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Assessment of Land Use and Land Cover Change from 2000 to 2019 in East Java Indonesia

Avaliação do Uso da Terra e Mudança da Cobertura do Solo de 2000 a 2019 em Java Oriental, Indonésia

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Abstract

This study aims to analyse land use, and land cover (LULC) changes in East Java province in Indonesia. The changes are analysed by comparing two maps (the national digital map and the map interpreted from Landsat-8). Supervised classification of Landsat image using maximum likelihood algorithm done an overall and kappa accuracy of 96.62% and 96.02 %, respectively. The classification produces nine (9) classes, i.e.: (1) the pavement or urban area, (2) heterogeneous agricultural land, (3) paddy field, (4) open water, (5) dense vegetation (forest), (6) sparse vegetation (plantation), (7) shrubland, (8) Wetlands, and (9) Sandy-clay-rock. Furthermore, three subsets areas are explored to study the LULC changes caused by the development of the transportation infrastructure; industrial sites; the agricultural sector; tourism; urbanisation and sub-urbanisation. The LULC change is more marked in the most urbanised areas (in and around the big cities), followed by LULC change in and around medium cities and rural areas. Regional development during the last two decades has increased built-up and plantation areas. Conversely, the development has reduced paddy fields, rural areas, and water bodies. The LULC changes have significantly changed the natural to a human-dominated landscape.

Keywords: Supervised ; RBI; Landsat-8

Resumo

Este estudo tem como objetivo analisar as mudanças no uso e cobertura da terra na província de Java Oriental, na Indonésia. As mudanças são analisadas comparando dois mapas (o mapa digital nacional e o mapa interpretado do Landsat-8). A classificação supervisionada da imagem Landsat usando o algoritmo de máxima verossimilhança obteve uma precisão geral e índice kappa de 96,62% e 96,02%, respectivamente. A classificação produz nove (9) classes, ou seja: (1) o pavimento ou área urbana, (2) terras agrícolas heterogêneas, (3) arrozais, (4) águas abertas, (5) vegetação densa (floresta), (6) vegetação esparsa (plantação), (7) arbustiva, (8) zonas úmidas e (9) rocha arenosa-argilosa. Além disso, três subáreas são exploradas para estudar as mudanças de uso e cobertura da terra causadas pelo desenvolvimento da infraestrutura de transporte; sítios industriais; o setor agrícola; turismo; urbanização e suburbanização. A mudança do UCT é mais marcada nas áreas mais urbanizadas (nas e em torno das grandes cidades), seguida da mudança do UCT nas e em torno das cidades médias e áreas rurais. O desenvolvimento regional durante as últimas duas décadas aumentou as áreas construídas e de plantio. Por outro lado, o desenvolvimento reduziu os arrozais, as áreas rurais e os corpos d’água. As mudanças do UCT mudaram significativamente a paisagem natural para uma paisagem dominada pelo homem.

Palavras-chave: Supervisionado; RBI; Landsat-8

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1 Introduction

Land use and land cover (LULC) change has become a global and critical issue in our environmental problems. These challenging issues may act as an obstacle to achieving the Millennium Development Goals (MDGs) agendas. At the local level, the LULC change may occur irregularly. However, the real LULC change has visualised the result of the competition of interest amongst stakeholders. This study presents the results of rigorous analysis of LULC change at the level of East Java province. Researchers usually study LULC changes through the investigation of two or more maps produced at different times. Conventional maps and satellite images can be interpreted to study the causal effects of LULC changes and their implications on society and the environment (Ptak & Ławniczak 2012; Nguyen 2020).

Landsat imagery is widely used to study LULC changes and has been published in research reports worldwide. For example, Fonji & Taff (2014) combined current data. Then, Klimanova et al. (2017) analysed the regional trends of land use/land cover transformation in Brazil during 2001—2012 using multiple data inputs. Furthermore, Elias et al. (2019) studied land cover changes (between 1973 and 2017) in Gazipur Sadar, Bangladesh. Many researchers have employed Landsat images to investigate LULC changes in other cases and locations (Mtibaa & Irie 2016; Hassen & Assen, 2018).

Other researchers have studied the relationship between LULC changes and the development of urban areas (Ahmed & Alla 2019; Nguyen 2020). There are many possible major causal-effect of the LULC change, i.e., the rapid development of urbanisation (i.e., urban sprawling, peri-urban migration), industrial development, transportation development, education and cultural activities, agricultural practices and tourism activities. However, the actual change may be caused by the combination of that sectoral development. Generally, the change is more accentuated, more rapid, and easier to capture in urban areas than in rural and natural ecosystems. Urban sprawl has become a popular term to describe LULC changes and their causal effects, such as the development of transportation networks, industrial sites, sub-urbanisation, and tourism (Łucka 2018; Ahmed & Alla 2019). The sprawl has to attract the interest of many researchers from all over the world. This urban sprawl and the causal effects related to LULC changes may occur in this study area.

Other researchers study the causal effect of LULC change related to the natural conservation area to achieve the natural ecosystem's sustainability (Dastgerdi et al. 2019; Klyuev 2019). Also, LULC change is related to the management of forested areas and the causal effect of the change in agricultural policy (Mangmeechai 2020).

The specific objective of the study is to describe the significant LULC change during the last two decades and to study the causal effect and primary driver of change on these regions. This paper investigates how LULC has changed during the last two decades (from 2000 to 2019) in East Java. East Java is the third province that is more developed and more urbanised in Indonesia. The population increased from 34 million in 2000 to more than 39 million people in the year 2019. Therefore, between 2000 and 2019, an increase in population numbers of 16.76% (+5.6M population) in East Java (BPS Jawa Timur 2017).

The increase in population demands more built-up areas for residences, public facilities, and city services. In adverse, the increase will be balanced by the decrease of other land occupations. Therefore, the demography dynamics (increasing and decreasing population) will change the natural ecosystem to more human-induced ones. This change may occur in a more extended area and longer time. The satellite imagery provides more information to track change and explain what, why and how the interaction of this phenomenon. The changes were interpreted by comparing two maps: the first map clip from a national digital map dated in 2000; and the second from Landsat-8 captured from 2015 to 2019.

2 Methodology and Data

2.1 Study Site and Input Data

The study was conducted in the East Java province (Figure 1), covering 47075.35 km^2. Primary input data were Landsat-8 OLI/TIRS images of the study area, selected based on minimum cloud cover present. The images were downloaded from the USGS website (USGS 2018). Table 1 shows the metadata related to the raw images used in the study. The images in Figure 1, were categorised as TIER 1 and the processing level L1TP (USGS 2019). The images were corrected using training areas and the Digital Elevation Model (DEM).

The other map was downloaded from the Indonesian Geospatial Agency *(Badan Informasi Geospatial, or BIG)* through its official website (BIG 2018). The National Digital Map Layer, *RBI (Rupa Bumi Indonesia),* produced in 2000, was employed to compare the classification results. The Landsat-8 imagery was captured from 2015 to 2019. All of the images and data were projected into WGS84 and UTM Zone 49S coordinate reference system. In practice, it is challenging to obtain Landsat imagery of this region with little or no cloud cover.

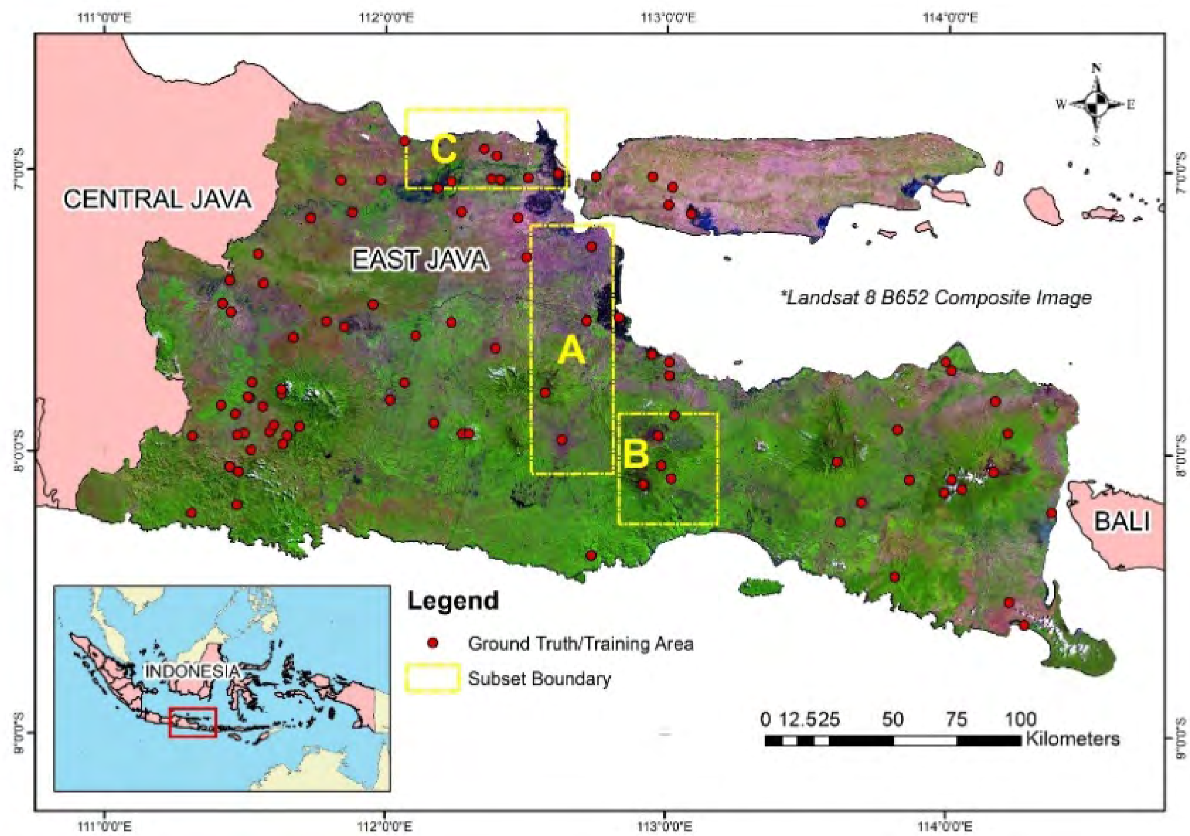

Figure 1 Study site - Raw Landsat-8, collected training areas and subset areas.

Table 1 Raw metadata.

Date Acquired	Path / Rows	Cloud Cover (%)	Land Cloud Cover (%)
06/11/2016	117/65	5.72	9.62
16/11/2015	117/66	4.34	5.46
10/01/2019	118/65	9.24	0.49
06/05/2017	118/66	3.46	1.07
07/01/2018	119/65	0.26	0.33
07/01/2018	119/66	11.29	0.42

2.2 Procedure

Image treatment is performed with MultiSpec (Landgrebe & Biehl 2018)), open-source software for image processing tasks. The image treatment procedure consisted of atmospheric correction and pan-sharpening, composite and clip, creating training area and supervised classification, accuracy assessment, post-processing, creating a land cover map, clip with polygon boundary and comparing , as shown in Figure 2.

The Semi-Automatic Classification Plugin (SCP) (Congedo 2017), available in QGIS (QGIS Development Team 2019), was used to process atmospheric correction using the DOS (Dark Object Subtraction) and Pan-sharpening algorithm.

Six Landsat-8 bands (2, 3, 4, 5, 6 and 7) were used to make a composite image. The images were then visualised using three bands (6, 5, and 2). LULC classes were created following the national standard, or SNI 7645:2014 (BSN 2014). The classification process followed the standard image treatment of Multispec (Landgrebe 2015). In this case, we use maximum likelihood algorithms to classify pixels. Supervised classification was processed with the aid of 90 training areas.

The area extent on two maps compared to interpret the change. The subset areas (i.e. the areas in yellow dotted rectangles A, B, C in Figure 1) were used to track change and discuss the importance of LULC changes, which represent the significant ones that have had a local effect on the region.

Subset A represents LULC changes related to the most urbanised area propagated complex urban and peri-urban migration phenomenon. Also, the track of change propagated by industrial, transportation, and tourism development. Subset B visualised the change that may occur in a more natural ecosystem. The area represents the natural conservation area managed by a national agent in conservation service *(TNBTS = Taman Nasional Bromo Tengger Semeru*). Moreover, Subset C observed the change that may occur in rural areas along with the coastal areas. The area is covered mainly by agricultural activities and coastal (fisheries) related activities. Finally, the LULC created from Landsat-8 is then compared to the RBI map.

The changes are assessed by comparing LULC change (in % and area km^2) between the two maps. The RBI map represented the LULC in 2000, while the Landsat map represented the LULC from 2015 to 2019. The area extent on two maps compared to interpret the change. This study uses nine (9) classes of land cover features (Table 2) to describe the land use and land cover. It is noted that some areas in the tropic (for example, in mountainous areas) are subject to permanent cloud coverage. Therefore, we still use the "cloud cover" class to obtain better classification processes.

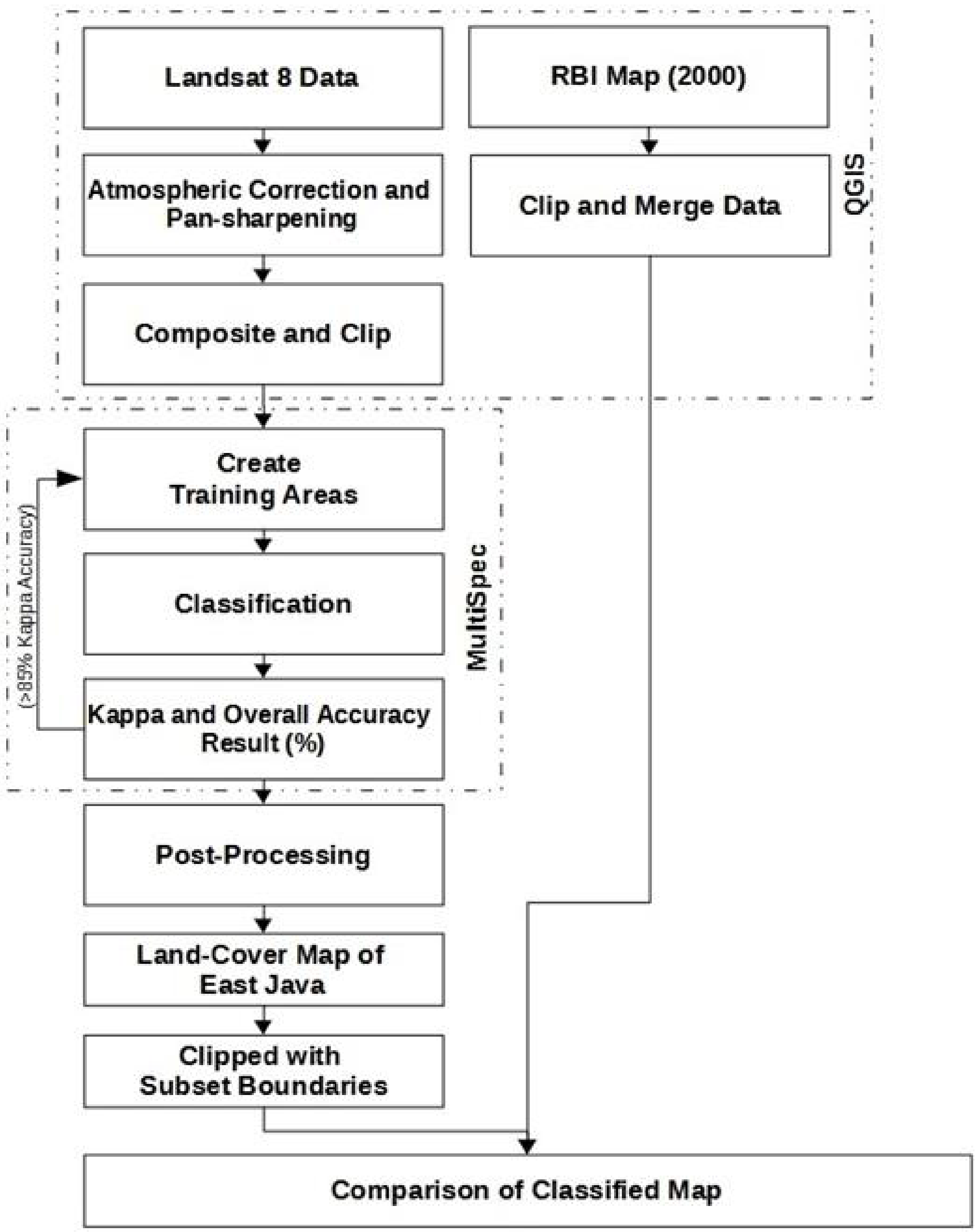

Figure 2 Flowchart of image treatment.

Table 2 Summary of the training areas.

No	Classes	Number Samples (Pixels)	% of the total area	Area (km²)
1	Pavement or urban area (PUA)	1946264.00	7.73	437.91
2	Heterogeneous Agricultural land (HAL)	2768567.00	11.00	622.93
3	Paddy Field (PF)	5282602.00	20.98	1188.59
4	Open Water Body (OWB)	211924.00	0.84	47.68
5	Dense vegetation- Forest (DVF)	4005367.00	15.91	901.21
6	Sparse vegetation-Plantation (SVP)	4548106.00	18.06	1023.32
7	Shrubland (SL)	904000.00	3.59	203.40
8	Wetlands (WL)	3521863.00	13.99	792.42
9	Sand-Clay-Rock (SCR)	1508818.00	5.99	339.48
10	Cloud Cover (CC)	480662.00	1.91	108.15
	Total	25178173.00	100.00	5665.09

Figure 3 shows the reference photos obtained from the field during the survey to visualise each class. The nine classes, as showns in Table 2 and Figure 3, represent the primary land cover observable through the Landsat image, as follow:

- Built-up or pavement or urban area (PUA) include all surface features in urbanised areas.
- Heterogeneous Agricultural Land (HAL) is included all types of agricultural areas un-dominated by paddy fields.
- Paddy field (PF) consists of all areas dominated by paddy, both technical irrigated or non-irrigated land.
- Open water body (OWB) represents the surface features such as lake, river and reservoir.
- Dense vegetation-forest (DVF) describes all annual vegetation types: primary tropical forest, secondary forest, and mixed plantation.
- Sparsely vegetated-plantation (SVP) areas represent all surface features that generally consist of annual vegetation mixed with the seasonal crop on the ground.
- Shrubland (SL) covers all surface features such as grass, mixed-grass, dry area with less vegetation, abandoned agricultural land.
- Wetland (WL) used to visualise wet area refers to the area dominated by water and vegetation. Wetlands are usually present along the sea borders. In east Java, this feature more dominated the northern part of the main island.
- Sand/Clay/Rock (SCR) represents the surface still covered by massif sand, rock and clay. The sand deposit is also found in other locations. Clay Rock represented the wasteland or abandoned land.
- Cloud Cover (CC) refers to the area on the image that is not classified because of cloud coverage above the surface. Only 1 % of the total area is not classified.

The area covered by the dense vegetation may represent primary tropical rainfall forest (in a few mountainous regions), secondary forest area or mixed plantation. Secondary forest refers to the forest area exploited for production purposes. The secondary forest area refers to the forest that can also be used for economic purposes activities. For example, a rubber plantation with having high canopy will appear and be captured as dense vegetation. A mixed plantation refers to native vegetation from the primary forest area and coffee or cocoa plantations located under the forest canopy.

The sparse vegetation class represents an area covered by annual vegetation plants and seasonal crops located under their coverage. This specific area may be found in the relatively dry area along the northern coastal region and the relatively wet area in the mountainous regions. Many seasonal crops are present under the coverage of annual vegetation. In the mountainous area, we can find, for example, Red and white cabbage, carrot, potatoes, celery and vegetables adapted to high altitude. However, people usually produce Mung bean, soybean, yardlong bean, and other legumes in the relatively dry coastal area.

3 Results

3.1 Classification Result

The classification of Landsat-8 produces overall and kappa accuracies of 96.62% and 96.02%, respectively in Table 3.

Table 3 shows that individual accuracy for each class is greater than the 9% threshold. In general, we can, therefore, state that individual accuracy for each class, overall and kappa accuracy meet the standard classification processes (Foody 2004, 2008).

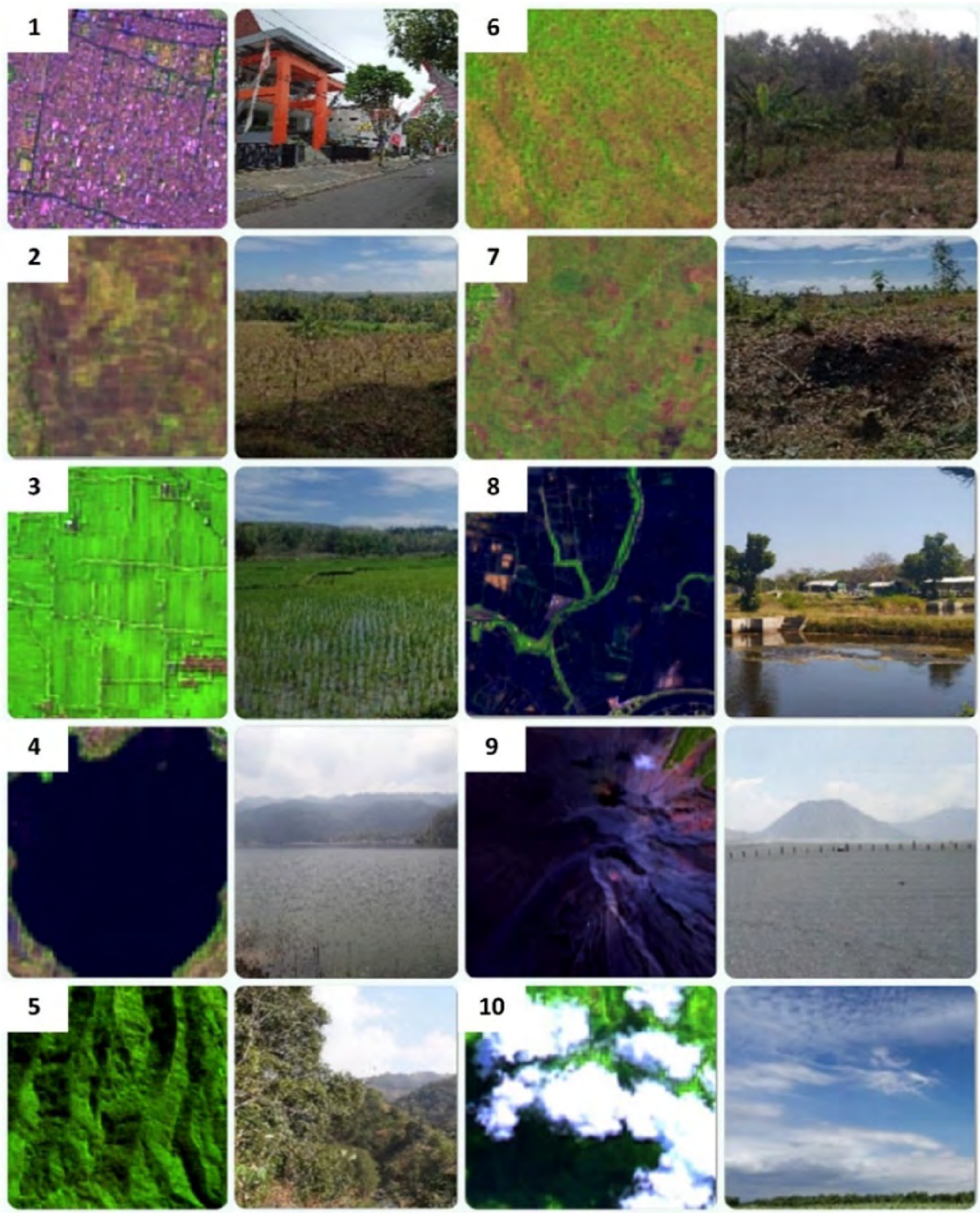

Figure 3 Reference photo and image visualisation of training class.

Table 3 Accuracy of classification processes.

Class	Ref. Acc	Class										Total
		PUA	HAL	PF	OWB	DVF	SVP	SL	WL	SCR	CC	
PUA	95,47	2253	25	4	0	0	0	19	0	49	10	2360
HAL	97,21	29	3340	0	0	0	56	0	0	11	0	3436
PF	94,65	2	0	831	0	42	3	0	0	0	0	878
OWB	99,68	2	0	0	5061	10	0	4	0	0	0	5077
DVF	96,57	0	0	91	0	3268	25	0	0	0	0	3384
SVP	91,77	2	129	12	0	20	2186	0	31	2	0	2382
SL	95,51	187	53	0	0	0	3	11032	0	276	0	11551
WL	99,25	0	3	4	0	0	0	0	924	0	0	931
SCR	99,64	0	0	0	0	0	0	0	0	5860	21	5881
CC	94,74	40	7	0	0	0	0	76	0	122	4413	4658
	Total	2515	3557	942	5061	3340	2273	11131	955	6320	4444	40538
	Rel.Acc.	89.58	93.9	88.22	100	97.84	96.17	99.11	96.7	92.72	99.3	

3.2 LULC Changes in the Overall Area

Figure 4 and Table 4 present the changes from the RBI to Landsat 8 in the overall study area.

It is shown in Table 4 that the built-up area increased ± 5.3% (+2525,5 km^2) during the last two decades. The overall LULC changes in the region can be traced by the area change (in km^2 and % of total area). As the population has increased, the demand for land for housing and urban services has also increased. Therefore, the land resources occupied by heterogeneous agricultural and paddy fields have been converted to fulfil demand. The conversion of agricultural areas into the pavement (urban areas) spreads around the region.

Figure 4 gives a general view of the LULC changes in this province area. The dense vegetation or forest cover increases by 12.61% (5960.47 km^2). As shown in the classified Landsat image, the paddy fields extend up to the hilly areas in the region. However, the RBI map is only seen from the middle elevation down to the coastal area.

Furthermore, in this study, the term' forest (DVF)' and 'plantation (SVP)' is used to classify the annual or permanent vegetation and to distinguish this type of coverage from other types (HAL, PF, PUA, and OWB). The RBI map classifies the area based on land use (i.e., irrigated paddy, non-irrigated paddy, rural areas, urban areas, forests, plantations, and water bodies). The Landsat image classifies the pixels based on their digital number values. Then the classified pixels obtained from landsat use to visualise the land cover class (i.e., DVF, SVP, HAL, PUA, SL, and OWB).

In general, these different methods of classification will give different results. In RBI, the class area extends (or zone) is more rigid and forms wider zones. Contrary, in the Landsat classification results, the class areas is formed more fragmented. Therefore, in Landsat, we can find more mixed zones composed of many classes areas. The LULC changes in the study also illustrate the development of built-up areas needed for urban inhabitant services due to the increased population. The increase in population demands more built-up areas for residences, public facilities, and city services.

3.3 LULC Change in Large Agglomeration

Subset A covers an area of 3113.82 km^2. LULC changes within it were observed as increases in the PUA up to 64.54% for 19 years. The land occupied for HAL and PF decreased by -61.60% and -18.53%. Figure 5 and Table 5 present the changes from RBI (2000) to Landsat 8 (2019).

The LULC changes in this subset area (see Figure 5) are characterised by the urban sprawl phenomenon (Łucka 2018). The urban sprawl is probably caused by the multiple effects of transportation infrastructure development, sub-urbanisation industrialisation, and tourism.

The sprawl as an impactt of transportation and sub-urbanisation development is observed from Surabaya, Sidoarjo, Mojokerto, Pasuruan and Malang City (Figure 5). The big cities of Surabaya and Sidoarjo are located in the northern part of this Subset, and in the southern part, we can find *Malang*. The north (*Surabaya*) and the south (*Malang*) are linked by two motorways (national and highway) which pass through Sidoardjo, Pasuruan

Regency and Malang Regency. This area (from north to south) is the most urbanised in East Java. The development of pavement in urban areas (from RBI to Landsat-8) is very distinguishable. The extend of pavement areas spread out irregularly and start from the two Big Cities (Surabaya and Malang). From Surabaya, the pavement areas spread to Gresik, Mojokerto and primarily to Sidoarjo areas. Most of the heterogeneous agricultural land (HAL) and paddy field (PF) are converted to pavement areas. During the last two decades, the economic development concentrated in the Capital (Surabaya and its surrounding cities) has attired migration of people from other regions of East Java. The demand for pavement areas to service housing, public infrastructure, city facilities, roads networks, industries are rapidly converted the land resources. Therefore, the existing agricultural land has been converted to the pavement.

As Surabaya's land resources and environmental capacity become crowded and saturated, the peri-urban areas have been exploited to meet the demand of pavement areas. This sub-urbanisation from the centre city (Surabaya) to the surrounding areas (Gresik, Sidoarjo, Mojokerto) sprawl irregularly (sporadic) in all directions. This urban sprawl occurred for a long time and visualised the actual competition of interest among agricultural sector, industry, housing demand, and transportation development. Therefore, more and more agricultural lands (2 and 3) decrease to meet rapid development demands in peri-urban areas, transportation, and industry. Landsat has therefore captured the urban sprawl influence driven by transportation development as the accumulation of built-up areas, which stretch out from the north to southern areas. This sprawl is linked to the development of major roads. Typically in Java, the distribution of urban areas follows and occurs around national routes. Generally, these cross-city centres continue to the sub-urban areas, connecting the rural areas with the cities, as shown in Figure 5.

Sub-urbanisation also accelerates the rapid sprawl of urban areas in the region. The subset area is considered to support the surrounding cities (i.e., Surabaya, Sidoarjo, Mojokerto, Pasuruan, and Malang). Sub-urbanisation contributes to the development of urban sprawl. Finally, the sprawl in the southwest around the mountainous areas has been caused by developed mass tourism sites. Many recreational or tourism sites are located in this direction. During the last decades, all these human activities accelerated the migration of people to the area and changed the LULC significantly. As the number of inhabitants increases, the demand for land for paddy fields also increases. As a result, more and more rural areas and forest plantations are being converted to paddy fields and built-up areas, the latter being used to service residential areas, industrial sites, tourism sites, and other public services areas.

Finally, the forest (DVF) and plantation (SVP) areas that were initially located within a certain perimeter (as shown on the RBI map) have now decreased and become more spread out. In the Landsat map, the forest-plantation areas are mixed with paddy fields and rural areas. The mixture appears in green, yellow, red, and light blue areas in the bottom left-hand corner. It means that natural forest plantations have partly converted to paddy fields, heterogeneous agricultural land (HAL), and built-up areas.

Table 4 LULC change in East Java Province.

Class	RBI		Landsat 8		Change	
	Area (km²)	(%)	Area (km²)	(%)	Area (km²)	(%)
PUA	5509.7	11.8	8035.3	17.1	2525.5	**5.3**
HAL	12756.5	27.3	6583.6	14.0	-6172.9	-13.3
PF	14043.1	30.0	10245.2	21.8	-3797.9	-8.2
OWB	94.8	0.2	47.1	0.1	-47.6	-0.1
DVF	4043.2	8.6	10003.6	21.3	5960.5	**12.6**
SVP	8674.5	18.5	9019.9	19.2	345.5	0.6
SL	475.4	1.0	250.2	0.5	-225.1	-0.5
WL	1131.0	2.4	871.3	1.9	-259.7	-0.6
SCR	83.0	0.2	1528.3	3.2	1445.3	**3.1**
CC	0.0	0.0	490.8	1.0	490.8	1.0
Total	46811.0	100.0	47075.3	100.0		

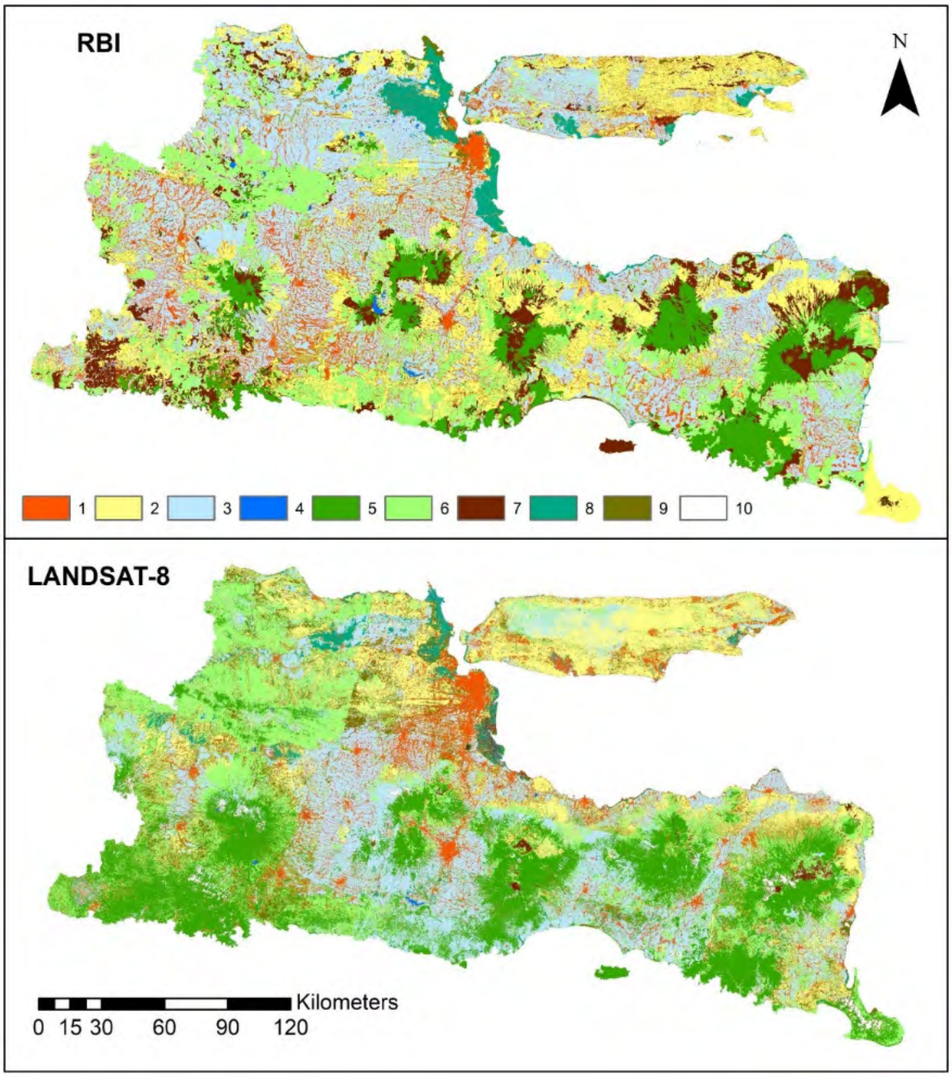

Figure 4 LULC changes in East Java. Note: (1) PUA, (2) HAL, (3) PF, (4) OWB, (5) DVF, (6) SVP, (7) SL, (8) WL, (9) SCR, (10) CC.

3.4 LULC Change in Mountainous Areas

Subset-B covers an area of 1673.87 km^2. Subset-B covers an area of Semeru Crater (Figure 6A), Bromo Crater (Figure 6G and 6H), and it's surrounding (Figure 6B, 6C, 6D, 6E, 6F). The region is located at an altitude of between 2000 and 3000 m above sea level.

The government agency is *Taman Nasional Bromo-Tengger-Semeru (TNBTS), which* manages the site for natural conservation. The agency conserves the primary humid-tropical forest and the supporting ecosystem around Mount Bromo, Tengger high land, and Mount Semeru. The primary humid tropical forest can only be found around the active craters in East Java, for example, in Mount Bromo and Semeru (Figure 6). Figure 6A shows the subset area and its natural and human-induced landscapes. Figure 6B visualise the Semeru Crater, the photo taken in April 2020. Figure 6C shows the shot of a primary humid tropical forest in the area of TNBTS. Figure 6D visualised the small agricultural village (Ranu Pane) found in the hilly areas located between the two craters. Figure 6E shows the small lake located below the village in the photo (6D). This lake more and more received sediment and agricultural residues from agricultural lands located above the lake. The lake used for tourism facilities has changed to a wetland and reply by aquatic vegetation.

Figure 6F captured the example of sparse vegetation cover (SVP) obtained below the primary tropical forest. This LULC class may appear as a regular plantation owned by private and government companies or a mixture landscape composed of annual vegetation and seasonal crop below the canopy. This type of agriculture practice also dominated the high land landscape in the surrounding regions of subset B. Then, Figures 6G and 6H photos of the dune (massif sand field on the top of the crater) taken from the Bromo crater.

Furthermore, Table 6 presents the LULC change calculated between RBI and Landsat-8. LULC changes were observed as increases in the PUA, PF, OWB, DVF, WL and SCR.

The pavement or build areas (PUA) increase by 4% of the total subset areas (Table 6). These areas appear as a diverse landscape (in Figure 6 - at the bottom-right and upper-left corner in the Landsat map), representing the residential cluster mixed with paddy fields and agricultural land. The PUA, in these cases, are occupied with serving local housing, villas or hotels to serve tourism and other villages facilities. As shown in Figure 6D, the mountainous agricultural area is used to plant seasonal commodities, including fruit and vegetables (such as carrots, cabbages, and potatoes).

However, the beautiful landscape is fragile in the face of environment-related disasters. In the rainy season, this dominant landscape located on the stepped terrain will propagate more runoff. Consequently, landslides and floods frequently occur, such as one event in April 2020 in Ranu Pane, a small mountain village located between the two craters, as shown in Figure 7.

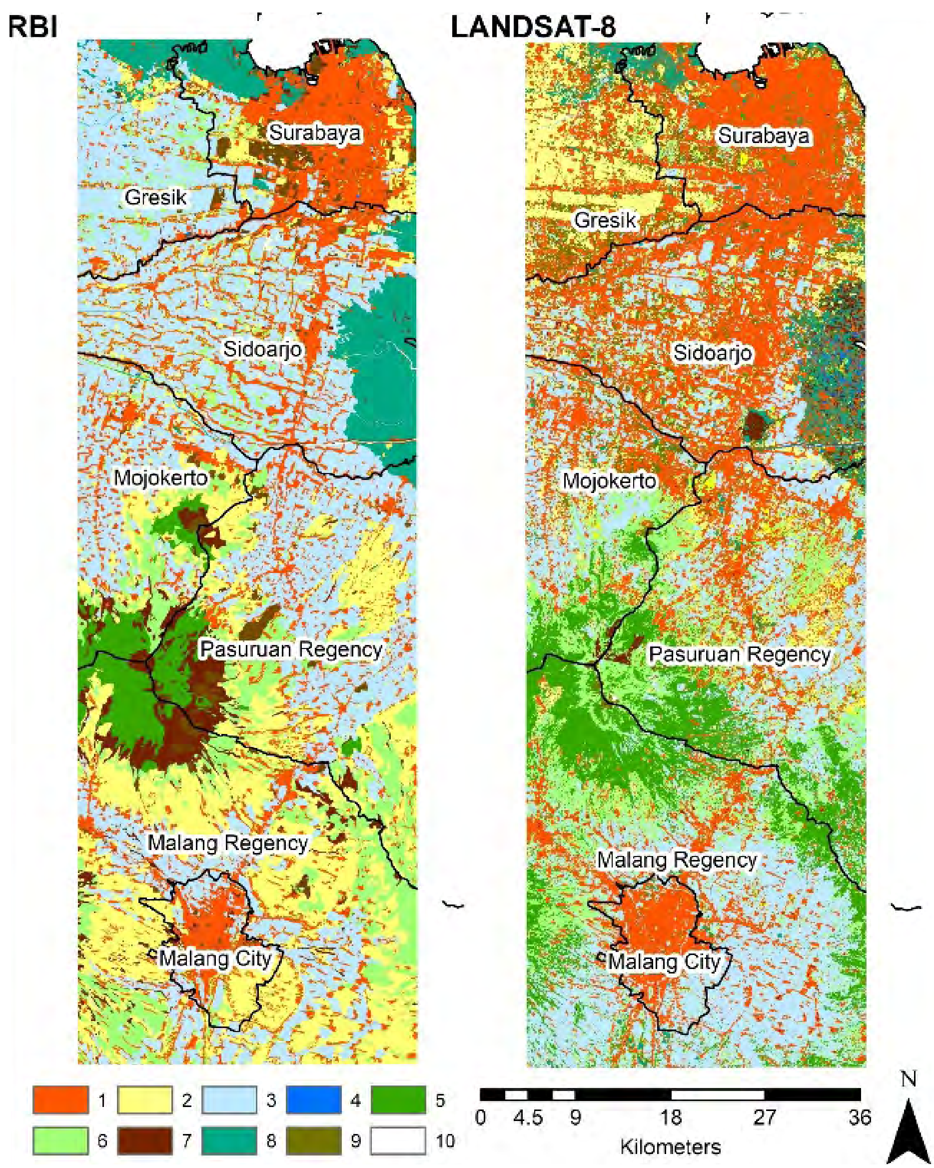

Figure 5 LULC changes in a large agglomeration. Legend: (1) PUA, (2) HAL, (3) PF, (4) OWB, (5) DVF, (6) SVP, (7) SL, (8) WL, (9) SCR, (10) CC.

Table 5 LULC Change in large agglomeration.

Class	RBI		Landsat-8		Change	
	km²	%	km²	%	km²	%
PUA	587.2	18.92	966.3	31.03	379.03	64.5
HAL	773.2	24.92	296.9	9.54	-476.3	-61.6
PF	1012.6	32.63	824.9	26.5	-187.6	-18.5
OWB	2.86	0.09	8.1	0.26	5.23	182.9
DVF	114.9	3.70	326.4	10.48	211.5	184.1
SVP	346.7	11.17	389.1	12.50	42.36	12.2
SL	84.36	2.72	33.1	1.06	-51.28	-60.7
WL	178.9	5.77	86.2	2.77	-92.74	-51.8
SCR	2.45	0.08	182.8	5.87	180.3	7361.2
Total	3113.8	100	3113.8	100		

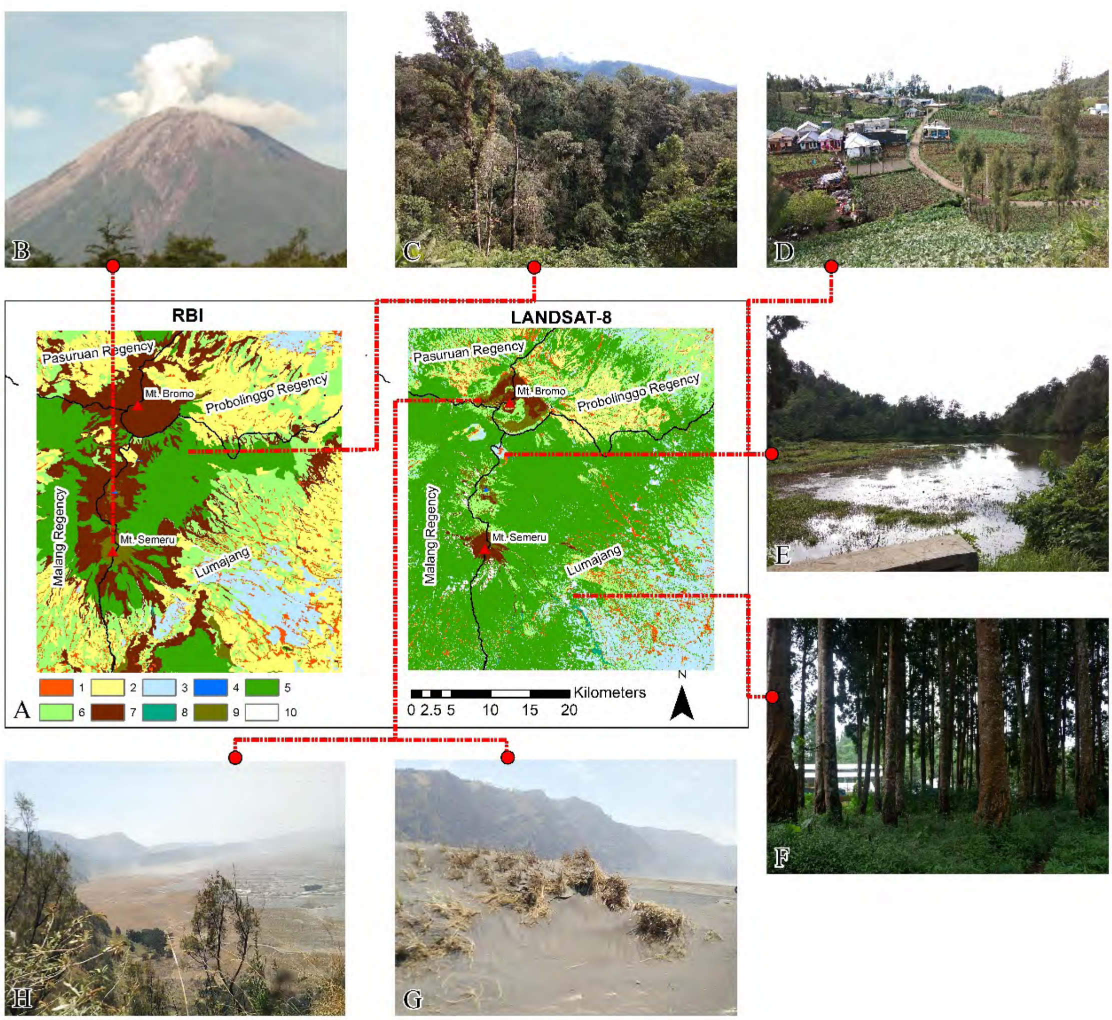

Figure 6 LULC changes in mountainous landscape areas: A. Subset comparison maps; B. Peak of Semeru; C. Primary humid tropical forest on TNBTS area; D. HAL on small village (Ranu Pane) between the mountains; E. Lake of Ranu Pane; F. SVP around the mountains; G. Sand dunes on Bromo crater; H. Sand dunes and shrub on Bromo crater Legend: (1) PUA, (2) HAL, (3) PF, (4) OWB, (5) DVF, (6) SVP, (7) SL, (8) WL, (9) SCR, (10) CC.

Table 6 LULC change in mountainous areas.

Class	RBI		Landsat		Change	
	km²	%	km²	%	km²	%
PUA	70.6	4.2	73.3	4.3	2.8	3.9
HAL	480.4	49.9	101.7	6.1	-378.7	-78.8
PF	117.6	6.7	215.1	12.9	97.5	82.9
OWB	0.4	0.0	0.5	0.0	0.1	35.5
DVF	338.6	20.3	952.8	56.9	614.2	181.4
SVP	286.5	17.2	240.3	14.4	-46.2	-16.1
SL	351.2	1.4	34.3	2.1	-316.9	-90.2
WL	0.4	0.0	5.4	0.3	5.1	1454.3
SCR	28.2	0.3	36.3	2.2	8.1	28.8
CC	–	–	14.1	0.8	–	–
Total	1673.9	100	1673.9	100		

Figure 7 Landslide and flood in the mountainous village "Ranu Pane" in April 2020: A. Landslide on sloping agricultural land; B. Residual mud and dirt on the residential areas; C. Residual mud on the local road.

Compared to RBI, the Landsat present more forested areas. It is noted that the RBI was produced in the year 2000. As an adverse effect from the political succession from Suharto regimes to the successor, unexpected social movements occurred after 1997 to 2000. Most of the forested areas are cleared and cut by people. It occurs in the most forested areas in East Java. Therefore, in the RBI map, although in the mountainous areas, the presence of the *shrubland class* is significant. By the time the government and stakeholders rehabilitated the shrubland to forested areas or plantation areas.

3.5 LULC Change in Agricultural - Coastal Areas

Subset C covers an area of 1262.2 km^2. The subset areas cover the Regency and City of Gresik, Lamongan and Tuban. In the RBI map, the land resources in Subset C is mainly occupied by heterogeneous agricultural land (HAL) along with the coastal areas. Then the more crowded paddy field area (3) occupied most land resources in *Lamongan* and *Tuban.* The wetland (WL) area more appears in the Regency of *Gresik*, as shown in Figure 8 and Table 7.

The wetland is utilised for shrimp cultures, fisheries and salt mining. This area is also subject to a relatively dry climate, represented by blocked areas of heterogeneous agricultural land. As the cities (Gresik, Lamongan, Tuban) grow, more agricultural, paddy fields and dense vegetation areas are converted to the pavement and sparse vegetation. Sparse vegetation represents the rural areas and plantation type land occupation.

The change (in the Landsat map) is characterised by the decreasing area occupied for heterogeneous agricultural land (HAL), paddy field (PF), dense vegetation –forest (DVF), Shrubland (SL) and Wetland (WL). This decrease is balanced by the increase in land resources occupation for pavement or urban areas (PUA), open water body (OWB), sparse vegetation – plantation (SVP), and sand/clay/rock (SCR) classes.

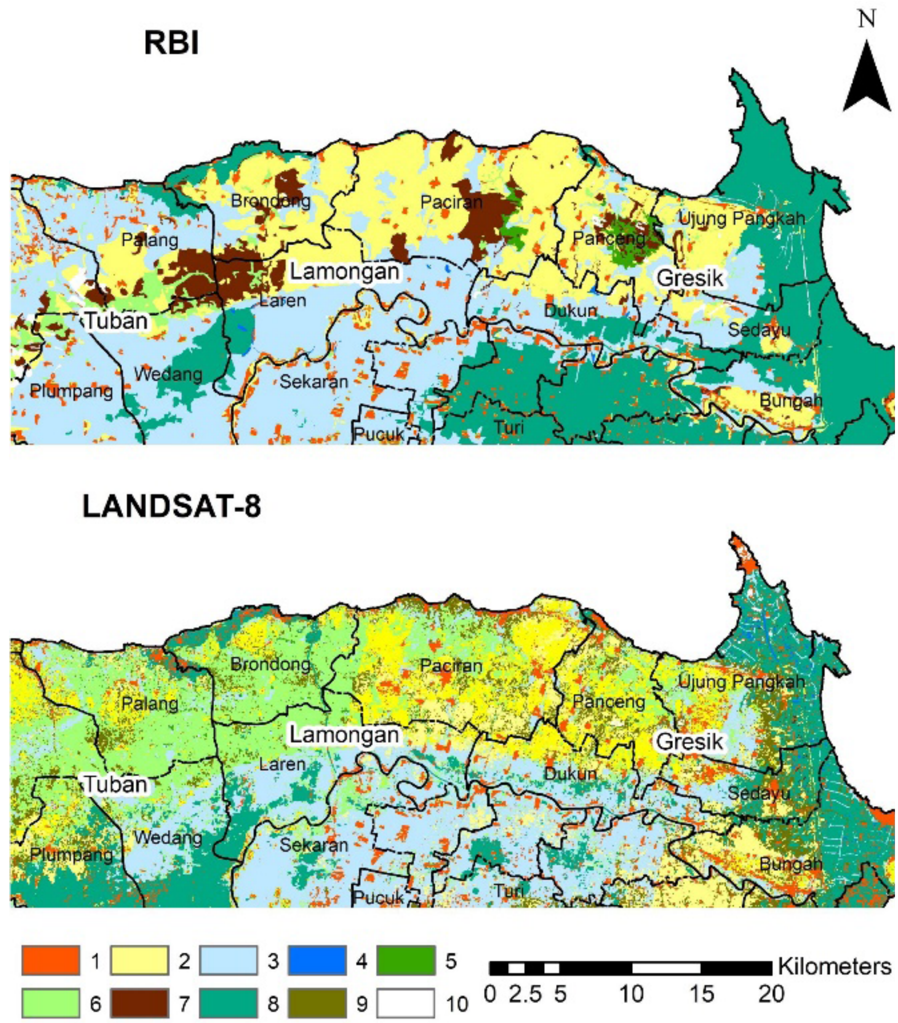

Figure 8 LULC in Agricultural - coastal areas. Legend: (1) PUA, (2) HAL, (3) PF, (4) OWB, (5) DVF, (6) SVP, (7) SL, (8) WL, (9) SCR, (10) CC.

Table 7 LULC change in agricultural - coastal areas.

Class	RBI		Landsat		Change	
	km²	%	km²	%	km²	%
PUA	65.4	5.2	90.2	7.1	24.8	38.0
HAL	350.7	27.8	254.0	20.1	-96.7	-27.6
PF	426.9	33.8	346.1	27.4	-80.8	-18.9
OWB	2.3	0.2	3.3	0.3	1.1	46.7
DVF	41.3	3.3	2.3	0.2	-39.0	-94.6
SVP	35.8	2.8	249.5	19.8	213.6	596.5
SL	13.1	1.0	1.1	0.1	-12.0	-91.3
WL	287.2	22.8	198.6	15.7	-88.7	-30.9
SCR	39.6	3.1	109.9	8.7	70.3	177.7
CC	0.0	0.0	7.4	0.6	-	-
	1262.2	100	1262.2	100.0		

4 Conclusion

The LULC changes in the whole area of East Java province have been analysed. The study site covers an area ± 47075.3 km^2. The Rupa Bumi Indonesia (RBI) digital map represents the LULC map in the year 2000. Then the change in LULC from 2000 to 2019 was interpreted through Landsat imageries captured between 2015 and 2019. The analysis was made by comparing the Landsat 8 to the national RBI map. The result shows that during the two decades, LULC has changed significantly in this province area. A more detailed view using three subsets areas shows the primary driving forces of LULC changes: the development in transportation infrastructure; sub-urbanisation; the development of and changes in agricultural practices; the development of industrial sites; and tourism activities. The changes tend to manifest themselves as urban sprawl, which is typically distributed irregularly. The regional development and population increase in the region during the last two decades have changed LULC significantly. The changes are seen in the increase in urban built-up areas (PUA) of 5.3 %, dense vegetation or forest (DVF) cover by 12.6%, and Sand/Clay/Rock (SCR) by 3.1%. The development has also significantly reduced the paddy field (PF) by -13.3%, heterogenous agricultural land (HAL) by -8.2 % and open water bodies (OWB) by -0.1%, shrubland (SL) by -0.5% and Wetlands (WL) by -0.6%. The study has also shown the capability of Landsat imagery to track the significant LULC changes in this region.

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Indarto Indarto: conceptualization; formal analysis; methodology; validation; writing-original draft; and Funding acquisition. **Entin Hidayah:** methodology; writing - review and supervision. **Farid Lukman Hakim:** Collecting data; formal analysis; validation; visualisation, and writing the first draft.

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Conflict of interest

The authors declare no potential conflict of interest.

Data availability statement

Model data are freely available on:

Reclassified RBI data are published at Figshare under the title: RBI Maps of East Java (2000), DOI: https://doi.org/10.6084/m9.figshare.19136858

Original RBI data can be downloaded from: https://tanahair.indonesia.go.id/portal-web

Classified Landsat Data for the area of study is available on request to: indarto.ftp@unej.ac.id

All data included in this study are publicly available in the literature.

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