Postprint: Distribution Characteristics of Soil Macrofauna Communities in Farmland Along Different Latitudinal Gradients in Heilongjiang Province

Authors: Cao Yang, Gao Meixiang, ZHANG Xueping, Dong Chengxu

Date: 2017-03-22T00:00:00+00:00

Abstract

Along a latitudinal gradient from high to low, study sites were selected in farmland habitats in Tahe, Dailing, and Mao' ershan. The hand-sorting method was used to investigate the community composition, horizontal structure, vertical structure, and diversity characteristics of macro-soil fauna in farmland ecosystems at different latitudes, and bivariate correlation analysis and canonical correspondence analysis were employed to elucidate the relationships between soil fauna communities and environmental factors, aiming to reveal the distribution characteristics and influencing factors of macro-soil fauna communities in farmlands along different latitudinal gradients in Heilongjiang Province. A total of 2,339 individuals belonging to 35 groups of macro-soil fauna were collected, classified into 2 phyla, 6 classes, 14 orders, and 35 families. Among these, Enchytraeidae, Lumbricidae, Carabida, and Staphylinidae were dominant groups, accounting for 58.84% of the total individuals. Common groups included Formicidae, Araneida, and Geophilomorpha, among eight groups, accounting for 32.79% of the total individuals. The results showed that: (1) Horizontal distribution: The horizontal distribution of individual density and richness (i.e., number of groups) of macro-soil fauna followed the pattern Mao' ershan > Dailing > Tahe. One-way ANOVA indicated no significant differences in individual density and richness of macro-soil fauna among different latitudinal regions. Shannon-Wiener diversity index (H') and Pielou evenness index (E) both showed Mao' ershan > Dailing > Tahe. Simpson dominance index (C) was highest in Tahe and Dailing, and lowest in Mao' ershan. Margalef richness index (D) was highest in Tahe, followed by Mao' ershan and Dailing. (2) Vertical distribution: There were no significant differences ($P < 0.05$) in individual density and richness of farmland soil fauna among the same vertical layers across the three latitudinal sites. Except for Mao' ershan where the number of soil fauna groups in the 5-10 cm soil layer increased compared to the surface layer, the individual density and richness of macro-soil fauna in other sites gradually decreased with increasing soil depth, showing obvious surface aggregation. (3) Relationship with soil environmental factors: Bivariate correlation analysis showed that the number of groups, individual density, diversity index, evenness index, and dominance index of macro-soil fauna in farmlands at different latitudes were not significantly correlated with soil pH, organic matter, total nitrogen, total phosphorus, and available phosphorus. Canonical correspondence analysis (CCA) further indicated that dominant and common groups had strong adaptability to environmental factors and were widely distributed across the three sites. The study demonstrates that the number of groups, individual density, and diversity index of macro-soil fauna in farmland ecosystems first increased and then decreased with increasing latitudinal gradient, but showed no significant differences among different latitudes. Different soil fauna groups were affected by environmental variables to varying degrees, and the influence of environmental factors on soil fauna at the local scale cannot be ignored. This research lays a foundation for studies on the spatial patterns and biodiversity maintenance mechanisms of soil fauna in farmland ecosystems at the regional scale.

Full Text

Distribution Characteristics of Soil Macro-Faunal Communities Along a Latitudinal Gradient in Farmland of Heilongjiang Province

Cao Yang[1,2], Gao Meixiang[1,2,*], Zhang Xueping[1,2], Dong Chengxu[1,2]

[1]College of Geographical Sciences, Harbin Normal University, Harbin 150025, China

[2]Key Laboratory of Remote Sensing Monitoring of Geographic Environment, Heilongjiang Province, Harbin Normal University, Harbin 150025, China

---

Abstract

Spatial patterns of soil faunal communities at a regional scale are important foundations for the maintenance and protection of belowground biodiversity. Although many studies have addressed the spatial patterns of soil animal communities in different habitats, few have focused on spatial patterns along latitudinal gradients. In this study, we determined the composition, horizontal structure, vertical structure, and diversity characteristics of soil macro-faunal communities in farmland systems along a latitudinal gradient. We selected three representative mountain areas along the latitudinal gradient: the Maoer Mountains (Maoer Mountain ecosystem station, 45°20 –45°25 N, 127°30 –127°34 E), the Xiaoxing' an Mountains (Dailing, 47°10 –47°14 N, 128°53 –128°55 E), and the Da Hinggan Mountains (Tahe, 52°09 –53°23 N, 123°19 –125°48 E). In each study area, three farmlands at least 50 m apart with similar conditions were randomly selected. In each farmland, four plots (5 m × 5 m) were randomly delineated. In each plot, four soil profiles (50 cm × 50 cm) were randomly collected and divided equally into three 5 cm strata to survey the soil macro-faunal communities. The hand-picking method of separation was used to determine the soil macro-faunal communities. Fieldwork was conducted in August 2011. Using bivariate correlation analysis and canonical correspondence analysis, we assessed the relationships between soil animal communities and environmental factors.

In total, 2339 individuals from 35 groups of soil animals were collected, which belonged to 2 phyla, 6 classes, 14 orders, and 35 families. Enchytraeidae, Lumbricidae, Carabidae, and Staphylinidae were dominant families, accounting for 58.84% of the total number of individuals. Formicidae, Araneidae, and Geophilomorpha were common groups, accounting for 32.79% of the total number of individuals. The results showed that: (1) In terms of horizontal distribution, individual density and richness (i.e., numbers of groups) at sites followed the order Maoer Mountain > Dailing > Tahe. Results of the one-way ANOVA revealed there were no significant differences in individual density or richness in the soil macro-faunal communities at different latitudes. The Shannon-Wiener diversity index (H) and Pielou evenness index (E) for sites followed the order Maoer Mountain > Dailing > Tahe. The Simpson dominance index (D) of Tahe and Dailing were higher than that of the Maoer Mountains, and the Margalef richness index (C) was greatest in Tahe, followed by the Maoer Mountains and Dailing. (2) In terms of vertical distribution, no significant differences were detected among the three different latitudinal areas for individual density or richness at the same vertical level ($P < 0.05$). Individual density and richness in soil macro-faunal communities decreased with increasing soil depth, except for soil macro-faunal communities from the Maoer Mountains at 5−10 cm, indicating an obvious surface aggregation. (3) Regarding the relationships between soil macro-faunal communities and soil environmental factors, the bivariate correlation analysis showed there were no significant correlations among richness, individual densities, diversity indices, evenness indices, richness indices, pH values, organic matter, total nitrogen, total phosphorus, and available phosphorus. Results of canonical correspondence analysis further indicated that the dominant and common groups were highly adaptable to environmental factors and were widely distributed in the three latitudinal areas. This study showed that the numbers of groups, individual densities, and diversity indices of the soil macro-faunal communities from the farmland ecosystem changed along a latitudinal gradient, but no significant changes were found in this study. Different soil animal groups at different latitudes are affected by environment variables. At the local scale, the influence of environmental factors on soil macro-fauna should not be ignored. The results of the study create a foundation for researching spatial patterns and mechanisms of biodiversity maintenance at regional scales.

Keywords: soil macro-fauna; community structure; diversity; different latitudes; farmland habitat

Introduction

Soil fauna are abundant and play crucial roles in farmland ecosystems as important decomposers positioned at the top of the soil food chain. They are essential for soil formation and development, decomposition of residues, promotion of soil material cycling and energy transformation, and modification of soil physicochemical properties, and can respond rapidly to environmental changes [1-5]. Investigating the spatial distribution characteristics of farmland soil macro-fauna along different latitudinal gradients and analyzing their response patterns to climate change are important foundations for biodiversity conservation under global change scenarios. They also provide essential basis for managing the structure and function of farmland ecosystems.

Numerous studies have shown that research on soil fauna has primarily focused on the impacts of farmland pollution caused by heavy metals and other contaminants, ecosystem degradation under human disturbance, climate change, various natural disasters, tourism activities, and global change on soil animal communities [6-11]. Studies on community composition, ecological characteristics, dynamic changes, diversity and evaluation indicators, and relationships between soil macro-fauna and environmental factors under different land use patterns have been widely conducted domestically. The indicator and remediation roles of soil fauna are also frequently reported [12-14]. Some research results indicate that soil animal numbers decrease with increasing latitude [6-11]. Studies on latitudinal gradient distribution patterns of biodiversity and species richness have been conducted both domestically and internationally, with some scholars investigating relationships between climate variables caused by different latitudes and species richness [15-18]. However, few studies have examined the community distribution of soil macro-fauna along different latitudinal gradients. Zhang et al. [19-25] conducted extensive and detailed research on soil fauna in Tahe and Maoer Mountain, but these studies focused on soil fauna in sample plots within specific regions, with limited research on community composition changes of soil macro-fauna between different latitudinal gradients [5,26-29].

The purpose of this study is to investigate the faunal composition, distribution characteristics, and patterns of soil macro-fauna under climate change caused by different latitudes, and to reveal the influencing factors. This research is significant for understanding the faunal composition and ecological-geographical distribution patterns of soil macro-fauna at different latitudes in Heilongjiang Province and their functional roles in ecosystems. The study aims to reflect community characteristics of soil macro-fauna at different latitudes in Heilongjiang Province, establish a foundation for regional-scale research on spatial patterns of soil fauna in farmland ecosystems, and provide data support for regional-scale biodiversity maintenance mechanism studies. Representative study areas were selected from high to low latitude, namely the eastern mountainous region of Heilongjiang Province.

---

1. Study Area Natural Conditions

The experiment was conducted in three locations across Heilongjiang Province:

Tahe Research Area: Located in Tahe County in northern Heilongjiang, on the northern slope of the Yilehuli Mountains in the Da Hinggan Range, with geographical coordinates of 52°09 –53°23 N, 123°19 –125°48 E. The area has an average elevation of approximately 600 m, experiences a cold temperate continental monsoon climate with long, cold winters and brief, hot-humid summers, an annual average temperature of -2.4°C, annual precipitation of 428 mm, a frost-free period of 80-100 days, and zonal soil type of brown coniferous forest soil.

Dailing Research Area: Located in Dailing District, Yichun City, Heilongjiang, on the eastern slope of the Dalidailing branch in the southern section of the Xiaoxing' an Mountains, with geographical coordinates of 47°10 – 47°14 N, 128°53 –128°55 E. The area has an average elevation of approximately 400 m, exhibits obvious temperate continental monsoon climate characteristics, an annual average temperature of 1.4°C, average annual maximum temperature of 7.5°C, annual precipitation of 676 mm, and zonal soil type of dark brown forest soil with small amounts of swamp soil and peat soil.

Maoer Mountain Research Area: Located in Maoer Mountain Experimental Forest Farm of Northeast Forestry University, within Shangzhi City, Heilongjiang, with geographical coordinates of 45°20 –45°25 N, 127°30 –127°34 E. The area features low mountains and hills with terrain higher in the north and lower in the south, an average elevation of 300 m, and a continental monsoon climate with an annual average temperature of 2.7°C, average temperature of the coldest month of -19.7°C, average temperature of the hottest month of 20.9°C, extreme maximum temperature of 31.8°C, extreme minimum temperature of -31.9°C, and zonal soil of dark brown forest soil [16-18].

---

2. Field Methods

In August 2011, three corn farmland plots with inorganic fertilizer application were randomly selected in Tahe, Dailing, and Maoer Mountain, with at least 50 m distance between each plot. In each latitudinal region, four 5 m × 5 m sample plots were randomly established within each of the three farmland plots. In each sample plot, four 50 cm × 50 cm soil profiles were randomly collected and divided equally into three 5 cm strata (0-5, 5-10, and 10-15 cm) to obtain large soil animal communities from different latitudinal farmland ecosystems. The hand-picking method was used for on-site separation of soil macro-fauna samples, which were then fixed in alcohol and brought back to the laboratory for classification. While surveying soil macro-fauna samples, soil physicochemical property analysis samples were also collected. In each latitudinal region, soil physicochemical property samples were obtained from the selected three farmlands.

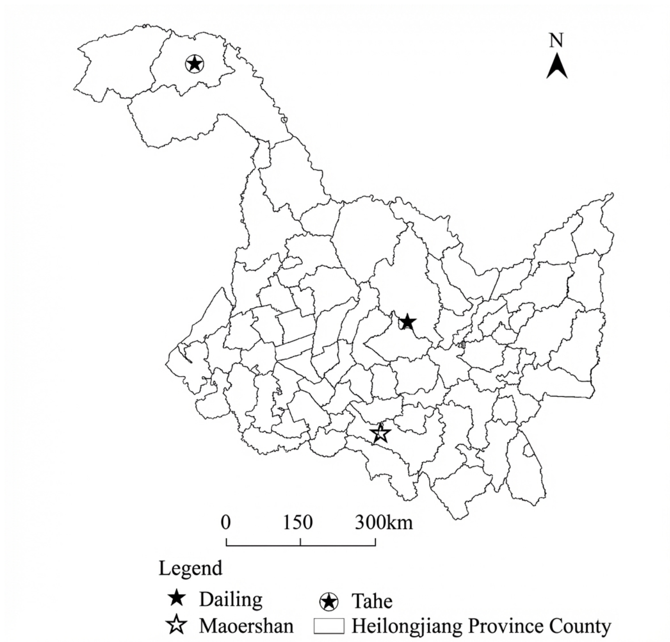

Figure 1: Figure 1

Distribution of sites in different latitude gradient

---

3. Laboratory Methods

Soil macro-fauna were identified and classified under a microscope according to Yin Wenying' s "China Soil Animal Identification Atlas" [30], with species identified to family level and some species to order level. Adults and larvae were counted separately, but only adults were included in the analysis. Concurrently with soil macro-fauna sampling, soil samples for physicochemical property analysis were collected near the sampling points in each latitudinal farmland ecosystem using a small shovel along the soil profile (0-5, 5-10, and 10-15 cm) and placed in ziplock bags for laboratory measurement. Aluminum boxes were used to obtain samples for measuring soil water content.

The main physicochemical indicators measured were: soil pH (measured by potentiometry), soil organic matter (measured by the Tjurin method), total phosphorus content (measured by sulfuric acid digestion), total nitrogen content (measured by the Kjeldahl method), available phosphorus (measured by 0.5 mol/L NaHCO colorimetry), and available potassium (measured by double acid extraction-molybdenum antimony colorimetry) [30]. Soil environmental characteristics are shown in Table 0.

Soil characteristics of farmland habitats from different latitudes in Heilongjiang Province (Mean±SE)

4. Data Analysis and Processing

The following diversity indices were used to analyze soil animal community structure diversity: Shannon-Wiener diversity index (H), Pielou evenness index (E), Simpson dominance index (D), and Margalef richness index (C). The formulas are as follows [21]:

H = -Σ(p_i × ln(p_i)), where p_i = n_i/N, n_i is the number of individuals of group i in the sample area, N is the total number of individuals of all groups in the sample area, and S is the number of groups in the sample area.

All data analysis and mapping were performed using SPSS 19.0, Origin 7.0, and CANOCO 5.0 software. One-way ANOVA (LSD) in SPSS 19.0 was used to compare significant differences in individual numbers and group numbers of soil macro-fauna at different latitudes. Bivariate correlation analysis was used to analyze correlations between environmental factors and soil animal community indicators. CANOCO 5.0 was used for canonical correspondence analysis (CCA) of the relationships between soil macro-fauna quantities, dominant groups, common groups, and soil environmental factors.

5. Results

5.1 Community Composition of Soil Macro-Fauna This study collected a total of 2339 soil macro-fauna individuals, with an average density of 778.33 individuals/m², belonging to 2 phyla, 6 classes, 14 orders, and 35 families. The dominant families (relative abundance >10%) were Enchytraeidae, Lumbricidae, Carabidae, and Staphylinidae, accounting for 58.84% of total individuals. Common groups (relative abundance 1%-10%) included Formicidae, Araneidae, Geophilomorpha, Lithobiomorpha, Juliformia, Porcellio spinicornis, Elateridae, Scarabaeoidea, and Hepialidae, accounting for 32.79% of total individuals. Rare groups (relative abundance <1%) included 23 families such as Curculionidae, Ghrysomelidae, Therevidae, Empidadae, and Rhagionidae, accounting for 8.37% of total individuals.

Community compositions of soil macro-fauna in farmland habitats from different latitudes of Heilongjiang Province

The Tahe experimental site yielded 601 soil macro-fauna individuals. Dominant groups were Staphylinidae, Enchytraeidae, Lumbricidae, and Carabidae, while common groups were Araneidae and Geophilomorpha, accounting for 67.94% of total individuals. Rare groups included Lithobiomorpha and Eumastacoidea, accounting for 5.2% of total individuals.

The Dailing experimental site yielded 1076 individuals. Dominant groups were Enchytraeidae, Lumbricidae, and Carabidae, while common groups were Araneidae, Geophilomorpha, Juliformia, and Staphylinidae, accounting for 26.86% of total individuals. Rare groups included Lithobiomorpha, Lucanidae, and Bibionidae, accounting for 5.2% of total individuals.

The Maoer Mountain experimental site yielded 662 individuals. Dominant groups were Enchytraeidae, Formicidae, and Geophilomorpha, while common groups were Lumbricidae, Araneidae, Scarabaeoidea, and Staphylinidae, accounting for 46.25% of total individuals. Rare groups included Ghrysomelidae, Bibionidae, and Dolichopodadae, accounting for 1.69% of total individuals.

The distribution characteristics of the same species differed among farmland habitats at different latitudes. For example, Staphylinidae was dominant at all latitudes, Bibionidae was a common group at Tahe and Maoer Mountain but dominant at Dailing, Lumbricidae was a common group at Dailing and Maoer Mountain but dominant at Tahe, and Juliformia was a rare group at different latitudes.

5.2 Horizontal Distribution Characteristics of Soil Fauna at Different Latitudes Individual density and richness of soil macro-fauna at Dailing were not significantly different from those at Tahe and Maoer Mountain, although individual densities of some groups differed among sites. For example, Geophilomorpha density was significantly higher at Dailing (130.00 individuals/m^2) than at Tahe and Maoer Mountain. The same group showed different dominance patterns across sites: Staphylinidae was dominant at Tahe and Dailing but common at Maoer Mountain; Bibionidae was dominant at Dailing but common at Tahe and Maoer Mountain; and Juliformia was dominant at Tahe but common at Dailing and Maoer Mountain.

Diversity indices showed that H and E indices were highest at Dailing, followed by Tahe, and lowest at Maoer Mountain. The D index was highest at Tahe, followed by Maoer Mountain and Dailing. The C index was highest at Tahe and Dailing. One-way ANOVA revealed no significant differences in diversity indices among the three sites.

5.3 Vertical Distribution Characteristics of Soil Fauna at Different Latitudes One-way ANOVA showed no significant differences in diversity indices among the three sites. Individual density and richness decreased with soil depth in all sites except for Maoer Mountain at the 5-10 cm layer, demonstrating obvious surface aggregation. No significant differences were detected in individual density or richness among latitudinal areas at the same vertical level ($P < 0.05$).

Individual density and richness in the 0-5 cm layer were highest at Dailing, followed by Tahe and Maoer Mountain. In the 5-10 cm layer, individual density was highest at Dailing, followed by Maoer Mountain and Tahe, while richness was highest at Maoer Mountain. In the 10-15 cm layer, individual density was highest at Dailing, followed by Tahe and Maoer Mountain, while richness was highest at Tahe. Soil fauna did not show regular changes with latitude within each soil layer.

Diversity analysis of soil macro-fauna (Mean±SE)

Different latitudinal sites showed differences in group composition and distribution within the same soil layer. Some groups were dominant, common, or rare across all layers, while some were only distributed in specific layers. For instance, Enchytraeidae was dominant in all layers at all sites, while Lucanidae was rare. Bibionidae, Ghrysomelidae, Tenebrionidae, and Therevidae were common species in the 0-5 cm layer at Tahe and Dailing. Carabidae was a rare species in the 0-5 cm layer at Tahe but common at Dailing and Maoer Mountain. Lithobiomorpha was a common species in the 5-10 cm layer at Dailing and Maoer Mountain but absent at Tahe. Some groups showed increasing density with soil depth, such as Carabidae and Elateridae at Maoer Mountain.

[FIGURE:2] Vertical distribution of individual density and species number of soil macro-fauna in farmland habitats from different latitudes

5.4 Correlation Analysis Between Soil Macro-Fauna Community Metrics and Soil Environmental Factors Bivariate correlation analysis revealed no significant correlations between community metrics (richness, individual density, diversity indices, evenness indices) and soil environmental factors (pH, organic matter, total nitrogen, total phosphorus, available phosphorus) across the three sites. However, some site-specific patterns emerged:

At Tahe, richness and D index were positively correlated with soil environmental factors, while individual density was negatively correlated with available phosphorus and total nitrogen. H and C indices were positively correlated with all factors except pH, while E index was positively correlated with pH but negatively correlated with other factors.

At Dailing, richness was positively correlated with available potassium and organic matter but negatively correlated with other factors. Individual density was positively correlated with pH but negatively correlated with other factors. H and D indices were negatively correlated with total nitrogen but positively correlated with other factors. E index was negatively correlated with total phosphorus and total nitrogen but positively correlated with other factors. C index was positively correlated with total nitrogen but negatively correlated with other factors.

At Maoer Mountain, richness was positively correlated with available potassium, while individual density was negatively correlated with available potassium. H and D indices were negatively correlated with total nitrogen but positively correlated with other factors. E index was negatively correlated with total phosphorus and total nitrogen but positively correlated with other factors. C index was positively correlated with total nitrogen but negatively correlated with other factors.

Overall, no significant correlations were found between soil macro-fauna community metrics and soil environmental factors across the three sites.

[FIGURE:3] Correspondence analysis ordination based on soil macro-fauna in farmland habitats from different latitudes

CCA ordination showed that Axis 1 and Axis 2 eigenvalues were 0.2274 and 0.1137 for Tahe, 0.2048 and 0.1087 for Dailing, and 0.2788 and 0.1317 for Maoer Mountain. Enchytraeidae and Geophilomorpha were widely distributed and represented dominant and common groups across all sites, clustering near the center of the ordination diagram. At Tahe, Empidadae and Elateridae showed strong correlations with total nitrogen, while Bibionidae and Geometridae were strongly correlated with soil organic matter. At Dailing, Araneidae and Lithobiomorpha showed strong correlations with soil organic matter. At Maoer Mountain, Formicidae and Empidadae showed strong correlations with total nitrogen.

---

6. Discussion

6.1 Community Composition Characteristics of Soil Macro-Fauna at Different Latitudes Investigation of soil macro-fauna at three different latitudes in Heilongjiang Province revealed that Enchytraeidae was the dominant group at all sites, demonstrating broad adaptability to different latitudes. Zhang et al. [20] reported similar results for Enchytraeidae as a dominant group in the northern Da Hinggan Mountains forest ecosystem, consistent with our Tahe site results. However, their study found Araneidae and Carabidae to be common groups, whereas our study identified them as dominant groups, indicating that species distribution differs between ecosystems at the same location. Sphingidae was not found in previous studies of Tahe and Maoer Mountain [20-22] but appeared only at our Dailing site, possibly due to different environmental factors or plot location selection.

The Maoer Mountain site showed the smallest richness and fewest group types, consistent with previous studies [21-22,31]. Each latitude and soil depth had its own unique groups due to environmental heterogeneity differences among regions. One-way ANOVA revealed no significant differences in richness among sites, indicating that richness is less affected by latitude. Soil macro-fauna show certain indicator roles for environmental changes, and research should focus more on analysis of different groups at different latitudes.

6.2 Spatial Distribution Characteristics of Soil Macro-Fauna at Different Latitudes Changes in microhabitats among different sites can cause subtle differences in soil animal community structure, with soil environmental factors being the main reason for changes in individual density and richness [31]. Individual density and richness showed an initial increase then decrease with increasing latitude. Tahe had the lowest individual density and richness due to its low annual average temperature. The higher individual density and richness at Dailing compared to Maoer Mountain may be attributed to: (1) higher soil organic matter, total phosphorus, and other soil factors at Dailing; (2) sampling conducted in August when Dailing receives concentrated precipitation, resulting in more soil animals; and (3) greater environmental stress at Maoer Mountain during sampling, such as different fertilization amounts and timing, leading to reduced soil animal density and richness [32-33].

No significant differences in richness and individual density among different latitudes were found, mainly because dominant and common groups showed strong environmental adaptability, maintaining relatively stable community structures across latitudinal and environmental gradients. Litter and resulting humus are important food sources for soil animals and provide insulation and moisture retention. As depth increases, soil organic matter nutrients decline, and aeration, water permeability, and temperature decrease, resulting in obvious surface aggregation characteristics of soil macro-fauna density and richness at different latitudes.

Vertical distribution patterns differed among latitudes. Except for Maoer Mountain' s richness in the 5-10 cm layer, individual density and richness at all sites decreased with increasing soil depth. Low-latitude sites showed similar values in middle and bottom layers, with significant declines beginning from the middle layer, while high-latitude sites showed gradual decreases from the surface. The maximum group and individual densities occurred in the surface layer at Dailing, while the minimum values occurred in the deepest layer at the highest latitude. The 5-10 cm layer at Maoer Mountain had the highest richness, H index, E index, and D index, possibly because abundant precipitation in August at Maoer Mountain reduced soil animal diversity in the 0-5 cm layer due to surface runoff, while the 5-10 cm layer provided more stable habitat quality for soil animal populations [34].

6.3 Correlation Analysis Between Soil Macro-Fauna and Soil Physicochemical Properties Although individual density and richness of soil fauna at the three latitudes were influenced by soil environmental factors, bivariate correlation analysis revealed no significant correlations between community metrics and soil factors, differing from results reported by Liu et al. [35] in the Zuojia Nature Reserve. Different soil animal groups at different latitudes showed different correlations with soil physicochemical environments. CCA revealed that Empidadae and Elateridae at Tahe, and Bibionidae at Dailing showed strong correlations with total nitrogen; Bibionidae and Geometridae at Tahe, and Araneidae and Lithobiomorpha at Dailing showed strong correlations with soil organic matter. Different soil animal groups have selective absorption and enrichment functions for certain elements, making studies on relationships between soil animal distribution and ecological environments at different latitudes important for promoting beneficial development of soil fauna, inhibiting harmful activities, and maintaining soil ecosystem balance.

---

7. Conclusion

Based on investigation of soil macro-fauna in three corn farmland plots at different latitudes in Heilongjiang Province, we conclude that:

1. The vertical distribution of individual density, richness, and diversity indices of soil macro-fauna generally shows surface aggregation and decreases with soil depth.
2. Individual density and richness of soil macro-fauna do not show regular patterns with increasing latitude, and community structure and diversity are influenced by both latitude and soil physicochemical properties. However, no significant differences in community structure metrics were found among different sites, indicating that most groups possess certain adaptability to the broad environmental conditions across different latitudes in Heilongjiang Province.
3. At the local scale, the influence of environmental factors on soil fauna cannot be ignored, providing an important foundation for research on spatial patterns and biodiversity maintenance mechanisms of soil fauna in farmland ecosystems at regional scales.

References

[1] **China Soil Animal Identification Atlas**. Science Press, 1998.
[2] **Review on Soil Animal Community Ecology in China**. Chinese Journal of Ecology, 2005, 24(12): 1477-1481.
[3] **Characteristics of Soil Animal Communities in the Forest-Steppe Ecotone of the Southeastern Inner Mongolia Plateau**, 2013, 22(4): 27-34.
[4] **Community Structure of Soil Macro-Fauna in Zhalong Nature Reserve**, 2012, 43(4): 781-786.
[5] **Effects of Different Land Use Patterns on Soil Macro-Fauna Communities on the North Shore of Qinghai Lake**, 2012, 21(2): 180-186.
[6] **Ecological Characteristics of Soil Fauna Communities in Litter**

Layers of Important Forest Communities in China, 2009, 29(6): 2938-2944.
[7] Gartner T B, Cardon Z G. Decomposition dynamics in mixed-species leaf litter. *Oikos*, 2004, 104(2): 230-246.
[8] Begon M, Harper J L, Townsend C R. *Ecology: Individuals, Populations and Communities*. Sunderland, Massachusetts: Sinauer Associates, Inc., 1986: 386-415.
[9] Zhao H L, Li J, Liu R T, Zhou R L, Qu H, Pan C C. Effects of desertification on temporal and spatial distribution of soil macro-arthropods in Horqin sandy grassland, Inner Mongolia. *Geoderma*, 2014, 223-225: 62-67.
[10] **Effects of Desertification on Temporal and Spatial Variation of Soil Macro-Arthropod Communities in Horqin Sandy Grassland**, 2013, 21(2): 394-400, 405.
[11] **Distribution Characteristics of Soil Animal Communities in Horqin Sandy Land**. Science Press, 2015.
[12] **Research Progress and Suggestions on Soil Fauna in Sandy Grassland**, 2013, 22(3): 70-77.
[13] **Research Progress on Soil Animal Ecology in Farmland Ecosystems in China**, 2009, 29(4): 656-662.
[14] **Chinese Journal of Ecology**, 2011, 30(12): 2898-2906.
[15] Rivadeneira M M, Fernández M, Navarrete S A. Latitudinal trends of species diversity in rocky intertidal herbivore assemblages: spatial scale and the relationship between local and regional species richness. *Marine Ecology Progress Series*, 2002, 245: 123-131.
[16] Qiao X J, Jabot F, Tang Z Y, Jiang M X, Fang J Y. A latitudinal gradient in tree community assembly processes evidenced in Chinese forests. *Global Ecology and Biogeography*, 2015, 24(3): 314-323.
[17] Gorelick R. Species richness and the analytic geometry of latitudinal and altitudinal gradients. *Acta Biotheoretica*, 2008, 56(3): 197-203.
[18] Fiera C, Ulrich W. Spatial patterns in the distribution of European springtails (Hexapoda: Collembola). *Biological Journal of the Linnean Society*, 2012, 105(3): 498-506.
[19] **Decomposition Efficiency of Eisenia fetida on Forest Litter**, 2005, 25(9): 2427-2433.
[20] **Characteristics of Soil Macro-Fauna Communities in the Northern Da Hinggan Mountains Forest Ecosystem**, 2008, 27(3): 509-518.
[21] **Study on the Relationship Between Forest Litter Decomposition and Soil Fauna in Maoer Mountain**, *Chinese Journal of Applied Ecology*, 1999, 10(4): 511-512.
[22] **Analysis of Soil Animal Community Composition and Diversity in Maoer Mountain, Heilongjiang**, 2006, 42(4): 71-77.
[23] **Decomposition of Coniferous Litter and Role of Soil Fauna in Xiaoxing' an Mountains**, 2000, 20(6): 552-556.
[24] **Functional Groups of Soil Macro-Fauna in Korean Pine Plantation and Natural Secondary Forest**, *Chinese Journal of Applied and Environmental Biology*, 2014, 20(1): 22-29.

[25] **Functional Groups and Ecological Distribution of Soil Fauna in Northern Da Hinggan Mountains Forest Ecosystem**, 2008, 39(5): 1017-1022.
[26] **Review on Soil Fauna Research**, *Life Science Research*, 2006, 10(4): 72-75.
[27] **Characteristics of Soil Macro-Fauna Communities in Japanese Larch Forests in Western Qinling Mountains**, *Chinese Journal of Applied and Environmental Biology*, 2013, 19(4): 611-617.
[28] **Community Structure and Composition of Soil Macro-Fauna Under Different Land Use Conditions in Changchun City**, 2006, 52(2): 279-287.
[29] **Characteristics of Soil Macro-Fauna Communities in Farmlands with Different Cultivation Years in the Middle Reaches of Heihe River Oasisification Process**, 2014, 34(10): 1254-1261.
[30] **Response of Soil Animal Community Structure to Different Management and Utilization Patterns in Farmland Ecosystem** [D]. Harbin Normal University, 2014: 19-22.
[31] **Community Composition and Structure of Four Soil Macro-Fauna Groups in Beijing Songshan**, 2002, 22(2): 215-223.
[32] **Effects of Different Fertilization Methods on Main Soil Fauna Groups in Purple Soil Farmland**, *Scientia Agricultura Sinica*, 2015, 48(5): 911-920.
[33] **Effects of Different Fertilization Treatments on Soil Insects in Black Soil Region of Jilin**, 2006, 26(4): 1122-1130.
[34] **Spatiotemporal Dynamics of Soil Macro-Fauna Community Structure in Three Temperate Forests**, 2013, 33(19): 6236-6245.
[35] **Relationship Between Soil Macro-Fauna and Soil Factors in Zuojia Nature Reserve**, 2008, 45(1): 130-136.

Figures

Source: ChinaXiv —Machine translation. Verify with original.

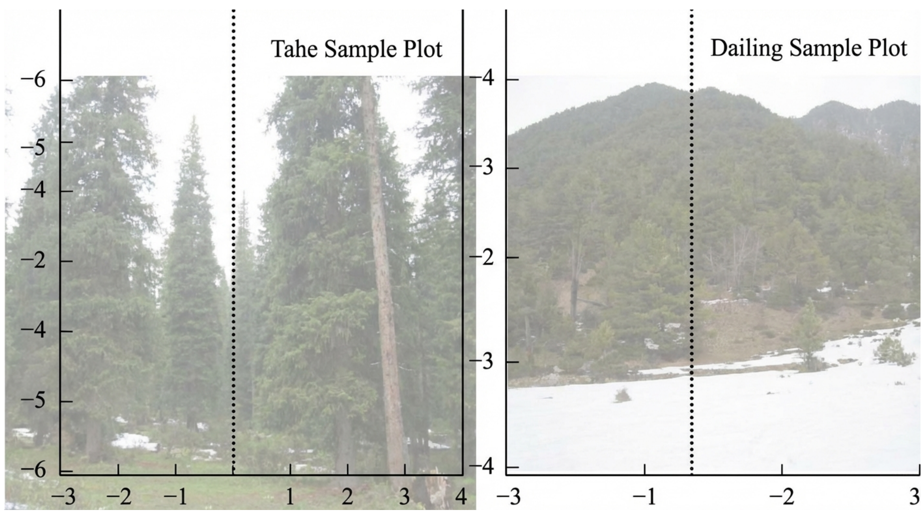

Figure 2: Figure 10

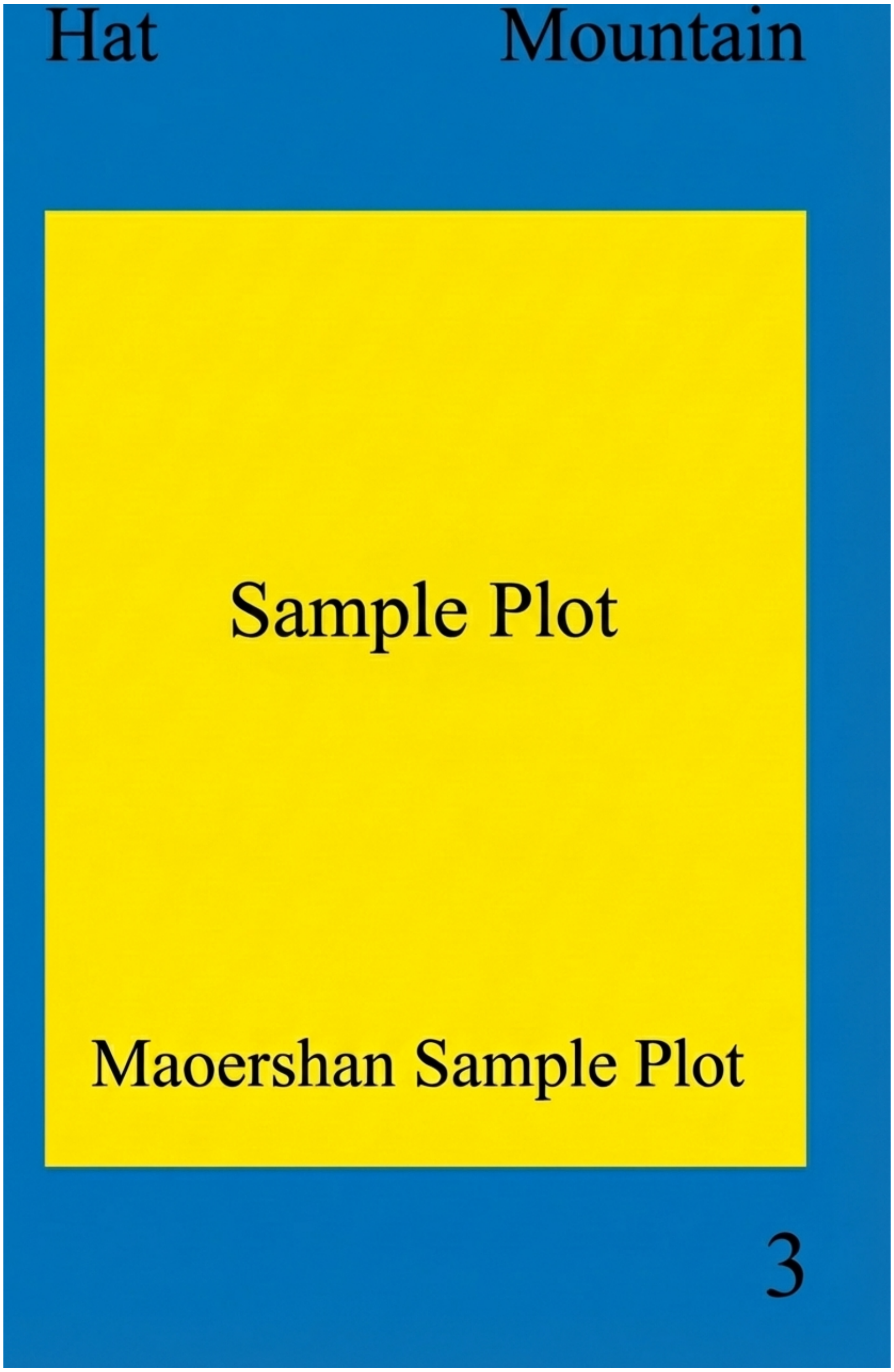

Figure 3: Figure 11