

Spatiotemporal Analysis of Land Use and Land Cover Change in Banjarbaru City (2002–2022) Using Google Earth Engine

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Abstract

This study analyzes spatiotemporal changes in land use and land cover (LULC) in Banjarbaru City over a twenty-year period (2002–2022) to examine the reorganization of its urban spatial structure in relation to economic growth, housing demand, and environmental conditions. Multi-temporal land cover data from the GLC-FCS30D dataset were processed on the Google Earth Engine platform, reclassified into seven dominant land-cover categories, and validated using 180 stratified validation points cross-checked against high-resolution satellite imagery. The mapped patterns indicate that built-up areas expanded from a compact urban core into a continuous urban fabric, while plantation and shrubland/forest cover declined substantially and agricultural land increased in spatial extent toward the urban periphery. Open and bare land also expanded as transitional land states associated with ongoing development. These trajectories correspond to broader structural changes documented in regional economic and housing studies, including increased residential land absorption driven by public housing affordability programs and shifts in sectoral economic contribution. The spatial restructuring of green and wetland areas indicates increasing fragmentation and reduced ecological buffering, aligning with research demonstrating declining carbon storage and heightened hydrological sensitivity as vegetated land is converted to urban surfaces. The results present a comprehensive characterization of Banjarbaru's land transition dynamics and provide a spatial basis for evaluating urban planning, green space management, and sustainability strategies.

Keywords: Land Use Change, Urban Expansion, Spatiotemporal Analysis, Google Earth Engine, Banjarbaru City

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1. Introduction

Banjarbaru has undergone a significant spatial and administrative transformation following its designation as the capital of South Kalimantan Province, which has accelerated demographic concentration, economic activities, and land development across the city. According to

demographic data reported by BPS Kota Banjarbaru (2025), the population growth rate reached 3.61% during the period 2021–2024, accompanied by an active labor force of approximately 135,271 individuals. Although these statistics extend beyond the primary observation period (2002–2022), they are included to describe the most recent demographic context that continues the long-term development trajectory examined in this study. In line with its urban development trajectory, the city has also gained national recognition for sustainability performance, being ranked seventh among 58 cities in the 2023 “10 Most Sustainable Cities in Indonesia” assessment under the UI GreenMetric criteria. The urban economy is primarily driven by the service, trade, and construction sectors, which have contributed to rapid conversion of land and increased demand for built-up areas. Such expansion aligns with previous observations that continuous population growth and development activities in Banjarbaru are expected to intensify over time, reinforcing the need to continuously monitor land conditions and environmental dynamics in the urban area. These structural changes underscore the importance of examining the city’s land use and land cover trajectory over multi-decadal periods to better understand the implications of its administrative elevation, economic reorientation, and sustainability positioning.

Land use and land cover (LULC) change is a central indicator of spatial transformation because it reflects how land is reorganized in response to demographic growth, economic expansion, and development priorities (Behradfar et al., 2025; Kamran et al., 2023; Gabisa et al., 2025). In rapidly developing urban contexts, these shifts illustrate how land allocation progressively reorients away from ecological and resource-based functions toward settlement expansion and service-oriented land demands (Tahir et al., 2025; Zhang et al., 2025; Zhou et al., 2024). The conversion of vegetated areas into built-up land alters ecological structure, reduces vegetative buffer capacity, and affects environmental stability, including carbon storage, surface reflectance, and habitat connectivity (Fang et al., 2022; Ru et al., 2024; Kang et al., 2025). These biophysical shifts have direct relevance to Banjarbaru, where rapid urban expansion has increasingly replaced forested and semi-natural areas with residential, commercial, and infrastructural development. For example, protected forest zones in the Kayu Tangi area have experienced substantial land conversion, with approximately 22.42% of the protected block transitioning into cultivation land, plantation areas, and settlement zones (Nasruddin & Siswanto, 2021). This indicates that landscape restructuring in Banjarbaru is not only a matter of urban development but also one that influences ecological resilience and land system stability.

The environmental consequences of LULC change in Banjarbaru have become particularly visible in peatland-dominated regions such as Liang Anggang, where increasing impervious surface coverage and vegetation disturbance intensify hydrological imbalance, accelerate surface runoff, and elevate fire susceptibility. Studies have shown that districts in Banjarbaru, including Cempaka, Landasan Ulin, and Banjarbaru Selatan, are dominated by high fire vulnerability categories, driven by the presence of agriculture, plantations, and shrubland with medium-to-high vegetation density (Saputra et al., 2021). These patterns demonstrate how land conversion in Banjarbaru is closely tied to elevated environmental risk, where spatial restructuring intersects with socio-economic activities such as land clearing, informal cultivation, and settlement expansion. Accordingly, assessing LULC change in Banjarbaru requires not only identifying spatial transitions but also understanding how these transformations interact with ecological processes, hazard exposure, and resource sustainability across the urban landscape.

Banjarbaru’s establishment as a provincial administrative center has intensified spatial and socio-economic restructuring, characterized by accelerated expansion of built-up areas, reallocation of land functions, and increasing development pressure. However, research on long-term LULC change in the city remains limited in both temporal extent and methodological consistency. Existing studies generally employ short comparison intervals, which constrain the ability to identify directional trends and cumulative impacts of landscape transformation. Previous studies have mapped fire susceptibility in Banjarbaru, but without connecting risks to historical land-use

trajectories (Saputra et al., 2023). Likewise, regional planning studies such as Suni et al. (2023) demonstrated the utility of remote sensing for urban governance but did not extend their analysis to multi-decadal temporal scales. Similar patterns are evident across Indonesian LULC literature, where mapping outputs frequently depict conditions at a single moment, rather than tracing systematic spatial evolution. This situates a clear research gap in the need for a consistent, long-term assessment capable of explaining Banjarbaru's development trajectory and associated environmental implications.

The application of Google Earth Engine (GEE) offers a suitable framework for multi-temporal LULC analysis due to its cloud-based processing environment, extensive satellite data archives, and integrated analytical tools for classification, time-series evaluation, and spatial computation. These capabilities enable efficient processing of large datasets while maintaining reproducibility across different temporal scales. Previous studies have demonstrated the reliability of machine learning classifiers within GEE, particularly Random Forest (RF) and Support Vector Machine (SVM), for producing stable and consistent LULC outputs across varied ecological and urban contexts (Feizizadeh et al., 2021; Amini et al., 2022; Basheer et al., 2022). Improvements in class discrimination can further be achieved through the incorporation of spectral-temporal metrics and vegetation indices, which enhance separability among structurally similar land types (Loukika et al., 2021; Nasiri et al., 2022). Within the Indonesian context, GEE has been shown to effectively address challenges related to cloud interference and processing limitations in large-area land cover mapping. In this study, the GLC-FCS 30D dataset is employed to provide annual, globally consistent 30-meter land cover layers, enabling direct temporal comparison without inter-dataset inconsistencies. Accordingly, this research aims to: (1) map LULC conditions in Banjarbaru for 2002, 2012, and 2022 using the GLC-FCS 30D dataset on the GEE platform; (2) analyze spatial and temporal patterns of LULC transition over the twenty-year period; and (3) identify dominant urban expansion characteristics to interpret the city's long-term development trajectory and its implications for spatial planning and environmental sustainability.

2. Method

A. Study Area

Banjarbaru City is located in the southeastern part of South Kalimantan Province, Indonesia, between 03°27'–03°29' S and 114°45'–114°48' E, approximately 35 km southeast of Banjarmasin. Administratively, the city is bordered by Martapura District, Banjar Regency to the north; Karang Intan District, Banjar Regency to the east; Tanah Laut Regency to the south; and Gambut District, Banjar Regency to the west. The total area of Banjarbaru is approximately 305.15 km², based on official regional statistics issued by the Central Bureau of Statistics (Badan Pusat Statistik/BPS). The city's topography is predominantly flat, with 88.04% of the area characterized by slopes of 0–2%, followed by 2–8% slopes covering 8.10%, slopes of 8–15% accounting for 0.35%, and areas with slopes greater than 15% comprising 3.51% of the total land area. Soil conditions are generally characterized by effective soil depths exceeding 90 cm, which support perennial vegetation growth and facilitate agricultural and land development activities. As the capital city of South Kalimantan Province, Banjarbaru is experiencing increasing administrative and economic pressures that drive accelerated development and spatial expansion within the urban area (BPS Kota Banjarbaru, 2025).

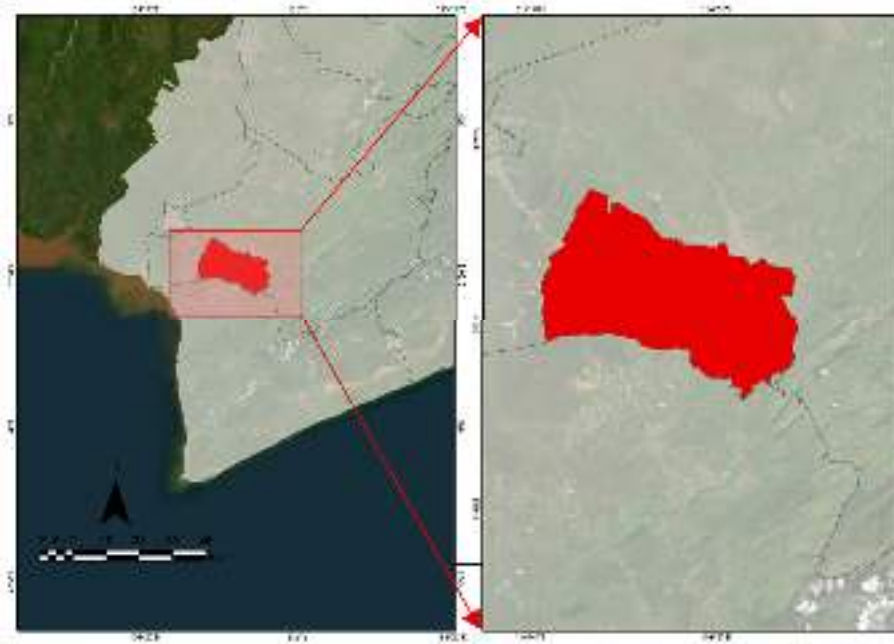


Figure 1. Research Location Map of Banjarbaru City, South Kalimantan, Indonesia

B. Data Collection

This study utilized the GLC_FCS30D land-cover dataset, which provides globally consistent annual land-cover classifications at a 30-meter spatial resolution for the period 1985–2022. The dataset was developed using continuous change detection and full Landsat time-series imagery processed on the Google Earth Engine (GEE) platform, followed by spatiotemporal refinement and temporal-consistency optimization to ensure stability across multi-year classifications. Validation using globally distributed reference samples reports an overall accuracy of approximately 80%, indicating reliable performance for both regional and large-scale analyses. In this study, land-cover layers for the years 2002, 2012, and 2022 were extracted to represent a 20-year temporal interval. Administrative boundary data for Banjarbaru City were obtained from the Indonesian Central Bureau of Statistics (BPS), and all spatial processing, clipping, and visualization operations were conducted in GEE. The selection of GLC_FCS30D was based on its temporal continuity, consistent classification scheme, and suitability for detecting land-cover dynamics in rapidly developing urban environments.

C. Data Processing and Analysis

The GLC_FCS30D dataset is provided as multi-band raster tiles with classification layers stored by year. To ensure compatibility with a temporal analysis workflow in Google Earth Engine (GEE), the dataset was first restructured into an ImageCollection format. The available $5^{\circ} \times 5^{\circ}$ tiles were mosaicked to produce a continuous spatial coverage for the study area. Subsequently, multi-band images corresponding to each temporal interval were separated into individual single-year layers and compiled into a unified ImageCollection. The five-year composite classifications (1985–2000) and the annual classifications (2000–2022) were then merged to form a single continuous temporal sequence. For this study, land-cover data for 2002, 2012, and 2022 were extracted from the ImageCollection to represent a 20-year time interval. To facilitate interpretation and reduce redundancy in the original classification system, the dataset was reclassified into six generalized land-cover classes relevant to the urban ecological context of Banjarbaru. These included: (1) built-up areas, (2) plantation and shrubland vegetation/forest cover, (3) agricultural land, (4) open or bare land, (5) wetland or peatland areas, and (6) water

bodies. The reclassification process was conducted based on spectral, structural, and functional similarity among original land-cover subclasses. All processing steps, including mosaicking, temporal restructuring, clipping to administrative boundaries, and reclassification, were executed within the GEE platform to ensure reproducibility and computational consistency. Although the GLC_FCS30D product has undergone extensive global validation, with reported overall accuracies of approximately 80% based on 84,526 distributed sample points, a localized accuracy check was conducted to ensure classification reliability within the context of Banjarbaru. A total of 180 validation points were generated using a stratified allocation approach (30 points per class across six LULC categories). Each point was cross-checked against high-resolution imagery in Google Earth Pro to assess label consistency. This procedure produced an indicative overall accuracy of approximately 82–85%, with class-wise accuracies generally ranging between 76–88% across the reclassified categories.

3. Result and Discussion

A. Spatial Pattern of Land Use and Land Cover

The results of this study present the spatial and temporal distribution of land use and land cover (LULC) in Banjarbaru for the years 2002, 2012, and 2022, based on the reclassified GLC-FCS30D dataset. The mapped outputs illustrate the extent and configuration of key land cover categories across the city, including built-up areas, plantation and shrubland/forest cover, agricultural land, wetland or peat areas, open or bare land, and water bodies. These maps allow for the observation of spatial patterns, degrees of landscape continuity, and emergent transitions occurring over the twenty-year period. The following subsections describe the LULC conditions for each reference year in detail, focusing on spatial arrangements, dominant land cover distributions, and visible changes in landscape structure across the study area.

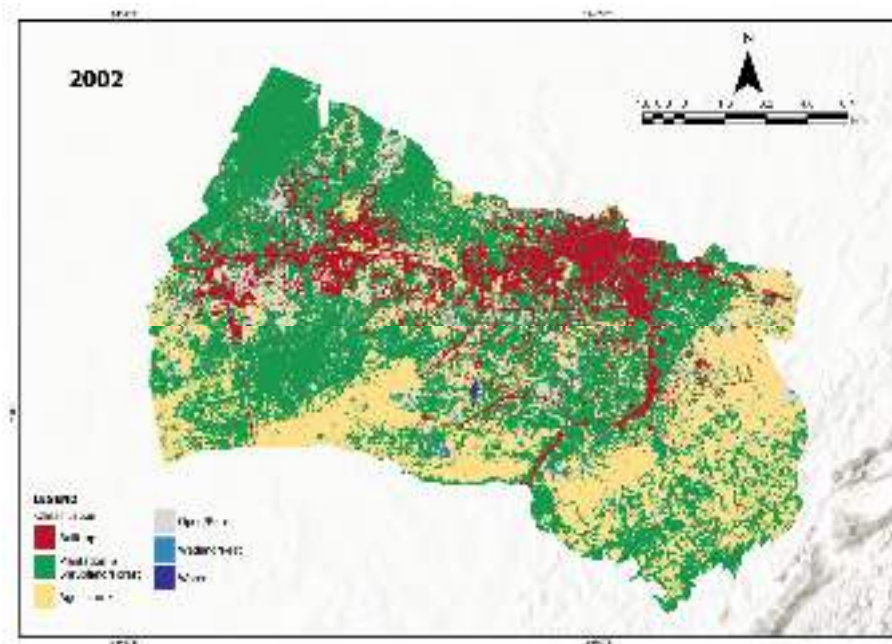


Figure 2. Land Use and Land Cover Map 2002

In 2002, the land use and land cover pattern in Banjarbaru was characterized by the predominance of vegetated areas, including shrubland, plantation zones, and remnant forested patches, which occupied large portions of the southern and southeastern sectors of the city. Built-up areas were concentrated primarily in the central to northern zones, forming a relatively compact urban core

aligned with the primary transportation corridors. Agricultural land was distributed extensively across the southern and eastern parts of the city, indicating that cultivation and agro-based land uses remained spatially dominant outside the urban center. Open or bare land appeared in limited and dispersed clusters, generally associated with transitional areas adjacent to developed zones. Wetland and peatland areas were present as small and scattered patches, reflecting localized hydrological depressions within the landscape. The spatial pattern in 2002 demonstrates a landscape in which urban land cover was still spatially concentrated, vegetated land maintained continuous coverage in the southern extent, and land conversion pressures had not yet resulted in large-scale fragmentation of natural or semi-natural land cover.

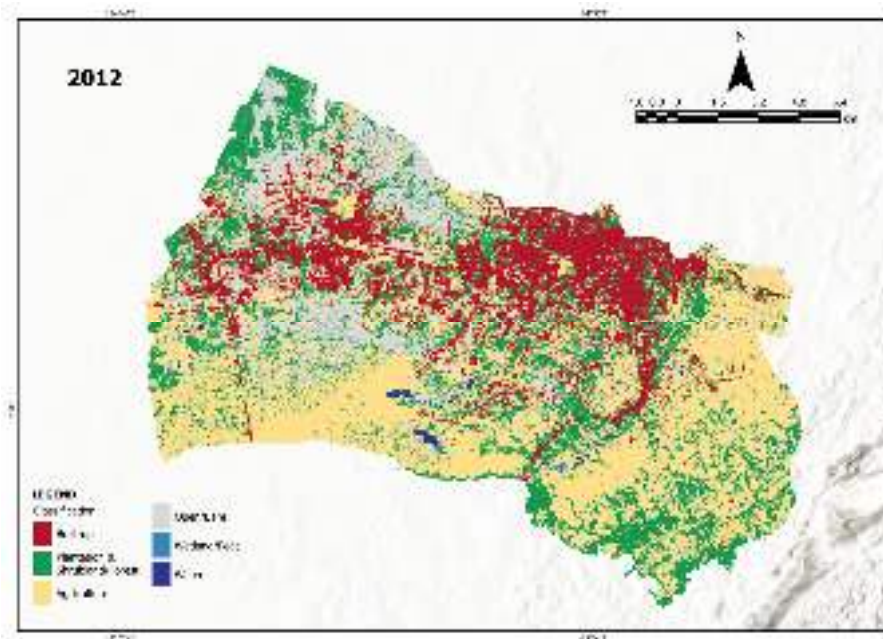


Figure 3. Land Use and Land Cover Map 2012

By 2012, the spatial extent of built-up land had expanded outward from the historical urban core, especially following major road networks spreading toward the western, central, and eastern parts of Banjarbaru. This expansion resulted in a more dispersed and interconnected urban configuration. Vegetated land cover experienced noticeable reductions and fragmentation, particularly in areas adjacent to newly developed built-up zones, indicating a shift toward a more heterogeneous landscape composition. Agricultural areas were increasingly displaced toward the southeastern and peripheral zones, reflecting a narrowing spatial distribution compared to 2002. The extent of open and bare land increased substantially, forming larger continuous patches that appeared to represent transitional phases between land clearing and subsequent development. Wetland and peatland areas became further fragmented, with several patches appearing more isolated from surrounding vegetation cover. The 2012 land cover map shows a transition from a compact urban form to a more spatially dispersed development pattern, with significant structural reorganization of vegetated and agricultural landscapes into mixed mosaics of built-up, open, and transitional land covers.

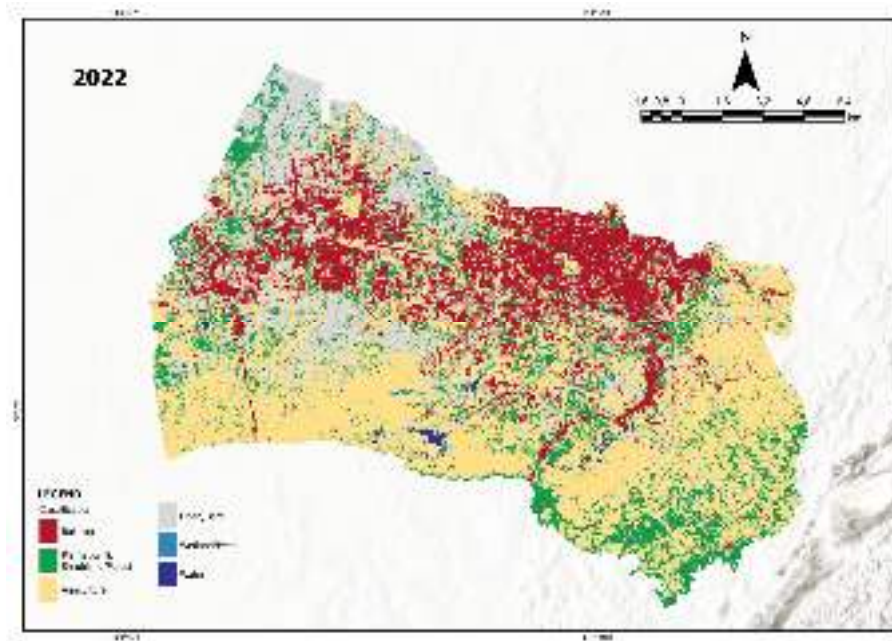


Figure 4. Land Use and Land Cover Map 2022

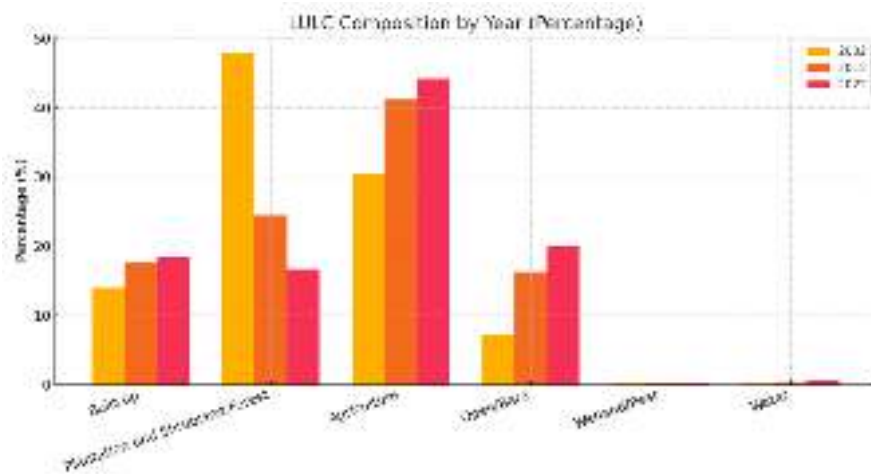
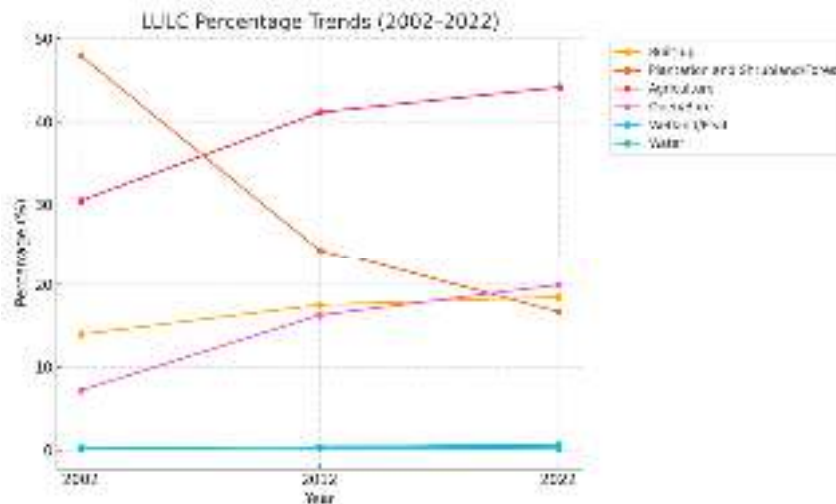
In 2022, built-up areas formed extensive and contiguous zones across the northern to central parts of Banjarbaru, indicating the establishment of a continuous urban fabric. The distribution of vegetated land was substantially reduced in the central region and persisted mainly in the southern and southeastern zones, where remaining plantations and shrubland were concentrated. Agricultural land experienced further spatial displacement toward the urban periphery, with its distribution becoming more constrained and fragmented compared to earlier periods. Open or bare land displayed wider spatial presence, appearing both at active development fronts and as interspersed patches within expanding urban districts. Wetland and peatland areas remained present but were increasingly isolated, with their spatial continuity diminishing relative to 2002 and 2012. The land cover arrangement in 2022 reflects a landscape dominated by consolidated built-up expansion, reduced interior vegetation continuity, and the persistence of natural and semi-natural land covers primarily at the periphery of the urban boundary.

B. Land Use and Land Cover Area Changes

Across the three observation years, the proportion of built-up land in Banjarbaru showed a steady increase from 42.53 km² (13.94%) in 2002 to 53.49 km² (17.53%) in 2012 and further to 56.32 km² (18.46%) in 2022. Plantation and shrubland/forest cover experienced a consistent decline in spatial extent, decreasing from 146.33 km² (47.97%) in 2002 to 74.53 km² (24.43%) in 2012 and subsequently to 50.88 km² (16.68%) in 2022. Agricultural land demonstrated expansion over time, with its area increasing from 93.03 km² (30.49%) in 2002 to 125.53 km² (41.14%) in 2012 and then to 134.70 km² (44.15%) in 2022. Open or bare land also expanded substantially, more than doubling in area from 21.91 km² (7.18%) in 2002 to 49.63 km² (16.27%) in 2012 and reaching 60.88 km² (19.95%) in 2022. Wetland and peatland areas remained the least extensive category throughout the study period, showing small but continuous reductions from 0.94 km² (0.31%) in 2002 to 0.77 km² (0.25%) in 2012 and to 0.52 km² (0.17%) in 2022. Water bodies increased gradually in spatial representation, rising from 0.34 km² (0.11%) in 2002 to 1.15 km² (0.38%) in 2012 and reaching 1.79 km² (0.59%) in 2022.

Table 1. Land Cover Area Changes

LULC	Area (km ²)			Percentage		
	2002	2012	2022	2002	2012	2022
Built-up	42.525	53.493	56.324	13.94	17.53	18.46
Plantation and Shrubland/Forest	146.333	74.529	50.877	47.97	24.43	16.68
Agriculture	93.032	125.525	134.697	30.49	41.14	44.15
Open/Bare	21.911	49.633	60.876	7.18	16.27	19.95
Wetland/Peat	0.944	0.769	0.524	0.31	0.25	0.17
Water	0.335	1.150	1.794	0.11	0.38	0.59

**Figure 5.** Chart of LULC Composition by Year**Figure 6.** Chart of LULC Percentage Trends (2002 – 2022)

When viewed in terms of proportional distribution, plantation and shrubland/forest cover accounted for nearly half of Banjarbaru's total land area in 2002, but its share decreased substantially over the subsequent two decades, becoming a considerably smaller component of the landscape by 2022. Agricultural land progressively became the dominant land cover type, surpassing plantation and shrubland/forest between 2002 and 2012 and reaching the highest

proportional share among all classes in 2022. The built-up land category expanded consistently but remained smaller in absolute proportion than agriculture, though its distribution shifted toward a more continuous spatial configuration by 2022. Open or bare land showed noticeable proportional increases across the three time points, indicating a growing presence of land in transitional or undeveloped conditions. Wetland and peatland areas exhibited a gradual reduction in proportional coverage across all observed years, maintaining minimal representation relative to other classes. Water bodies, while increasing in area, continued to occupy a small share of the overall landscape throughout the study timeframe.

C. Analysis of Spatiotemporal Land Cover Transitions (2002–2022)

The spatial progression of land conversion shown in Figure 2, Figure 3, and Figure 4 illustrates a steady reorganization of Banjarbaru's urban structure during the 2002 to 2022 period. Table 1 records how built-up areas increased from 42.53 km² (13.94%) in 2002 to 56.32 km² (18.46%) in 2022, reflecting a shift in land allocation toward residential and service functions. This expansion corresponds with Banjarbaru's positioning as an administrative and service hub, where improving network connectivity and the growth of commercial activities have influenced land-use decisions. Salbiah and Chandriyanti (2023) note that transportation and warehousing have been major contributors to local GRDP, guiding spatial growth along mobility routes, which aligns with the concentration of new built-up expansions visible in Figure 3 and Figure 4. The rising demand for housing, including subsidized residential development, further accelerates this pattern. Qatrunnada and Maulina (2025) emphasize that pricing structures and credit access significantly shape residential land absorption, which is evident in the gradual outward spread of urban blocks replacing former agricultural and shrub-covered areas. Meanwhile, the shift in the proportion of agricultural land, expanding from 30.49% to 44.15% by 2022, reflects the integration of previously mixed-cover zones and the modification of peri-urban cultivation practices, signaling both physical expansion and functional restructuring at the urban fringe, a pattern commonly associated with dynamic land-use transitions in peri-urban regions where agricultural land interacts intensively with expanding urban systems (Prayoga et al., 2023).

The decline in plantation and shrubland or forest cover, which dropped from 146.33 km² (47.97%) in 2002 to 50.88 km² (16.68%) in 2022 as listed in Table 1, corresponds with the fragmented vegetation patterns visible in Figure 3 and Figure 4. Vegetated areas appear more isolated in the southern parts of the city, indicating a weakened continuity of green space. This aligns with the challenges identified by Forasidah (2021), who highlights how competing interests between private land ownership and municipal planning limit efforts to preserve green open space. On a broader environmental scale, the loss of continuous vegetation cover has implications for carbon storage. Zhu et al. (2022) demonstrate that land conversion toward built-up surfaces reduces carbon sequestration capacity, and that restoring such ecosystems is often difficult in the short term. The spatial patterns in Figure 3 reflect this transition clearly, as vegetation no longer forms integrated ecological systems but instead remains as scattered peripheral patches, altering their functional role from ecological regulators to residual landscape units.

From an environmental standpoint, the substantial reduction in vegetation cover has direct implications for ecological stability and the biophysical functioning of the city. Shahfahad et al. (2022) highlight that the conversion of vegetated land into built-up surfaces is closely associated with heightened Urban Heat Island (UHI) intensity and declining thermal comfort, a phenomenon that is particularly relevant for Banjarbaru, where both Table 1 and Figure 3 indicate a marked decrease in vegetative cover over time. In addition, the reduction in vegetation combined with the expansion of impervious surfaces may lead to decreased infiltration capacity and disrupted groundwater balance, aligning with the findings of Siddik et al. (2022) regarding the influence of LULC changes on groundwater recharge dynamics. The loss of vegetated land also affects carbon storage capacity, consistent with Zhu et al. (2022), who note that transitions from natural land to built-up areas significantly reduce carbon reserves ecosystem. In terms of surface hydrology,

changes in land cover are linked to water quality alterations, as discussed by Brontowiyono et al. (2022), where residential and agricultural activities contribute to increased surface runoff and pollutant loads entering water bodies. Overall, the observed LULC dynamics reflect an intensification of anthropogenic pressures on the city's ecological components, expressed spatially in the mapped patterns and numerically in the class changes documented in Table 1.

4. Conclusion

The observed land use and land cover dynamics in Banjarbaru during the 2002–2022 period indicate a continued reorganization of urban spatial structure, marked by the expansion of built-up areas, the displacement and fragmentation of vegetated and shrubland zones, and the growing presence of transitional open land along development corridors. The consolidation of built-up continuity and the outward relocation of agricultural and ecological land classes correspond to increasing demand associated with transportation infrastructure, housing development, and administrative activities. These spatial shifts coincide with reduced continuity of vegetated surfaces, associated with changes in local environmental regulation functions, surface runoff processes, and ecosystem stability. Several limitations should be acknowledged. The analysis is based on the GLC-FCS30D global land-cover dataset at a 30-m spatial resolution, which may not capture fine-scale urban morphological variation, small vegetation fragments, or short-term land transitions occurring at parcel or neighborhood scales. Classification outputs depend on globally trained algorithms and standardized classification schemes, which may introduce local-level classification uncertainty despite the use of stratified validation points. Temporal representation is also restricted to three observation years (2002, 2012, and 2022), which constrains the detection of intermediate transition phases and short-duration land conversion processes.

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