroecosystems. Proc Royal Soc B: Biol Sci 281:20132144. https://doi.org/10.1098/rspb.2013.2144

Yeshaneh GT (2015) Assessment of micronutrient status in different land use soils in maybar lake Watershed of Albuko District, South Wello Zone, North Ethiopia. Am J Environ Protect 3(1):30–36