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SPATIO-TEMPORAL ANALYSIS OF LAND COVER CHANGE (1990–2021) AND ITS IMPLICATIONS ON HYDROLOGICAL RISK IN THE CENTRAL CILIWUNG WATERSHED (DEPOK–SOUTH JAKARTA)

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ABSTRACT

The Central Ciliwung Watershed represents a strategic hydrological transition zone between upstream and downstream Jakarta that has experienced rapid urban transformation over the past three decades. This study analyzes spatio-temporal land cover change from 1990 to 2021 and evaluates its implications for hydrological risk. Multi-temporal Landsat Collection 2 Level-2 imagery (30 m spatial resolution) for 1990, 2000, and 2011 and Sentinel-2 Level-2A imagery (10 m spatial resolution) for 2021 were processed. Sentinel-2 imagery was resampled to 30 m to ensure spatial consistency. Atmospheric correction and cloud masking were applied using QA bands and Scene Classification Layer (SCL). Supervised classification with the Random Forest algorithm produced an overall accuracy of 87.6% and a Kappa coefficient of 0.84. Built-up land expanded from 8,240.24 ha (23.9%) in 1990 to 29,258.90 ha (86.3%) in 2021, while agricultural and vegetated areas declined substantially. Increasing impervious surfaces reduce infiltration capacity and elevate runoff coefficients, potentially intensifying peak discharge. These findings highlight the importance of integrated watershed-scale planning and infiltration-based urban drainage strategies.

Keywords: *Land Cover Change, Hydrological Risk, GIS, Random Forest, Ciliwung Watershed*

1. INTRODUCTION

The Ciliwung Watershed plays a critical role in maintaining hydrological balance in the Greater Jakarta Metropolitan Area and is widely recognized as one of the most flood-prone river basins in Indonesia (Rahayu et al., 2024). The watershed's cross-administrative nature complicates coordinated flood risk management between upstream and downstream regions. Rapid urban expansion in the Depok–South Jakarta corridor has intensified land cover transformation over the last three decades, significantly altering watershed characteristics.

Land cover conversion from vegetated and agricultural land to built-up areas increases impervious surfaces and reduces soil infiltration capacity, thereby modifying runoff generation processes (Hudalah et al., 2024). Previous research confirms that land conversion in the Ciliwung Basin contributes to increased peak discharge and flood volume (Farid et al., 2022). However, most studies emphasize hydrological modeling rather than long-term structural land cover transformation analysis.

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The 30-year period from 1990 to 2021 represents the most intensive phase of peri-urban expansion in the Jakarta–Depok fringe. A multi-decadal assessment is therefore essential to capture cumulative spatial transformation and its hydrological implications. This study quantifies land cover change and evaluates its contribution to hydrological risk in the Central Ciliwung Watershed.

2. RESEARCH METHODOLOGY

This research was conducted in the Central Ciliwung Watershed, encompassing Depok City and South Jakarta Administrative City. The study area represents a transitional hydrological zone influencing downstream flood dynamics.

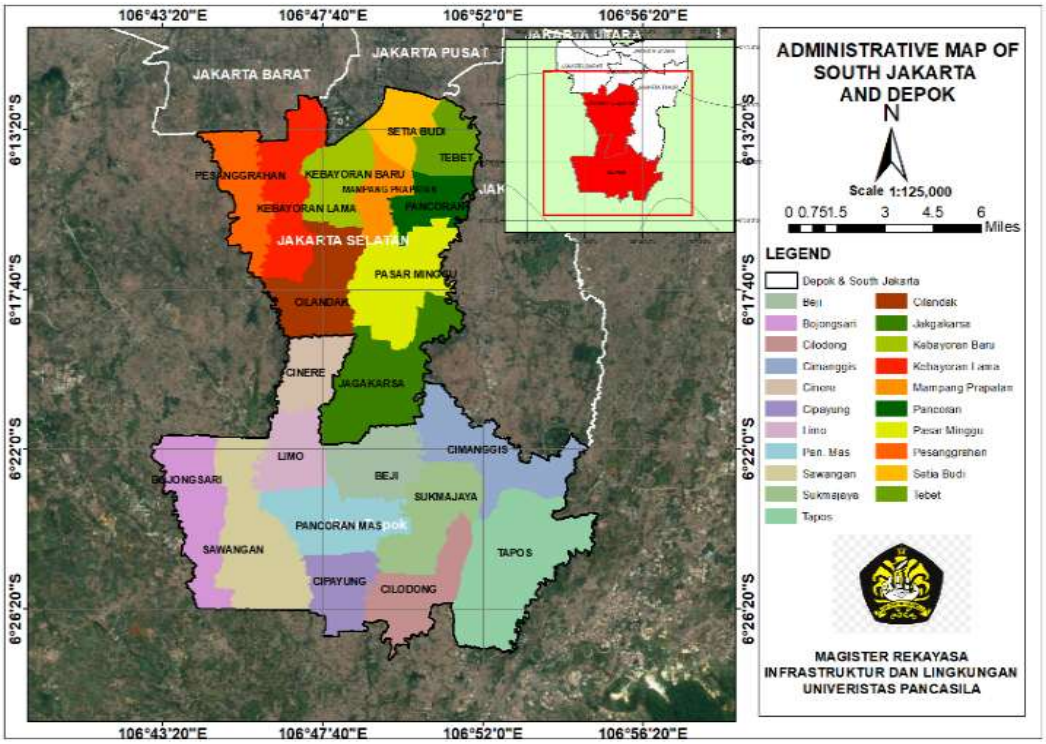

Figure 2.1 Research location of the central Ciliwung watershed (Depok City-South Jakarta)

Source: Ina-Geoportal or BIG (watershed and administrative boundaries) and USGS and Copernicus (satellite imagery), processed by the author

Multi-temporal satellite imagery was used for the years 1990, 2000, 2011, and 2021. Landsat Collection 2 Level-2 imagery (30 m resolution) was used for 1990–2011, while Sentinel-2 Level-2A imagery (10 m resolution) was used for 2021. To maintain comparability, Sentinel-2 imagery was resampled to 30 m using bilinear interpolation. All imagery products were atmospherically corrected to surface reflectance level. Cloud masking was conducted using the QA_PIXEL band for Landsat and Scene Classification Layer (SCL) for Sentinel-2 imagery.

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Supervised classification was performed using the Random Forest algorithm due to its robustness in heterogeneous peri-urban landscapes. Five land cover classes were defined: built-up area, dryland agriculture, mixed vegetation, open land, and water bodies. Accuracy assessment was conducted using 150 stratified random validation points derived from high-resolution imagery and visual interpretation. The classification produced an overall accuracy of 87.6% and a Kappa coefficient of 0.84.

Post-classification comparison was applied to quantify land cover changes across time periods.

3. ANALYSIS AND DISCUSSION

Land cover maps for 1990, 2000, 2011, and 2021 illustrate progressive urban expansion across the watershed.

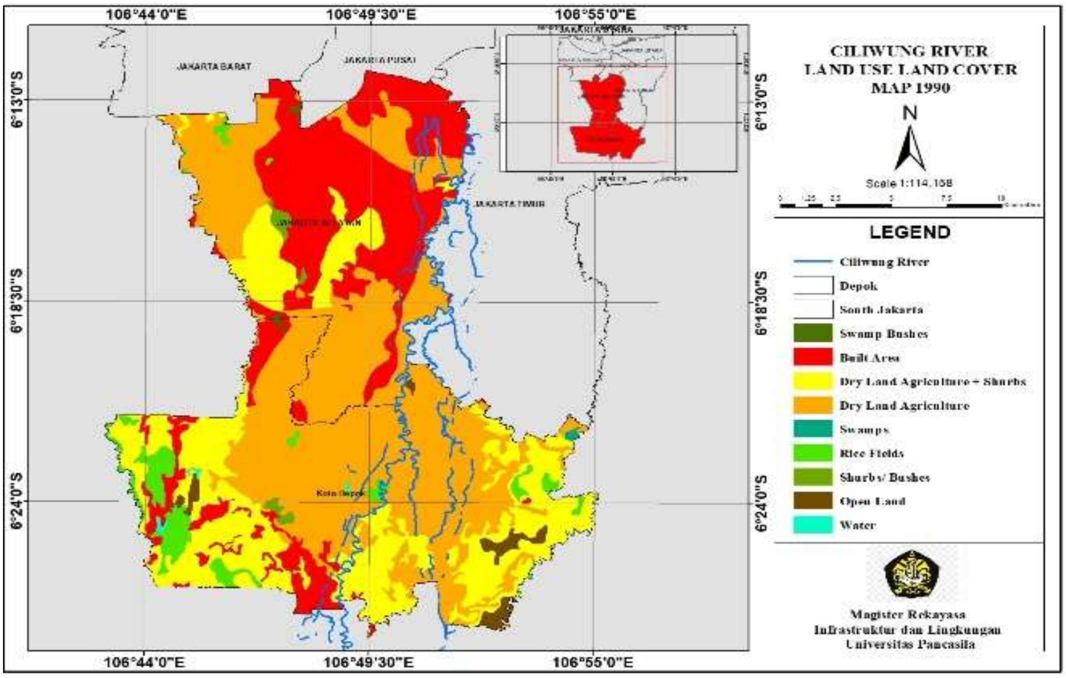

Figure 3.1 Land use map of the central Ciliwung watershed in 1990

Source: Ina-Geoportal or BIG and USGS Earth Explorer, processed by the author

Figure 3.1 presents the land cover distribution in 1990, when the watershed was still dominated by dryland agriculture and mixed vegetation. Built-up areas were spatially concentrated in limited clusters, primarily near administrative and transportation centers. The relatively low proportion of impervious surfaces during this period suggests higher infiltration capacity and stronger natural buffering functions within the watershed system.

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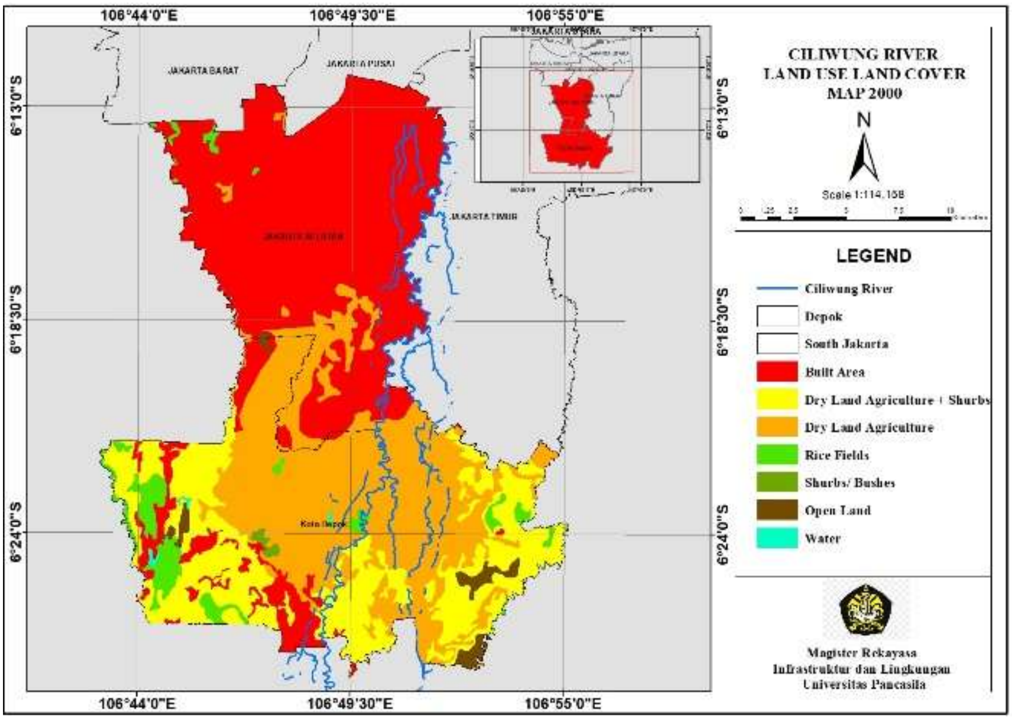

Figure 3.2 Land use map of the central Ciliwung watershed in 2000

Source: Ina-Geoportal or BIG and USGS Earth Explorer, processed by the author

Figure 3.2 shows noticeable expansion of built-up areas by 2000, particularly along transportation corridors and urban fringes. Agricultural land began to fragment, indicating early stages of peri-urban transformation. The spatial pattern reflects corridor-driven development, which gradually altered land surface characteristics and reduced vegetative cover continuity. This transition marks the beginning of structural watershed modification.

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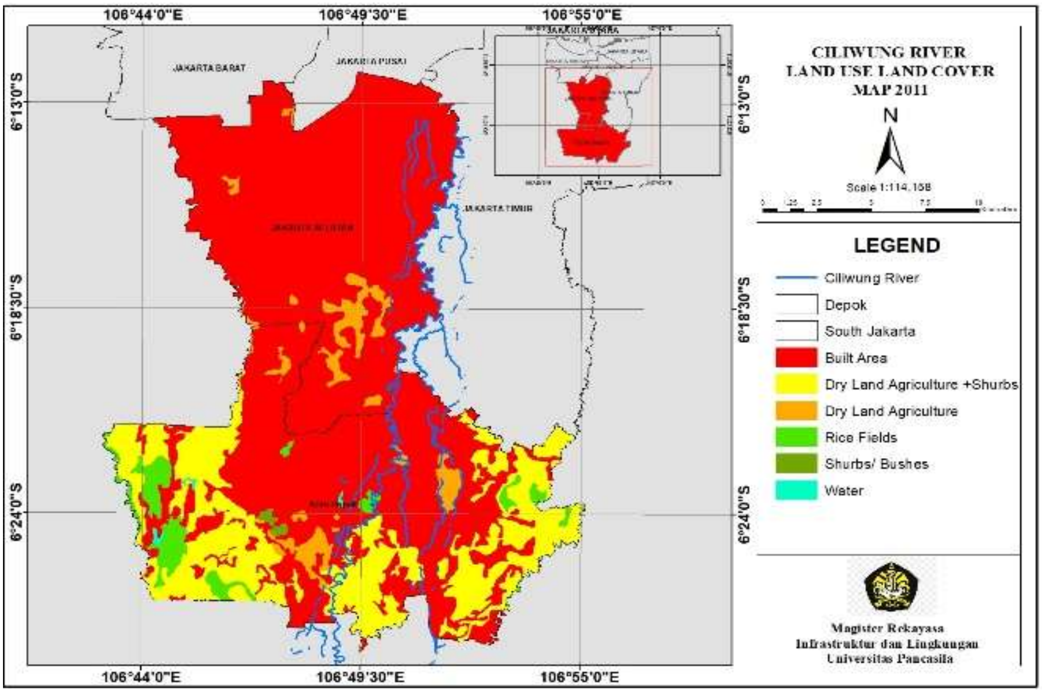

Figure 3.3 Land use map of the central Ciliwung River Basin in 2011

Source: Ina-Geoportal or BIG and USGS Earth Explorer, processed by the author

As shown in Figure 3.3, urban expansion accelerated significantly by 2011. Built-up areas expanded outward from previously established urban cores, replacing dryland agriculture and mixed vegetation. The increasing spatial dominance of impervious surfaces suggests a substantial shift in land surface hydrological response. The reduction of vegetated cover likely decreased interception capacity and increased direct surface runoff generation.

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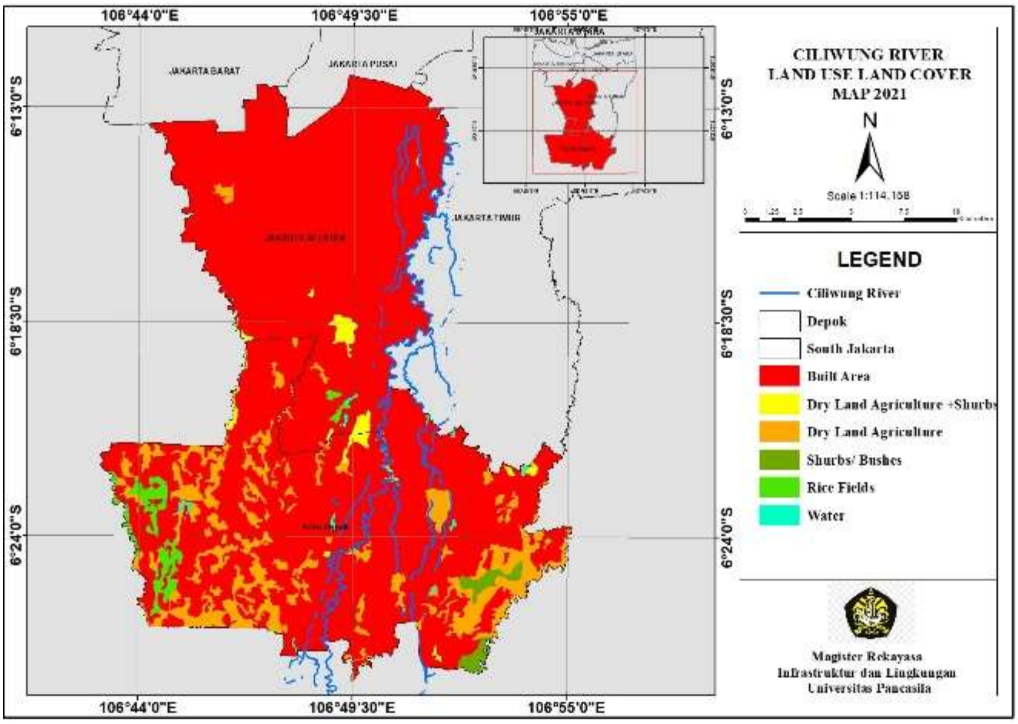

Figure 3.4 Land use map of the central Ciliwung watershed in 2021

Source: Ina-Geoportal or BIG and USGS Earth Explorer, processed by the author

Figure 3.4 demonstrates the dominance of built-up land in 2021, covering the majority of the watershed area. Agricultural land appears highly fragmented and substantially reduced compared to earlier years. The spatial continuity of urban surfaces indicates intensified land sealing, which significantly alters infiltration dynamics. This condition reflects advanced urban consolidation within the watershed.

The analysis reveals substantial transformation during the 1990–2021 period. Built-up land expanded from 8,240.24 ha (23.9%) in 1990 to 29,258.90 ha (86.3%) in 2021, while dryland agriculture and mixed vegetation declined significantly. Spatially, expansion was concentrated in northern Depok and along the Jagakarsa–Pasar Minggu corridor, reflecting corridor-driven metropolitan growth.

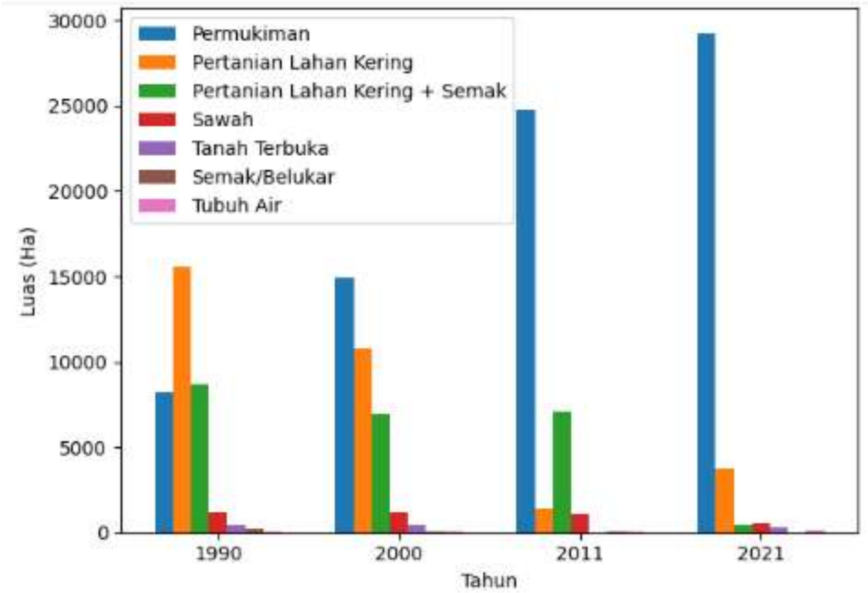

Figure 3.5 Land use area in 1990, 2000, 2011, and 2021.
Source: Processed by the author, 2025.

The dominance of built-up land increases impervious surface ratios, which directly influence hydrological response. Based on the Rational Method (Q = C i A), increasing impervious area raises the runoff coefficient (C), resulting in higher peak discharge and shorter concentration time. Reduced vegetation also decreases interception and soil storage capacity, weakening natural watershed buffering functions. These structural changes confirm that land cover transformation significantly contributes to hydrological risk intensification in the Central Ciliwung Watershed.

4. CONCLUSION AND SUGGESTIONS

The Central Ciliwung Watershed has undergone substantial structural transformation over the past three decades. Built-up land expansion has fundamentally altered watershed characteristics, reducing infiltration capacity and increasing runoff potential. The cumulative effect of impervious surface growth contributes to elevated peak discharge and heightened flood risk.

Strengthened land conversion control, protection of green open spaces, infiltration-based urban drainage implementation, and integrated watershed-scale spatial planning are essential to mitigate hydrological risk. Long-term land cover monitoring should be incorporated into urban watershed management strategies to ensure sustainable flood mitigation in the Ciliwung Basin.

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