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Multi-Scale Effects of Landscape Stucture on Epigaeic Arthropods Diversity in Arable Land System: A Case in Changtu County of Northern China

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Abstract: Understanding the multi-scale effects of arable land landscape on epigaeic arthropod diversity is essential for biodiversity conservation and agroecosystem services. Our study explored the overall effect of landscape elements on epigaeic arthropod diversity at three scales of landscape, habitat, and field. We selected 11 areas to sample using the trap method, and construct models of landscape elements and biodiversity data. The results showed that: (1) On the landscape scale, 1500 m was the optimal radius. Shannon's diversity index and interspersion and juxtaposition index can explain the diversity of epigaeic arthropods at the level of 76.7%. (2) On the habitat scale (the radius less than 100 m), habitat types significantly affected the species number, Pielou evenness index, and individual number of epigaeic arthropods ($p < 0.05$). The distribution of epigaeic arthropods had an obvious margin effect. (3) On the field scale, we also revealed The Shannon diversity index and Pielou evenness index of herb vegetation structure can explain the change of epigaeic arthropod community structure at the level of 69.1%. We believe that an appropriate scale is the best lever to protect agricultural biodiversity. Our research can promote multi-scale integrated conservation of regional biodiversity and sustainable development of agricultural systems.

Keywords: agro-ecosystems; non-crop habitats; biodiversity conservation; margin effects; sustainability

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Citation: Zhang, Y.; Yang, Y.; Bian, Z.; Wang, S. Multi-Scale Effects of Landscape Stucture on Epigaeic Arthropods Diversity in Arable Land System: A Case in Changtu County of Northern China. *Land* **2022**, *11*, 979. https://doi.org/10.3390/land11070979

Academic Editor: Alexander Khoroshev

Received: 28 May 2022
Accepted: 24 June 2022
Published: 26 June 2022

1. Introduction

The arable land system of sustainable development can greatly reduce the negative environmental impact caused by the continuous population growth. The arable land system is composed of intensive farmland and non-crop habitats (such as ditches, woodlands, grasslands, and among others.) [1–3]. The arable land system coexists with the surrounding physical space (e.g., different land use types), and at the same time coexists with the natural ecology and other factors, and exchanges material energy and information to form micro-ecological space. In the past few decades, the increase in crop yields has been mainly achieved through agricultural intensification. A homogeneous arable land system has brought considerable productivity and also led to the loss of biodiversity [4,5]. The unsustainability of the arable land system is becoming more and more obvious in the context of the global popularity of COVID-19. Replanning a multi-functional landscape to form a reasonable landscape structure is an effective way to enhance the sustainability of the arable land system [6,7].

As the dominant species in terrestrial ecosystems, arthropods provide a wide range of ecosystem services such as pest control, crop pollination, and decomposition to maintain soil fertility [8,9]. The non-crop habitats within an agro-ecological mosaic landscape have the potential to provide biodiversity and ES, which directly affect the stability of arable land system landscape structure and ecosystem [10,11]. The farmland landscape is the main component of the arable land system landscape, providing key ecosystem services, especially in the form of food. Compared with farmland, non-crop habitats have more diverse species, so they are considered the key areas for biodiversity conservation. Non-crop habitats can form corridor networks, connecting fragmented, isolated, or residual patches into a whole ecological region, which is convenient for biological migration in a landscape, thereby increasing gene exchange and the selection and utilization of different resource patches to maintain population stability [12]. For example, shrublands, flower strips, and grasslands around farmland provide food sources for predators such as spiders and pelagic beetles, and overwintering sites, thereby regulating pests promptly by maintaining a stable population of natural enemies, and providing alternative food sources such as pollen for pollinators such as bees [13,14]. Bosch-Serra et al. summarized through a large number of cases that more than 63% of the species living in farmland depended on non-crop habitats [15]. Studies have also shown that 20% of non-crop habitats in agricultural landscapes are the threshold for ecosystem processes associated with biodiversity conservation [16,17].

ES provided by agrobiodiversity and functional biodiversity can be enhanced by diversifying landscape elements such as non-crop habitats surrounding the fields [18,19]. Abundance, species richness, and evenness of epigaeic arthropods are all influenced by both habitat scale and landscape scale characteristics, although not necessarily to the same extent [20,21]. In regions with single landscape composition and configuration, biodiversity is more sensitive to landscape heterogeneity. The optimal scale of landscape heterogeneity affecting pollinator diversity in plain landform-dominated areas is 500 m [22,23], while in hilly landform-dominated areas, the optimal scale is 2000 m [24]. In addition, compared with the habitat scale, the landscape (geomorphic type) scale has a more significant impact on pollinator diversity. The spatial scale has gradually become a key factor in the study of arthropod ecosystem services. In recent years, scholars have further proved that the increase in land-use intensity is beneficial to pests at the landscape scale by exploring the effects of agricultural intensification on crop insects and biological control at different scales [25,26]. However, low agricultural intensity management measures at the field scale, such as pesticide use, rotation intercropping, and organic farming, can alleviate these effects. The degree of biological control potentially achieved in afield is thus dependent on how epigaeic arthropods respond to these multi-scale factors, so determining the ideal arable land system landscape that would favor biodiversity conservation and ecosystem production becomes a complex task [27–29].

On the landscape scale, the landscape index is considered to be an effective means to describe the landscape structure. There is an optimal scale for the response of epigaeic arthropod diversity to the landscape structure, but the optimal scale is not immutable [30,31]. It is mainly affected by the natural background characteristics such as topography, the characteristics of biological groups, and the differences in seasons and agricultural production behaviors [32,33]. At the same time, there is a minimum scale of landscape scale research, for example, scholars have found that there is no significant correlation between landscape heterogeneity and the interaction between predators and pests of epigaeic arthropods at the scale of 1000 m in the plain area [34]. In this case, the study at the habitat scale can more appropriately reflect the impact of non-crop habitats on arthropods. The diversity of epigaeic arthropods at the habitat scale is mainly affected by habitat types and farmland margin characteristics. The results of the study on the effects of agroforestry systems on predatory arthropods showed that the abundance and diversity of arthropods in forest habitats were significantly higher than those in cultivated land [35,36]. Different types of habitat margins formed a variety of farmland margins, which have complex vegetation structures as a channel connecting adjacent two habitats. It not only has the common biological populations of adjacent two habitats, but also has its unique species, so it can support more abundant biological communities than the habitat center [37]. The effects of landscape and habitat factors should be considered at the scale of significant correlation influence, because the outcome in terms of biological control ultimately depends on trophic and non-trophic links within interaction networks, which is a rarely addressed but important element to consider [38–40].

In this study, to make landscape design on the spatial scale related to arthropod species, we focused on the influence mechanism of landscape structure at different scales (landscape and habitat) on the diversity of epigaeic arthropods. More specifically, we propose the following research objectives: (1) On the landscape scale, we analyze the scale effect of the response of epigaeic arthropod diversity to landscape heterogeneity, and determine the optimal scale and minimum scale of the impact. (2) On the habitat scale, we predicted that: (i) the differences in epigaeic arthropod community structures in different habitat types were analyzed. (ii) The margin effect affects the distribution of epigaeic arthropods. (3) On the field scale, the vegetation structure of field margin strips was the main factor affecting the differences in epigaeic arthropods. (4) Clarify the landscape and environmental factors affecting epigaeic arthropods at two scales and construct the optimal model.

2. Materials and Methods

This study is carried out from three scales of landscape, habitat, and field, respectively, to explore the impact of landscape pattern, habitat type, and vegetation structure characteristics on epigaeic arthropod diversity, and to summarize the multi-scale effects of landscape structure on epigaeic arthropod diversity in the same area. At different scales, there are differences in the landscape structure affecting epigaeic arthropods, and the materials methods are also different.

2.1. Study Area

Changtu County is located in the south of Northeast China Plain (123°32′–124°26′ E, 42°3′–43°2′ N), with an administrative area of 4317 km^2 and a total cultivated land area of 2667 km^2 (Figure 1). It is a famous agricultural county in China. The county is dominated by an arable land system landscape, which is a typical dry farming area in the northern plain. It is the world's "golden corn belt" and the largest peanut distribution center in Northeast China, which is also the significance of this study. The landform of the whole county transits from east to west from the hilly area to Liaohe plain area. The soil types mainly include dark brown soil, black soil, meadow soil, and aeolian sandy soil. The mangang plain in the central and southern part of the county is one of the key grain-producing areas in the county with a deep soil layer and developed agriculture. Changtu county belongs to the middle temperate humid monsoon continental climate, the average annual temperature is 7.0 °C, and the average annual rainfall is 607.5 mm [41]. Spring and autumn monsoon, long cold period, long crop growth cycle, and sparse natural vegetation. There are broad-leaved forest-based farmland shelterbelt systems and other non-crop habitats around farmland. Due to intensive farming methods, the homogenization of arable land system landscape is deepened and the sustainability of the agricultural system is reduced.

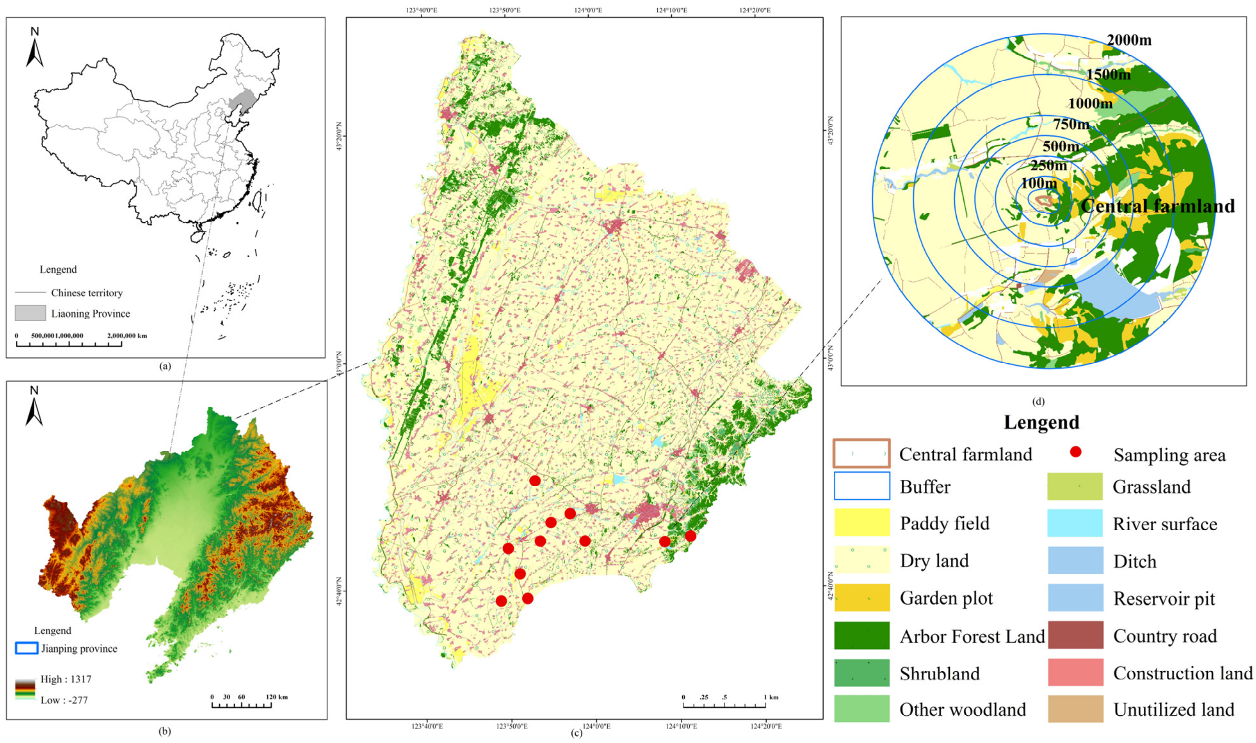

Figure 1. Location map of study area. (**a**) Location in China; (**b**) Location in Liaoning Province; (**c**) Changtu County land-use status map and the location of each sampling area; (**d**) Specific design of sampling area. Indicators representing the surrounding landscape are calculated in the concentric buffer zone around each central farmland (radius 100−2000 m).

2.2. Biodiversity Sampling

In 2021, we selected 11 sampling areas to plant maize crops (Figure 2). According to the difference in habitat (2 orchards, 3 native grasslands, 3 other woodlands, 3 arbor woodlands) around cultivated land, it can be divided into 8 types of habitats: orchard, adjacent to an orchard, native grassland, adjacent to native grassland, other woodland, adjacent to other woodland, arbor forest land, adjacent to arbor forest land.

Epigaeic arthropods diversity sampling: the 'five-point sampling method' was used in the cultivated land. Three sampling points were set in the farmland margin and adjacent habitats, and three trap bottles (trap spacing greater than 10 m) were set at each sampling point, a total of 363 (0). Specific layout method: A 500 mL plastic cup with a bottom diameter of 5 cm, a top diameter of 10 cm, and a height of 12 cm was buried in the soil. The mouth of the cup was flat with the surface, and 150–200 mL ethylene glycol solution (20% concentration) and detergent (a drop) were poured into the cup. A plastic cover was installed above each trap and fixed with iron wire to play a protective role. After 6 days of trap placement, the captured epigaeic arthropods were stored in a PE bottle containing 75% alcohol until indoor identification. Vegetation diversity sampling: the farmland margin in the study area is mostly the transition zone between farmland and non-crop habitats. According to the different adjacent habitats of farmland, farmland margin can be divided into four types: farmland-orchard, farmland-native grassland, farmland-other woodland, and farmland-tree woodland. Six sampling plots of herb vegetation were randomly arranged around the trap of farmland margin in the sampling area. Considering the width of the vegetation zone (0.8–1.5 m) between the non-crop habitat and the farmland in the plot, as well as the composition and homogenization of herbaceous plants, we chose a plot of 0.5 × 0.5 m. The name, number of plants (clumps), average height (AH), and coverage (AC) of vegetation in the plots were recorded. In addition to directly reflecting biodiversity by the number of species (*S*), we use the Shannon diversity index (*H*) to reflect the number of species in a sample of a certain size. Differently, the Margalef richness index

(*Ma*) reflects the chance of an individual appearing in a sample that includes all species in the community and was therefore chosen to characterize vegetation diversity. In addition, the species evenness index (*E*) is used to reflect the relative density of species in the sample, and to measure the proximity of different species in quantity. The diversity indices were calculated using PAST software [42]. The specific formula is as follows:

$$H = -\sum P_i \ln P_i \tag{1}$$

$$E = H / \ln S \tag{2}$$

$$Ma = (S - 1) / \ln N \tag{3}$$

P_i is the proportion of the number of individuals in group i, S is the number of species groups, and N is the total number of individuals.

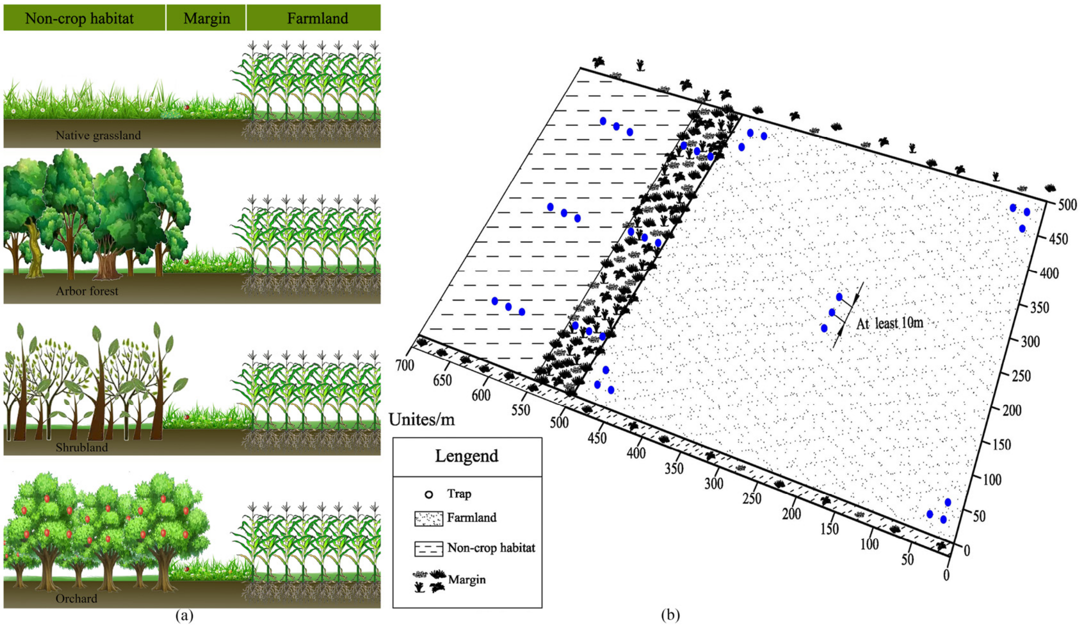

Figure 2. Sample plot and trap layout scheme. (**a**) is the profile diagram of the 4 types of sampling areas, and the overall structure is non-crop habitat-margin-farmland. Non-crop habitats are divided into native grassland, arbor forest, shrubland and orchard. (**b**) is the specific method of trap layout in each sample area.

2.3. Landscape Metrics

To comprehensively consider the impacts of land use (social attribute) and land cover (natural attribute), we reclassify the land use/cover in the study area into 10 first-level categories and 14 second-level categories based on the "LUCC classification system" (Appendix A). In particular, to reflect the degree of heterogeneity of the landscape, we selected 8 landscape structure indices: largest patch index (LPI), landscape shape index (LSI), Shannon's diversity index (SHDI), patch richness density (PRD), contagion index (CONTAG), interspersion and juxtaposition index (IJI), landscape division index (DIVISION), aggregation index (AI). To obtain the landscape index, the land vector data of the study area is rasterized in ArcGIS 10. 2 (ESRI Geoinformatik, Hannover, Germany). The size of the particle is the key to effectively extracting information. We determine the optimal conversion particle size is 5 m, and Fragstats 4.2 software was used to calculate the concentric buffer (radius of 100, 250, 500, 750, 1000, and 1500 m) to describe the surrounding landscape indicators. The formulas used were as follows:

$$\text{LPI} = \frac{\overset{n}{\underset{j=1}{max}}(a_{ij})}{A}(100) \tag{4}$$

$$\text{LSI} = \frac{e_i}{mine_i} \tag{5}$$

$$\text{SHDI} = -\sum_{i=1}^{m}[P_i \ln(P_i)] \tag{6}$$

$$\text{PRD} = m/A \tag{7}$$

$$\text{CONTAG} = [1 + \sum_{i=1}^{m}\sum_{j=1}^{n}\frac{P_{ij}\ln(P_{ij})}{2\ln(m)}](100) \tag{8}$$

$$\text{IJI} = \frac{-\sum_{i=1}^{m}\sum_{k=i+1}^{m}\left[\left(\frac{e_{ik}}{E}\ln\frac{e_{ik}}{E}\right)\right]}{\ln(m-1)}(100) \tag{9}$$

$$\text{DIVISION} = \left[\frac{g_{ij}}{max \to g_{ij}}\right](100) \tag{10}$$

$$\text{AI} = \left[\frac{g_{ij}}{max \to g_{ij}}\right](100) \tag{11}$$

where, i and j are the number of patch types; m and n are the number of patch types; P_{ij} is the probability that belongs to types i and j; a_{ij} is the area of a particular type of landscape; g_{ij} is the number of similar adjacent patches of corresponding landscape types, e_i is the margin length of i element; A is the area of the whole landscape; N is the total number of patches in the landscape.

2.4. Statistical Analyses

Pearson correlation analysis was conducted between the diversity of farmland epigaeic arthropods and the landscape indices under different radii to analyze the impact of landscape variables on the diversity of farmland epigaeic arthropods at the landscape scale, and determine the optimal radius of this impact and the research scale of habitat scale. The index related to epigaeic arthropods is selected as the dependent variable, and the landscape index related to its obvious indigenousness is selected as the independent variable. Ridge regression analysis is used to solve the collinearity problem of independent variables in linear regression analysis. Then, the optimal model is selected according to the Akaike Information Criterion for small samples (AICc, the smaller the AICc value is, the better the model is).

Hierarchical clustering was used to analyze the similarity of epigaeic arthropod community structures in different habitats, which was completed in R software [43]. The effects of different habitats on the diversity of epigaeic arthropods were analyzed by one-way ANOVA. The linear regression model was constructed by selecting the epigaeic arthropod correlation index as the dependent variable and removing the linear herb vegetation structure factor as the independent variable. This analysis is completed by SPSS software. In addition, a Redundancy analysis (RDA) was used to explore the relationship between the structural factors of herb vegetation on farmland margin and the dominant species of common epigaeic arthropod species, and the two-dimensional ranking diagram of dominant and common species—key environmental factors were plotted. This analysis is calculated by CANOCO 5.

3. Results

We obtained the optimal radius at the landscape scale, the research scope at the habitat scale, and the characteristics of the plot scale itself, and analyzed the influence of environmental factors on epigaeic arthropods at various scales.

3.1. Arthropods and Plant Communities

We captured 9389 epigaeic arthropods, including 2148 in farmland, 4403 in the margin, and 2838 in non-crop habitats, belonging to 5 classes, 10 orders, 25 families, and 44 species (Appendix C). When individuals accounted for more than 20% of the total catch, it was considered the dominant group; when the proportion is 1–20%, it was considered the common group; when less than 1%, it was considered the rare group. The study captured mainly Gryllidae, accounting for 60% of the total, followed by Carabidae, accounting for 20% of the total. Formicidae, Theridiidae, and other three families constituted a common group. The remaining 18 families formed a rare group.

In terms of plant diversity, we collected 2569 herb plants, belonging to 3 classes, 21 orders, 21 families, and 42 species (Appendix B). Gramineae were mainly collected in this study, accounting for 44% of the total, followed by Asteraceae and Asterales, accounting for 18% and 10% of the total, respectively. Commelinaceae, Cyperaceae, Asclepiadaceae, and five other families formed a common group. The remaining 14 families formed a rare group.

3.2. Scale Responses of Epigaeic Arthropods Diversity on the Landscape Scale

There was no significant correlation between biodiversity index and landscape index at a 100 m radius (Table 1). At 1500 m radius, the correlation between the biodiversity index of epigaeic arthropods and the landscape index was the most significant. Species number (S_a) was negative correlated with LPI ($p < 0.05$) and CONTAG ($p < 0.01$), but positively correlated with IJI ($p < 0.01$), PRD ($p < 0.05$) and SHDI ($p < 0.01$). Shannon diversity index (H_a) was significantly positively correlated with PRD and SHDI ($p < 0.05$). Therefore, 100 m is the scale to study the diversity of epigaeic arthropods on the habitat scale. The 1500 m which the landscape index has the highest correlation with the biodiversity index, is the optimal radius to study the influence of landscape heterogeneity on epigaeic arthropod diversity on the landscape scale (Table 1).

Based on this, under the radius of 1500 m, the biodiversity index of epigaeic arthropods was used as the dependent variable, and the landscape index significantly related to it was used as the independent variable for ridge regression analysis, and the optimal model was selected according to the AICc value (Table 2). The species number (S_a) of epigaeic arthropods and five landscape indices including LPI, PRD, CONTAG, IJI, and SHDI, established 31 models, among which IJI and SHDI could explain the species number (S) of epigaeic arthropods at 76.7% level. The Shannon diversity index (H_a) of epigaeic arthropods and two landscape indices including PRD and SHDI were used to construct three models, among which PRD could explain the Shannon diversity (H_a) of epigaeic arthropods at 32% level.

Table 1. Correlation analysis between farmland epigaeic arthropod diversity and landscape indices at different scales.

Buffer Radius	Biodiversity Indices	Average Value	LPI	LSI	CONTAG	IJI	DIVISION	PRD	SHDI	AI
100 m	S_a	16.55	−0.255	−0.329	−0.100	0.028	0.252	0.424	0.021	−0.285
	H_a	1.77	−0.105	−0.207	0.005	0.353	0.100	0.283	−0.069	−0.238
	E_a	0.38	0.031	−0.129	0.164	0.449	−0.042	0.075	−0.160	−0.048
250 m	S_a	16.55	−0.680 *	0.139	−0.528	0.355	0.636 *	0.507	0.530	−0.392
	H_a	1.77	−0.299	0.099	−0.188	0.095	0.262	0.315	0.191	−0.289
	E_a	0.38	0.132	−0.075	0.223	−0.149	−0.152	0.040	−0.213	−0.016
500 m	S_a	16.55	−0.590	0.290	−0.816 **	0.873 **	0.572	0.419	0.775 **	−0.532
	H_a	1.77	−0.044	0.255	−0.401	0.524 *	0.034	0.103	0.310	−0.435
	E_a	0.38	0.455	0.007	0.137	0.025	−0.465	−0.180	−0.228	−0.106
750 m	S_a	16.55	−0.592	0.631 *	−0.820 **	0.752 **	0.546	0.495	0.821 **	−0.743 **
	H_a	1.77	−0.035	0.315	−0.305	0.157	−0.014	0.295	0.308	−0.410
	E_a	0.38	0.468	−0.063	0.235	−0.389	−0.513	0.007	−0.240	0.003
1000 m	S_a	16.55	−0.590	0.581	−0.809 **	0.698 *	0.526	0.651 *	0.820 **	−0.645 *
	H_a	1.77	−0.043	0.387	−0.345	0.173	−0.020	0.428	0.370	−0.434 *
	E_a	0.38	0.465	0.067	0.194	−0.379	−0.514	0.075	−0.170	−0.095
1500 m	S_a	16.55	−0.622 *	0.123	−0.841 **	0.780 **	0.564	0.651 *	0.864 **	−0.230
	H_a	1.77	−0.069	0.355	−0.487	0.324	0.027	0.566 *	0.525 *	−0.422
	E_a	0.38	0.451	0.382	0.019	−0.223	−0.472	0.267	0.016	−0.406
2000 m	S_a	16.55	−0.663 *	0.028	−0.849 **	0.743 **	0.563	0.519	0.862 **	−0.109
	H_a	1.77	−0.157	0.423	−0.531 *	0.331	0.058	0.558	0.571 *	−0.439
	E_a	0.38	0.389	0.539	−0.019	−0.200	−0.453	0.356	0.067	−0.513

Note: ** indicates significant relationship between two variables with $p < 0.01$; * significant relationship between two variables with $p < 0.05$. LPI, largest patch index; LSI, landscape shape index; CONTAG, contagion index; IJI, interspersion and juxtaposition index; DIVISION, landscape division index; PRD, patch richness density; SHDI, Shannon's diversity index; AI, aggregation index. Sa, Ha, Ea represent species, Shannon diversity index, and Pielou evenness index of epigaeic arthropods, respectively.

Table 2. Ridge regression model and optimal model selection of landscape index and biodiversity index.

Dependent Variable	Optimal Model Equation	R^2	Sp^2	k_i	n	AICc
S_a	$S_a = -1.783 + 0.190 \times IJI + 7.606 \times SHDI$	0.767	41.359	4	11	50.945
H_a	$H_a = 0.138 + 1.256 \times PRD$	0.320	1.582	3	11	13.046

Note: Sa and Ha represent species and Shannon diversity index of epigaeic arthropods. IJI, interspersion and juxtaposition index; PRD, patch richness density; SHDI, Shannon's diversity index. R^2, coefficient of determination; Sp^2, sum of squares of model residuals, k_i, model order. n, number of samples. AICc, Akaike Information Criterion.

3.3. Effects on Epigaeic Arthropods on the Habitat Scale

3.3.1. Effects of Habitat Types on Epigaeic Arthropods Community Structure

According to the hierarchical distance cluster analysis results (Figure 3), the eight types of habitats can be divided into two categories. The habitats adjacent to orchard farmland (HT1) and orchard (HT2) are one category, and the other types are another. The results showed that native grassland (HT4), shrubland (HT6), arbor forest land (HT8), and their adjacent farmlands had similar epigaeic arthropod community structure. The composition of epigaeic arthropods in farmlands adjacent to shrubland (HT5) was the closest to that in farmlands adjacent to arbor forest land (HT7), while the composition of epigaeic arthropods in farmlands adjacent to orchards (HT1) and orchards (HT2) was significantly different from that in other habitats.

The results of single factor analysis of variance (Table 3) showed that habitat types had significant effects on species number (Sa), Pielou evenness index (Ea), and individual number (N) of epigaeic arthropods ($p < 0.05$), but had no significant effect on Shannon diversity index (H). According to Figure 4, shrubland (HT6) had the most obvious effect on increasing the number of epigaeic arthropod individuals, and adjacent native grassland farmland (HT3) had the worst effect. The adjacent orchard farmland (HT1) had the largest number of epigaeic arthropod species (S), and the adjacent arbor forest farmland (HT7) had the smallest number. The distribution of epigaeic arthropods of the orchard (HT2) was the most uniform, and the evenness of (HT5) adjacent shrubland farmland was the smallest.

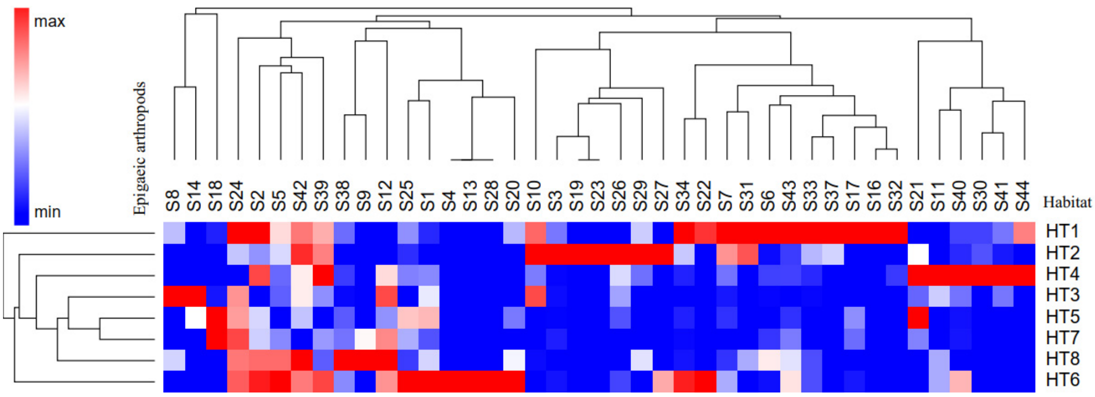

Figure 3. Heatmap of normalized number of epigaeic arthropods in different habitats. HT1 is adjacent to orchard farmland, HT2 is orchard, HT3 is adjacent to native grassland farmland, HT4 is native grassland, HT5 is adjacent to shrubland farmland, HT6 is shrubland, HT7 is adjacent to forest farmland, HT8 is arbor forest land. S1–S44 are epigaeic arthropod species, and the names are shown in the Appendix C. Use color depth to present proportion.

Table 3. Variance analysis of epigaeic arthropod diversity index in different habitats.

Habitat Types	Sa	Ha	Ea	Na
HT1	21.50 ± 2.12	2.18 ± 0.04	0.42 ± 0.06	63.10 ± 18.24
HT2	18.00 ± 1.41	2.16 ± 0.12	0.49 ± 0.10	44.67 ± 6.60
HT3	13.00 ± 2.65	2.09 ± 0.25	0.58 ± 0.09	31.07 ± 6.47
HT4	17.00 ± 2.65	1.91 ± 0.36	0.43 ± 0.03	40.90 ± 6.20
HT5	13.33 ± 2.08	1.39 ± 0.53	0.40 ± 0.08	36.87 ± 2.72
HT6	17.00 ± 4.36	1.53 ± 0.60	0.29 ± 0.11	65.22 ± 13.11
HT7	11.33 ± 2.52	1.44 ± 0.24	0.38 ± 0.04	31.33 ± 10.08
HT8	14.00 ± 4.00	1.85 ± 0.20	0.47 ± 0.07	37.29 ± 20.64
F	2.997	2.090	3.781	3.439
p	0.038 *	0.114	0.016 *	0.023 *

Note: * significant relationship between two variables with $p < 0.05$. The value in the table is mean ± standard deviation. Sa, Ha, Ea, Na represent species, Shannon diversity index, Pielou evenness index and numbers of epigaeic arthropods, respectively. HT1 is adjacent to orchard farmland, HT2 is orchard, HT3 is adjacent to native grassland farmland, HT4 is native grassland, HT5 is adjacent to shrubland farmland, HT6 is shrubland, HT7 is adjacent to forest farmland, HT8 is arbor forest land.

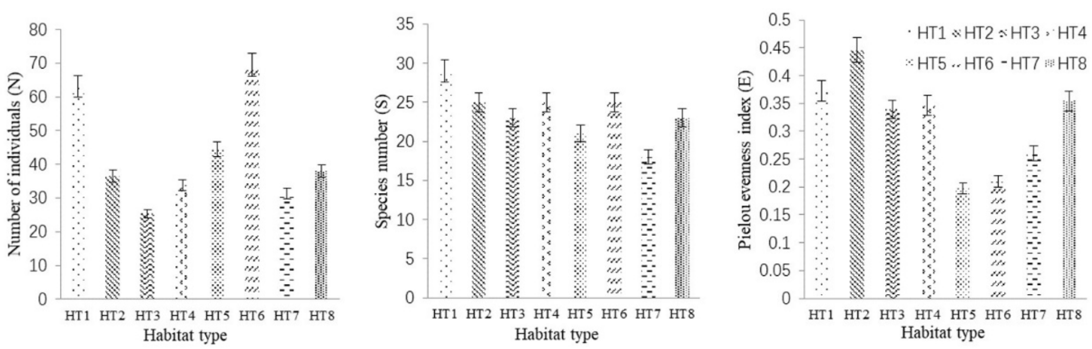

Figure 4. Analysis of the impact of habitat on epigaeic arthropod diversity. HT1 is adjacent to orchard farmland, HT2 is orchard, HT3 is adjacent to native grassland farmland, HT4 is native grassland, HT5 is adjacent to shrubland farmland, HT6 is shrubland, HT7 is adjacent to forest farmland, HT8 is arbor forest land.

3.3.2. Margin Effect of Epigaeic Arthropods

The number of individuals and species (S) of epigaeic arthropods at the farmland margin of four types were significantly higher than those in adjacent farmland and non-crop habitats (Figure 5). In addition to the orchard type sample area, the Shannon diversity index (H) of epigaeic arthropods at the farmland margin was higher. For the different biodiversity indexes of epigaeic arthropods, the four types of farmland boundaries are shown as follows, the number of epigaeic arthropods: farmland–shrubland > farmland–arbor forest > farmland–native grassland > farmland–orchard; Shannon diversity index (H) of epigaeic arthropods: farmland land-orchard > farmland land-native grassland > farmland land-forest > farmland land-shrubland; species number of epigaeic arthropods (S): farmland land-shrubland > farmland land-arbor forest > farmland land-orchard > farmland land-native grassland; pielou evenness index (E): farmland land-orchard > farmland land-native grassland > farmland land-forest > farmland land-shrubland. Epigaeic arthropods have obvious margin effects. The field margin strips of the study area were the transition zone between non-crop habitat and farmland habitat. The herb vegetation structure was the main factor for this effect.

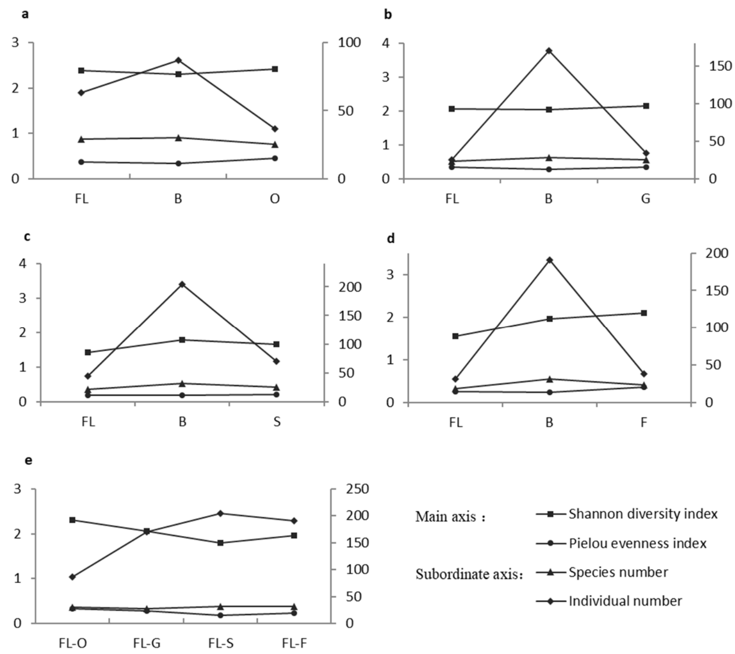

Figure 5. Effect of margin effect on epigaeic arthropod diversity. FL, farmland; O, orchard, G, native grassland; S, shrubland; F, arbor forest, B, margin. (**a**,**b**) respectively compared the biodiversity index values of four different margin types. (**a**) farmland-margin-orchard, (**b**) farmland-margin-native grassland, (**c**) farmland-margin-shrubland, (**d**) farmland-margin-arbor forest, and (**e**) four different types of margin.

3.4. Effects of Epigaeic Arthropods on the Field Scale

3.4.1. Effects of Herb Vegetation Structure on Epigaeic Arthropod Diversity

To further understand the relationship between epigaeic arthropods and herb vegetation characteristic factors, we calculated Pearson's correlation coefficients (Table 4). The Shannon diversity index of epigaeic arthropods (Hs) was significantly positively correlated with the Shannon diversity index (Hv), Average height (AH), Average cover (AC), and Margalef richness (Ma) of herb vegetation, while significantly negatively correlated with Pielou evenness (Ev). Pielou evenness (Es) of epigaeic arthropods was significantly positively correlated with species number (Sv) and Pielou evenness (Ev) of herb vegetation, while significantly negatively correlated with Average height (AH), Average cover (AC), and Margalef richness (Ma).

Table 4. Pearson's correlation coefficients of herb vegetation characteristic index and epigaeic arthropod diversity characteristic index.

Variables	Sa	Ha	Ea	Sv	Hv	Ev	AC	AH
Ha	0.636 *							
Ea	−0.136	−845 **						
Sa	0.216	0.731 *	0.809 **					
Hv	0.049	0.091	−0.118	0.472				
Ev	−0.103	−791 **	0.942 **	−0.665 *	−0.313			
AC	0.398	0.762 **	−725 *	0.685 *	−0.027	−0.760 **		
AH	0.054	0.788 **	−0.964 **	0.699 *	−0.252	−0.942 **	0.654 *	
Ma	0.241	0.745 **	−0.799 **	0.979 **	0.441	−0.669 *	0.640 *	0.685 *

Note: ** indicates significant relationship between two variables with $p < 0.01$; * significant relationship between two variables with $p < 0.05$. Sa, Ha, Ea, represent species, Shannon diversity index and Pielou evenness index of epigaeic arthropods, respectively. Sv, Hv, Ev, AC, AH, Ma represent pecies, Shannon diversity index, Pielou evenness index, Average heigh, Average cover and Margalef richness index of herb vegetation.

In addition, the variance expansion factor was used to test whether six characteristic variables which represent herb vegetation structure showed collinearity among groups. The results showed that there was collinearity between herb vegetation characteristic variables (Table 5). Stepwise linear regression was used to exclude variables that lead to multicollinearity. Finally, four variables are input into the linear regression model. Since the variance expansion factor (VIF) of all covariates in the model is less than 10, there is no multicollinearity problem in the modeling process.

Table 5. Variance inflation factors for the test of collinearity.

Vegetation Characteristics	Hv	AC	AH	Ma	Sv	Ev
VIF1	26.037	5.986	28.131	38.907	22.316	48.272
VIF2	4.736	2.122	6.373	9.181	-	-

Note: VIF 1, variance inflation factors before removing variables; VIF 2, variance inflation factors after removing variables. Sv, Hv, Ev, AC, AH represent pecies, Shannon diversity index, Pielou evenness index, Average heigh, Average cover of herb vegetation. R^2, coefficient of determination; Sp^2, sum of squares of model residuals, k_i, model order. n, number of samples. AICc, Akaike Information Criteron for small samples.

The biodiversity index of epigaeic arthropods was used as the dependent variable, and the structural factors of herb vegetation related to its obvious indigenousness were used as independent variables for linear regression analysis, and the optimal model was screened according to the AICc value (Table 6). Epigaeic arthropod diversity (Hs), Pielou evenness (Es) herb vegetation Shannon diversity (Hv), average height (AH), coverage (AC), and Margalef richness (Ma) were constructed in 15 models, respectively. Hv and Ma can explain epigaeic arthropod Shannon diversity (Hs) at the level of 77.3%, and Hv, Ma, AC, and AH can explain Pielou evenness (Es) of epigaeic arthropod at the level of 97.2%.

Table 6. Linear regression optimal model screening.

Dependent Variable	Optimal Model Equation	R^2	Sp^2	k_i	n	AICc
Ha	$Ha = 1.483 - 0.916 \times Ma + 1.026 \times Hv$	0.773	0.494	4	11	2.243
Ea	$Ea = 1.970 + 0.932 \times Hv - 0.787 \times Ma - 0.100 \times AC + 0.002 \times AH$	0.972	0.004	6	11	−46.736

Note: Ha, Ea represent Shannon diversity index and Pielou evenness index of epigaeic arthropods. Hv, AH, AC, Ma represent Shannon diversity index, Average heigh, Average cover and Margalef richness index of herb vegetation. R^2, coefficient of determination; Sp^2, sum of squares of model residuals, ki, model order. n, number of samples. AICc, Akaike Information Criterion.

3.4.2. Effects of Herb Vegetation Structure on Distribution of Epigaeic Arthropod Community

The sum of eigenvalues of the four axes of RDA is 0.8124, which cumulatively explains 100% of the species-environment relationship. Monte Carlo test shows that (First Axis, F = 16.8, P = 0.046; All Axis, F = 5.2, P = 0.042) can better explain the relationship between the herb vegetation structure on farmland margin and the distribution of epigaeic arthropod community. The results of partial RDA analysis (Table 7) showed that the effects of herb vegetation Shannon diversity (Hv) and Pielou evenness (Ev) on the distribution of epigaeic arthropod community reached the significant indigenous level (F = 6.5, P = 0.028, F = 30.5, P = 0.014), and the two explained 69.1% of the various number of epigaeic arthropod communities. RDA two-dimensional sort graph (Figure 6) with four explanatory variables was drawn.

Table 7. Partial RDA of relative contribution of each herbaceous vegetation structure factors to variation of the distribution of the epigaeic arthropod community.

Name	Explains (%)	Contribution (%)	F	P
Hv	42.1	47.4	6.5	0.028
Ev	27	30.5	7	0.014
Ma	6.2	7	1.8	0.220
Sv	5.9	6.7	1.9	0.216

Note: Sv, Hv, Ev, Ma represent pecies, Shannon diversity index, Pielou evenness index, and Margalef richness index of herb vegetation.

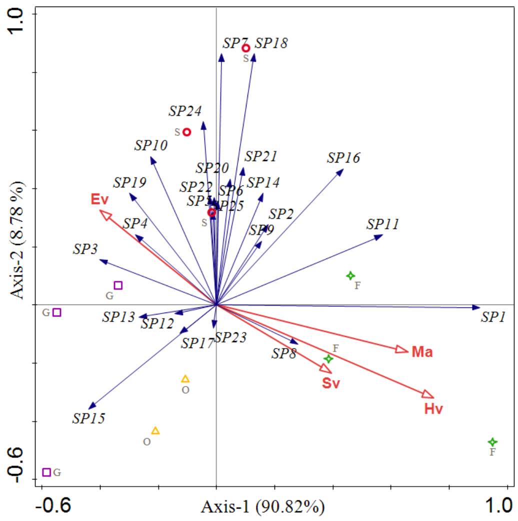

Figure 6. The RDA two-dimensional ordination diagram of the relationships of the environmental variables with distribution of epigaeic arthropods. SP1-SP25 represent different families of epigaeic arthropods, as detailed in Appendix B. Sv, Hv, Ev, Ma represent pecies, Shannon diversity index, Pielou evenness index, and Margalef richness index of herb vegetation.

4. Discussion

The arable land system can be interpreted as a heterogeneous region composed of habitat patches with certain biodiversity and intensive agricultural land, and the regional scope is the key. The interaction between species and environment at different scales is different, and the appropriate scale analysis is particularly important [35,44]. Studies have shown that landscape structure affects the dynamic evolution and species richness of complex populations on a large scale [21,45,46]. The analysis of plant and bird diversity in the agricultural landscape in Europe shows that landscape heterogeneity has a scale effect on biodiversity [3]. Species diversity has a strong scale dependence on landscape heterogeneity, due to the limited range of activities, the research on epigaeic arthropods is mostly on a small scale [47,48]. The studies on epigaeic arthropods at the habitat scale show that the implementation of compound planting pattern and other methods is conducive to the formation of microhabitats suitable for survival such as natural enemies (such as spiders, armor), and plays an important role in increasing biodiversity, especially natural enemy diversity. In addition to increasing crop diversity, on the field scale, the construction of adjacent non-crop habitats in farmland is the key to affecting natural enemy diversity and pest biological control in farmland [49,50]. Therefore, the diversity and community composition of epigaeic arthropods in arable land system landscapes are affected by different scale factors, and landscape reconstruction should be carried out from multiple scales.

In general, most of the current studies on agricultural biodiversity at home and abroad focused on large-scale sampling [51–53], while in small and medium-scale, different habitat types were used to distinguish and discuss [54,55]. How to combine margin characteristics, habitat types, and landscape structure to comprehensively discuss the landscape at different levels, which requires profound exploration and solution.

For studies aiming to describe the arable land system landscape structure, we propose metrics that reveal more information about connectivity, fragmentation, and diversity, such as contagion index, patch richness density, and Shannon's diversity index, as they jointly reflect how a given matrix facilitates or hinders migration and re-colonization of habitat patches or remnants [56]. In this study, the relationship between the diversity of epigaeic arthropods and landscape structure in the northern plains was found at different landscape scales, which supported the previous study [57]. The smaller the degree of human disturbance, the higher the connectivity, the richer the patch types, the greater the number of epigaeic arthropod species, and the greater the Shannon diversity index. The higher the landscape heterogeneity, the richer the diversity of epigaeic arthropods.

Landscape attributes are significantly different with the different landscape scales concerned by the research. The larger the selected landscape scale is, the closer the landscape attributes are to the global common level. The smaller the selected landscape scale is, the more obvious the uniqueness of landscape attributes is [58]. Therefore, there is an optimal scale for the response of biodiversity to landscape structure at the landscape scale, but this scale is not unique. In the existing studies, Clough et al. considered that the radius range of 500 m was the appropriate scale to study the response of spiders to landscape structure [22], and there were also studies on the impact of landscape elements on the distribution of beetle diversity at the scale of about 1000 m [59]. In this study, when the radius is 100 m, the landscape elements have no significant impact on the diversity of epigaeic arthropods. Between 250 m and 1500 m, with the increase of radius, the correlation between each landscape index and biodiversity index increased as a whole, and the correlation was the most obvious at 1500 m, and the correlation decreased at 2000 m. Therefore, we believe that 1500 m is the optimal scale of landscape elements affecting the diversity of epigaeic arthropods. Multi-scale studies are conducive to eliminating misjudgments under general rules, so as to comprehensively evaluate species diversity and find appropriate scales for biodiversity conservation [60,61].

In terms of which scale should be used in future works that address how landscape features affect epigaeic arthropods (e.g., [62–64]), we found an optimal scale for the landscape scale. For the habitat scale, domestic and foreign scholars have done a lot of research on the impact of different habitats on epigaeic arthropods, mainly concentrating on the natural, semi-natural, and artificial three habitat types, and discussed the impact of different habitat types on the diversity of epigaeic arthropods [65–67]. A large number of studies have found that different land use types have different impacts on soil fauna communities, especially the distribution characteristics of dominant groups and common groups in various land-use types [68,69].

This is further complemented in our study, for example, according to the distribution characteristics of habitat classification, *Harpalus sinicus*, *Pheropsophus occiptalis*, *Holotrichia oblita Faldermann*, *Chrysacris liaoningensis*, etc., as the same category, mainly distributed in the orchard. Non-crop habitats have more epigaeic arthropod diversity [70] due to their own vegetation conditions and less human disturbance, namely margin effects. At the same time, the spillover effect also affects the diversity of epigaeic arthropods in the surrounding farmland habitats. We concluded that the community structure of epigaeic arthropods in grassland, shrubland, arbor land, and their adjacent farmland habitats in the arable land system landscape of the plain area was similar.

As a way of spatial connection of different types of habitats, the margin is of great significance in the ecological process, and its community groups and the overall number are higher than those of adjacent habitats, namely the margin effect [37,71]. Margin not only contains the characteristics and components of adjacent habitats, but also forms more environmental characteristics that are not included in adjacent habitats according to their characteristics, resulting in more functions and characteristics [72]. In this study, the number of individuals and species (S) of epigaeic arthropods at the margin of four types of non-crop-farmland habitats (orchard, shrub land, arbor forest land, and grassland) were significantly higher than those of adjacent farmland and other non-tillage habitats, and the margin effect was significant. The study area benefited from the three-north shelter forest system in northern China. Previous studies focused on the impact of farmland shelter forests on biodiversity or arable land yield. Constrained by the inherent thinking of local farmers, herbaceous plant clumps separated from farmland management (fertilization, pesticides, etc.) are considered negative factors of the agricultural ecosystem. This study provides a new idea for farmers to implement farmland management measures on the habitat scale.

Vegetation structure in non-crop habitats, as a major habitat control factor, is considered to be an environmental variable affecting biodiversity and ecosystem services in farmland [73–75]. Garratt et al. argued that complex and continuous understory vegetation can significantly improve the diversity of pollinators and natural enemy groups of epigaeic arthropods in farmland [71]. Tougeron et al. believed that at the habitat scale, the margin type or the distance to the margin affected the activity density and parasitic rate of beetles and spiders [3]. On the habitat scale, we found that there was a significant relationship between the distribution of epigaeic arthropod community and the vegetation structure through the redundancy analysis (RDA). The Shannon diversity and Pielou evenness of herb vegetation were important factors affecting the composition of the epigaeic arthropod community. The composition of heterogeneous herb vegetation structure can often provide diversified microhabitats for a variety of taxonomic groups, thus providing a broader niche for the habitat survival of more organisms [61,76,77]. In addition, due to the weak migration ability of most epigaeic arthropods, it is necessary to strengthen the protection of habitat scale, especially the restoration and protection of plant diversity in habitat, so as to play a positive role in improving the biodiversity of epigaeic arthropod communities in arable land system landscape to a certain extent.

In the main grain-producing areas of northern China, the plain area represented by Changtu County in the study area undertakes the important task of ensuring regional and even national food security. Agricultural production is characterized by a small number of planting plants and livestock species to replace the natural state of biodiversity, resulting in a wide range of environmental structure that tends to simplify and single [78,79]. In addition, due to China's relevant policies, the farmland management measures implemented by farmers are limited to the arable land they own, which makes the management of arable land a single scale and lacks systematicness and integrity. Our research results clarify the key points of cropland system protection at multiple scales, and provide a detailed reference for the implementation of policies related to the sustainable development of cropland systems in northern China in the future. Optimizing arable land system landscape structure and enhancing landscape heterogeneity are effective ways to protect biodiversity and ecosystem services [80]. Of course, there is no "one-size-fits-all" answer to the preservation of agricultural biodiversity. The appropriate scale is the optimal lever for the protection of agricultural biodiversity, which promotes the accurate implementation of agricultural management measures at different scales. Combined with the macro layout at the landscape scale and the dynamic adjustment at the habitat scale, the overall landscape layout, and microenvironment control can be used to maintain regional agricultural biodiversity and enhance the sustainability of the agricultural system, so as to improve the agricultural ecological environment and ensure the safety of the food system.

In the future, this study can classify and discuss epigaeic arthropods, and further clarify the interaction between different functional groups at different scales. In addition, climate, soil, and other environmental variables can also be introduced to make a more comprehensive discussion of other regions. In addition, this study chose to obtain biodiversity data during the crop maturity period (September). In future research, data from other seasons can be combined to enhance the broad applicability of the research conclusions.

5. Conclusions

Discussing the response of epigaeic arthropod diversity to environmental changes at multiple spatial scales in detail is essential for the sustainable development of the arable land system in the context of global change and biodiversity crisis. Based on landscape data and biodiversity data, from the perspective of biodiversity conservation, we used scale leverage (landscape, habitat, and field) to clarify the direction of efficient implemen-tation of agricultural system management measures in the northern plains of China.

We conclude that at the landscape scale, the landscape structure has a significant scale effect on the diversity of epigaeic arthropods, and 1500 m is the optimal radius for improving the biodiversity level by optimizing the landscape structure. On this scale, the largest patch index, patch richness density, contagion index, interspersion and juxtaposition index, and Shannon diversity index significantly affected the biodiversity of epigaeic arthropods. The greater the landscape heterogeneity, the higher the level of epigaeic ar-thropod diversity. This result can point out the direction for the large-scale changes in landscape patterns in the study area. 100 m radius is the habitat scale to explore the factors affecting the diversity of epigaeic arthropods. On this scale, habitat types affect the diver-sity of epigaeic arthropods, and have a significant impact on the abundance and commu-nity structure richness of epigaeic arthropods, as well as the relative density between spe-cies. The number of epigaeic arthropods in the shrubland is the most abundant, the farmland adjacent to the orchard has the largest number of species, and the number of epigaeic arthropods of different species in the orchard is more evenly distributed. The rational layout of non-crop habitat patches and farmland is an effective way to protect the diversity of epigaeic arthropods at the field scale. To some extent, our study showed that field margin strips should be the unique cornerstones of agro-ecological landscape design strategies on this scale. The species and quantity distribution of epigaeic arthropods have obvious margin effects, and the herb vegetation structure of farmland margin is the main influencing factor for this effect. On the field scale, Shannon diversity, Pielou even-ness, average height, average cover, and Margalef richness of herb vegetation are important environmental factors affecting the diversity and community structure of epigaeic arthropods.

Biodiversity is the basis for a sustainable arable land system. Our findings underscore that, in agricultural landscapes dominated by arable land, combining precise implementation at various scales with comprehensive coordination at multiple scales has greater potential to support regional biodiversity than focusing on a single scale. We believe that using spatial scales to protect biodiversity is consistent with the reality of agricultural management, which is of great significance to the rational distribution of the arable land system.

Author Contributions: Conceptualization, Z.B.; methodology, Y.Y; software, Y.Y. and Y.Z.; validation, S.W.; formal analysis, Y.Y. and Y.Z.; investigation, Y.Y. and Y.Z.; resources, Y.Y.; data curation, Y.Z.; writing—original draft preparation, Y.Z.; writing—review and editing, Z.B. and Y.Z.; visualization, Y.Y. and Y.Z.; supervision, S.W.; project administration, Z.B.; funding acquisition, Z.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Natural Science Foundation of Liaoning Province (Grant No. 2019-ZD-0709).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used to support the findings of this study are available from the corresponding author upon request.

Acknowledgments: Thank you to the reviewers for their valuable feedback on the manuscript. Thank you to the team members for their hard work in field sampling.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Land use and cover type division in Changtu County.

Serial Number	Level 1 Type	Serial Number	Level 2 Type
01	Cultivated land	011	Paddy field
		012	Dry land
02	Garden plot	020	Garden plot
03	Forest	031	Arbor Forest Land
		032	Shrubland
		033	Other woodland
04	Grassland	040	Grassland
05	River and canal	051	River surface
		052	Ditch
06	Reservoir pit	060	Reservoir pit
07	Tidal flat	070	Tidal flat
08	Country road	080	Country road
09	Construction land	090	Construction land
10	Unutilized land	100	Unutilized land

Appendix B

Table A2. Statistical table of herb vegetation.

Herb Vegetation			Latin Names
Monocots	Oales Small	Poaceae Barnhart	*Eleusine indica* (L.) Gaertn. *Digitaria sanguinalis* (L.) Scop. *Cynodon dactylon* (L.) Pers. *Echinochloa crus-galli* (L.) P. Beauv *Etaria viridis* (L.) Beauv.
	Farinosae	Subordo Commelinineae	*Commelina communis* L.
	Cyperales	Cyperaceae Juss.	*Cyperaceae* *Cyperusrotundus* L.
Dicotyledoneae	Euphorbiales	Euphorbiaceae Juss.	*Acalypha australis* L.
	Campanulales	Asteraceae Bercht. & J. Presl	*Cirsium japonicum* Fisch. ex DC. *Ixeris polycephala* Cass. *Erigeron canadensis* L. *Artemisia caruifolia* Buch.-Ham. ex Roxb *Ambrosia artemisiifolia* L. *Aster tataricus* L. f. *Xanthium sibiricum* Patrin ex Widder *Artemisia mongolica* (Fisch. ex Bess.) Nakai *Ambrosia trifida* L. *Siegesbeckia orientalis* L. *Chrysanthemum indicum* L.
	Contortae	Asclepiadaceae	*Metaplexis japonica* (Thunb.) Makino
	Rosales Bercht. & J. Presl	Leguminosae	*Sesbania cannabina* (Retz.) Poir.
	ubiflorae	Convolvulaceae	*Convolvulus arvensis* L.
	Asterales Link	Asteraceae Bercht. & J. Presl	*Bidens pilosa* L. *Artemisia argyi* Lévl. et Van.
	Urticales	Moraceae Gaudich.	*Humulus scandens* (Lour.) Merr.
	entrospermae	Chenopodiaceae	*Dysphania ambrosioides* (Linnaeus) Mosyakin & Clemants *Kochia scoparia* (L.) Schrad.
	Polygonales	Polygonaceae	*Polygonum perfoliatum* L. *Polygonum aviculare* L. *Rumexacetosa* L.
	Lamiales Bromhead	Lamiaceae Martinov	*Leonurus japonicus* Houtt *Lagopsis supina* (Steph. ex Willd.) Ik.-Gal. ex Knorr.
	Santalales R. Br.	Santalaceae R. Br.	*Thesium chinense* Turcz.
	Malvales Juss.	Malvaceae Juss.	*Abutilon theophrasti* Medicus
	Geraniales Juss.	Geraniaceae Juss.	*Geranium wilfordii* Maxim.
	Apiales Nakai	Apiaceae Lindl.	*Cnidium monnieri* (L.) Cuss.
	Parietales	Violaceae Batsch	*Viola hamiltoniana* D.Don
	Asterales Link	Asteraceae Bercht. & J. Presl	*Cirsium setosum* *Artemisiaselengensis* Turcz.
	Caryophyllales	Chenopodiaceae	*Chenopodium album* L.
Sphenopsida	*Equisetales*	Equisetaceae Michx. ex DC.	*Equisetum arvense* L.

Appendix C

Table A3. Statistical table of epigaeic arthropod types and numbers in different habitats.

Epigaeic Arthropods			Number (Families)	Latin Names	Number (Specie)
Insecta	Coleoptera	Carabidae	SP1	*Chlaenius micans*	S1
				Harpalus pallidipennis	S2
				Harpalus sinicus	S3
				Calosoma maximoviczi	S4
				Dolichus halensis	S5
				Harpalus rubefactus	S6
				Harpalus griseus	S7
				Chlaenius praefectus	S8
				Chlaenius junceus	S9
				Pheropsophus occipitalis	S10
				Lachnolebia cribricollis	S11
				Harpalus calceatus	S12
				Callida splendidula	S13
		Hydrophiloidea	SP2	*Laccobius inopinus*	S14
		Staphylinidae	SP3	*Pinophilus punctatissimus*	S15
				Scydmaeninae Oligota	S16
		Tenebrionindae	SP4	*Opatrum subaratum*	S17
				Gonocephalum reticulatum	S18
		Melolonthidae	SP5	*Holotrichia oblita*	S19
				Trematodes tenebrioides Pallas	S20
		Chrysomelidae	SP6	*Monolepta hieroglyphica*	S21
		shining leafchafer	SP7	*Anomala aulax Wiedemann*	S22
		Cetoniidae	SP8	*Oxycetonia jucunda Faldermann*	S23
	Orthoptera	Gryllidae	SP9	*Teleogryllus emma*	S24
				Loxoblemmus doenitziStein	S25
		Acrididae	SP10	*Haplofropis*	S26
				Chrysacris liaoningensis	S27
		Catantopidae	SP11	*Calliptamus abbreviatus Ikonn*	S28
				Shirakiacris shirakii	S29
		Pyrgomorphidae	SP12	*Atractomorpha sinensis Bolvar*	S30
		Gryllotalpidae	SP13	*Gryllotalpa spps*	S31
	Dersmaptera	Labiduridae	SP14	*Earwig Furficulidae*	S32
	Hymenoptera	Formicidae	SP15	*Camponotus japonicus*	S33
				Formica japonica	S34
	Hemiptera	Nepidae	SP16	*Ranatra chinensis Mayrt*	S35
		Aradidae	SP17	*flat bug*	S36
		Coreidae	SP18	*Corizus albomarginatus Blöte*	S37
Arachnoidea	Opiliones	Phalangiidae	SP19		S38
	Araneae	Agelenidae	SP20		S39
		Theridiidae	SP21		S40
Diplopoda	Polydesmida	Paradoxosomatidae	SP22	*Asiomorpha coarctata*	S41
		Strongylosomidae	SP23	*Prospirobolus joannsi*	S42
Myriapoda	Geophilomorpha	Scolopendridae	SP24	*Scolopendra mutilans*	S43
Malacostraca	Isopoda	Onsicidae	SP25	*Armadillidium vulgare*	S44

Note: Identification of epigaeic arthropods to the species level (spiders identified to families level) used Zeiss stereomicroscope (ZEIS: Stemi 2000-C).

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