International Journal of Advanced Engineering and Technology Research
ISSN: 3106-8677 (Print), ISSN: 3106-8685 (Online) | Vol. 1, No. 3, 2026

Driving Mechanisms and Spatial Differentiation of Cultivated Land Non-Agriculturalization in Qixian County

Lanyang Jiao *

School of Geography and Environmental Science, Henan Polytechnic University, Jiaozuo 454003, China

* **Corresponding author**: (Email: 212304010038@home.hpu.edu.cn)

Abstract: Investigating the driving mechanisms and spatial differentiation of cultivated land non-agriculturalization is important for identifying conversion risk and improving regional land use management. Taking Qixian County in Henan Province, China, as the study area, this paper used the identified results of cultivated land non-agriculturalization and constructed 1 km × 1 km grid cells as evaluation units. The grid-based rate of cultivated land non-agriculturalization was used as the dependent variable. From the perspectives of natural conditions, locational conditions, and socioeconomic development, eight driving factors were selected, including elevation, slope, distance to roads, distance to rivers, distance to railways, distance to township centers, night-time lights, and population density. Ordinary least squares, Geodetector, XGBoost, and SHAP were jointly employed to analyze the driving mechanisms and spatial differentiation of cultivated land non-agriculturalization. The results indicate that the process was not controlled by a single factor, but by the combined effects of natural, locational, and socioeconomic factors. The OLS model achieved the highest explanatory power for 2020–2025 ($R^2 = 0.682$), followed by 2020–2023 ($R^2 = 0.562$), whereas the value for 2023–2025 was much lower ($R^2 = 0.279$). Elevation, slope, and night-time lights were the key factors, showing that topographic constraints and human activity intensity jointly shaped the spatial pattern of cultivated land non-agriculturalization in Qixian County.

Keywords: Cultivated land non-agriculturalization, driving mechanism, Geodetector, SHAP, spatial differentiation, XGBoost.

1. Introduction

Research on cultivated land change and its driving factors has long been an important topic in land use change studies. Previous studies have shown that changes in cultivated land quantity and use generally exhibit significant spatiotemporal variation and are jointly influenced by natural conditions, socioeconomic development, and locational factors [1]. At the same time, cultivated land non-agriculturalization, as an important manifestation of land use transition, is not caused by a single factor, but by the combined effects of population concentration, economic development, topographic constraints, and land use policies [2].

Methodologically, studies on driving mechanisms have gradually shifted from single statistical analyses to integrated multi-method frameworks. Geodetector can identify the correspondence between spatial differentiation and influencing factors [3]. XGBoost is capable of handling complex nonlinear relationships among variables [4], and SHAP can further explain feature importance and contribution direction in machine-learning models [5]. Therefore, integrating traditional statistical methods with machine-learning approaches can help reveal the dominant factors and spatial differences of cultivated land non-agriculturalization more comprehensively.

Qixian County, located in northern Henan Province, is a typical agricultural county in the plain area. In recent years, county expansion, township construction, transportation development, and agricultural restructuring have caused evident changes in cultivated land use. Based on the identified results of cultivated land non-agriculturalization, this study establishes an integrated analytical framework to investigate its driving mechanisms and spatial differentiation, so as to provide support for county-level cultivated land protection and land use regulation.

2. Study Area and Data Sources

2.1. Study Area

Qixian County is located in Hebi City, Henan Province, in the transition zone from the eastern piedmont of the Taihang Mountains to the North China Plain. The overall terrain is higher in the west and lower in the east, with hills and low mountains in the west and plains in the east. Cultivated land resources are relatively concentrated, agricultural conditions are favorable, and transportation facilities and urban construction activities are active. Owing to the clear differences in natural topography and human activities, the county exhibits strong spatial heterogeneity in land development and cultivated land transition.

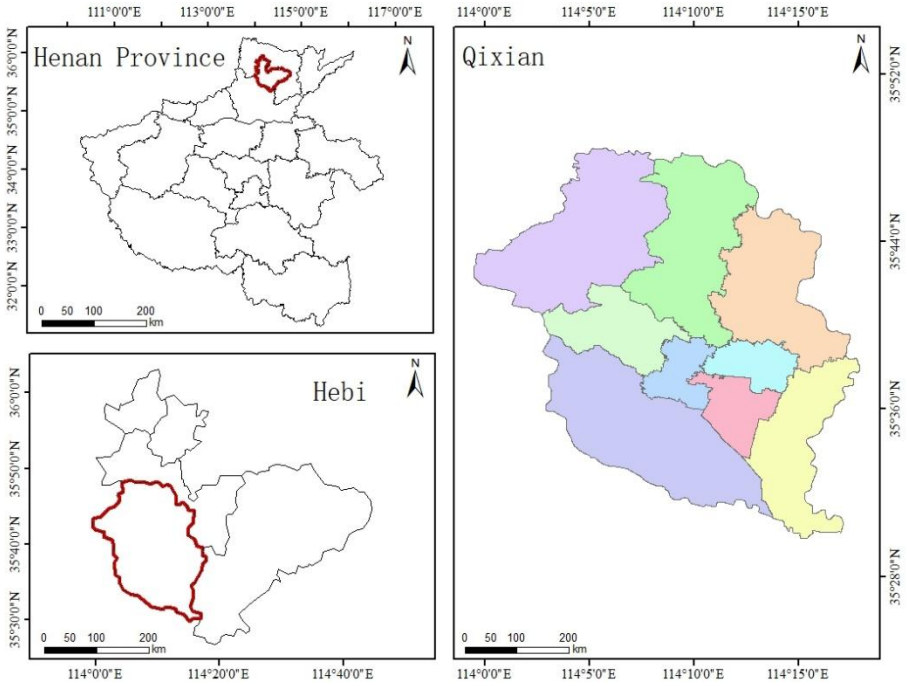

Figure 1. Location of the study area in Qixian County

2.2. Data Sources and Driving Factors

Based on the identified results of cultivated land non-agriculturalization, the study area was divided into 1 km × 1 km grid cells, and the rate of cultivated land non-agriculturalization within each grid cell was used as the dependent variable. Considering natural, locational, and socioeconomic influences, eight driving factors were selected: elevation, slope, distance to roads, distance to rivers, distance to railways, distance to township centers, night-time lights, and population density. The relevant data were mainly derived from SRTM DEM, VIIRS night-time light products, GHSL population data, and OpenStreetMap road, river, and railway datasets.

Table 1. Driving factor system of cultivated land non-agriculturalization in Qixian County.

Factor type	Driving factor	Meaning
Natural factor	Elevation	Reflects topographic relief and the natural constraint on cultivated land use
Natural factor	Slope	Reflects surface inclination and farming convenience
Locational factor	Distance to roads	Reflects transport accessibility
Locational factor	Distance to rivers	Reflects proximity to the river system
Locational factor	Distance to railways	Reflects regional transport connection
Locational factor	Distance to township centers	Reflects the influence of urban radiation and development activities
Socioeconomic factor	Night-time lights	Reflects human activity and economic development intensity
Socioeconomic factor	Population density	Reflects population concentration

3. Methods

3.1. Evaluation Unit Delineation and Dependent Variable Construction

To improve the spatial expression of the driving mechanism analysis, 1 km × 1 km grid cells were used as the basic evaluation units. On the basis of the identified cultivated land non-agriculturalization results, the proportion of converted cultivated land area to total cultivated land area within each grid cell was calculated and used as the dependent variable y to characterize the intensity differences of cultivated land non-agriculturalization among spatial units.

3.2. OLS Regression Model

The ordinary least squares model was used to identify the linear relationships between the driving factors and the rate of cultivated land non-agriculturalization, and the model goodness of fit was employed to evaluate the overall explanatory ability of the driving factors in different periods. Separate models were constructed for 2020–2023, 2023–2025, and 2020–2025.

3.3. Geodetector

Geodetector is a method for identifying the relationship between spatial differentiation and influencing factors. Its core indicator, the q statistic, measures the explanatory power of a factor for the spatial distribution of the dependent variable; a larger q value indicates stronger explanatory power [3]. In this study, Geodetector was used to analyze the impact intensity of each driving factor on the spatial differentiation of cultivated land non-agriculturalization.

3.4. XGBoost and SHAP

XGBoost is an efficient gradient boosting tree algorithm that can capture complex nonlinear relationships among variables and rank feature importance [4]. To further interpret model outputs, SHAP was introduced to quantify the contribution of each variable to the prediction results, thereby identifying dominant factors and their relative importance [5].

4. Results and Analysis

4.1. OLS Regression Results

The OLS results show that the explanatory power of cultivated land non-agriculturalization in Qixian County differed among periods. The model for 2020–2025 had the highest explanatory power (R^2 = 0.682), followed by 2020–2023 (R^2 = 0.562), whereas the value for 2023–2025 was only 0.279. This suggests that the driving pattern of cultivated land non-agriculturalization was more stable at the longer temporal scale, while short-term variations were more strongly influenced by stage-specific factors. Overall, slope showed a relatively stable and strong linear effect in all three periods, indicating that natural topographic conditions played a fundamental role in shaping the spatial differences.

Table 2. Comparison of OLS regression results of cultivated land non-agriculturalization in different periods.

Period	R^2	Result characteristics
2020–2023	0.562	Moderate explanatory power, with evident stage-specific influences.
2023–2025	0.279	Relatively low explanatory power and weaker short-term fluctuation.
2020–2025	0.682	Highest explanatory power and a more stable long-term pattern.

4.2. Geodetector and Machine-Learning Results

The Geodetector results indicate that elevation and slope had the strongest explanatory power, suggesting that natural topographic conditions imposed an evident basic constraint on cultivated land non-agriculturalization. In comparison, night-time lights, population density, and distances to roads and township centers also showed a certain degree of explanatory ability, indicating that human activities and spatial accessibility also played important roles.

The XGBoost and SHAP results further verified the importance of elevation, slope, and night-time lights. Elevation and slope mainly reflect the influence of topographic conditions on the stability of cultivated land use, whereas night-time lights capture the disturbance of regional development intensity and economic activity. The consistency among different methods demonstrates that cultivated land non-agriculturalization in Qixian County was jointly driven by natural, locational, and socioeconomic factors rather than by a single dominant factor.

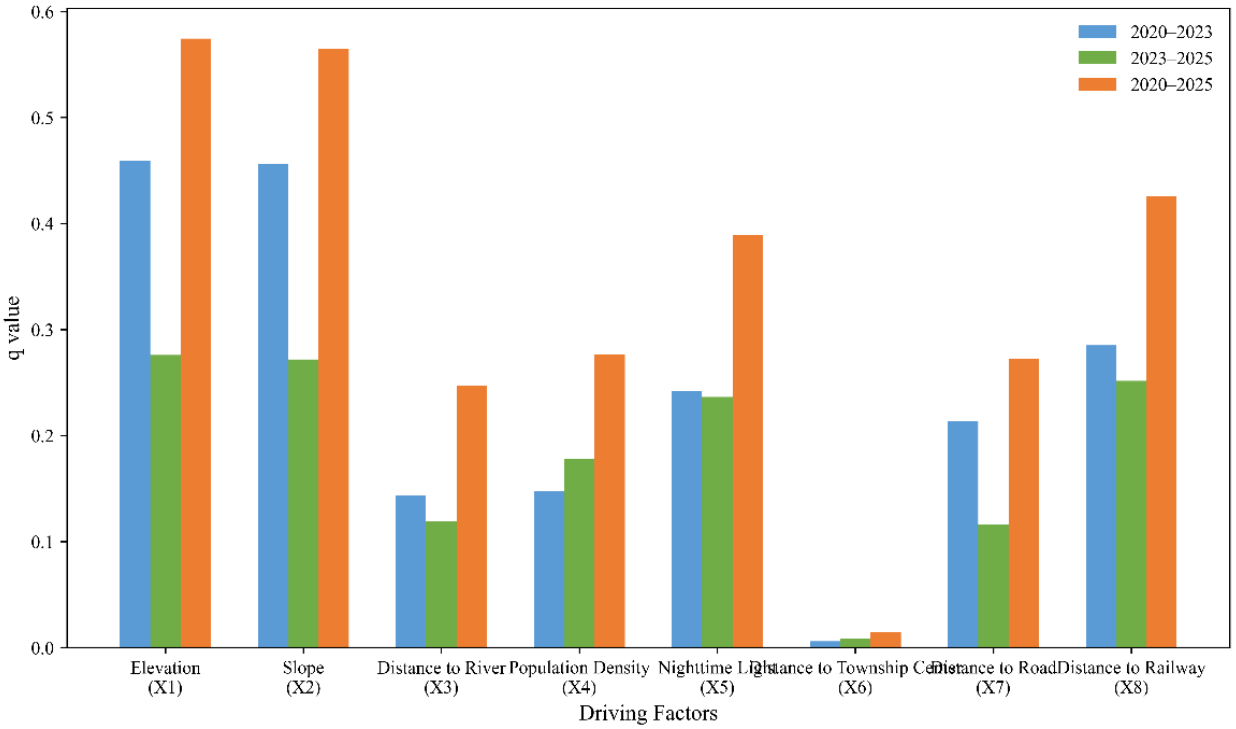

Figure 2. Comparison of Geodetector q values

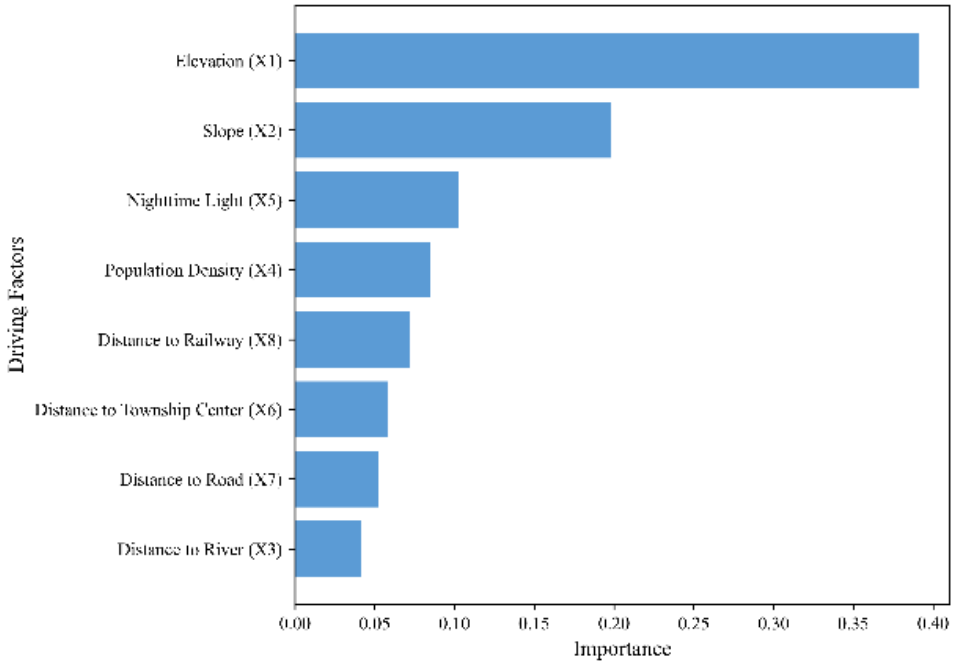

Figure 3. Feature importance ranking from XGBoost

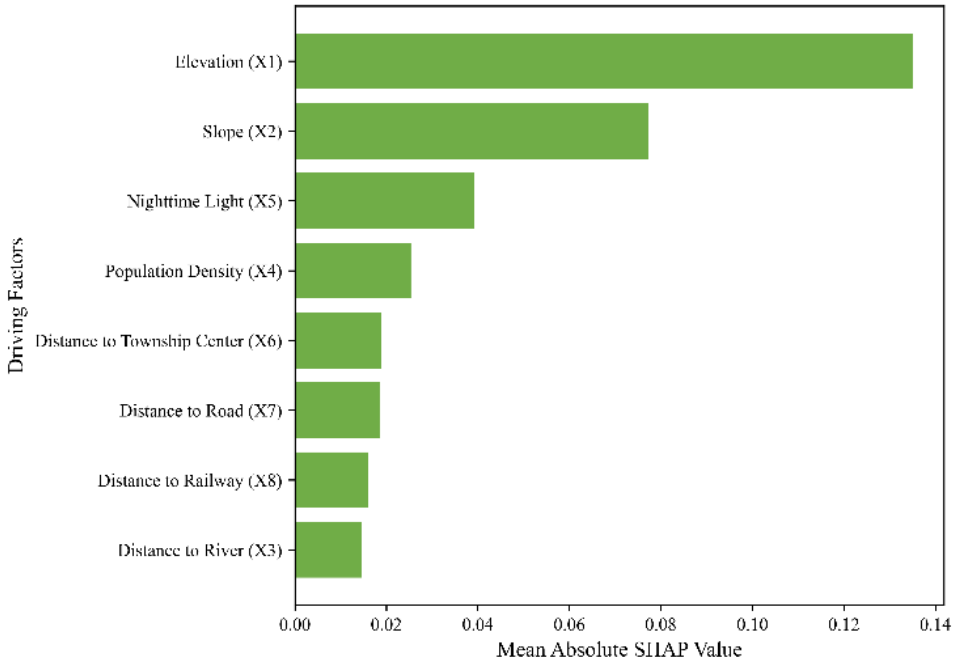

Figure 4. SHAP importance ranking

4.3. Discussion of Spatial Differentiation

The integrated results show that cultivated land non-agriculturalization in Qixian County exhibited clear spatial differentiation. The eastern plain area has flatter terrain, more contiguous cultivated land, better transportation conditions, and relatively higher levels of economic activity and population concentration, and is therefore more prone to conversion from cultivated land to orchard/woodland, construction land, or other land uses. In contrast, the western hilly region is constrained by terrain undulation and less favorable farming conditions, resulting in a relatively stable cultivated land pattern and a lower degree of non-agriculturalization. This indicates that the spatial pattern of cultivated land non-agriculturalization was shaped by the combined effects of topographic constraints and development intensity.

5. Conclusion

Using Qixian County as a case study, this paper combined OLS, Geodetector, XGBoost, and SHAP to analyze the driving mechanisms and spatial differentiation of cultivated land non-agriculturalization on the basis of 1 km × 1 km grid units. The results show that cultivated land non-agriculturalization in Qixian County was not controlled by a single factor, but jointly driven by natural, locational, and socioeconomic factors. The OLS model achieved the highest explanatory power for 2020–2025 ($R^2 = 0.682$), followed by 2020–2023 ($R^2 = 0.562$), while the value for 2023–2025 was much lower ($R^2 = 0.279$), indicating that the long-term driving pattern was relatively stable. Elevation and slope were the dominant factors with the strongest explanatory power, and night-time lights also showed high importance, reflecting the

coupled influence of topographic constraints and human activity intensity. Overall, cultivated land non-agriculturalization in Qixian County displayed clear spatial differentiation, and the findings can provide support for cultivated land protection, land use management, and territorial spatial optimization.

Acknowledgment

This study was supported by the project "Research and Demonstration of Key Technologies for the Henan Provincial Territorial Spatial Planning Implementation Monitoring Network (CSPON) System."

References

[1] Li, J., Han, J., Zhang, Y., Sun, Y., Peng, B., Xie, X., Guo, C., Ye, H. Analysis of spatiotemporal changes and driving forces of cultivated land in China from 1996 to 2019. *Frontiers in Environmental Science*, 2022, 10: 983289.

[2] Chen, Y., Wang, S., Wang, Y. Spatiotemporal evolution of cultivated land non-agriculturalization and its drivers in typical areas of southwest China from 2000 to 2020. *Remote Sensing*, 2022, 14(13): 3211.

[3] Wang, J. F., Xu, C. D. Geodetector: Principle and prospective. *Acta Geographica Sinica*, 2017, 72(1): 116–134.

[4] Chen, T., Guestrin, C. XGBoost: A scalable tree boosting system. In: *Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, 2016: 785–794.

[5] Lundberg, S. M., Lee, S. I. A unified approach to interpreting model predictions. In: *Advances in Neural Information Processing Systems 30*, 2017: 4765–4774.