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Spatial Clustering and Determinants of Agricultural to Urban Land Conversion at the Neighborhood Level: Evidence from Konya, Türkiye

Mevlut Uyan
Konya Technical University

Abstract: Urban expansion processes exert significant pressure on agricultural land, particularly in rapidly growing cities. This study analyzes the spatial distribution and determinants of agricultural-to-urban land conversion at the neighborhood level in Konya, Türkiye, for the period 1990–2018. First, the spatial pattern of agricultural land loss was examined using Global Moran's I and Local Moran's I (LISA) statistics. Global Moran's I result ($I = 0.2037$, $p < 0.01$) indicates that agricultural land conversion exhibits statistically significant positive spatial autocorrelation, suggesting that land-use transitions are spatially clustered rather than randomly distributed. LISA analysis further reveals that high conversion clusters are primarily concentrated along the southwestern urban growth corridor of the city. To identify the key determinants of agricultural land conversion, an Ordinary Least Squares (OLS) regression model was employed. The results demonstrate that the initial urban land ratio and distance to the city center are statistically significant predictors of conversion intensity. The negative coefficients of both variables indicate that agricultural land conversion increases in neighborhoods located closer to the city center and in areas with higher initial levels of urban development. Although the explanatory power of the model is moderate ($R^2 = 0.239$), the presence of spatial clustering highlights the importance of spatial interaction effects and neighborhood spillover dynamics in shaping land-use transitions. Overall, the findings suggest that urban growth in Konya follows a spatially structured and directional pattern. These results underline the critical role of spatial planning policies in guiding urban expansion and protecting agricultural land resources. The study demonstrates that neighborhood-level spatial analysis provides valuable insights for understanding urban land transformation processes and for developing sustainable land management strategies.

Keywords: Agricultural land conversion, Spatial econometrics, Urban expansion, Spatial autocorrelation

Introduction

Urban expansion has become one of the most influential drivers of land-use change worldwide, particularly in rapidly growing metropolitan regions. As cities expand to accommodate increasing population, economic development, and infrastructure demands, agricultural lands located at the urban fringe are often subjected to conversion pressures (Güneralp et al., 2020; Muchelo et al., 2024; Sheng & Huang, 2025). This transformation is not only a matter of spatial reallocation of land resources but also has broader implications for food security, environmental sustainability, ecosystem services, and regional socio-economic structures (Beckers et al., 2020; Kannan et al., 2021). Understanding the spatial dynamics of agricultural land loss has therefore become a critical research topic in urban and regional planning, land-use science, and spatial economics (Uyan & Ertunç, 2024).

Urban growth processes rarely occur randomly across space. Instead, they tend to exhibit directional and clustered patterns shaped by accessibility conditions, existing urban structure, and spatial interaction effects among neighboring areas (Gomes et al., 2018; Huang et al., 2020). Land located closer to urban cores typically experiences higher development pressure due to increased land value, better accessibility, and stronger agglomeration economies (Novotný et al., 2022). Similarly, areas with an already established urban structure often serve as nuclei for further expansion through processes of spatial diffusion and contiguous growth (Biłozor & Cieślak, 2021).

Ignoring the spatial dependence inherent in land-use change processes may lead to incomplete or biased interpretations (Qiu et al., 2007). Agricultural land conversion often demonstrates spatial spillover effects, meaning that land use decisions in one neighborhood can influence or be influenced by changes occurring in adjacent areas (Richards, 2018). This phenomenon highlights the importance of applying spatial statistical methods that explicitly account for spatial autocorrelation and local clustering patterns. Exploratory spatial data analysis (ESDA) techniques, including Global Moran's I and Local Indicators of Spatial Association (LISA), provide valuable tools for identifying whether land-use transitions follow systematic spatial structures (Salvati & Carlucci, 2014; Uyan & Ertunç, 2024). These methods allow researchers to detect clusters of high or low conversion intensity and to reveal potential spatial outliers, thereby offering insights into the underlying mechanisms of urban expansion (Abelairas-Etxebarria & Astorkiza, 2020).

Despite the growing body of literature on urban growth and land-use change, neighborhood level analyses remain relatively limited, particularly in medium sized cities undergoing accelerated transformation. Many existing studies focus on regional or metropolitan scales, potentially overlooking localized dynamics that are critical for effective spatial planning and policy development. Neighborhood-level investigations can capture spatial heterogeneity and provide a more detailed understanding of how urban expansion interacts with agricultural land systems (Follmann et al., 2021).

Konya represents a particularly relevant case for examining these processes. As one of Türkiye's major agricultural production centers, the city has experienced significant urban growth over recent decades. Rapid population increase, economic diversification, and infrastructure development have contributed to the outward expansion of urban land uses, often at the expense of productive agricultural areas. The spatial configuration of this expansion, however, remains insufficiently understood. Identifying whether agricultural land loss follows clustered spatial patterns and determining the key drivers of such transformations are essential for developing sustainable urban growth strategies and land protection policies.

In this context, the present study aims to analyze the spatial distribution and determinants of agricultural-to-urban land conversion at the neighborhood level in Konya between 1990 and 2018. Specifically, the study addresses two main research questions:
(i) Does agricultural land conversion exhibit significant spatial clustering across neighborhoods?
(ii) To what extent do initial urban land structure and accessibility to the city center explain the observed spatial variation in conversion intensity?

By integrating exploratory spatial statistical techniques with spatial econometric modeling approaches, this study seeks to reveal the spatial dependence structure underlying land-use transitions and to provide empirical evidence that can support more effective urban growth management and agricultural land protection policies.

Study Area

Konya, one of the largest provinces in Türkiye in terms of area, is located in the Central Anatolia Region. The city is notable for its extensive agricultural areas, semi-arid climate conditions, and increasing urban growth dynamics in recent years. Konya plays an important role in the national economy, especially in terms of grain production and irrigation-based agricultural activities. However, in recent years, population growth, industrialization, transportation investments, and urban development projects have created significant pressures for transformation on agricultural areas surrounding the city.

The study area selected is the Konya city center and the neighborhoods located around it. The main reason for choosing the neighborhood scale is to reveal the spatial heterogeneity of urban sprawl processes in more detail. When examining land use changes in the city between 1990 and 2018, it is observed that urban areas have expanded especially in regions close to the city center and along certain transportation axes. This situation leads to the fragmentation of agricultural areas and their transformation into urban uses.

Konya's topographical structure is largely flat and suitable for agriculture, and this feature facilitates the spatial continuity of urban sprawl. Furthermore, industrial areas and transportation infrastructure investments developing around the city center are among the important spatial factors accelerating land-use transformation. In this context, Konya offers a suitable study area for examining the spatial patterns of agricultural land loss and analyzing the spatial determinants of urban sprawl processes. Although the study area initially consisted of 122 neighbourhoods, only 65 neighbourhoods were included in the analysis (Figure 1). Neighbourhoods that did not contain any agricultural land in 1990 were excluded from the study in order to ensure a meaningful evaluation of agricultural-to-urban land conversion dynamics.

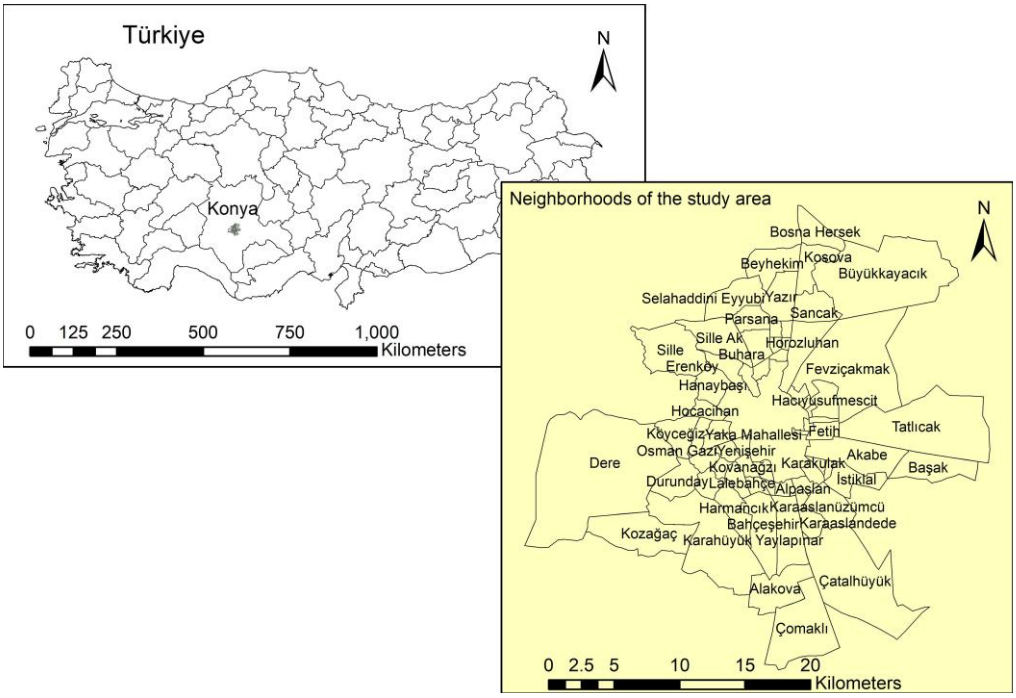

Figure 1. Location of the study area and neighborhood boundaries in Konya, Türkiye

Data Sources

This study utilized multiple spatial and statistical datasets to analyze agricultural-to-urban land conversion at the neighborhood level. Land-use data were derived from the CORINE Land Cover datasets for the years 1990 and 2018, which provide consistent and standardized information on land cover changes across Europe. Neighborhood boundary data were obtained from official administrative spatial datasets. Population statistics were collected from national statistical records corresponding to the study period. Distance-based accessibility variables, including distance to the city center and distance to major road networks, were calculated using geographic information system (GIS) techniques. All spatial data processing and spatial statistical analyses were conducted using ArcGIS Pro software. Exploratory spatial data analysis, including Global Moran's I and LISA, as well as regression modeling procedures, were performed within the GIS environment.

Method

Spatial Weights Matrix Construction

In spatial statistical analyses, defining spatial relationships among observational units is a fundamental step. In this study, spatial interaction among neighborhoods was represented by constructing a spatial weights matrix based on the Queen contiguity criterion. Under this approach, neighborhoods sharing either a common boundary or a vertex were considered spatial neighbors. This method is widely used in spatial econometric and spatial statistical applications due to its ability to capture both edge and corner adjacency relationships (Griffith & Paelinck, 2018). The spatial weights matrix was row-standardized to ensure comparability across neighborhoods with different numbers of neighbors. This standardization allows spatial lag effects to be interpreted as weighted averages of neighboring observations and helps prevent scale-related bias in spatial autocorrelation statistics (Elhorst, 2013).

Spatial Autocorrelation Analysis

To investigate whether agricultural to urban land conversion exhibits a systematic spatial pattern, Global Moran's I statistic was employed. Moran's I measures the degree of spatial autocorrelation by evaluating whether similar values of a variable tend to cluster in geographic space (Hussein et al., 2023; Zhang et al., 2023). A positive and statistically significant Moran's I value indicates spatial clustering, while a negative value suggests spatial dispersion (Majumder and Cajee, 2026).

$$Moran'sIndex = \frac{n}{S_0}\frac{\sum_i \sum_j w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2}$$

Where n is the number of spatial units, x_i and x_j represent the rate of conversion of agricultural land to urban use in locations i and j, $\bar{x}$ is the mean conversion of agricultural land to urban use value, w_{ij} denotes the spatial weight between spatial units, and S_0 is the sum of all spatial weights ((Baek et al., 2022).

The statistical significance of Moran's I was evaluated using standardized z-scores and associated p-values (Kerry et al., 2024). In this study, the analysis aimed to determine whether neighborhoods experiencing high levels of agricultural land conversion were spatially concentrated rather than randomly distributed across the study area.

Local Spatial Autocorrelation (LISA)

While Global Moran's I provide an overall measure of spatial dependence, it does not reveal the specific locations of spatial clusters. Therefore, Local Indicators of Spatial Association (LISA) were used to identify localized spatial patterns of agricultural land conversion. LISA analysis enables the classification of neighborhoods into four categories: high-high clusters (areas with high conversion surrounded by similar areas), low-low clusters (areas with low conversion surrounded by similar areas), high-low outliers, and low-high outliers. These classifications provide valuable insights into spatial diffusion processes and help identify urban growth corridors as well as relatively stable agricultural zones (Anselin, 1995).

Regression Modeling

To examine the determinants of agricultural land conversion, an Ordinary Least Squares (OLS) regression model was employed. The dependent variable represents the proportion of agricultural land converted to urban use at the neighborhood level. Explanatory variables included the initial urban land ratio and distance to the city center, which are theoretically linked to urban growth dynamics and accessibility conditions. OLS is a non-spatial statistical method used to model the relationship between a dependent variable and one or more independent variables. It assumes that observations are spatially independent and randomly distributed, meaning the value at one location does not influence the value at another (Gao et al., 2020; Moindjié et al., 2022).

The regression model aims to quantify the extent to which spatial variation in agricultural land conversion can be explained by structural urban characteristics and location-based accessibility factors. The inclusion of these variables is consistent with urban economic theory, which suggests that land-use transitions are strongly influenced by proximity to urban cores and existing development patterns.

OLS regression provides a baseline analytical framework for evaluating the relationship between the intensity of agricultural land conversion and selected explanatory variables. In this study, the initial urban land ratio (URBAN1990_PCT) and distance to the city center (DIST_CENTER_KM) were included as independent predictors. The main dependent variable, AGRI_URBAN_PCT, measures the intensity of agricultural-to-urban land conversion by quantifying the percentage share of agricultural land transformed into urban use at the neighborhood level over the study period.

These variables were selected based on urban economic and land-use change theories, which emphasize the role of accessibility and existing urban structure in shaping urban expansion processes. Areas located closer to the city center generally experience stronger development pressure due to higher land values, better infrastructure availability, and increased economic activity. Similarly, neighborhoods with higher initial levels of urban development are more likely to undergo further land-use transformation through spatial diffusion and contiguous urban growth mechanisms.

The OLS model can be expressed as:

$$AGRI\_URBAN\_PCT = \beta_0 + \beta_1\ URBAN1990\_PCT + \beta_2\ DIST\_CENTER\_KM + \varepsilon$$

where β represents the estimated regression coefficients and ε denotes the random error term.

Model Diagnostics

Several diagnostic tests were conducted to evaluate the validity and robustness of the regression model. Multicollinearity among explanatory variables was assessed using Variance Inflation Factor (VIF) values. Model stability and heteroskedasticity were evaluated through the Koenker (Breusch–Pagan) statistic, while the Jarque–Bera test was used to examine the normality of residuals.

Additionally, spatial autocorrelation in model residuals was examined using Moran's I statistic to determine whether spatial dependence remained after controlling for explanatory variables. This step is crucial in spatial econometric analysis, as significant residual spatial autocorrelation may indicate model misspecification or omitted spatial processes. Through these diagnostic procedures, the study ensures that the regression results provide reliable insights into the spatial determinants of agricultural land conversion.

Results

Figure 2 illustrates the spatial distribution of agricultural land converted to urban use between 1990 and 2018 together with the extent of urban areas in 1990. The map clearly demonstrates that urban expansion in Konya has occurred outward from the existing urban core toward peripheral agricultural zones.

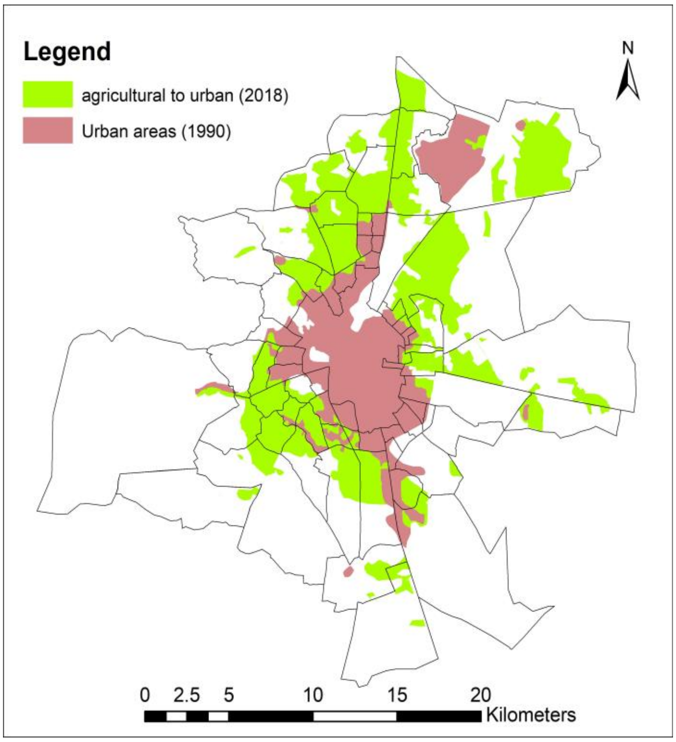

Figure 2. Spatial distribution of agricultural-to-urban land conversion between 1990 and 2018 and the extent of urban areas in 1990

Global Spatial Autocorrelation of Agricultural Land Conversion

The spatial distribution of agricultural-to-urban land conversion was first examined using the Global Moran's I statistic. The analysis results indicate a statistically significant positive spatial autocorrelation (Moran's I = 0.2037, z = 2.72, p < 0.01), suggesting that neighborhoods with similar levels of agricultural land conversion tend to be spatially clustered rather than randomly distributed across the study area (Table 1).

Table 1. Global Moran's I statistics for agricultural-to-urban land conversion

Moran's I	Expected Index	Variance	z-score	p-value
0.2037	-0.0154	0.0064	2.72	0.0065

This finding implies that agricultural land loss in Konya follows a spatially structured pattern influenced by urban expansion dynamics. High conversion intensity is not evenly distributed but instead concentrates in specific parts of the city, reflecting directional urban growth processes.

Local Spatial Clustering Patterns (LISA)

To further explore the spatial configuration of agricultural land conversion, LISA analysis was conducted. The LISA cluster map (Figure 3) reveals the presence of significant high–high spatial clusters, indicating neighborhoods with high conversion rates surrounded by similar high-conversion neighborhoods. These clusters are primarily concentrated along the southwestern urban growth corridor, highlighting the directional nature of urban expansion in Konya. The emergence of low–low clusters in peripheral areas suggests relatively stable agricultural zones where urban development pressure remains limited. The identification of spatial clusters demonstrates that agricultural land conversion is influenced not only by local characteristics but also by spatial interaction effects among neighboring neighborhoods. This pattern is consistent with spatial diffusion mechanisms commonly observed in urban growth processes.

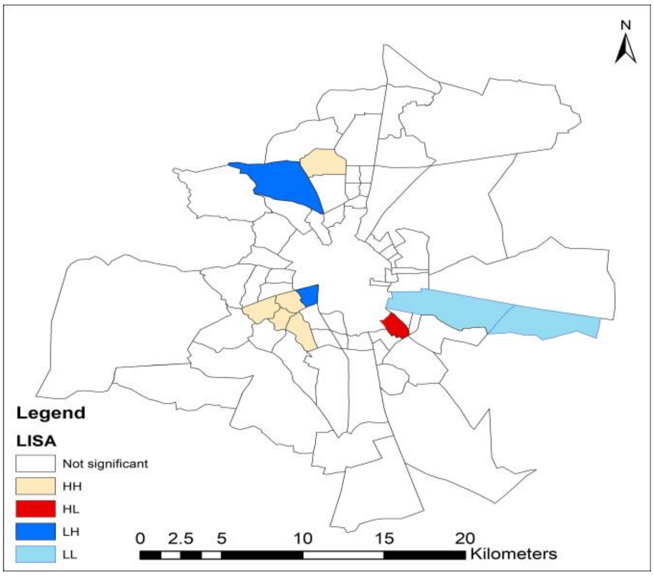

Figure 3. LISA cluster map illustrating spatial clusters of agricultural-to-urban land conversion intensity

Determinants of Agricultural Land Conversion: OLS Results

Table 2. OLS regression results for agricultural-to-urban land conversion

Variable	Coefficient	Std. Error	t-Statistic	p-value	VIF
Constant	112.31	15.51	7.24	0.047	-
URBAN1990_PCT	-0.566	0.157	-3.61	0.001	1.48
DIST_CENTER_KM	-6.84	1.63	-4.19	0.000	1.48
Model Diagnostics					
Indicator		Value			
Number of observations		65			
R^2		0.239			
Adjusted R^2		0.215			
AICc		671.96			
Koenker (BP) p-value		0.10			
Jarque–Bera p-value		0.22			

*Dependent variable: AGRI_URBAN_PCT

To quantify the factors influencing agricultural land conversion intensity, an Ordinary Least Squares (OLS) regression model was estimated. The model results (Table 2) indicate that both the initial urban land ratio (URBAN1990_PCT) and distance to the city center (DIST_CENTER_KM) are statistically significant predictors of agricultural-to-urban land conversion. The negative coefficient of the distance variable suggests that neighborhoods located closer to the urban core experience higher conversion intensity. Similarly, the negative relationship between the initial urban land ratio and agricultural land conversion implies that areas with a more developed urban structure tend to undergo further land transformation due to contiguous urban growth and spatial spillover effects. Although the model explains a moderate proportion of the spatial variation in agricultural land conversion ($R^2 = 0.239$), the regression results highlight the importance of accessibility conditions and existing urban development patterns in shaping land-use transitions.

Spatial Interpretation of Regression Findings

The combined results of spatial autocorrelation analysis and regression modeling indicate that agricultural land conversion in Konya is driven by spatially structured urban expansion processes. The presence of clustered high-conversion neighborhoods near the urban core supports the argument that land-use transformation follows accessibility gradients and development corridors. Furthermore, the spatial clustering identified through LISA analysis suggests that neighborhood-level land-use change is influenced by spillover dynamics, where urban expansion in one area increases the likelihood of conversion in adjacent areas. These findings emphasize the need to interpret regression results within a spatial econometric framework, acknowledging that land-use transitions are embedded in broader spatial interaction systems.

Discussion

The results of this study provide strong evidence that agricultural land conversion in Konya follows a spatially structured urban expansion pattern rather than occurring randomly across neighborhoods. The statistically significant positive Global Moran's I value confirms that neighborhoods experiencing high levels of agricultural-to-urban land conversion tend to be located near similar neighborhoods. This finding supports the argument that land-use transitions are influenced by spatial interaction mechanisms and neighborhood spillover effects.

The presence of high–high clusters identified through LISA analysis further indicates that urban growth in Konya is directional and corridor-based, particularly along the southwestern development axis. Such spatial clustering patterns are consistent with the concept of contiguous urban growth, where expansion occurs outward from existing urban cores through processes of spatial diffusion. Similar spatial dynamics have been reported in urban growth studies emphasizing the role of accessibility gradients and infrastructure-led development (Aljoufie et al., 2013; Anees et al., 2020).

Regression analysis results highlight the importance of initial urban structure and accessibility conditions in shaping agricultural land conversion. The negative relationship between distance to the city center and conversion intensity suggests that agricultural lands located closer to urban cores are more vulnerable to transformation (Liu et al., 2011; Huang et al., 2014). This finding aligns with classical urban economic theories, including bid–rent theory, which predicts that land values and development pressure decrease with increasing distance from the central business district (Chidi, 2019; Wang & Qiu, 2017).

The significance of the initial urban land ratio variable indicates that neighborhoods with an already established urban fabric are more likely to experience further land-use transformation. This pattern reflects path dependency in urban growth processes, where previous development creates structural conditions that facilitate additional expansion. The observed spatial clustering also suggests that land conversion decisions are not purely local but are influenced by development trends in adjacent neighborhoods (Krisztin et al., 2022).

Although the explanatory power of the regression model is moderate, the results underline the importance of incorporating spatial perspectives in land-use change analysis. Agricultural land loss is shaped not only by economic and accessibility factors but also by spatial dependence effects, which may arise from shared infrastructure, planning decisions, and market dynamics operating at broader spatial scales. From a planning perspective, the concentration of agricultural land conversion near urban growth corridors raises concerns regarding urban sprawl and the fragmentation of productive agricultural landscapes. If left unmanaged, such spatially clustered expansion may lead to irreversible land degradation, reduced agricultural productivity, and increased pressure on natural resources. Therefore, spatially informed urban growth management strategies are essential for balancing development needs with agricultural land protection objectives.

Conclusion

This study examined the spatial distribution and determinants of agricultural-to-urban land conversion at the neighborhood level in Konya between 1990 and 2018. The findings demonstrate that agricultural land loss exhibits significant spatial clustering, indicating that urban expansion follows a structured and directional pattern rather than a random process. Global and local spatial autocorrelation analyses revealed that high conversion intensity is concentrated in neighborhoods located near the urban core and along major development corridors. Regression modeling further confirmed that initial urban land structure and proximity to the city center are key drivers of agricultural land transformation. These results highlight the critical role of accessibility and existing development patterns in shaping land-use change dynamics.

The study contributes to the growing body of literature emphasizing the importance of spatial analytical approaches in understanding urban growth processes. By integrating exploratory spatial statistics with regression-based analysis, the research provides empirical evidence that agricultural land conversion is influenced by spatial interaction mechanisms and neighborhood spillover effects. From a policy perspective, the results underline the necessity of proactive spatial planning and agricultural land conservation strategies. Identifying high-risk conversion zones through spatial analysis can support decision-makers in guiding urban expansion toward more sustainable development pathways. Future research may benefit from incorporating full spatial econometric models and additional socio-economic variables to further explore the complex drivers of land use transitions.

Scientific Ethics Declaration

* The author declares that the scientific ethical and legal responsibility of this article published in EPHELS journal belongs to the author.

Conflict of Interest

* The author declares that there is no conflict of interest

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Author(s) Information

Mevlut Uyan
Konya Technical University
Vocational School of Technical Sciences, Konya, Türkiye
ORCID iD: https://orcid.org/0000-0002-3415-6893
*Contact e-mail: *muyan@ktun.edu.tr*

*Corresponding author(s) contact e-mail

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