EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology, 2025, 26(12), 250–262
https://doi.org/10.12912/27197050/214267
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Received: 2025.10.20
Accepted: 2025.11.15
Published: 2025.12.01

Land use dynamics in urban and rural areas of East Java (2015–2025)

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ABSTRACT

Land use land cover (LULC) changes analysis is important for understanding the dynamics of urbanization and rural transformation that determine the direction of sustainable regional development. This study analyzes changes in the LULC in East Java Province by comparing two maps resulting from the classification of Sentinel-2 imagery in 2015 and 2025. The images were processed using the Random Forest algorithm using Google Earth Engine (GEE) to generate LULC maps and then integrated with demographic data to understand the relationship between spatial dynamics and population pressure. A total of 518 training samples were interpreted using collected ground control point (GCP) data, Google Earth Pro, and GEE satellite basemaps. The collected training samples were divided into 70% training data and 30% validation data. Eight classes of LULC types were identified, including built-up areas (BU), heterogeneous agricultural land (HAL), bare soil (BS), rice fields (PF), open water (OW), vegetation (VG), shrubs (SH), and wetlands (WL). The analysis results show that in urban areas such as Surabaya, the built-up area has increased by +7.78%, while rice fields have decreased by 5.75% in the last ten years. Conversely, in rural areas such as Jember, rice fields have increased by +2.56%, while forest cover has decreased by 5.19% due to conversion to agricultural land and plantations. These findings emphasize the contrasting dynamics between urban expansion and rural transformation that affect the spatial structure and environmental balance in East Java.

Keywords: East Java, Google Earth Engine, LULC change, rural, urban.

INTRODUCTION

LULC mapping is an important subject that has been widely explored by many researchers. LULC mapping plays an important role, i.e, for spatial planning, environmental change monitoring, natural resource management, disaster mitigation and adaptation (Gashu and Gebre-Egziabher, 2018; Hu et al., 2019; Shih et al., 2025). LULC changes analysis is crucial in managing rural-urban dynamics in the face of population growth pressures (Gaur and Singh, 2023).

East Java Province is the second-largest contributor to the Indonesian economy (BPS, 2025). Over the past few decades, the province has experienced increasing spatial pressure due to population growth, industrialization, and accelerated urbanization. This transformation has triggered a shift in land use from productive agriculture to residential, industrial, and urban areas leading to extensive urban sprawl (Kamran et al., 2023). LULC chages reduce soil productivity, threaten food security, increase surface temperatures, and reduce carbon storage. These conditions underscore the need for careful and sustainable land management. (Sarif et al., 2024). Urbanization in East Java is centered in the Gresik-Bangkalan-Mojokerto-Surabaya-Sidoarjo-Lamongan (Gerbangkertosusila) region (Azim and Priyanto, 2025). Urban development focuses on expanding built-up areas and urban infrastructure. The conversion of agricultural land and green open spaces continues to increase due to weak spatial planning controls. This has led to a reduction in open space in peri-urban areas. While in rural areas, communities are shifting economic activities toward agro-industrial and service sectors (Mandala et al., 2023). This transformation confirms that LULC changes and physical landscape modifications are directly driven by socio-economic dynamics at the regional level.

LULC changes analisys in East Java during 2015–2025 helps us understand the patterns, directions, and impacts of landscape transformation on regional sustainability. This study aims to explore the relationship between urban expansion and rural transformation in East Java province by integrating LULC and demographic change data. These findings are expected to provide a clear and comprehensive picture of spatial dynamics and serve as a guide for policy makers in sustainable and adaptive spatial planning in East Java.

METHOD

Study area and scope

East Java province located in the eastern region of Java Island, Indonesia. The province consist of 29 regencies and 9 cities with total area ±47,075.35 km² (Mandala et al., 2024). East Java was chosen as the object of this study because this province has uniqueness. East Java is one province known as a national food barn, boasting the largest harvested areas, high productivity, and top rice production in Indonesia. The province is recognized as one of the nation's primary food-producing regions, featuring extensive harvested areas, high agricultural productivity, and the highest rice output in Indonesia. East Java also has the third most densely populated city in Indonesia (BPS-Statistics Indonesia, 2025) (Figure 1).

Data and sources of information

Sentinel-2 imagery (2015 and 2025) was obtained from the Copernicus Open Access Hub. The image data is then processed using the Google Earth Engine Code Editor. Sentinel-2 imagery has a spatial resolution of 10 × 10 meters and high temporal coverage. (Wuyun et al., 2025). This study uses secondary data from the East Java Statistics Agency (BPS) containing population size and density information. This data supports the analysis of changes in the LULC and its

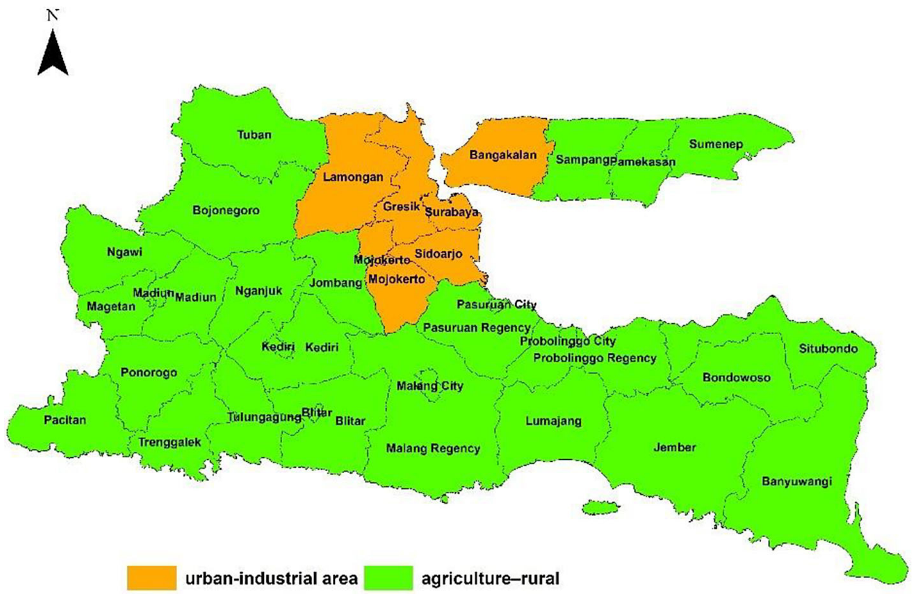


Figure 1. Study area

relationship to socio-economic dynamics, particularly in industrial and agricultural areas (Badan Pusat Statistik Provinsi Jawa Timur, 2024).

Analysis stages

Image processing and LULC classification

The image processing stage in this research begins with the pre-processing of Sentinel-2 imagery, which includes cloud masking and reflectance normalization. This step is performed to improve the quality of the imagery that will be used in the compositing process. The complete workflow is illustrated in Figure 2.

The next stage is the image compositing. The Sentinel-2 surface reflectance (SR) dataset is filtered based on the research date range, the study area boundaries, and a cloud percentage of less than 20%. All images meeting the criteria are then processed using the cloud masking function and merged into a median composite to obtain a more stable spectral representation. This composite is subsequently clipped according to the boundaries of the East Java region.

In the training area preparation stage, all land cover samples are grouped into eight main categories: Built-up (BU), heterogeneous Agri-land (HAL), bare soil (BS), paddy field (PF), open water (OW), vegetation (VG), shrub land (SH), and wetland (WL). Each sample is buffered to generate a representative polygon as the basis for extracting spectral values from ten Sentinel-2 optical bands (B2, B3, B4, B5, B6, B7, B8, B8A, B11, and B12) (Jovanović et al., 2021). The extracted dataset is then randomly split into training data (70%) and validation data (30%).

The model training is performed using the Random Forest algorithm. The trained model is applied to the image composite to generate the classification map. The model's performance is evaluated using the validation data through a confusion matrix, overall accuracy, and the kappa coefficient (Mandala, et al., 2024). Additionally, supplementary evaluation is conducted using the AcaTaMa plugin in QGIS to ensure the consistency and reliability of the accuracy values obtained.

Validation and critical analysis

A total of 518 ground control points (GCPs) were distributed across East Java Province to represent eight land use and land cover (LULC) classes. The GCPs were obtained through visual interpretation of Sentinel-2 imagery in Google Earth Pro and verified through field surveys conducted in 2015–2024. These samples were then interpreted using Google Earth Pro and Google Earth Engine (GEE) satellite basemaps to generate training data for classification. The dataset was divided into 70% for training and 30% for validation, with an accuracy threshold above 85% considered acceptable for spatial change analysis (Zhang et al., 2025).

The model's performance is evaluated using the validation data through a confusion matrix, overall accuracy, and the kappa coefficient. Additionally, supplementary evaluation is conducted using the AcaTaMa plugin in QGIS to ensure the consistency and reliability of the accuracy values obtained. The validation process utilized 518 independent sample points that were excluded from the training phase. These samples were specifically used to generate the Confusion Matrix to quantitatively assess the accuracy of the LULC classification for the 2015 and 2025 base map.

The classification accuracy was quantified using the following key metrics derived from the Confusion Matrix: Overall Accuracy (OA), Producer's Accuracy (PA), User's Accuracy (UA),

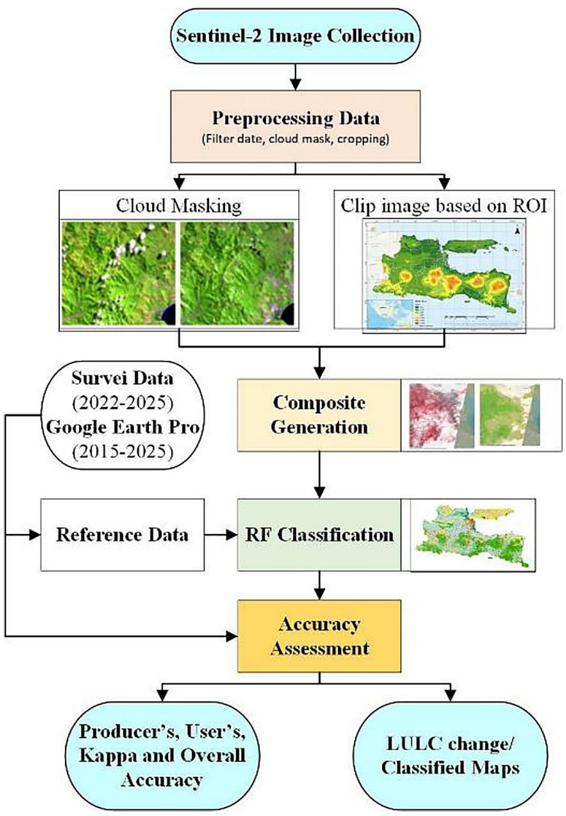


Figure 2. Flowchart of Sentinel-2 image preprocessing and LULC classification process

and the Kappa Coefficient KA (Hou and Hou, 2019). Supplementary evaluation is conducted using the AcaTaMa plugin in QGIS to ensure the consistency and reliability of the accuracy values obtained. The formulae used for calculating these metrics are presented below:

$$User's\ Accuray\ (t) = \frac{Ntt}{N+t} \quad (1)$$

$$Producer's\ Accruracy\ (t) = \frac{Ntt}{Nt+} \quad (2)$$

$$Overall\ Accuracy = \sum_{t=1}^{8} \frac{Ntt}{N} \quad (3)$$

$$Kappa\ Coefficient = \frac{\sum_{t=1}^{8} Ntt - \sum_{t=1}^{8}(Nt + N+t)}{N^2 - \sum_{t=1}^{8}(Nt + N+t)} \quad (4)$$

where: *t* is the LULC type; *Ntt* is the pixel number correctly classified in type *t*; *N+t* is the pixel number of type t in the reference data; *Nt+* is the pixel number of type t in the data that are waiting to be verified; and N is the total pixel number (518).

The entire analysis and classification process was performed using QGIS 3.22 and GEE to ensure efficient and consistent multitemporal satellite imagery processing.

Figure 3 shows the spatial distribution of all GCPs collected across the study area. GCPs and Sentinel-2 image samples were prepared to represent all eight LULC classes in this study. These images were used actively during the supervised training and validation process to improve classification accuracy. The distinct spectral and physical characteristics of each class can be observed in Figure 4, which shows paired GCP and Sentinel-2 images for every LULC type.

RESULTS AND DISCUSSION

Accuracy assessment

Table 1 shows an overall accuracy of 92.64% in 2015 and 91.70% in 2025. With Kappa coefficients of 91.09% and 90.03%. The producer's accuracy (PA) and user's accuracy (UA) ranged from 90% to 93%. These results indicate that the classification method used is robust and capable of producing accurate and consistent LULC maps over time. Based on Table 2, BU class shows high classification accuracy. From the confusion matrix, UA reached 94.29%, obtained from 132 correct pixels out of a total of 140 pixels predicted as BU. PA was 94.96%, calculated from 132 correct pixels out of a total of 139 BU reference pixels. These values indicate that the identification of the BU class was carried out with a very good level of accuracy.

The analysis of AU and AP in Table 2 shows variations in reliability between classes. The OW class has the highest accuracy with an AU of 100%, indicating its highly distinctive spectral characteristics, resulting in almost no misclassification. The BU and VG classes also show high accuracy, each above 94%. The SH class showed the lowest accuracy with AU 86.21% and AP 80.65%. This pattern reflects spectral confusion with the PF and HAL classes and appears in several misclassifications in row 7. The most relevant

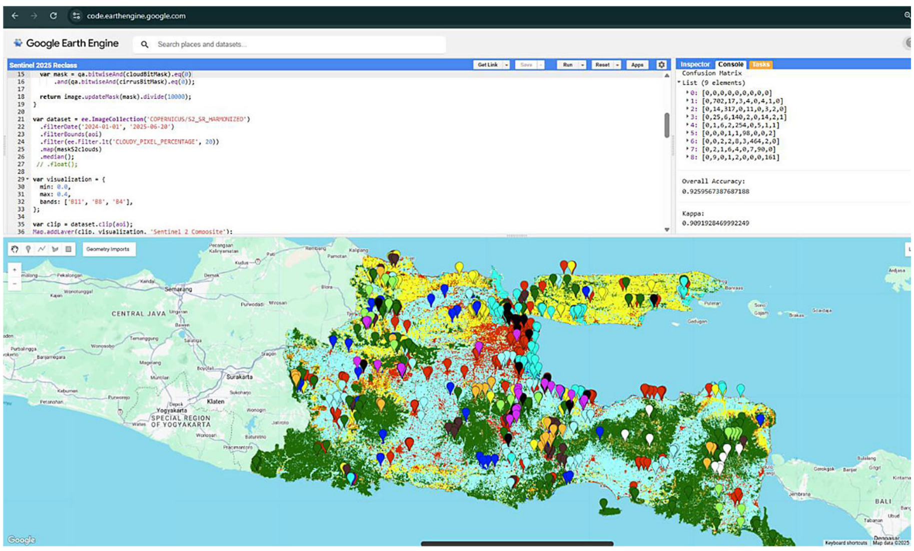


Figure 3. Distribution of GCPs used for LULC classification and validation in East Java

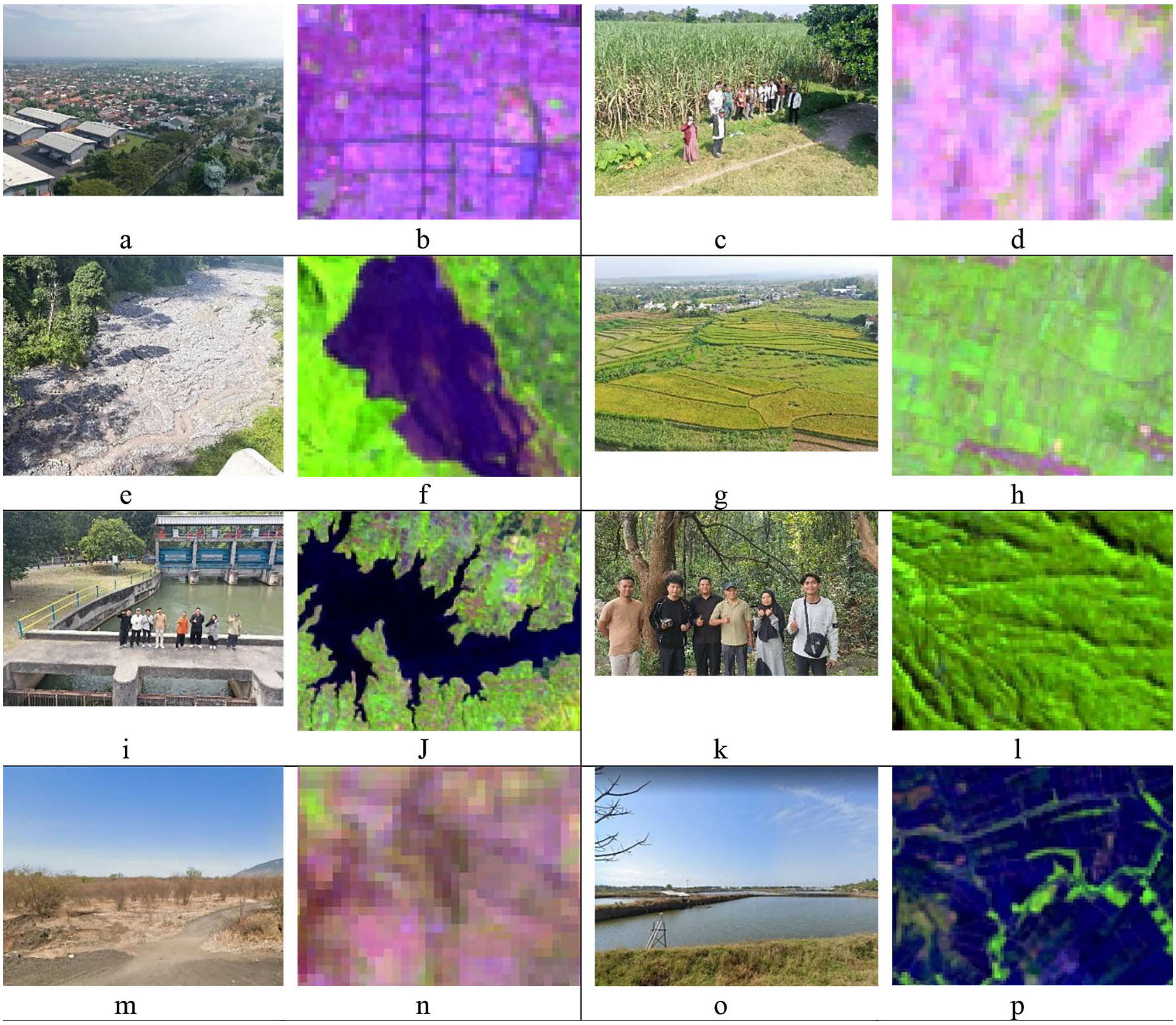


Figure 4. Ground photographs and Sentinel-2 image for each of the eight LULC classes in East Java. Each pair of panels (left: ground photo; right: Sentinel-2 image) represents one LULC class: (a–b) BU, (c–d) HAL, (e–f) BS, (g–h) PF, (i–j) OW, (k–l) VG, (m–n) SH, and (o–p) WL

Table 1. LULC accuracy assessment results

Assessment	Year	Classes								OA	KA
		BU	HAL	BS	PF	OW	VG	SH	WL		
UA (%)	2015	92.93	91.78	100.00	90.60	100.00	94.49	85.33	91.18	92.64	91.09
PA (%)		91.54	92.63	91.46	92.58	100.00	95.71	82.05	100.00		
UA (%)	2025	93.69	92.92	88.93	96.21	95.19	97.66	86.49	96.70	93.45	93.80
PA (%)		85.67	93.10	100.00	97.19	97.00	98.90	83.17	95.37		

Note: UA (user's accuracy), PA (producer's accuracy), OA (overall accuracy), KA (Kappa accuracy).

classes for analyzing urbanization dynamics (BU and HAL) demonstrated accuracy values above 89%. Thus, the error rate is acceptable and does not impact the validity of land use change interpretations in East Java. The minimum KA and OA values have exceed the minimum image accuracy criterion of 80% (Selmy et al., 2023).

Classification results

Figure 2. show the LULC classification for both years 2015 and 2025. The analysis identified eight major LULC classes, i.e, built-up area (BU), heterogeneous agricultural land (HAL), bare soil (BS), paddy field (PF), open water (OW),

Table 2. Confusion matrix of LULC Accuracy in 2025

Parameter	BU	HAL	BS	PF	OW	VG	SH	WL	Row	PA
BU	132	3	4	0	0	0	1	0	140	94.29
HAL	2	65	1	3	0	1	1	0	73	89.04
BS	3	2	43	0	0	3	0	0	51	84.31
PF	0	0	0	43	0	1	1	0	45	95.56
OW	0	0	0	0	31	0	0	3	34	91.18
VG	1	1	0	3	0	104	1	0	110	94.55
SH	1	1	0	3	0	1	25	0	31	80.65
WL	0	0	1	1	0	0	0	32	34	94.12
Column	139	72	49	53	31	110	29	35	518	518
UA	94.96	90.28	87.76	81.13	100.00	94.55	86.21	91.43		
OA	0.92	91.70								
KA	0.90	90.03								

vegetation (VG), shrubland (SH), and wetland (WL). Figure 5 shows that LULC in East Java is generally dominated by PF and VG.

PF class has the largest land area (>40%) of the total land area. Then, VG accounts for around 30%. These findings highlight the dominance of agriculture in the East Java landscape. However, LULC analysis in 2025 indicate a gradual shift toward BU and HAL in several regions.

LULC changes (gains and losses)

Table 3. shows the dynamics of LULC in East Java from 2015 to 2025. The results indicate substantial spatial transformation in several LULC types. PF becomes the most dominant type of LULC in 2015 and 2025. Occupying 18,981.66 km² (40.32%) in 2015 and decreasing to 13,015.25 km² (27.65%) in 2025. This represents

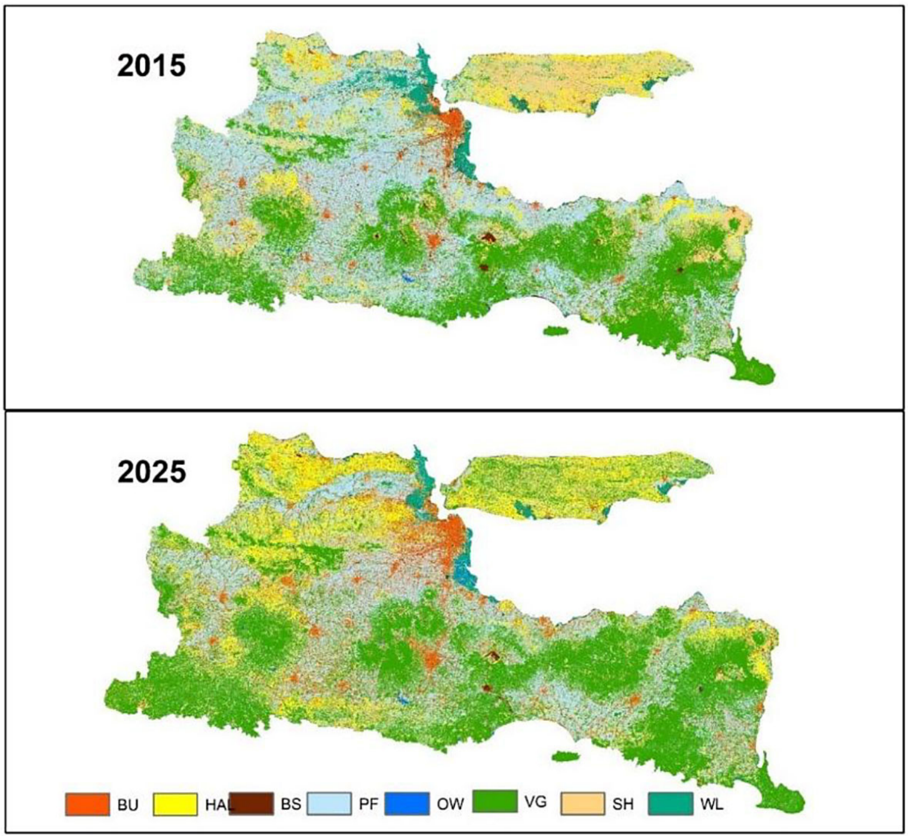


Figure 5. LULC classification of East Java

a net reduction of 8,692.59 km² (-12.67%) in ten years. There was a significant conversion of PF into other land uses, especially BU and HAL in urban areas such as Surabaya.

Table 3 also shows significant expansion in VG and HAL. The VG area increased from 14,930.11 km² (31.72%) in 2015 to 18,227.17 km² (38.72%) in 2025. The total net area increase was 7,136.91 km² (+7.00%). Similarly, HAL increased substantially by 2,147.53 km² (+6.44%). This expansion reflects the intensification of mixed land use systems that combine agricultural and residential components.

The area of BU showed significant growth, from 2,403.84 km² (5.11%) in 2015 to 3,854.79 km² (8.19%) in 2025. The total net increase was 724.35 km² (+3.08%). This pattern indicates a continuous process of urbanization and spatial densification, particularly around large cities and industrial areas.

BS, SH, and WL experienced varying declines over the past ten years. SH decreased by 1,119.80 km² (-3.24%). BS shrank by 336.05 km² (-0.34%). Meanwhile, WL showed a slight decline of 70.08 km² (-0.33%). Meanwhile, OW showed a slight increase of 69.58 km² (+71.74%). The increase in OW is likely related to the expansion of reservoirs, aquaculture ponds, or water infrastructure projects for agriculture.

The spatial-temporal dynamics of LULC changes between 2015 and 2025 (Figure 5) show a dual transformation pattern across the East Java landscape. There is an expansion of BU and a reduction of PF in urban areas driven by population growth and increasing economic activity, especially in industrial and metropolitan areas. On the other hand, regeneration of VG and HAL cover in rural and peri-urban areas. The increase in VG and HAL is related to the implementation of land conservation and rehabilitation initiatives and the utilization of production forests.

The continuous decline in PF area indicates high pressure on agricultural land due to rapid regional development and land conversion processes. Unmanaged urban expansion will impact long-term resilience and challenge sustainable development. Changes in the LULC significantly impact the resilience of socio-ecological systems. Changes in the PF and VG will affect food availability, resources, and the balance between humans and the environment (Mallick et al., 2021). Urban growth and rural transformation create tensions between economic progress and ecological sustainability. According to Ewane (2021), integrating resilience-based land management approaches is crucial to balance regional development with environmental stability.

LULC change in the urbanised and industrial areas

Gresik-Bangkalan-Mojokerto-Surabaya-Sidoarjo-Lamongan (Gerbangkertosusila) have occupied the most urbanized areas in East Java Province. In this region there are around 3.305 medium-large industrial units and more than 68 thousand small industries (BPS-Statistics of Jawa Timur Province, 2025). Surabaya is an industrial center with the highest population density in Gerbangkertosusila. Its rapid economic activity has made it a major center of urbanization in East Java.

Table 4 presents the spatial distribution and changes in LULC in Surabaya between 2015 and 2025. The analysis shows that the built-up area increased from 154.92 km² (46.68%) in 2015 to

Table 3. LULC area of each class

LULC types	2015		2025		Net change	
	km²	%	km²	%	km²	%
BU	2,403.84	5.11	3,854.79	8.19	724.35	3.08
HAL	2,877.62	6.11	5,910.54	12.56	2,147.53	6.44
BS	725.66	1.54	567.56	1.21	-336.05	-0.34
PF	18,981.66	40.32	13,015.25	27.65	-8,692.59	-12.67
OW	144.29	0.31	166.56	0.35	69.58	0.05
VG	14,930.11	31.72	18,227.17	38.72	7,136.91	7.00
SH	6,130.84	13.02	4,607.10	9.79	-1,119.80	-3.24
WL	881.33	1.87	726.38	1.54	70.08	-0.33
Total	47,075.35	100.00	47,075.35	100.00	724.35	3.08

Table 4. LULC Surabaya

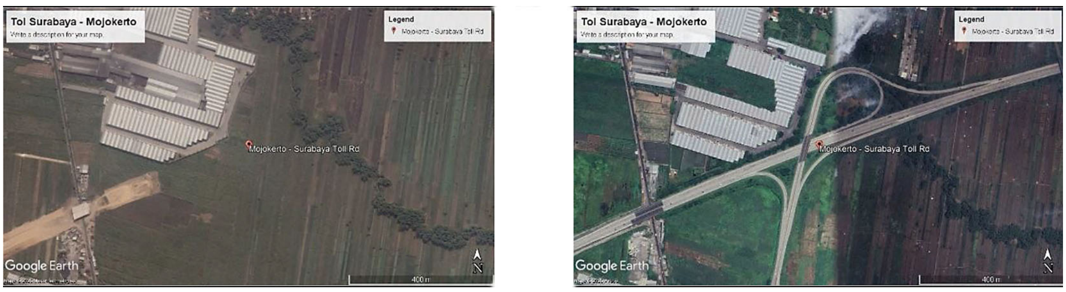
LULC types	2015		2025		Net change	
	km²	%	km²	%	km²	%
BU	108.72	3.23	174.53	5.19	65.81	1.96
HAL	29.26	0.87	123.35	3.67	94.09	2.80
BS	27.87	0.83	20.31	0.60	-7.57	-0.22
PF	884.44	26.29	970.48	28.85	86.04	2.56
OW	6.50	0.19	4.03	0.12	-2.47	-0.07
VG	2014.00	59.86	1839.30	54.67	-174.70	-5.19
SH	288.29	8.57	222.60	6.62	-65.68	-1.95
WL	5.20	0.15	9.68	0.29	4.48	0.13
Total	3,364.2767	100.00	3364.2767	100.00	0.00	0.00

180.73 km² (50.64%) in 2025. The total net increase was 25.81 km² (+7.78%). The transformation of LULC shows a clear trend towards the dominance of BU. This reflects the ongoing urban expansion and spatial densification of the city. This expansion is in line with the city's demographic growth. The population of Surabaya increased from 2,848,583 in 2015 to 2,921,996 in 2025. Population density increased from 8,708.58 in 2015 to 8,933.01 people/km² in 2025. These demographic pressures have increased the demand for residential, industrial, and public infrastructure, which has driven urban expansion throughout the metropolitan area.

Since 2015, Surabaya has experienced significant industrial and infrastructure development. This includes the development of areas in the western region (Benowo and Pakal) and the revitalization of densely populated residential areas in the central and northern regions. Furthermore, large-scale infrastructure projects, such as the Middle East Ring Road, the Surabaya-Mojokerto toll road, and the modernization of Tanjung Perak Port, have strengthened connectivity and encouraged land development in the suburbs. Figure 6 shows the difference in LULC for the Surabaya-Mojokerto toll road area in 2015 and 2025.

In contrast, the area of PF and VG shows a substantial decline. The area of PF decreased from 59.53 km² (17.94%) in 2015 to 40.46 km² (12.19%) in 2025. This represents a decrease of -19.07 km² (5.75%), while VG decreased by 4.21 km² (-1.29%) over the past 10 years. These changes indicate the conversion of agricultural land and green open spaces into residential and industrial areas, particularly in the eastern (Rungkut, Gununganyar) and western (Lakarsantri, Sambikerep) areas of Surabaya. These areas were originally productive agricultural land. This pattern reflects a broader peri-urban transformation driven by rising land prices, infrastructure expansion, and a socio-economic shift away from agriculture (Harlis and Seo, 2024).

The increase in SH by 11.75 km² (3.54%) over the past 10 years indicates the presence of



a b

Figure 6. Google Earth imagery showing the expansion of built-up areas along the Surabaya–Mojokerto Toll Road corridor. (a) 2015: The surrounding area was still dominated by agricultural and open land, (b) 2025: Rapid urban development and industrial expansion are evident, with a significant increase in residential and commercial structures

vacant or transitional areas that have been cleared but not yet developed. These areas can also include reclaimed coastal and industrial land awaiting further use. This type of transition phase is common in areas with high urbanization rates. In such conditions, land use changes often occur more rapidly than formal land use determinations.

The Surabaya's LULC changes between 2015 and 2025 demonstrate a pattern of intensive urbanization (Figure 7). The loss of PF and VG has contributed to increased surface temperatures, reduced groundwater infiltration capacity, and ecological fragmentation. Efforts to mitigate these impacts include establishing a policy of at least 20% Green Open Space, developing city parks, and restoring urban forests. These efforts align with the findings of Lynch (2021), who highlighted the importance of policy standards and riparian zone protection. Both play a role in shaping functional open space configurations and enhancing urban resilience. Similarly, Şenik and Uzun, (2022) emphasize that green open space contributes significantly to urban well-being, population health, and ecosystem services.

Maintaining ecological balance amidst rapid economic growth remains a significant challenge for Surabaya. Changes in Surabaya's LULC demonstrate the complex interactions between population pressures, development policies, and environmental carrying capacity. Moving forward, spatial management needs to prioritize adaptive and data-driven planning by integrating sustainable land use zoning, green infrastructure, and ecological protection. This step is crucial for Surabaya's continued development as a resilient and inclusive metropolitan area.

LULC change in the agricultural-rural area

Jember Regency is a fertile region influenced by young volcanic soil, high rainfall, and the surrounding mountainous topography. Jember is one of the agricultural and plantation development areas in East Java. Most of the area lies at an altitude of 0–100 meters above sea level, with an average annual rainfall of around 1,623 mm. This region produces a variety of agricultural and plantation commodities, including rice, corn, soybeans, sugar cane, chili peppers, citrus fruits, coconuts, coffee, cocoa, and tobacco (BPS-Statistics of Jember Regency, 2025). Table 5. illustrates the spatial and temporal changes in LULC in Jember Regency between 2015 and 2025. The most significant changes are seen in PF, BU and HAL. BU area increased from 108.72 km² (3.23%) in 2015 to 174.53 km² (5.19%) in 2025. The total increase was 65.81 km² (1.96%). This change reflects urbanization and the development of new residential, commercial, and educational areas. HAL area increased significantly by 94.09 km² (2.80%) in the last 10 years. This change indicates a shift towards a rural landscape with productive forest and mixed land uses.

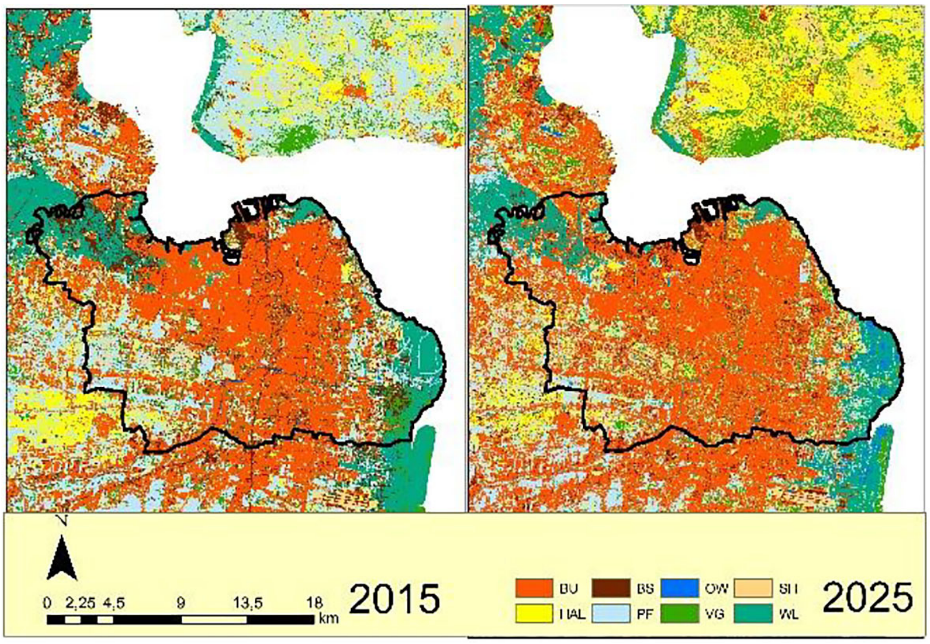


Figure 7. LULC map of Surabaya City for 2015 and 2025

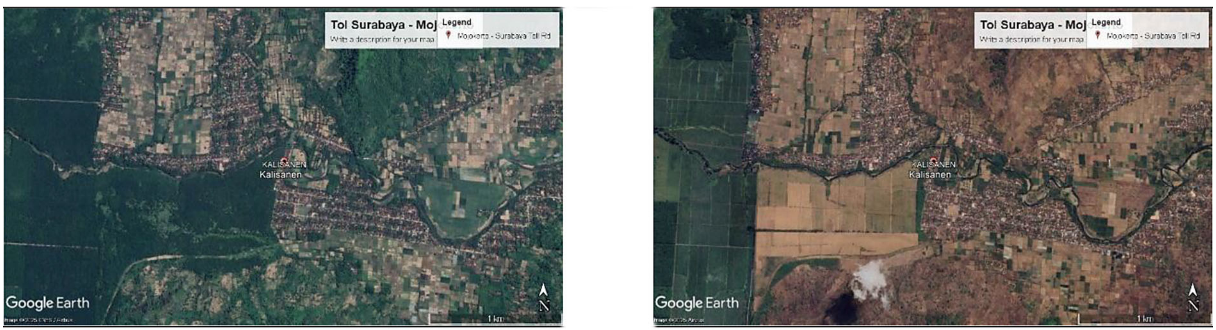
Table 5. LULC Jember

LULC types	2015		2025		Net change	
	km²	%	km²	%	km²	%
BU	154.92	46.68	180.73	50.64	25.81	7.78
HAL	15.14	4.56	18.16	3.02	3.03	0.91
BS	39.44	11.89	21.62	9.65	-17.83	-5.37
PF	59.53	17.94	40.46	23.09	-19.07	-5.75
OW	1.17	0.35	3.43	0.03	2.26	0.68
VG	21.95	6.61	17.74	1.04	-4.21	-1.27
SH	5.84	1.76	17.59	4.52	11.75	3.54
WL	33.88	10.21	32.15	8.01	-1.73	-0.52
Total	331.8747	100.00	331.8747	100.00	0.00	0.00

The PF area also increased slightly, from 884.44 km² (26.29%) in 2015 to 970.48 km² (28.85%) in 2025. The total PF area increased by 86.04 km² (2.56%). This trend indicates that Jember remains one of the agricultural centers in East Java. This is also supported by irrigation development projects such as the spillway on the embankment in 2025. The increase in PF can also be attributed to government initiatives to encourage rural productivity and food security (Firdaus et al., 2022).

On the other hand, VG experienced a significant decline, from 2014.00 km² (59.86%) in 2015 to 1839.30 km² (54.67%) in 2025. The total decline was 174.70 km² (-5.19%). This decline indicates the continued conversion of VG areas to HAL and BU. VG underwent a process of conversion to HAL due to the issuance of new regulations permitting state forests for productive activities such as horticultural crops, agroforestry, or plantations, without changing the forest's primary function (Permen LHK Nomor P.83/MENLHK/SETJEN/KUM.1/10/2016). One area in Jember Regency that experienced extensive land conversion, significantly reducing vegetation cover, was Kalisanen. This contributed to increased surface runoff and frequent flooding. The impact of the conversion from VG to BU was periodic flooding in Kalisanen during the rainy season over the past decade (Rafif et al., 2024). Figure 8 shows the clear transformation of the Kalisanen landscape over the past ten years. In 2015, the area was largely covered by VG, which transformed into HAL in 2025. This transformation process extends to the foothills. The uncontrolled conversion of VG to BU has altered the hydrological balance of the area. Kalisanen has been reported to be affected by flooding in recent years, especially during the rainy season (Rafif et al., 2024).

In contrast, the SH decreased by 65.68 km² (-1.95%) and the BS decreased slightly by 7.57 km² (0.22%) in the last 10 years. These modest land changes indicate land stabilization and a reduction in idle or degraded land. The WL area increased slightly by 4.48 km² (0.13%) in the last 10 years. This increase is likely related to the construction of the spillway irrigation reservoir at Tanggul. Figure 9 shows a moderate level of LULC transformation in Jember Regency, mainly resulting from population growth, agricultural



a b

Figure 8. (a) Google Earth imagery in 2015; (b) Google Earth imagery in 2025

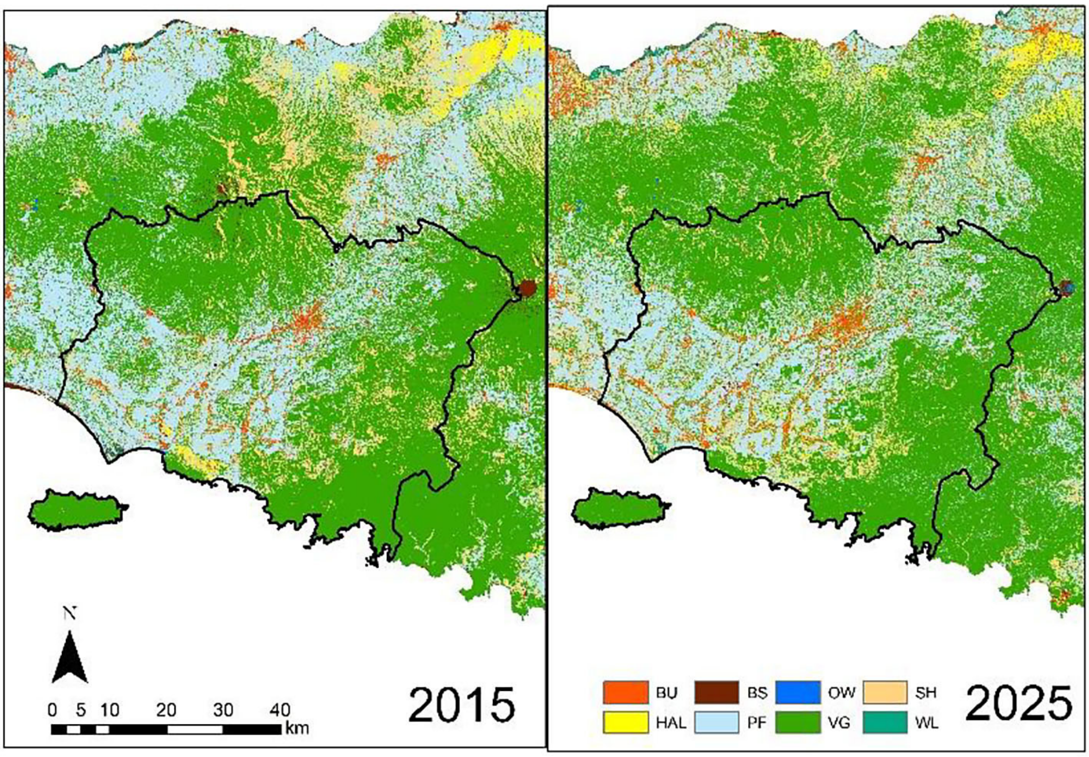


Figure 9. LULC map of Jember City for 2015 and 2025

expansion, and rural development. The transition from VG to HAL and BU occurs gradually, without drastically changing the overall landscape structure. Although the population increased from 2,407,115 in 2015 to 2,603,817 in 2025, this growth did not cause significant landscape shifts. This indicates that land transformation in Jember is relatively stable and controlled. Maintaining a balance between ecological stability and rural economic growth remains a major challenge for regional planners in implementing the Jember Regional Spatial Plan (Rafif et al., 2024).

CONCLUSIONS

BU and HAL in East Java expanded between 2015 and 2025, while PF and VG decreased. Urban areas like Surabaya experienced rapid land conversion driven by population growth and economic activity, while rural areas like Jember showed moderate transformation related to agricultural expansion. Descriptive demographic validation confirmed the relationship between population density and land conversion intensity. These findings provide new evidence on urban-rural land dynamics and support future policies for sustainable spatial planning and agriculture.

Acknowledgements

This work was supported by DRTPM-Kemendikbudristek 2023 using skim Penelitian Fundamental regular lead by Marga Mandala (SK o. 11909/UN25/LT/2025; Contract No. 4555/UN25.3.1/LT/2025)

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