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Investigation of Fire-İnduced Disaster-Related Land Cover Changes in Çanakkale Province Between 2020 and 2025

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ABSTRACT: Within this context, the province of Çanakkale has been affected by several major fires occurring between 2020 and 2025, leading to notable alterations in land cover across the region. An examination of the annual distribution of fires reveals that the highest number occurred in 2025, while the monthly distribution indicates that the most ecologically destructive impacts were concentrated between June and October.

In this study, land-use classes for Çanakkale were identified using Sentinel-2 satellite imagery with a spatial resolution of 10 metres. Fire-induced land-cover changes between 2020 and 2025 were detected through intersection-based change analysis and land-use class comparison methods. Real-time fire data provided by the Fire Information for Resource Management System (FIRMS), developed by the National Aeronautics and Space Administration (NASA), were utilised to delineate fire boundaries within the provincial limits. These boundaries were extracted by converting GeoTIFF files into vector format. Subsequently, the altered land-use classes were overlaid with the fire boundaries, enabling the identification of land-cover changes directly attributable to fire events. The vegetation structure affected and destroyed by the fires was further determined using forest management plans within the administrative boundaries of Çanakkale.

In conclusion, this study quantifies the spatial extent of fire-induced land-cover loss in Çanakkale and elucidates the structural dimension of ecological damage. The findings provide a scientific basis for future restoration and rehabilitation efforts.

KEYWORDS: Forest Fire, FIRMS, Ecological Planning, GIS, Land Cover Change, Çanakkale.

INTRODUCTION

Climate change is currently recognised as one of the most decisive global challenges affecting both ecosystems and human life. Increasing greenhouse gas emissions have led to rising global temperatures, which in turn have contributed to droughts, extreme weather events, and a higher frequency of natural disasters (Intergovernmental Panel on Climate Change, 2021). According to reports by the World Meteorological Organization, the number and severity of climate-related disasters have risen markedly over the past three decades (World Meteorological Organization, 2021). This escalation is clearly observed in diverse climate-induced hazards, including prolonged heatwaves, meteorological and agricultural droughts, flash floods and inundations caused by intense rainfall, tropical cyclones, coastal flooding triggered by sea-level rise, and large-scale forest fires.

Climate change, driven by anthropogenic activities that accelerate greenhouse gas emissions, has resulted in global temperature increases, irregularities in precipitation regimes, and a notable rise in the frequency of extreme meteorological events (IPCC, 2021; WMO, 2021). This process affects not only natural ecosystems but also socio-economic systems, thereby amplifying disaster risks.

Natural disasters are generally classified into geological, meteorological, hydrological, and biological categories (United Nations Office for Disaster Risk Reduction, 2020). Within this classification, forest fires stand out as a critical hazard, increasingly frequent and widespread under the influence of climate change, with profound ecological and economic consequences. A forest fire is defined as a freely spreading blaze that destroys all living and non-living components within a forest ecosystem (General Directorate of Forestry, 2022). Although fire constitutes a natural element of ecosystem regimes, anthropogenic pressures and climatic variability have transformed it into a destructive disaster (Bowman et al., 2020).

In recent years, rising temperatures, intensifying droughts, and human activities have further heightened fire risk on a global scale. Several major fires occurring between 2020 and 2025 illustrate this trend:

* 2020 Australian Fires: Approximately 18 million hectares were burned, with millions of organisms affected (NASA, 2020).
* 2023 Canadian Fires: The country experienced its largest fire season in history, with hundreds of thousands evacuated (Government of Canada, 2023).

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* 2025 Kazakhstan and Algeria Fires: According to World Bank reports, fires have become a year-round global threat rather than a seasonal phenomenon (World Bank, 2025).

These global examples demonstrate that forest fires are not merely ecological issues but also economic and social disasters. In the case of Turkey, regions within the Mediterranean climate zone are particularly vulnerable during the summer months. Within this context, the province of Çanakkale has drawn attention due to the intensity of fires experienced between 2020 and 2025, making it the focal point of this study.

The sensitivity of the issue is underscored by the 13% increase in forest fires in 2020 compared with 2019, and the destruction of 325,000 hectares of forest within only two months in 2021 (Sarıdoğan et al., 2022). Globally, more than four million hectares of forest are damaged annually due to ongoing climate change processes (Ulusoy, 2020). Fires destroy forests, pastures, and crops, while degrading natural habitats and ecosystems characterised by coexisting species (Ilgar, 2024). Forest fires, an escalating threat of considerable severity, exert direct impacts on trees as well as positive and negative effects on forest soils, flora, and fauna (Özkazanç et al., 2011).

According to forest management surveys, Turkey's forested area covers approximately 20,703,122 hectares. Based on this figure, forests account for 26.4% of the country's total land area. In comparison, the proportion is 30.7% in Germany, 46.7% in Greece, 47.0% in Italy, 67.8% in Japan, 32.4% in the United States, and 76.7% in Finland. Accordingly, Turkey is considered a country of moderate forest wealth (Doğanay et al., 2011).

MATERIALS AND METHODS

This study was conducted within the administrative boundaries of Çanakkale Province, located in north-western Turkey. Çanakkale exhibits transitional climatic characteristics between the Mediterranean and Black Sea climates, with hot and dry summers and mild, rainy winters. The annual mean temperature across the province ranges between 14–15 °C, while the average annual precipitation is approximately 600–700 mm (MGM, 2024). During the summer months, temperatures exceeding 35 °C combined with low humidity levels pose a high risk of forest fires. The highest recorded temperature during the study period was 39.8 °C on 18 July 2024, whereas the maximum daily precipitation was 82 mm on 29 January 2021 (MGM, 2025).

Çanakkale is strategically situated in the south-western part of the Marmara Region, between the Aegean and Marmara Seas. The province is characterised by mountainous and rugged terrain, particularly in the Kazdağları and surrounding areas, which accelerates the spread of fires. In addition, forest ecosystems dominated by pine species (*Pinus brutia, Pinus nigra*) and broad-leaved stands exhibit high flammability (Ministry of Agriculture and Forestry, 2025). Agricultural lands, rural settlements, and touristic areas are interwoven with forest ecosystems, thereby increasing the risk of human-induced fires (Kavgacı et al., 2023). Between 2020 and 2025, significant land-use changes occurred in the Aegean and Marmara regions due to disaster-related and other factors. These changes, occurring at different times, have caused considerable ecological damage. In this study, land-use changes within the administrative boundaries of Çanakkale (Figure 1) were examined.

The primary materials of the research comprised Sentinel-2 satellite imagery obtained via the Copernicus Browser (URL 1), GeoTIFF-format fire data from NASA's Fire Information for Resource Management System (FIRMS) (URL 2), and land-use GeoTIFF datasets provided by ESRI (URL 3), along with relevant documentation. Four Sentinel-2 images corresponding to the study area were mosaicked using ArcGIS tools and clipped to the provincial boundaries. FIRMS GeoTIFF data covering fire records between 2020 and 2025 were converted into vector format to delineate fire boundaries. Similarly, ESRI GeoTIFF datasets representing land use in 2020 and 2025 were clipped to the study area and converted into vector format. Subsequently, both datasets were analysed using the Intersection module in QGIS to generate a land-use change map, thereby quantifying the areas affected.

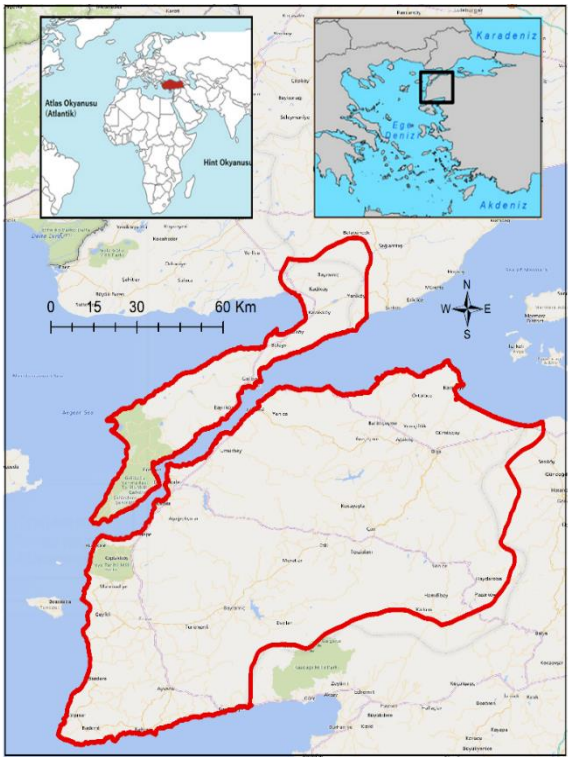


Figure 1. Location of the Study Area

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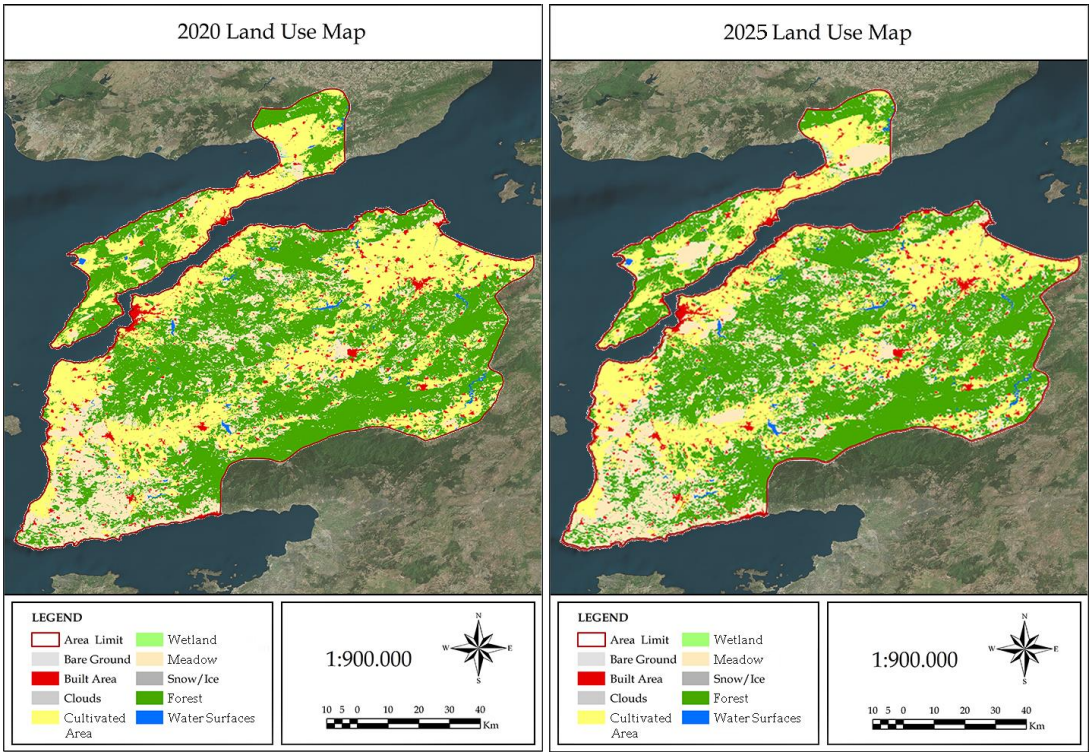


Figure 2. Land Use Maps for the Year 2020-2025

The 2020 land-use change map was produced by converting GeoTIFF datasets into vector format, whereas the 2025 land-use change map was generated using data derived from Landsat-2 satellite imagery (Figure 2). The land-use maps for 2020 and 2025 constitute the fundamental datasets enabling the quantification of changes within the study area and the identification of transformations across different land-use categories. Through comparative analyses, these maps reveal the temporal dynamics of land-use within the study area and allow for a detailed assessment of the spatial distribution of such changes.

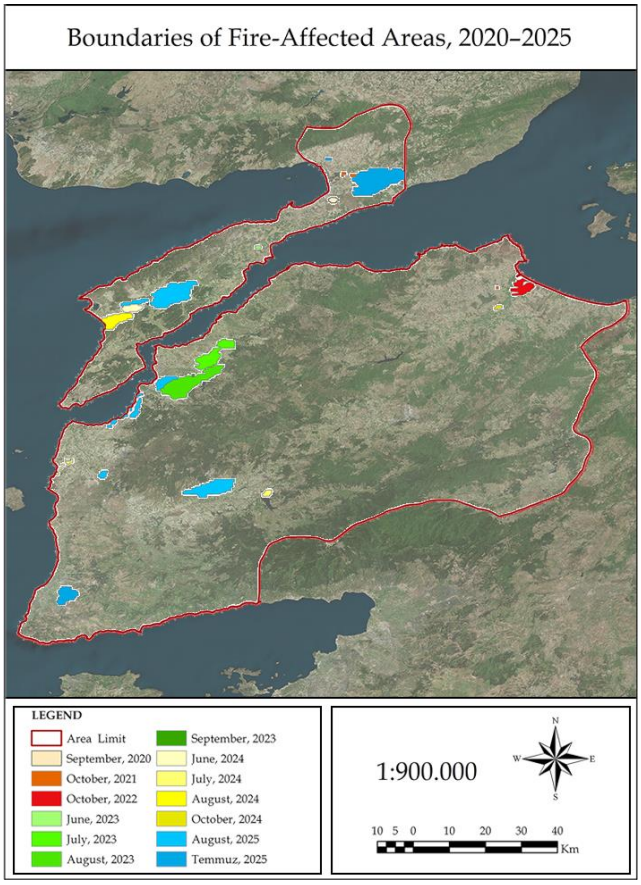


Figure 3. Burned Area Boundaries Between 2020 and 2025

RESULTS

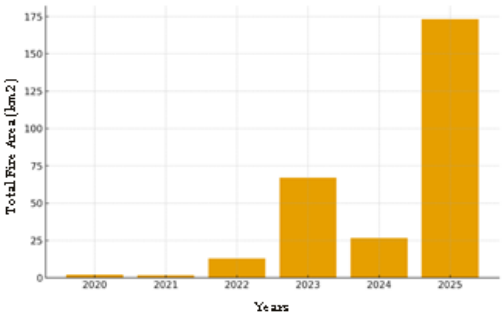
To determine the impacts of fires on land cover between 2020 and 2025, fire boundaries were delineated, digitised, and the necessary maps were produced. Land-use changes within the areas affected by fires in different years were examined, enabling the identification of the direction of change and its associated environmental implications. The transformations observed in land cover before and after fire events reveal how land use has been influenced by fires and into which categories the land cover has evolved, thereby facilitating the evaluation of long-term effects.

Table 1. Areal Extent of Wildfires Occurring in Çanakkale Province Between 2020 and 2025

Year / Month	**Burned Area**						
	2020 Year	2021 Year	2022 Year	2023 Year	2024 Year	2025 Year	**2020-2025**
June	-	-	-	0,6 km²	7,2 km²	-	7,8 km²
July	-	-	-	24,4 km²	3,8 km²	72,1 km²	100,3 km²
August	-	-	-	41,9 km²	14,8 km²	101,1 km²	157,8 km²
September	2,0 km²	-	-	0,2 km²	-	-	2,2 km²
October	-	1,7 km²	12,9 km²	-	0,8 km²	-	15,4 km²
TOPLAM	2,0 km²	1,7 km²	12,9 km²	67,1 km²	26,6 km²	173,2 km²	**283,5 km²**

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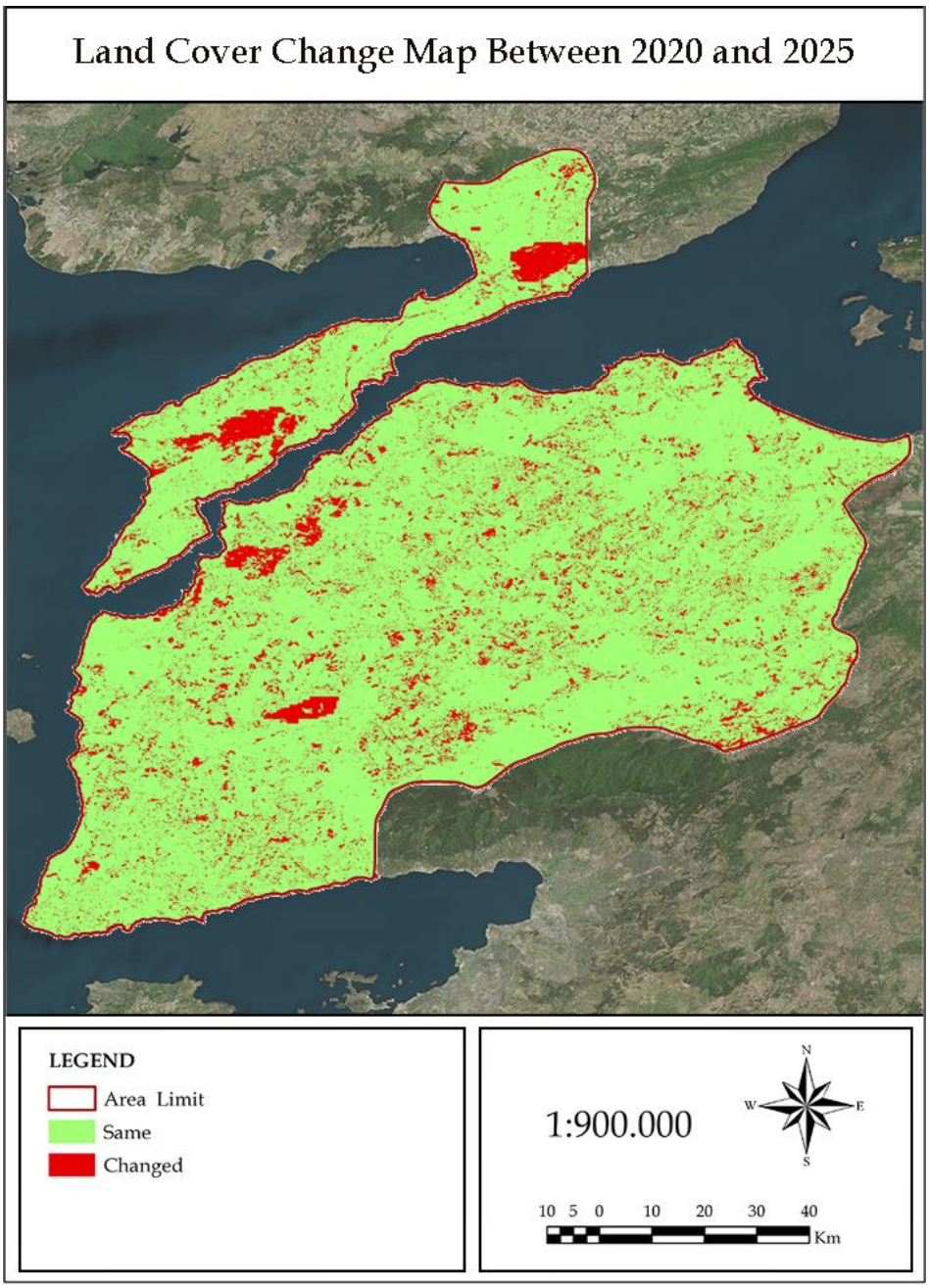
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In this study, the boundaries of fire-affected areas were derived from data processed by NASA using satellite imagery of global fire events and obtained in GeoTIFF format through the Fire Information for Resource Management System (FIRMS) platform.

In Çanakkale Province, the boundaries of fire-affected areas between 2020 and 2025 were digitised using ArcGIS software. The fire zones for each year were categorised according to the month in which the events occurred, and appropriate colour classifications were applied. As illustrated in Table and Figure 4, the annual and monthly distribution of fires, together with the extent of the areas affected, were visually represented. This evaluation enables the clear observation of temporal trends in fire-affected areas and facilitates the comparison of variations in fire magnitude over time.

Figure 4. Fire-affected areas between 2020 and 2025



The intersection analysis of land-use classes for 2020 and 2025 revealed the spatial distribution of both unchanged and transformed areas within the study region. In the maps, areas marked in green tones represent regions that either remained unaffected by fires or successfully preserved their land cover during the five-year period, whereas areas highlighted in red indicate zones where land use underwent transformation. These changes were associated with a range of environmental factors, including fires, fluctuations in agricultural activities, rural settlement expansion, and natural dynamics.

The concentration of change areas in specific regions demonstrates the spatial distribution of the ecological impacts of fires and provides a critical indicator for evaluating post-fire land-cover dynamics. This situation signifies a weakening of ecosystem integrity within the affected regions. Accordingly, the intersection analysis offers an essential spatial data foundation for land management, risk assessment, and decision-making processes concerning ecosystem change.

The values of spatial increase and decrease presented in Table 2 for the period 2020–2025 make a substantial contribution to the interpretation of variations in land-use change.

The comparison of land-use classes for 2020 and 2025 reveals that significant land-cover transformations have occurred within the study area over the past five years. Overall, notable trends of increase and decrease affecting ecosystem integrity were observed. Losses amounting to 157.3 km² in forest areas and 184.2 km² in agricultural land were largely attributable to the impacts of fire events.

Figure 5. Land-use change map between 2020 and 2025

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Table 2. Spatial distribution of land-use change in Çanakkale Province between 2020 and 2025

Land Use/Cover Change				
Land Use Land Cover	2020 Year	2025 Year	Between 2020 and 2025	Situation Analysis
Bare Ground	10,7 km²	8,4 km²	-2,3 km²	2,3 km² reduced
Built Area	326,5 km²	357,7 km²	31,2 km²	31,2 km² increased
Clouds	0,01 km²	0,004 km²	-0,01 km²	0,01 km² reduced
Cultivated Area	2973 km²	2788,8 km²	-184,2 km²	184,2 km² reduced
Wetland	3,3 km²	2,8 km²	-0,5 km²	0,5 km² reduced
Meadow	1713,2 km²	2020,8 km²	307,6 km²	307,6 km² increased
Snow/Ice	0,004 km²	0,001 km²	-0,003 km²	0,003 km² reduced
Forest	4343 km²	4185,7 km²	-157,3 km²	157,3 km² reduced
Water Surfaces	80,2 km²	85,8 km²	5,6 km²	5,6 km² increased

Across natural ecosystems (forests, wetlands, and snow cover), a total reduction of 157.7 km² was recorded, while built-up areas and water surfaces exhibited an increase of 36.8 km². This outcome demonstrates that both human activities and environmental conditions have substantially altered land cover in the region. The identified changes are critical in terms of ecosystem services, biodiversity, and sustainable land management.

The intersection of land-cover datasets for 2020 and 2025 revealed the spatial and temporal dynamics of change within the study area. The change matrix derived from the overlap of classes in both years demonstrated that significant transformations in land use had occurred. According to the analytical findings, losses were observed in bare ground, clouds, agricultural land, wetlands, snow cover, and forest areas, whereas increases were recorded in rangeland, wetlands, and built-up areas.

Within the Bare Ground class, a loss of 2.3 km² was identified. This reduction is most likely associated with vegetation growth, the expansion of agricultural land, or increased settlement pressure. Similarly, the decline of 0.003 km² in the Snow/Ice class indicates a reduction in snow persistence, attributable to climatic changes in the region.

The Built Area class exhibited a substantial increase of 31.1 km². This finding clearly reflects spatial expansion driven by intensive urbanisation, infrastructure development, or population growth in recent years. Such an increase in built-up areas has the potential to exert considerable pressure on natural ecosystems.

A notable expansion of 307.6 km² was recorded in the Rangeland class. This category represented the most significant gain among land-use types during the study period, explicitly highlighting the class transformation in land cover induced by fire events between 2020 and 2025. Conversely, the Crops class experienced a reduction of 184.2 km², suggesting that agricultural land may have been converted into other land-use categories. This transformation could be linked to restructuring in rural land-use patterns or the intensification of non-agricultural activities.

The Trees class showed a decline of 157.3 km². This loss may be attributed to deforestation, fire events, unplanned settlement expansion, or agricultural practices. Given that forest cover represents one of the most ecologically critical classes, this reduction constitutes a significant warning in terms of biodiversity and ecosystem services.

An increase of 5.6 km² was detected in the Water class. This expansion may be explained by reservoir or pond enlargement, seasonal water accumulation, changes in the hydrological cycle, or the widening of floodplains. In contrast, the Flooded Vegetation class recorded a loss of 0.5 km², which can be associated with hydraulic modifications, drainage activities, or drought conditions.

Finally, the minor change of 0.01 km² in the Clouds category reflects classification discrepancies arising from image interpretation and does not carry direct ecological significance in terms of land-cover change.

DISCUSSION

In this study, land-use changes derived from the comparison of land-cover data based on satellite imagery for 2020 and 2025 provide significant insights into the assessment of landscape dynamics. Through intersection analysis, the overlay of classes from both years has enabled the detailed identification of which land types underwent temporal change and how these transformations were spatially distributed.

The findings indicate that the study area experienced notable transitions, particularly the conversion of agricultural land into grassland/rangeland, forest losses, and an increase in settlement areas. These transitions can be associated with socio-economic activities, climatic conditions, fire history, or the balance between conservation and utilisation. Certain class changes are critical in terms of ecosystem functioning and exert direct impacts on the long-term sustainability of landscape integrity.

These land-use changes may also have significant implications for ecosystem services. For instance, the reduction of forested areas adversely affects biodiversity, while the expansion of agricultural land places pressure on water consumption, erosion susceptibility, and soil fertility.

Overall, the land-use pattern of the study area underwent a marked transformation during the period 2020–2025. Monitoring these transformations is of critical importance for future landscape planning, water resource management, and ecological risk assessments. In particular, processes such as post-fire recovery, rural land-use pressures, and urbanisation trends contribute to a more detailed understanding of landscape dynamics and provide a scientific foundation for sustainable land management decisions.

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