Effects of Structural Characteristics of Non-agricultural Landscape Elements on Plant Species Diversity in Agricultural Landscapes: A Case Study of Fengqiu County (Postprint)

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Abstract

Non-agricultural habitats in agricultural landscapes play a crucial role in maintaining and enhancing biodiversity within these landscapes. To investigate the influence of structural attributes of non-agricultural habitats on plant species diversity in agricultural landscapes, Fengqiu County in the lower Yellow River plain region was selected as the study area. Plant diversity surveys were conducted on non-agricultural habitats at 42 sampling points within the study area, and non-agricultural landscape elements within a 1 km radius of each sampling point were extracted to analyze the effects of plant species composition and the composition, structure, and spatial configuration of landscape elements in different non-agricultural habitats on plant species diversity. The results indicate that: among different types of non-agricultural habitats, species composition had relatively more shared species and fewer endemic or indicator species; woodlands and hedgerows exhibited relatively higher species diversity, while plant species composition in ditch habitats showed significant differences compared to the other two habitat types; species richness was highest when the composition ratio of woodlands to hedgerows/ditches was equivalent; landscape indices had significant effects on plant species in different non-agricultural habitats, with landscape fragmentation and human disturbance indices being particularly influential. In future processes of structural optimization of agricultural landscapes in this region, approaches should begin with the modification of non-agricultural landscape elements. By adjusting and establishing different types and proportions of non-agricultural landscape elements, and rationally modifying their structure and spatial configuration, an important research foundation can be laid for ultimately achieving effective management and sustainable, healthy development of agricultural landscapes.

Full Text

Preamble

Non-agricultural landscape structure and its effect on plant species diversity in agricultural landscapes: A case study in Fengqiu County

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Abstract

Non-agricultural habitats are crucial components of agricultural landscapes, and their complex structure and function play a vital role in maintaining and enhancing biodiversity. However, intensive agricultural development has led to widespread loss of these habitats, resulting in simplified landscape structure and severely damaged ecosystem functions. To explore how structural attributes of non-agricultural landscape elements affect plant species diversity, we established 42 sample plots in Fengqiu County, a typical agricultural region in the lower Yellow River plain. Using the Braun-Blanquet method, we investigated vegetation in non-agricultural habitats (artificial forests, hedges, and ditches) within these plots. Remote sensing imagery and landscape pattern analysis were employed to extract and classify non-agricultural habitats within a 1 km radius of each sample point using ArcGIS 10.0, analyzing their composition, structure, and spatial configuration. A total of 186 species belonging to 50 families and 164 genera were recorded, with six dominant families (Compositae, Gramineae, Leguminosae, Cruciferae, Labiatae, and Solanaceae) accounting for 51.6% of all species. Artificial forests and hedges exhibited relatively high species diversity, while ditch communities showed distinct species composition. Species richness peaked when the proportion of artificial forests was similar to that of hedges/ditches. Landscape metrics significantly affected plant species diversity across different non-agricultural habitats, with landscape fragmentation and human disturbance indices showing particularly strong effects. These findings suggest that future agricultural landscape optimization should focus on transforming non-agricultural landscape elements by adjusting their types, proportions, and spatial configurations to enhance landscape heterogeneity, thereby providing an important foundation for effective agricultural landscape management and sustainable development.

Keywords: agricultural landscape; non-agricultural habitat; biodiversity; Yellow River plain

Introduction

Non-agricultural habitats represent critical semi-natural components of agricultural landscapes. Due to relatively stable heterogeneous environments and reduced human disturbance, they serve as primary habitats for flora and fauna. Numerous studies have examined relationships between non-agricultural habitats and biodiversity, focusing on habitat types, vegetation structure, species composition, and management impacts. The consensus is that non-agricultural habitats provide essential resources and environments for most species in agricultural landscapes, benefiting biodiversity conservation and natural pest control by supporting predator habitats and reproduction. Research indicates that complex landscapes with high proportions of non-agricultural habitats better maintain biodiversity, and constructing elements such as woodlands and vegetated buffer strips can enhance landscape heterogeneity and promote healthy, sustainable agricultural ecosystems.

However, continuous agricultural expansion and intensification have eliminated many non-agricultural habitats, creating highly homogeneous landscapes with severe fragmentation and destroyed plant diversity. Different plant species attract different biological groups, and diverse plant communities provide varied food, shelter, and breeding sites, thereby protecting biodiversity at larger scales. Higher plant diversity increases natural enemy populations, significantly suppressing pests, reducing crop damage, and improving yields, thus stabilizing agroecosystems. As understanding deepens regarding landscape structure-biodiversity-ecosystem function relationships, scientists increasingly advocate a landscape perspective for biodiversity conservation and ecosystem service maintenance in agricultural landscapes. Domestic studies demonstrate the importance of non-agricultural habitats for plant diversity, yet research on how non-agricultural landscape structure affects species diversity remains limited. Building rational agricultural landscape structures that maintain high productivity while effectively protecting biodiversity represents a key future research focus.

Our study area, Fengqiu County in the lower Yellow River plain, is a major commercial grain base with long agricultural history and high intensification. Previous research has examined agricultural landscape heterogeneity, non-agricultural habitat composition, and biodiversity. However, questions remain about the specific roles of non-agricultural habitats, whether differences in type and proportion affect plant diversity, and how to optimize these elements for landscape function restoration. We hypothesized that: (1) habitat type and area proportion differences significantly affect plant species diversity, and (2) more complex non-agricultural landscape structure correlates with higher plant species diversity. This study explores relationships between structural characteristics of non-agricultural landscape elements and plant species diversity, providing a foundation for landscape optimization methods and multifunctionality mechanisms.

1. Study Area Overview

The study area is located in Fengqiu County, Xinxiang City, Henan Province (34°53 -35°14 N, 114°14 -114°45 E), a major commercial grain base on the northern bank of the Yellow River in the typical alluvial plain of the lower reaches. The region has a warm temperate semi-arid monsoon climate with mean annual precipitation of 615.1 mm and temperature of 13.9°C. The terrain slopes gently from southwest to northeast, with fluvo-aquic soils. The zonal vegetation is warm temperate deciduous broadleaf forest, but natural vegetation has been severely degraded. Most artificial forests are distributed around farmland, roads, ditches, and settlements, forming the main woodland types. Hedges and ditches are also distributed throughout the landscape, with hedges typically linear along roads or ditches, and ditches primarily serving as irrigation channels. Most are small excavated ditches with minimal water during non-irrigation periods, covered by herbaceous vegetation.

2. Methods

2.1 Data Sources and Landscape Element Extraction

Google Earth remote sensing imagery (1 m × 1 m resolution) served as the primary data source. After preprocessing including geometric correction and map projection using ERDAS IMAGINE, seamless mosaics were created for Fengqiu County. Based on previous research, we divided the study area into 2 km × 2 km grids and randomly established sample points within them. Previous studies showed that species richness and diversity correlate strongly with landscape heterogeneity at this scale. Using ArcGIS 10.0, we visually interpreted the preprocessed imagery to extract major non-agricultural landscape elements within 1 km of each sample point, primarily woodlands, hedges, and ditches (hedges defined as single-row trees planted along roads or farmland edges). To examine whether element types and proportions affect plant species, we classified the 42 sample points into four landscape structure types based on different proportions of non-agricultural habitats: Type I (forest 40%, hedge/ditch 60%), Type II (60% < forest 80%, 20% hedge/ditch <60%), Type III (40% < forest 60%, 40% hedge/ditch <60%), and Type IV (forest >80%, hedge/ditch <20%). Figure 1 shows sample site distribution, while Figure 2 illustrates the four landscape structure types.

2.2 Plant Community Survey

In 2011 and 2012, we surveyed plant species diversity in major non-agricultural landscape elements using the Braun-Blanquet method. For each habitat type, we established 1 m × 1 m quadrats (3 for forests, 18 for hedges, 28 for ditches, totaling 35 per sample point), recording geographic coordinates and conducting surveys in spring, summer, and autumn. Most tree layers in artificial forests and hedges consisted of single-species poplar (*Populus*), with virtually no shrub layer, so we focused on herbaceous layer data. A total of 42 sample points were surveyed.

2.3 Plant Data Processing

Since surveys were repeated seasonally, we calculated mean values for each species per sample point. Plant species richness (number of species per quadrat) represented diversity. Species importance value (IV) was calculated as: IV = relative frequency, with all species' IV summing to 1. All plant data processing was conducted using PC-ORD 5.0.

2.4 Landscape Metrics Selection and Calculation

We selected metrics representing: (1) shape complexity (Landscape Shape Index, LSI); (2) fragmentation (Mean Patch Size, MPS); (3) connectivity (Patch Density, PD; Contagion Index, CONTAG; Fragmentation Index, FN; Connectivity Index, CONNECT); and (4) human disturbance (Number of Villages, NUM_V; Village Area, AREA_V). All calculations were performed in ArcGIS 10.0 and FRAGSTATS 4.2.

2.5 Statistical Analysis

We used Redundancy Analysis (RDA) to examine landscape index effects on plant species diversity across structure types. Detrended Correspondence Analysis (DCA) indicated linear distribution suitability for RDA. We used landscape indices as environmental factors for ordination with plant species under different landscape structures. All analyses were conducted in Canoco for Windows 4.5.

3. Results

3.1 Species Composition in Different Non-agricultural Habitats

Statistical analysis revealed 186 species across different non-agricultural habitats. Six major families (Compositae, Gramineae, Leguminosae, Cruciferae, Labiatae, Solanaceae) accounted for 51.6% of total species. Species distribution patterns showed: 56% (104 species) occurred in all three habitats, 18% (34 species) grew in forests and hedges, and some species were habitat-specific, reflecting adaptations to particular conditions. Dominant species composition varied among habitats (Figure 3). *Cynodon dactylon* and *Humulus scandens* were dominant in forests and hedges, with *C. dactylon* showing particularly strong dominance in hedges, indicating high similarity between these habitats. Ditch communities differed substantially, with dominant species including *Imperata cylindrica*, *Calystegia hederacea*, and *Phragmites australis*. Shared species were numerous between forests and hedges, while each habitat contained unique species.

3.2 Landscape Structure Classification and Species Diversity

Classification results (Table 2) showed forests dominated total non-agricultural area (549.85 ha, 31.0%), making them the most important element. Forest-dominated structure types (I and II) covered larger areas, while ditch-dominated types were smaller (401.02 ha, 18.8%). The spatial distribution revealed large artificial forests concentrated centrally near Fengqiu County town, while hedges and ditches scattered mainly in southern areas, likely due to proximity to the Yellow River facilitating irrigation infrastructure.

Comparing species richness across habitats and landscape structures (Figure 4), ditches showed lowest richness. All mixed landscape structure types exhibited higher richness than single habitats, with minimal difference between forests and hedges. The structure type with balanced forest and hedge/ditch proportions showed highest species richness, followed by forest-dominated types, while hedge/ditch-dominated types showed lower richness.

3.3 Landscape Structure Effects on Dominant Plant Species

RDA ordination (Figure 5) revealed differential effects of landscape indices on species. Most species showed similar habitat preferences, primarily influenced by Mean Patch Size (MPS), village area (AREA_V), and Contagion Index (CONTAG), reflecting how area, connectivity, and human disturbance affect distribution. Dominant species appearing in all three habitats (*Setaria viridis*, *C. dactylon*, *Conyza canadensis*) showed distribution patterns similar to overall species trends. Species in ditches and forests (e.g., *Ranunculus sceleratus*, *Alternanthera philoxeroides*) responded significantly to fragmentation indices (PD, FN), showing negative correlations.

3.4 Effects of Landscape Structure Characteristics on Species Diversity Across Structure Types

RDA analysis (Figure 6) showed significant differences in how landscape metrics affected species diversity across the four structure types. In forest-dominated types, diversity was primarily influenced by fragmentation indices (FN, PD) and human disturbance indices (NUM_V, AREA_V). In ditch-dominated types, fragmentation indices (FN) and contagion (CONTAG) were most significant. In balanced forest-hedge/ditch types, most species diversity correlated positively with contagion and fragmentation indices, but negatively with patch density. These results indicate that plant diversity is substantially affected by landscape fragmentation and human disturbance, while shape and patch size effects are relatively minor.

4. Discussion

4.1 Effects of Non-agricultural Habitat Type and Quality on Plant Diversity

Various landscape elements constitute primary non-agricultural habitats that provide ecosystem services including biological control and biodiversity conservation. Studies show that increasing non-agricultural habitats significantly promotes plant diversity. Our results confirm that habitat type differences significantly affect species diversity. Plant composition in Fengqiu is dominated by widespread species (Compositae, Gramineae), with forests and hedges supporting higher richness than ditches. Each habitat contains unique species adapted to specific conditions, demonstrating that diverse habitat types provide resources and corridors for species conservation and dispersal. However, non-agricultural habitats cover only small areas with high fragmentation and low quality (mostly single-species poplar forests). Future landscape construction should increase habitat types, improve forest structure complexity, reduce ditch hardening, and introduce more native plants while preserving dominant species, thereby enhancing biodiversity.

4.2 Effects of Landscape Structure Complexity on Plant Diversity

Mixed non-agricultural habitats show higher species richness than single-type habitats. Species richness peaked when forest and hedge/ditch proportions were balanced, confirming our hypothesis that habitat area proportion differences significantly affect diversity. This supports the "Habitat Heterogeneity Hypothesis" —more complex habitat structure provides more niches and resources, supporting greater species diversity. The results provide targets for regional non-agricultural landscape construction: increasing habitat types and adjusting element quantities and area proportions to achieve optimal configuration for biodiversity maintenance.

4.3 Rational Landscape Configuration for Biodiversity Conservation

In human-disturbed landscapes, patch size and connectivity strongly influence species richness, migration, and survival. Enhanced connectivity among non-agricultural elements increases biodiversity. Non-agricultural habitats provide water filtration, sedimentation, refuge, overwintering sites, and pollination services. However, intensive agriculture has reduced habitat types and increased fragmentation in Fengqiu, lowering connectivity and biodiversity. We recommend establishing corridors between habitat patches at larger scales, using ditches as primary sources and sinks to create ecological networks linking various non-agricultural patches. This would protect biodiversity, improve landscape connectivity, and optimize agricultural landscape patterns.

5. Conclusions and Prospects

Our results confirm both hypotheses: non-agricultural habitat type and area proportion differences significantly affect plant species diversity, and more complex landscape structure supports higher diversity. These findings provide practical guidance for agricultural landscape reconstruction and land consolidation in Fengqiu County and offer insights into biodiversity maintenance mechanisms. Effective landscape construction requires considering multi-scale composition, structure, and spatial configuration of non-agricultural elements to maximize ecological, productive, and social benefits. As farmers are primary stakeholders, future landscape planning should incorporate their preferences and perceptions alongside government policies to achieve sustainable agricultural ecosystem management.

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Figures

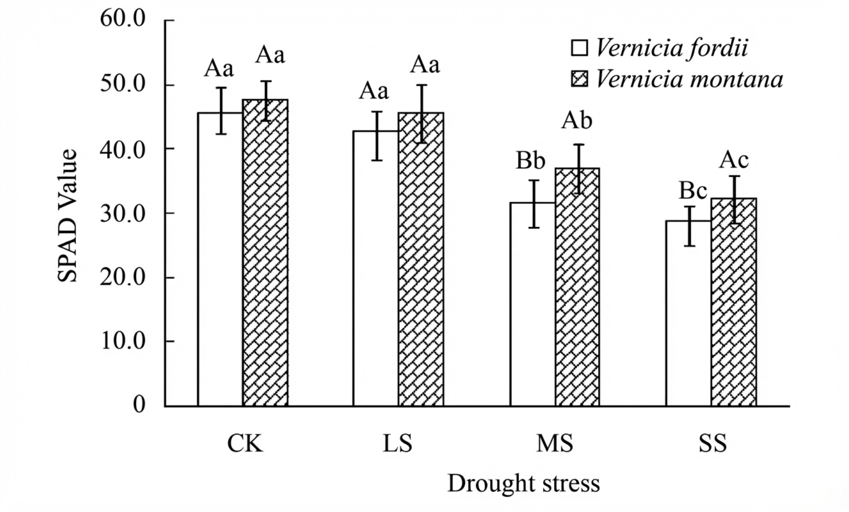

Figure 1: Figure 1

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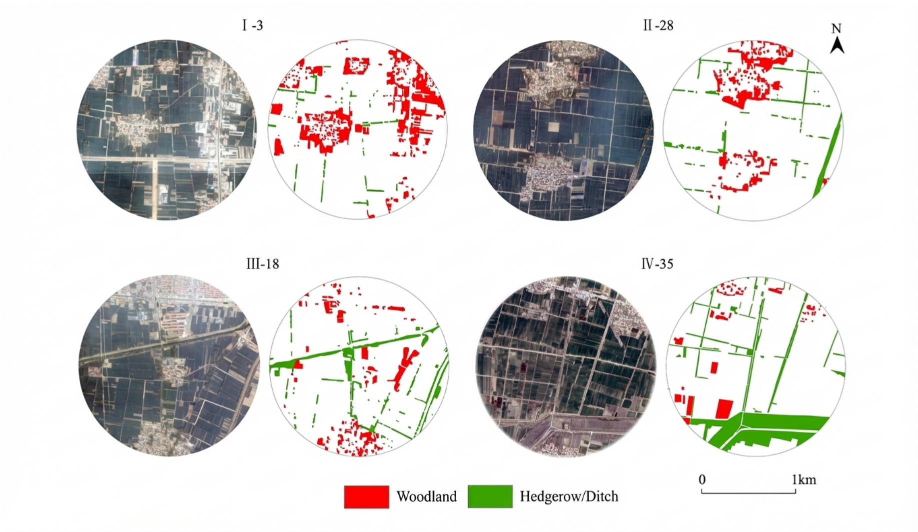

Figure 2: Figure 2