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Exploring Driving Factors Affecting the Spatial Distribution of Farmhouses in Yuanshan Township, Yilan County, Based on a Discrete-Time Hazard Model

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Abstract: This study explores the driving factors affecting the spatial distribution of **farmhouse residences** in the non-urban area of **Yuanshan Township, Yilan County**, utilizing data from 2020 to 2023. Taiwan faces severe agricultural land loss due to increasing farmhouse construction since the promulgation of the Spatial Planning Act in 2018. Yilan County exhibits the highest proportion of farmhouse area in Taiwan (17.85%). The research employs a **Discrete-Time Hazard Model (DTHM)** to identify conversion risk factors. Results indicate that the hazard rate is significantly influenced by regulatory context and natural constraints. The **Time Dummy Variable** exhibited the most significant impact (Risk Reduction 60.55%), confirming a sharp decline in expansion velocity during the study period, likely due to decreased market enthusiasm. **Road Adjacency** (Risk Reduction 39.70%) and **Slope Classification** (Risk Reduction 33.03%) were the strongest spatial constraints, while **Population Density** (Risk Increase 1.48%) was the primary socioeconomic driver. The findings underscore the need for targeted policies addressing natural constraints and closing regulatory loopholes that promote non-adjacent construction.

Keywords: Farmland Conversion; Residential Development; Farmhouse Distribution; Discrete-Time Hazard Model

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1. Introduction

Taiwan faces severe challenges regarding agricultural land, including **fragmentation** and the **loss of cultivated land** due to increasing construction of farmhouses and illegal uses since the promulgation of the Spatial Planning Act in 2018. Despite agriculture's small economic share, maintaining **food security** is a critical national concern.

The 2023 Agricultural and Farmland Resource Inventory highlights that current arable land (approx. 690,000 ha) falls short of the national demand (740,000–810,000 ha). This necessitates strengthening regulations, as conversion to non-agricultural uses (factories, residences, and farmhouses) is rapidly depleting farmland. The key loophole emerged after the 2000 amendment to the Agricultural Development Act, which allowed ostensibly "legal" farmhouses to function as pure residences, bypassing effective land-use control.

This study focuses on **farmhouse residences** in **Yilan County** (highest proportion of farmhouse area in Taiwan, 17.85%). Specifically, **Yuanshan Township** is selected due to its highest proportion of non-urban agricultural land used for residences (20.8%) in the county. The study utilizes a **Discrete-Time Hazard Model** to explore the **driving factors** affecting the spatial distribution of these residences between **2020 and 2023**, aiming to provide a policy basis for future farmland management.

2. Methodology

This study aims to explore the driving factors affecting the spatial distribution of farmhouse residences in the non-urban area of Yuanshan Township, Yilan County, utilizing the Discrete-Time Hazard Model (DTHM), which is suitable for analyzing time-series data related to land use change. This section compiles the key influencing factors and details the research procedure, model principles, and materials.

2.1. Compilation of Driving Factors and Materials

To ensure a comprehensive analysis, this research synthesized findings from previous studies on farmhouse construction and agricultural land conversion in Yilan County [1-5]. The key potential factors influencing farmland conversion were categorized into four dimensions: Accessibility (Transportation), Landscape and Natural Environment, Socioeconomic Conditions, and Planning and Policy Environment.

Based on land use change drivers, these potential factors were classified into four core categories—Socioeconomic Environment, Natural Environment, Land Use Interaction, and Planning Environment—and consolidated into 26 candidate explanatory variables for the Discrete-Time Hazard Model (as summarized in Table 1).

Table 1. Key Candidate Variables for Modeling Farmhouse Residence Distribution

Category	Key Candidate Variables
Socioeconomic Environment	Average Crop Price within 50 meters, Tourism and Recreation Potential Index, Nearest Distance to Scenic Spots, B&B and Hotel Density, Industrial Use Area within 1 kilometer, Nearest Distance to Industrial Use, Population Density, Commercial Use Area within 1 kilometer, Commercial Use Area Density, Cultivated Land Area within 1 kilometer, Housing and Land Price, Local Settlement Area Density
Natural Environment	Nearest Distance to Streams and Rivers, Flood Potential Level, Slope Classification
Land Use Interaction	Farmhouse Residence Area Density
Planning Environment	Distance to Railway Station, Distance to Bus Station, Distance to National Freeway, Distance to Provincial Highway (including Expressway), Distance to County Road, Distance to Township Road, Road Adjacency, Distance to Bicycle Path, Distance to City Center (Yilan City, Luodong Township), Distance to Township Center, Distance to Parks and Green Spaces, Distance to Leisure Agriculture Area

2.2. Research Procedure and Variable Selection

The research procedure begins by organizing the collected influencing factors and historical Farmhouse Residence geographic data (from 2020 and 2023) into grid-based spatial units.

To establish a stable and interpretable model, all independent variables will undergo a collinearity check before inclusion in the Discrete-Time Hazard Model.

- Testing Method: Collinearity is checked through OLS regression (Ordinary Least Squares regression), grouped by category.
- Inclusion Criteria: Only variables with a Variance Inflation Factor (VIF) of less than 5 will be included.
- Overall Requirement: The average VIF value for all final variables included in the model must be less than 2, ensuring coefficient stability and interpretability[6].

2.3. Discrete-Time Hazard Model (DTHM)

This study employs the Discrete-Time Hazard Model (DTHM), also known as the Discrete-Time Survival Model. DTHM is suitable for land use change prediction where event occurrence time is discrete (e.g., measured annually), as it combines Survival Analysis with the Logit model. This approach allows the model to handle censored data and reflect the dynamic influence of driving forces over time, which traditional Logit regression cannot[7].

The model analyzes the Hazard Rate $h(t)$, defined as the conditional probability of an event (conversion to Farmhouse Residence) occurring at a specific time, given that it has not occurred previously[8]:

$$\ln\left(\frac{h_{it}}{1-h_{it}}\right) = (\alpha_1 D_{1it} + \alpha_2 D_{2it} + \cdots + \alpha_T D_{Tit}) + (\beta_1 Z_{1it} + \beta_2 Z_{2it} + \cdots + \beta_p Z_{pit})$$

Where $\ln\left(\frac{h_{it}}{1-h_{it}}\right)$ represents the log-odds of the event occurrence, D is the time dummy variable, α is its coefficient, Z is the variable factor value, and β is the factor coefficient.

For this research, due to the use of only a two-period dummy variable structure (2020 and 2023), the model is not suitable for long-term forecasting. For predicting future land change probabilities, the time effect coefficient $\propto_t$ will be fixed as a constant of 1. This ensures that the baseline risk level for the prediction map is an extrapolation based on the 2020–2023 conditions.

The simplified Logit Hazard Model used in this research is therefore:

$$logit[h_i(t)] = \beta_0 + \propto_t + \beta_1 X_{1it} + \beta_2 X_{2it} + \cdots + \beta_p X_{pit}$$

Where $h_i(t)$ is the hazard probability for grid i during time interval t, β_0 is the intercept term, $\propto_t$ is the time effect coefficient, and X_{pit} and β_p are the values and coefficients for the explanatory variables, respectively.

3. Results and Discussion

This chapter presents the results of the factor collinearity diagnosis and discusses the main driving factors affecting the spatial distribution of farmhouse residences in Yuanshan Township, Yilan County, based on the Discrete-Time Hazard Model (DTHM) analysis.

3.1. Factor Collinearity Diagnosis

Based on the collinearity testing results for 2020 and 2023, this study removed the following eight variables from the initial candidate set: Distance to Railway Station, Distance to National Freeway, Distance to County Road, Distance to City Center (Yilan City, Luodong Township), Distance to Township Center, Tourism and Recreation Potential Index, Nearest Distance to Scenic Spots, and Distance to Leisure Agriculture Area. A final set of 20 factors was ultimately selected for inclusion in the Discrete-Time Hazard Model analysis. The removed factors were not necessarily non-influential, but were deemed covered by other, more representative factors that sufficiently captured the influence of their respective dimensions.

3.2. Discrete-Time Hazard Model Results

This study employed the Discrete-Time Hazard Model (DTHM) to analyze the Hazard Rate of Farmhouse Residence occurrence, which is the conditional probability of a grid cell converting to a Farmhouse Residence.

The final results indicated the following significant factors:

Significant Positive Influencing Factors: Industrial Use Area within 1km, Population Density, Nearest Distance to Streams and Rivers, Farmhouse Residence Area Density, and Distance to Provincial Highway (including Expressway). An increase in the values of these factors will increase the risk of a buildable agricultural lot converting into a Farmhouse Residence.

Significant Negative Influencing Factors: The Time Dummy Variable, Average Crop Price within 50m, Nearest Distance to Industrial Use, Commercial Use Area within 1km, Commercial Use Area Density, Cultivated Land Area within 1km, Flood Potential Level, Slope Classification, Distance to Bus Station, Distance to Township Road, Road Adjacency, and Distance to Bicycle Path. An increase in the values of these factors will decrease the risk of conversion.

In terms of practical application, the factors with the greatest influence on the hazard rate, ordered by magnitude, are limited to the Time Dummy Variable, Road Adjacency, Slope Classification, Flood Potential Level, and Population Density, as shown in the table below.

Table 2. Significant Factors and Their Influence Intensity on Farmhouse Residence Hazard Rate

Factor	Direction	Intensity
Time Dummy Variable	Negative	Risk Reduction **60.55%**
Flood Potential Level	Negative	Risk Reduction **6.46%**
Slope Classification	Negative	Risk Reduction **33.03%**
Road Adjacency	Negative	Risk Reduction **39.70%**
Population Density	Positive	Risk Increase **1.48%**

4. Conclusion

This study successfully utilized a **Discrete-Time Hazard Model (DTHM)** to identify the dominant factors affecting the conversion of buildable agricultural land to farmhouse residences in Yuanshan Township. The model highlighted that the conversion risk is primarily governed by **market dynamics** and **natural constraints**. The greatest suppressive effect came from the **Time Dummy Variable**, reducing risk by **60.55%** , which is attributed to a decrease in market investment enthusiasm during the 2020–2023 period. Strong spatial inhibitory factors included **Road Adjacency**, reducing risk by **39.70%** , a result that confirms the regulatory relaxation encouraging non-adjacent construction has shifted development risk away from road-adjacent parcels. **Slope Classification** (33.03% risk reduction) and **Flood Potential Level** (6.46% risk reduction) reinforced the avoidance of natural hazards and high development costs. Conversely, **Population Density** was the primary socioeconomic driver, increasing risk by **1.48%** , indicating that convenience and better amenities in high-density areas drive conversion pressure. Future policy must therefore focus on strengthening enforcement based on **natural constraints** and critically addressing the regulatory loophole that promotes non-adjacent construction.

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