

Analysis of Land Use Change Between 1996 and 2024 in the Central District of Adıyaman (Southeastern Türkiye)

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Abstract: Land use and land cover change analysis provides critical evidence for environmental management, post-disaster reconstruction and risk-sensitive urban planning. This study evaluates land use change in the central district of Adıyaman, southeastern Türkiye, using Landsat satellite images acquired for 1996, 2011 and 2024. After geometric, radiometric and atmospheric preprocessing, land use classes were mapped using the Spectral Angle Mapper classification method and evaluated by accuracy assessment and kappa statistics. The results show a marked transformation of the landscape during the 28-year period. Agricultural lands decreased substantially, while settlement and bare land classes expanded in response to urban growth, land degradation and post-earthquake reconstruction pressures. The most recent map also indicates increasing demand for low-rise residential development after the 6 February 2023 Kahramanmaraş earthquakes. Overall accuracies were 85.46%, 87.52% and 91.74% for 1996, 2011 and 2024, respectively, with kappa values of 0.83, 0.82 and 0.89. These results indicate reliable classification performance and demonstrate the value of satellite-based monitoring for guiding sustainable land use policies in disaster-prone urban environments.

Keywords: Geographic information systems, Land use change, Remote sensing, Satellite images, Spectral angle mapper

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1. Introduction

Land use and land cover (LULC) describe the physical cover of the Earth surface and the human activities associated with that cover. Although these terms are often used together, land cover refers to biophysical surface characteristics, whereas land use refers to the socioeconomic function assigned to land units (Kumari et al., 2024). Monitoring LULC change is therefore essential for assessing urban expansion,

agricultural transformation, ecosystem degradation and the sustainability of regional development (Moghaddam and Cao, 2024).

Remote sensing and geographic information systems (GIS) provide effective tools for analysing land surfaces (Agapiou et al., 2014; Elmahdy and Mohamed, 2016) and detecting land use changes over large areas and across multiple time periods (Zhao et al., 2023; Shi et al., 2025; Bharath et al., 2025; Babitha et al., 2025). Multi-temporal satellite imagery enables consistent comparison of spectral responses, while robust preprocessing steps, including geometric, radiometric and atmospheric corrections, improve the reliability of classification outputs (Mather and Tso, 2016). Such analyses are particularly important in regions where rapid urbanization intersects with agricultural pressure, environmental degradation and disaster risk.

Satellite image analysis encompasses supervised classifiers such as support vector machines (Pal and Mather, 2005), hybrid segmentation methods (Awad, 2018), and deep learning approaches (Yuan et al., 2020). Domain adaptation supports image segmentation across differing data domains (Liang et al., 2023), while high-resolution urban land-cover databases provide complementary mapping resources (Zhang et al., 2022).

Adıyaman is a relevant case for LULC monitoring because the city has experienced both long-term urban expansion and abrupt post-disaster planning pressures. The 6 February 2023 Kahramanmaraş earthquakes caused severe damage across southeastern Türkiye and intensified the need to identify safer settlement areas, manage reconstruction and protect productive land. In this context, spatially explicit land use information can support planning decisions that balance housing demand, agricultural sustainability and environmental protection.

This study aims to quantify and interpret land use changes in and around the central district of Adıyaman between 1996, 2011 and 2024. Landsat satellite images were classified using the Spectral Angle Mapper (SAM) method, and the reliability of the classifications was evaluated using overall accuracy and kappa statistics. The study contributes to post-disaster land management by documenting how settlement, agricultural land, bare land and water body classes have changed over nearly three decades.

2. Material and Method

2.1. Study area

The study area covers the central district of Adıyaman and its surrounding environment in southeastern Türkiye (Figure 1). The region includes plains, valleys and mountainous areas that produce strong spatial variability in elevation, slope, aspect and land cover. This geomorphological diversity influences local

climatic conditions, vegetation patterns, erosion potential and the suitability of land for agriculture and settlement.



Figure 1. Study area

Topographic and land cover characteristics were evaluated using a digital elevation model, slope, aspect and CORINE land cover data (Figure 2). The digital elevation model was obtained from ASTER GDEM with an approximate spatial resolution of 28 m. Higher elevations occur mainly in the northeastern part of the area, whereas lower elevations dominate the southern sectors. Steeper slopes are associated with greater erosion susceptibility and may constrain agricultural and residential development. CORINE land cover data indicate a heterogeneous landscape composed mainly of agricultural lands, forested areas, bare surfaces and settlement areas.

2.2. Satellite data and preprocessing

Landsat satellite images representing 1996, 2011 and 2024 were obtained from the USGS Earth Explorer platform. These dates were selected to provide a multi-temporal framework for evaluating land use change before and after major urban growth and the 2023 earthquakes. All images were processed in a GIS and remote sensing environment. Geometric correction was applied to ensure spatial alignment

among dates, while radiometric and atmospheric corrections were used to reduce sensor-related and atmospheric effects. These steps are necessary to ensure that differences among the classified maps represent land surface change rather than image acquisition or preprocessing artefacts.

2.3. Spectral Angle Mapper classification and accuracy assessment

The Spectral Angle Mapper (SAM) method was used as the supervised classification algorithm. SAM treats the spectral values of each pixel as a vector and calculates the spectral angle between the image pixel and reference spectra. Pixels with smaller spectral angles are assigned to the corresponding reference class. The method is widely used in remote sensing because it is relatively insensitive to illumination differences and can detect spectral similarity across multispectral and hyperspectral datasets (Kruse et al., 1993). Applications of SAM include urban expansion mapping, tree-condition discrimination and land degradation mapping (Zare Naghadehi et al., 2021; Mudaliar, 2022; Benzougagh et al., 2024).

Four land use classes were mapped: settlement, bare land, agricultural area and lake/water body. Training and reference information was derived from field observations, Google Earth imagery and visual interpretation of the satellite scenes. Classification accuracy was evaluated using error matrices, producer's accuracy, user's accuracy, overall accuracy and kappa statistics (Congalton, 1991; Olofsson et al., 2014). The workflow used in the analysis is summarized in Figure 3.

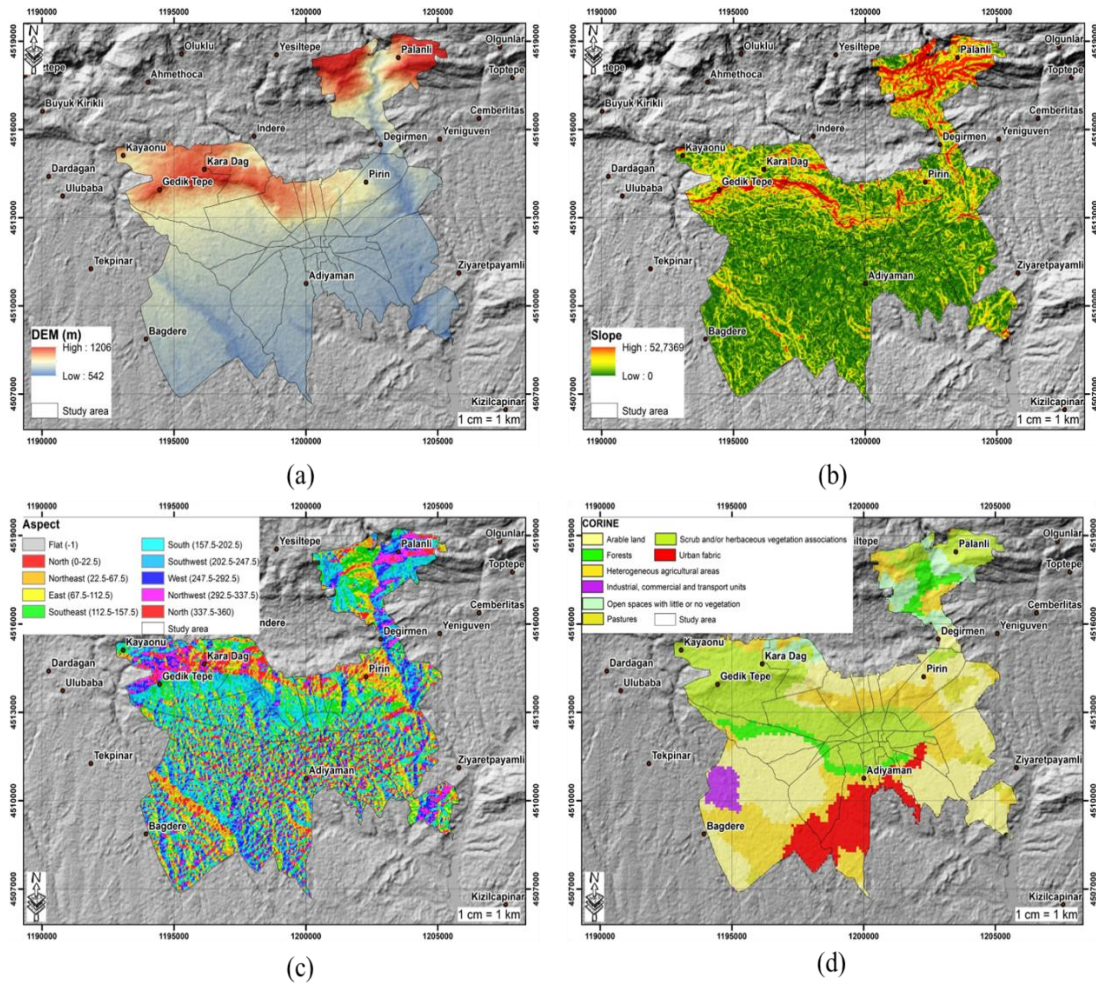


Figure 2. Digital Elevation Model (a), Slope (b), Aspect (c), and CORINE (d) Maps of the Study Area.

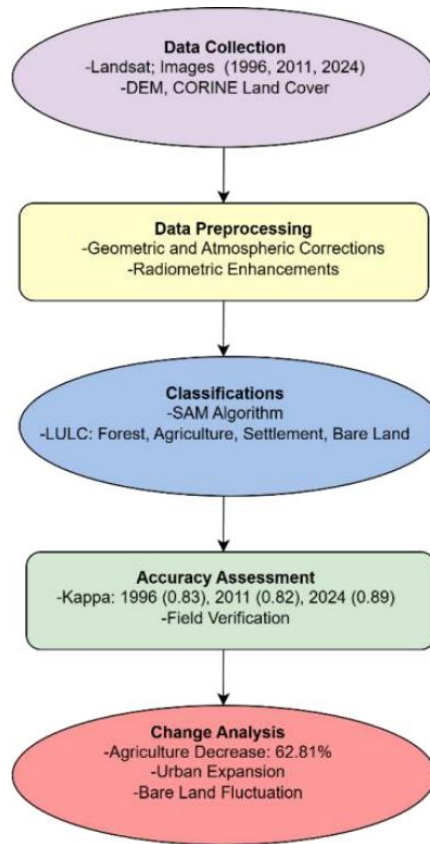
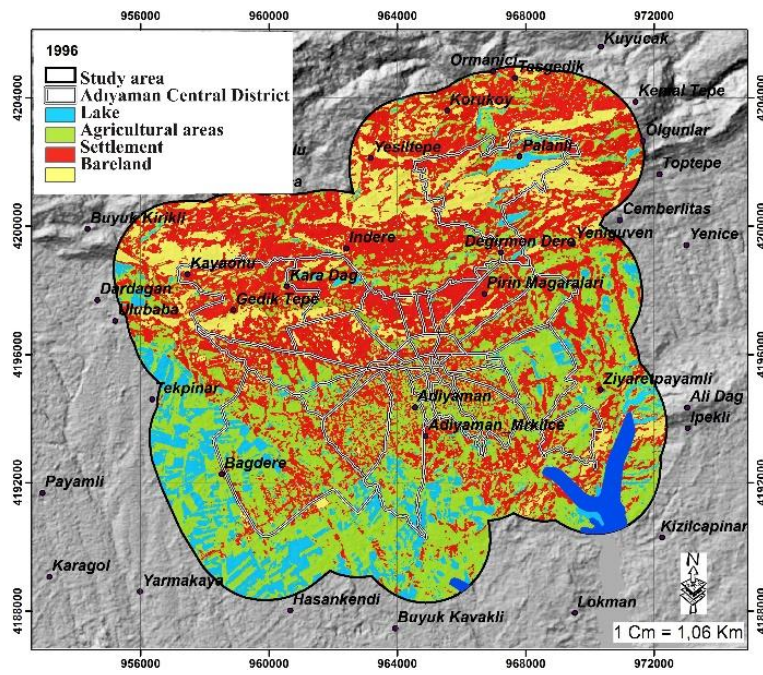


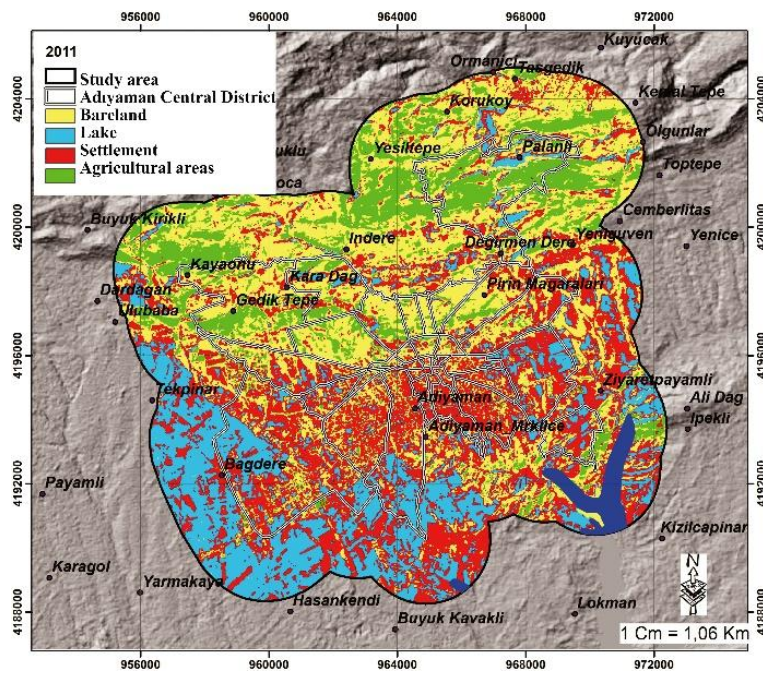
Figure 3. Analysis Scheme of the Data Used in the Study.

3. Results

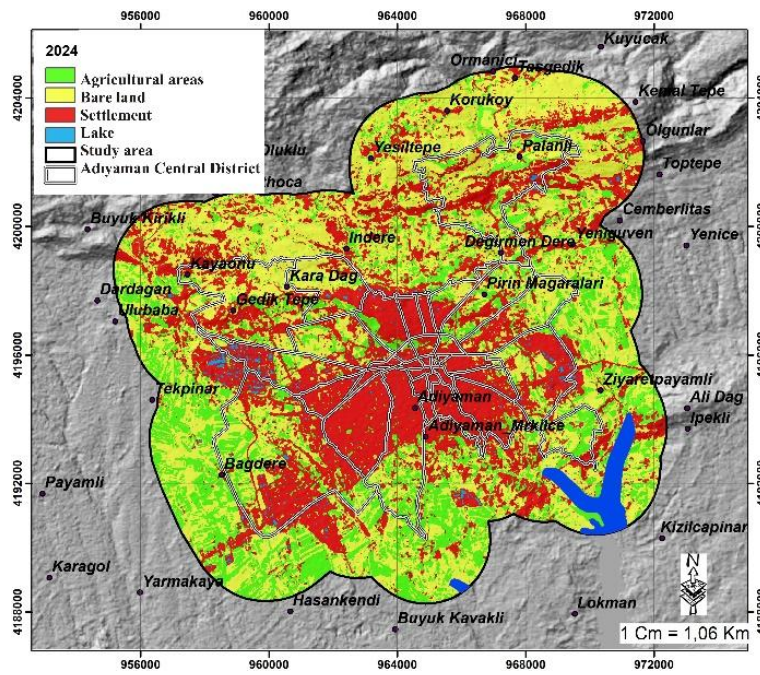
The classified land use maps for 1996, 2011 and 2024 reveal a clear spatial transformation in Adıyaman Central District and its surroundings (Figure 4). In 1996, settlement areas were relatively limited and mainly concentrated around the city centre. By 2011, urban expansion had progressed outward from the centre. In 2024, settlement areas became more extensive, particularly in the southern and southeastern parts of the study area. This expansion is consistent with population growth, infrastructure development and the increasing demand for new residential areas after the 2023 earthquakes.



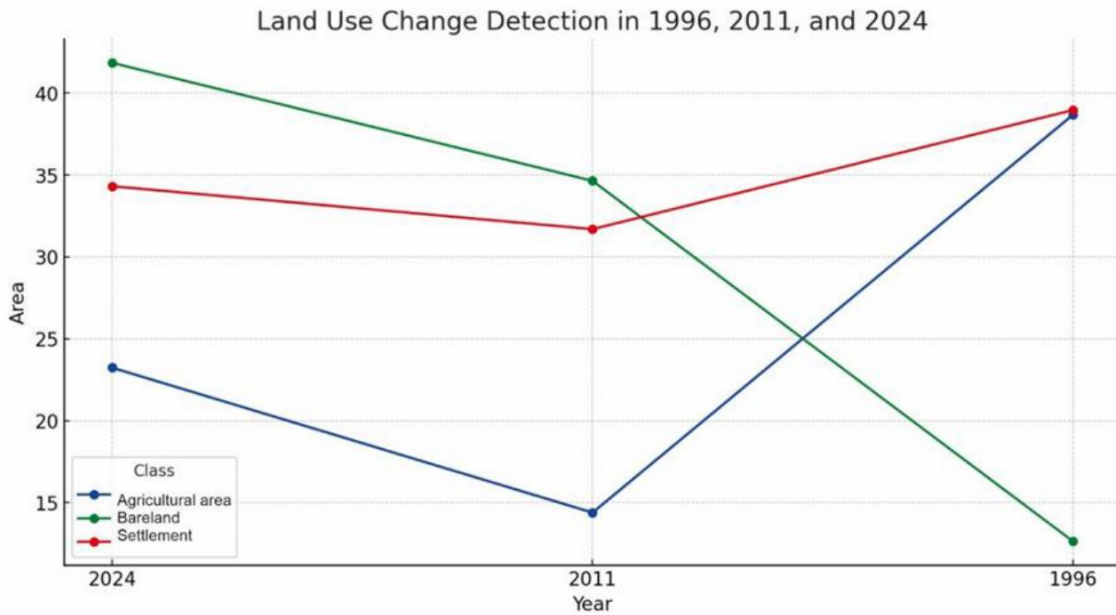
(a)



(b)



(c)

Figure 4. Land use maps for 1996 (a), 2011 (b) and 2024 (c).**Figure 5.** Percentage change in land use classes for 1996, 2011 and 2024.

The accuracy assessment results indicate reliable classification performance for all three dates (Table 1). Overall accuracy increased from 85.46% in 1996 to 87.52% in 2011 and 91.74% in 2024. Kappa values of 0.83, 0.82 and 0.89 also indicate strong agreement between the classified maps and reference data.

Table 1. Accuracy analysis results obtained after classification of each satellite image.

1996 (%) Overall Accuracy = % 85,46 Kappa Value = 0.83						
Class	Settlement	Bareland	Agricultural area	Lake	Producer's Accuracy	User accuracy
Settlement	87,01	5,94	1,56	2,78	87,01	89,42
Bareland	8,62	87,2	3,52	1,75	87,2	74,12
Agricultural area	1,63	4,25	79,16	0,06	79,16	86,33
Lake	2,74	2,61	15,76	95,41	95,41	96,45
Total	100	100	100	100		
2011 (%) Overall Accuracy = % 87,52 Kappa Value = 0.82						
Class	Settlement	Bareland	Agricultural area	Lake	Producer's Accuracy	User accuracy
Settlement	86,93	6,94	3,1	6,41	72,25	88,94
Bareland	2,45	83,19	4,02	4,96	92,46	81,45
Agricultural area	3,62	4,36	92,46	3,78	89,14	81,45
Lake	7	5,51	0,42	80,85	86,99	84,44
Total	100	100	100	100		
2024 (%) Overall Accuracy = % 91,74 Kappa Value = 0.89						
Class	Settlement	Bareland	Agricultural area	Lake	Producer's Accuracy	User accuracy
Settlement	88,26	3,62	0,5	1,23	84,63	78,13
Bareland	1,23	84,53	0,06	0,25	96,14	98,41
Agricultural area	3,89	4,1	98,59	1,49	89,63	89,36
Lake	6,62	7,75	0,85	97,03	84,25	97,03
Total	100	100	100	100		

4. Discussion

The results of this study indicate that the central district of Adiyaman has undergone a considerable land use transformation between 1996 and 2024. The observed changes are not limited to simple spatial expansion of settlement areas; rather, they reflect a broader reorganization of the landscape driven by urban growth, agricultural land conversion, land degradation processes and post-disaster reconstruction pressures. In this respect, the study area represents a dynamic urban–rural transition zone where environmental, socioeconomic and disaster-related factors interact.

One of the most significant findings is the long-term pressure on agricultural lands. Agricultural areas were more dominant in the earlier phase of the study period, particularly in the northern and western parts of the region. However, the decrease observed by 2011 suggests that agricultural land was progressively converted into settlement areas or transitional bare surfaces. This change is important

because agricultural land loss may directly affect local production capacity, rural livelihoods and the long-term sustainability of land resources. In rapidly urbanizing and disaster-prone regions, the conversion of productive land into built-up areas should therefore be evaluated not only as a spatial planning issue, but also as an environmental and socioeconomic risk.

The expansion of settlement areas reflects the increasing demand for urban land in Adiyaman. This trend became more evident in the 2024 classification, particularly in the southern and southeastern parts of the study area. The spatial pattern of this expansion may be associated with both long-term urban development and the changing settlement preferences that emerged after the 6 February 2023 Kahramanmaraş earthquakes. Following the earthquakes, the demand for safer residential zones and low-rise housing appears to have increased pressure on available peripheral lands. However, this interpretation should be approached carefully, because the satellite-based classification directly shows land cover change, whereas post-earthquake migration, housing preference and reconstruction decisions require additional demographic, cadastral and planning data for direct confirmation.

Bare land also showed a dynamic behaviour during the study period. The increase in bare land between 1996 and 2011 may indicate land clearing, construction preparation, degradation of agricultural surfaces or erosion-prone exposed areas. The subsequent decrease by 2024 suggests that some of these surfaces may have been converted into settlement areas or reused for agricultural purposes. Therefore, bare land should not be interpreted as a fixed land cover class only; it may also represent a transitional land use stage associated with urban expansion, abandoned agricultural areas, construction processes or post-disaster land preparation.

The relative stability of water bodies suggests that this class was less affected by urban expansion compared with agricultural and bare land categories. Nevertheless, small changes in water surfaces may be related to seasonal hydrological variability, image acquisition dates or classification uncertainty. Since water resources are essential for ecological continuity, irrigation and local environmental balance, future studies should examine surface water dynamics together with precipitation variability, drought conditions and land use pressure. Hydrological modelling in the Nyong River Basin further illustrates that land-use change and climatic variability can jointly influence runoff (Ebodé, 2023).

The accuracy assessment results support the reliability of the produced land use maps. Overall accuracy values of 85.46%, 87.52% and 91.74% for 1996, 2011 and 2024, respectively, together with kappa coefficients of 0.83, 0.82 and 0.89, indicate strong classification performance. These values show that the Spectral Angle Mapper method produced consistent and reliable results for multi-temporal Landsat-

based land use analysis. The higher accuracy obtained for 2024 may be related to improved image quality, clearer spectral separability among classes or more reliable reference information from recent high-resolution imagery and field observations.

Despite these strong accuracy values, some classification uncertainties should be considered. Settlement and bare land classes may exhibit similar spectral responses, especially in areas where construction sites, roads, exposed soils and low-density built-up surfaces coexist. Likewise, agricultural areas with sparse vegetation cover may be confused with bare land depending on crop type, phenological stage and image acquisition season. These uncertainties are common in medium-resolution Landsat-based classifications and highlight the importance of combining satellite imagery with field verification, Google Earth interpretation and accuracy assessment (Congalton, 1991; Olofsson et al., 2014).

From a planning perspective, the findings reveal that Adıyaman has gradually shifted from a more agriculture-dominated landscape toward a more urbanized and fragmented land use structure. This transformation is particularly critical in the post-earthquake period, because reconstruction needs may accelerate land conversion around the city. Therefore, future land use planning should not focus only on the rapid production of new residential areas. It should also consider agricultural land protection, geological suitability, slope conditions, infrastructure capacity, environmental sensitivity and long-term urban resilience.

Overall, the results demonstrate that remote sensing and GIS-based land use monitoring provide an effective basis for understanding spatial transformation in disaster-prone urban environments. The observed decrease in agricultural areas, expansion of settlements and transitional behaviour of bare land indicate the need for an integrated land management strategy in Adıyaman. Such a strategy should balance post-disaster housing demand with the protection of productive land, ecosystem services and sustainable urban development. In this context, the generated land use maps can provide useful scientific evidence for local authorities, planners and decision-makers involved in reconstruction and regional development processes.

5. Conclusion

This study analysed land use changes in the central district of Adıyaman between 1996, 2011 and 2024 using Landsat satellite imagery and the Spectral Angle Mapper classification method. The results show that the study area has experienced significant land use transformation over nearly three decades. The most notable changes include the expansion of settlement areas, the decline and spatial reorganization of agricultural lands and the dynamic conversion of bare land surfaces. The classification accuracy results

indicate that the produced maps are reliable for evaluating long-term land use change. Overall accuracy values above 85% and kappa coefficients above 0.80 confirm strong classification performance for all three periods. These results demonstrate that medium-resolution Landsat imagery, when combined with appropriate preprocessing, supervised classification and accuracy assessment, can effectively support regional-scale land use monitoring. The findings have important implications for post-disaster planning in Adıyaman. The 2023 earthquakes increased the need for safer and more resilient settlement areas, but future urban expansion should be managed carefully to avoid uncontrolled conversion of agricultural and environmentally sensitive lands. Therefore, reconstruction and development policies should be guided by spatial evidence, geological suitability analyses and sustainable land management principles. In conclusion, this study provides a useful remote sensing-based assessment of land use change in a rapidly transforming and disaster-affected urban environment. The results can contribute to risk-sensitive urban planning, agricultural land protection and sustainable reconstruction strategies in Adıyaman and similar regions affected by both long-term urbanization and sudden natural disasters.

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Author Contributions

Conceptualization: S.T. and Y.İ.; Investigation: S.T. and Y.İ.; Material and Methodology: S.T. and Y.İ.; Visualization: S.T. and Y.İ.; Writing-Original Draft: S.T. and Y.İ.; Writing-review & Editing: S.T. and Y.İ. All authors have read and agreed to the final version of the manuscript.

Conflict of Interest

The authors have no conflicts of interest to declare.

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