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Land Use and Land Cover (LULC) Change in Eastern Areas of East Java From 1972 To 2021: Learning From Landsat Image

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ABSTRACT

Urban development, population growth, high traffic jams, and intensive disaster events are indicators of changing the landscape of the eastern area of East Java. Investigating these changes is vital for planning and environmental protection in the future. This study examines changes in land use and land cover (LULC) during the past 50 years in the eastern part of East Java from 1972 to 2021. The changes are examined by contrasting four maps derived from Landsat images (1972, 1997, 2013, and 2021). The following are the main study procedures: (1) data inventory, (2) field survey, (3) image processing and classification, and (4) interpretation of LULC changes. With Google Earth Engine, all photos are downloaded (GEE). Landsat image classification was completed using the maximum likelihood algorithm with an overall Kappa accuracy of>85%. Eight (8) major classifications are therefore produced by the classification: (1) the pavement or urban area (PUA); (2) heterogeneous agricultural land (HAL); (3) bare soil (BS); (4) paddy field (PF); (5) open water body (OWB); (6) vegetation/ plantation (VG); (7) shrubland (SL); and (8) wetlands (WL). In the areas with rapid development, the LULC change is more pronounced, i.e., Pasuruan, Jember, and Banyuwangi Regencies. LULC change in and near mid-regency and the rural regions comes next. Over the past fifty years, regional growth has resulted in increases in PUA (+4.4 percent), PF (+12.2 percent), and VG (+17.9 percent). On the other hand, the development has decreased SL, BS, and HAL by 5.8 and 15.9 percent, respectively (-13.1 percent). LULC alterations for human activities have profoundly altered the natural landscape.

1. INTRODUCTION

Changes in land use and cover (LULC) are becoming a primary global concern in our environmental issues. The accomplishment of the agenda items for the Millennium Development Goals (MDGs) may be hampered by these complex problems. At the local level, there might be irregularities in the LULC change. On the other hand, the actual LULC reform has captured the outcome of stakeholders' competing interests.

The most common method researchers use to investigate LULC changes is by using multiple maps produced at different times. The interpretation of satellite images can be used to examine the reasons for LULC changes and how they affect the environment and society (Nguyen 2020; Ptak & Ławniczak 2012).

It is well recognized that LULC changes may be studied using Landsat images, and research publications on this topic have been published worldwide. For example, Fonji & Taff (2014) used satellite data to monitor LULC change in Latvia. Elias *et al*. (2019) also investigated LULC in Gazipur Sadar, Bangladesh, from 1973 to 2017. Then, using multiple data inputs, Klimanova *et al*. (2017) examined the LULC change at the regional levels in Brazil between 2001 and 2012. Several studies have used Landsat images to examine LULC changes in various places and situations (Hassen & Assen, 2018; Mtibaa & Irie, 2016). Several studies explain the relationship between development in urban areas and LULC changes (Ahmed & Alla, 2019; Nguyen, 2020). The fast rise of urbanization, transportation and industrial development, education, and cultural activities, tourism activities, and agricultural practices are only a few of the numerous potential primary causative effects of the LULC change.

LULC change due to the growth of transportation networks, industrial sites, sub-urbanization, and tourism is commonly called "urban sprawl" (Łucka 2018; Ahmed & Alla 2019). Many scholars from around the globe have expressed interest in the urban sprawl. This research region may experience both urban sprawl and the causative consequences of LULC changes. To ensure the sustainability of the natural environment, other researchers investigate the causal effects of land use and land cover change on the natural protection area (Klyuev, 2019; Dastgerdi *et al*., 2019). In addition, there is research on the causal relationship between forest area management and agricultural policies on changes in LULC (Mangmeechai, 2020).

This study aims to describe LULC changes over 50 years and the causal impacts and main drivers of LULC changes in this region. This paper investigates how LULC has changed in eastern East Java during the last 50 years (from 1972 to 2021). East Java is ranked number one as Indonesia's province with the highest population growth and urban development. The population in East Java increased by 15 million people from 25.5 million to 40.8 million from 1972 to 2021 (BPS, 1972; BPS, 2022). As the population increases, the need for built-up areas for housing and public facilities will increase. A decrease in other land tenure will offset this increase. Therefore, demographic dynamics will change natural ecosystems. Changes due to human growth and activities can occur over large areas and long periods. Satellite imagery can track changes and explain what, when, why, and how these phenomena interact. These changes are interpreted by comparing several map editions interpreted from Landsat imagery from 1972 to 2021.

Several districts in Eastern Areas of East Java are dominated by agricultural land because many areas have fertile soil. The fertile land in East Java causes this due to weathering of volcanic eruption material in the past (Permatasari *et al*., 2016). Recently, as the industrial sector has expanded, so has the land converted from agriculture to non-agricultural uses. East Java has a high population growth rate of around 0.96%, thus encouraging significant land use changes in the built area (Islami *et al*., 2022; Indarto & Hakim, 2021). Studies in the Eastern Areas revealed that rice fields, mangrove forests, and secondary forests were the land uses and land covers that tended to diminish between 1995 and 2019. However, there was a noticeable rise in the area of ponds, plants, and towns (Wahyuni *et al*., 2021). This change in land use significantly impacts the area's plant cover and airflow processes, both directly and indirectly (Priyadarshini *et al*., 2019; Astuti *et al*., 2019; Sujarwo *et al*., 2021). For the sake of future planning and environmental preservation, these changes must be investigated.

2. MATERIALS AND METHODS

2.1. Study Site and Input Data

The study was conducted in the Eastern part of East Java Province (Figure 1), covering an area of 47,075.35 km^2. East Java is ranked number one as Indonesia's province with the highest population growth and urban development. The Primary input data for the research were Landsat 1 MSS, Landsat 5 ETM, and Landsat-8 OLI/TIRS images, which were chosen based on the amount of cloud cover present. Free cloud cover images were downloaded from the Google Earth Engine (GEE) Platform. Table 1 shows the metadata related to the raw images used in the study.

The Landsat-8 imagery was captured dated from 1972 to 2021. In reality, acquiring Landsat imagery of this area with small cloud cover (>5%) is difficult. Clouds frequently taint (cover) the optical picture data acquired in tropical regions like East Java (Tseng *et al*., 2008). In cloudy regions, the actual ground information is obscured by clouds, limiting the applicability of optical images (Pouliot & Latifotic, 2018).

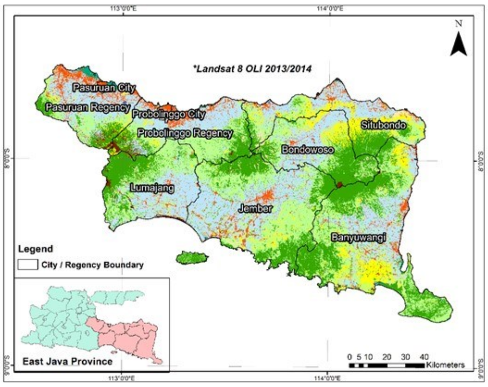

Figure 1. Study site

Table 1. Raw metadata

Year	Satellite Type	Acquisition period	Data Type	Composite
1972	Landsat-1 MSS	01/08/1972- - 31/12/1972	1 Tier 2 DN Values	Green, Red, NIR 1 - 2
1997	Landsat-5 ETM	01/01/1997- - 31/12/1997	1 Tier 1 SR	Blue, Green, Red, NIR, SWIR 1 - 2
2013	Landsat-8 OLI	01/01/2013- - 31/12/2014	1 Tier 1 SR	Blue, Green, Red, NIR, SWIR 1 - 2
2021	Landsat-8 OLI	01/01/2020- - 31/07/2021	1 Tier 1 SR	Blue, Green, Red, NIR, SWIR 1 - 2

Furthermore, for multi-temporal remote sensing applications (such as LUCL), cloud-covered data will produce irregular time intervals, increasing difficulty in further time series analysis (Wu *et al*., 2018). Minimizing data loss in optical satellite imagery due to cloud cover will impact data availability and multi-time analysis (Zhou *et al*., 2022).

Using the GEE could anticipate this obstacle. Finally, the best quality images obtained by GEE are in 1972, 1997, 2013-2014, and 2020-2021.

2.2. Procedure

This research procedure is divided into two stages: image treatment and LULC classification. The image treatment included post-processing, generating a land cover map, clipping with a polygon border, constructing a training area and supervised classification, atmospheric correction, pan-sharpening, composite, clip, and comparing. MultiSpec is open-source software used for image processing jobs (Landgrebe & Biehl, 2018). There are two pathways in the picture treatment process (Figure 2).

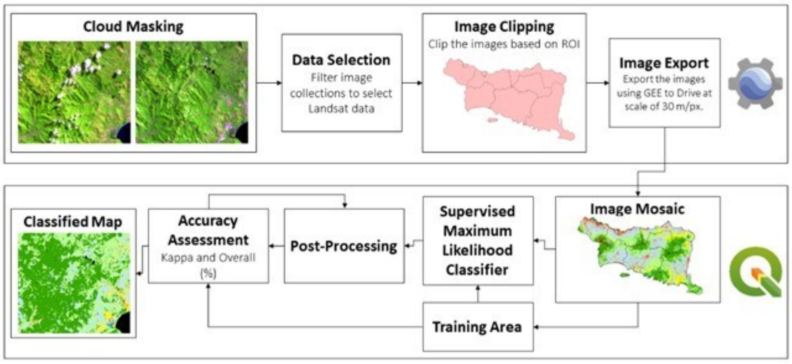

Figure 2. Flowchart of This Study

Cloud-free Landsat images were downloaded using the Google Earth Engine (GEE) platform. This platform is used because the mosaic image is smoother (Figure 3a.) compared to manual mosaics using the QGIS application (Figure 3b).

Figure 3. Comparison of image mosaics: (a) using GEE, and (b) using QGIS

Post-processing was used in this study to improve the classification findings' ability to reflect the conditions in the field to lower classification errors, lessen the impact of salt and paper, and increase accuracy. Most of the QGIS software's filter and sieve capabilities are used for this step. The majority filter is used to reduce the "salt and paper effect" phenomenon, in which isolated pixels appear in the bulk of pixels. In parallel, raster polygons lower than the predetermined threshold (in pixels) are removed using the sieve and replaced with pixel values from the closest neighboring polygon (QGIS Development Team, 2019).

The accuracy test was conducted to obtain information on the classification results' accuracy level. The method used is to use an error matrix (confusion matrix) to obtain the overall and Kappa accuracy values. Overall accuracy is the percentage of the number of pixels classified correctly (located on the matrix diagonal) divided by the total number of pixels. Kappa accuracy is a measure of the difference between the number of pixels classified correctly (diagonal matrix) and the number of pixels expected to be classified completely correctly from matching the map classification results and the reference map. Field survey data obtained is used as a reference in this accuracy test.

The algorithm used is the maximum likelihood for the image classification process. Two hundred training areas are used as input for the guided classification sample. The subset area is used to determine the changes in LULC and discuss the importance of the changes. Subset A shows changes in LULC in three regencies and one city, which includes Ngawi Regency, Magetan Regency, Madiun Regency, and Madiun City. Subset B shows big cities in East Java Province: Surabaya City, Mojokerto City, Mojokerto Regency, and Sidoarjo Regency. Cities and regencies in Subset B are the areas with the largest economic, trade, and industrial activities in East Java Province. At the same time, Subset C shows the Jember region. The selection of subset areas is based on the focus of regional development (Regional Planning Agency, 2018).

The atmospheric correction was processed using the Pan-sharpening technique and DOS (dark object subtraction) in the Semi-automatic classification plugin (SCP) (Congedo, 2016), which is accessible in QGIS (QGIS Development Team, 2019). A composite image was created using six Landsat-8 bands: bands 2, 3, 4, 5, 6, and 7. Three bands were then used to visualize the pictures (6, 5, and 2). The national standard, SNI 7645:2014, was followed in creating the number of LULC courses (BSN, 2014). The categorization procedure was carried out using Multispec's conventional image processing (Landgrebe, 2015). Here, we categorize pixels using maximum likelihood techniques. Ninety (90) training areas helped with the processing of supervised categorization.

3. RESULTS AND DISCUSSION

3.1. Classification result

LULC types in this study were divided into eight (8) classes, namely (1) PUA, (2) HAL, (3) BS, (4) PF, (5) OWB, (6) VG, (7) SL, and (8) WL. Each type of LULC represents a different shape of the earth's surface (Table 3). Figure 4 illustrates a comparison of satellite images with actual land conditions.

Table 2. LULC types

No	LULC Types	Abb	Explanation
1	Pavement or Urban Area	PUA	An earth's surface is characterized by artificial and often impermeable construction and pavement layers.
2	Heterogeneous Agricultural Land	HAL	the surface of the earth planted with secondary crops
3	Bare Soil	BS	Represents the surface that is covered by sand and rock. The sand is most commonly found in coastal areas. Rocks are mostly in the mining and mountain/hill areas.
4	Paddy Field	PF	The earth's surface is dominated by rice plants, both technically irrigated and non-irrigated.
5	Open Water Body	OWB	Represents surface features such as lakes, rivers, and reservoirs.
6	Vegetation	VG	Represents all non-agricultural plants, including woody perennial plants, primary tropical forests, secondary forests, and mixed plantations.
7	Shrubland	SL	It covers all surface features such as grass, mixed grass, dry areas with less vegetation, and abandoned agricultural land.
8	Wetland	WL	Visualizing wet areas refers to areas dominated by water and vegetation. Wetlands are usually present along the sea borders. This feature dominated the northern part of the main island in East Java.

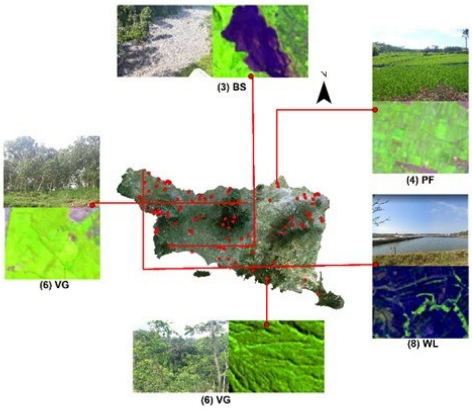

Figure 4. Reference photo and image visualization of training class

Landsat image classification in 1927, 1997, 2013, and 2021 resulted in the overall and Kappa accuracy shown in Table 3. It shows each land cover class's individual, overall, and kappa accuracy. The smallest kappa accuracy value was obtained in 1972 at 76.41%. The kappa accuracy value is included in the substantial agreement category, where the value of the kappa accuracy suitability category for the substantial agreement category ranges from 61% to 80% (Viera & Garrett, 2005). The kappa accuracy value from the classification results in 2013 was 85.20%. In 2021 it was 87.31%, and the highest in 1997 was 93.65%. Table 3 also shows that the accuracy values for each class (Kappa and overall accuracy) have met the minimum USDG threshold with a value above 75% (Foody, 2004; 2008).

Table 3. Accuracy of classification processes

Class	1972		1997		2013		2021	
	PA	UA	PA	UA	PA	UA	PA	UA
PUA	80.65	64.66	96.77	90	71.58	88.31	79.37	86.96
HAL	76.56	90.21	95.26	95.77	90.65	88.11	95.65	81.48
BS	60.64	62.64	77.78	95.45	90.00	100.00	89.47	77.27
PF	85.08	83.24	100.00	91.28	88.69	79.41	96.52	90.77
OWB	100.00	100.00	100.00	96.67	100.00	100.00	75.86	73.33
VG	92.13	96.14	92.50	100.00	87.79	91.85	89.95	95.77
SL	73.28	58.18	75.86	95.65	76.62	71.08	85.42	93.18
WL	100.00	91.67	97.30	100.00	91.67	100.00	78.26	100.00
Overall Acc.		**80.64**		**95.18**		**86.36**		**90.27**
Kappa Acc.		**76.41**		**93.65**		**85.20**		**87.31**

Note: PA = Proceducers Accuracy; UA = User Accuracy

3.2. LULC Changes in the Overall Area

The Landsat can identify and separate the LULC features into eight (8) classes, i.e., (1) PUA, (2) HAL, (3) BS, (4) PF, (5) OWB, (6) VG, (7) SL, and (8) WL. Figure 5 illustrates LULC that has occurred over the last 50 years in the study area. Table 4 shows the LULC change from Landsat imagery from 1972 to 2021. Residential areas showed an increase; in 1972, the residential area was 2.05%, and in 1997, it was 4.15%. In 2013, it was 7.91%, and in 2021, it was 9.65%. The increase in the residential area is caused by the increasing population of the East Java Province, so the need for housing is also increasing. In addition, the construction of toll roads, new road networks, and changes in paddy land cover to residential areas have occurred almost completely in East Java Province.

The need for land for housing and urban service areas has grown along with the population. As a result, land resources formerly used for diverse agriculture and paddy fields have been transformed to meet demand. Agricultural regions are being transformed throughout the region into paved or urban areas. The OWB class has increased from 1972 to 2021. This increase is due to the construction many new dams in East Java Province. The construction of reservoirs in East Java is more devoted to irrigation and raw water.

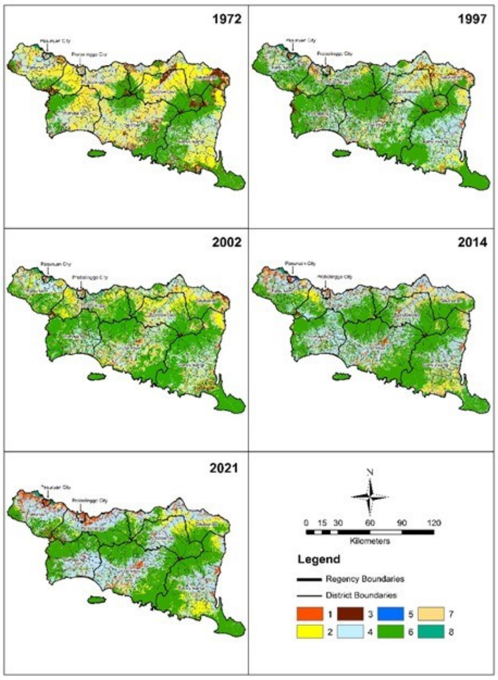

Figure 5. LULC changes in East Java 1972-2021 (Note : (1) PUA, (2) HAL, (3) BS, (4) PF, (5) OWB, (6) VG, (7) SL, (8) WL)

Table 4. LULC change in the Eastern part of East Java

Class	1972		1997		2013		2021	
	Area(km²)	(%)	Area(km²)	(%)	Area(km²)	(%)	Area(km²)	(%)
PUA	966.30	2.05	1954.36	4.15	3722.72	7.91	4544.19	9.65
HAL	16132.16	34.27	5557.63	11.81	5792.55	12.30	8492.56	18.04
BS	4419.63	9.39	1492.36	3.17	184.31	0.39	466.55	0.99
PF	7913.06	16.81	17369.30	36.90	12540.79	26.64	16560.60	35.18
OWB	42.04	0.09	77.01	0.16	162.87	0.35	180.86	0.38
VG	9059.03	19.24	17219.75	36.58	19449.36	41.32	15079.29	32.03
SL	8172.14	17.36	2369.42	5.03	4322.16	9.18	628.11	1.33
WL	370.99	0.79	1035.52	2.20	900.59	1.91	1123.18	2.39
Total	**47075.35**	**100.00**	**47075.35**	**100.00**	**47075.35**	**100.00**	**47075.35**	**100.00**

There is a significant difference between the classification data and actual land use data from BPS in 1972 (BPS, 1972). For example, according to BPS, HAL's land area was 21,972 km^2, while the classification results showed data of 16,132 km^2. Misclassification occurred in the 1972 Landsat image due to the limited spectral information in the Landsat 1 image. Landsat 1 satellite imagery has a spatial resolution of 80 meters (Tsuchiya & Oguro, 2007), which makes the visualization of the earth's surface features less clear. In addition, the number of bands that were composited for classification only amounted to 4 bands, causing a lack of information to visualize the appearance of East Java Province that year. As a result, we may see more mixed zones with several class regions in Landsat. The study's LULC modifications also show how built-up regions have developed and become necessary for the services provided to urban residents as a result of population growth. Due to the growing population, there must be more built-up areas for homes, public spaces, and city services.

3.2.1. LULC Change in Subset A (Pasuruan)

Subset A is an area of 3239.62 km^2 located in Pasuruan Regency. Figure 6 and Table 5 show land cover changes from 1972, 1997, 2013, and 2021. In general, it can be seen that there have been significant changes in land use in Pasuruan from 1972 to 2021. This is related to the policy of the East Java Provincial Government regarding the development of industrial estates in several districts such as Sidoarjo, Surabaya, Jombang, and Pasuruan in 1989 (Amanda *et al*., 2021).

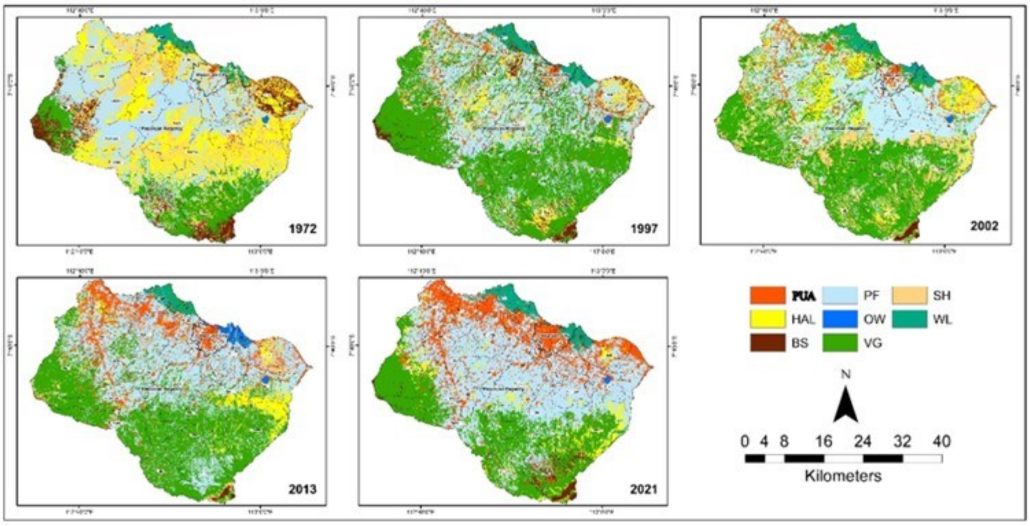

Figure 6. LULC changes in a large agglomeration

Table 5. LULC Change in subset A (Pasuruan)

Class	1972		1997		2013		2021	
	km²	%	km²	%	km²	%	km²	%
PUA	**60.77**	**1.88**	**84.62**	**2.61**	**303.45**	**9.37**	**408.16**	**12.60**
HAL	1298.44	40.08	114.40	3.53	231.29	7.14	1144.20	35.32
BS	207.17	6.39	28.57	0.88	0.78	0.02	50.21	1.55
PF	581.21	17.94	1615.66	49.87	1034.57	31.93	1168.70	36.08
OWB	0.91	0.03	11.33	0.35	15.69	0.48	48.96	1.51
VG	164.60	5.08	1363.31	42.08	1070.73	33.05	418.76	12.93
SL	924.74	28.54	18.89	0.58	582.68	17.99	0.62	0.02
WL	1.79	0.06	2.85	0.09	0.43	0.01	0.00	0.00
Total	**3239.62**	**100.00**	**3239.62**	**100.00**	**3239.62**	**100.00**	**3239.62**	**100.00**

The industrial area development policy will certainly affect changes in land use in Pasuruan. This can be seen in Table 5, where the urban area (PUA) increased significantly from 60.77 km^2 (1.88%) to 408 km2 (12.60%). The largest industrial area in Pasuruan Regency is the Rembang Industrial Estate (PIER) in Pasuruan, the largest area in East Java with an initial area of 254 hectares (Agustini & Winarni, 2014). The area of industrial estates is also increasing every year; currently, the PIER area has an area of 510 hectares. In the PIER, eighty-five (80) industries are divided into three categories: food and beverage, manufacturing, and chemicals (Nainggolan *et al.*, 2021). There was an increase in built-up and industry in Pasuruan in 2002-2018. It is projected that the built-up land will increase by 130 ha (13.62%), and industry will increase by 68 ha (20.7%) in 2026 (Prayitno *et al.*, 2020).

3.2.2. LULC Change in Subset B (Banyuwangi)

Subset-B covers an area of 2036.57 km^2 in Banyuwangi Regency. Banyuwangi Regency is located in the eastern region of East Java province. Figure 7 and Table 6 show the results of land cover change classification from 1972 to 2021. From 1997 to 2013, population growth experienced a very significant increase.

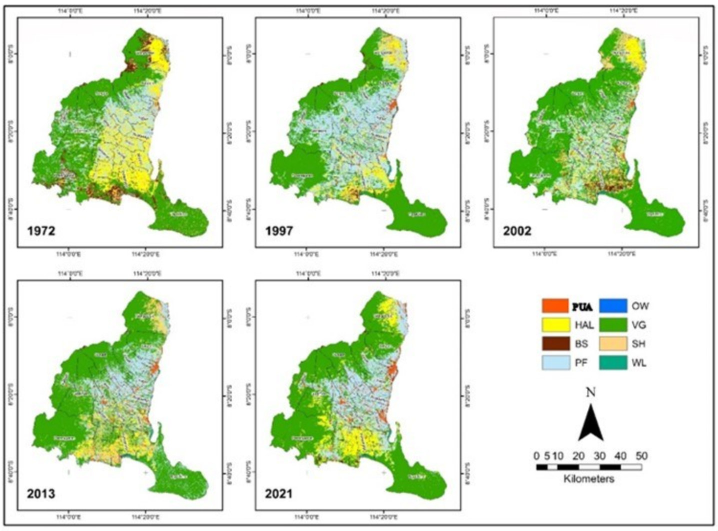

Figure 7. LULC changes in a large accumulation.

Table 6. LULC change in subset B (Banyuwangi)

Class	1972		1997		2013		2021	
	km²	%	km²	%	km²	%	km²	%
PUA	**104.48**	**5.13**	**244.63**	**12.01**	**664.56**	**32.63**	**935.57**	**45.94**
HAL	472.70	23.21	179.11	8.79	104.99	5.16	58.76	2.89
BS	141.04	6.93	99.02	4.86	22.62	1.11	42.55	2.09
PF	535.32	26.29	952.03	46.75	747.53	36.71	590.52	29.00
OWB	2.17	0.11	1.70	0.08	8.27	0.41	12.36	0.61
VG	194.98	9.57	312.73	15.36	242.52	11.91	181.90	8.93
SL	429.61	21.09	54.76	2.69	42.78	2.10	0.00	0.00
WL	**156.27**	**7.67**	**192.58**	**9.46**	**203.30**	**9.98**	**214.91**	**10.55**
Total	**2036.57**	**100.00**	**2036.57**	**100.00**	**2036.57**	**100.00**	**2036.57**	**100.00**

This is indicated by the area of settlements formed in 1997, 244.63 km2 (12.01%), and 664.56 km^2 (32.63%) in 2013. As a result of this rapid population growth rate, the area of agricultural land has decreased, and the build-up area (PUA) has increased. Banyuwangi is an area that has the highest population density in East Java Province (BPS Jawa Timur, 2022).

Furthermore, Banyuwangi Regency is a developing area for Super Priority Tourism Destinations in Indonesia. In the last five years, Banyuwangi district has aggressively developed the tourism sector (Alfiyan *et al*., 2023). Therefore, changes in the natural landscape are very visible, especially in coastal areas. Economic activity and trade are concentrated in this city. There was an increase in the wetland area from 156 ha to 214 ha (Table 6). It can be explained that the conversion of land and forest production plantations causes the growth of wetlands in Banyuwangi Regency. There is a tendency for changes in built-up land of 1,193 ha/year trade and service areas of 28.4 ha/year in Banyuwangi Regency until 2036 (Firmansyah *et al*., 2018).

3.2.3. LULC Change in Subset C

Subset C is Jember Regency, which covers an area of 3309.60 km^2. Figure 8 and Table 7 show the development of land cover change from 1972 to 2021. In the Jember Regency, many vegetative areas have been turned into agricultural land (BPS, 2021). It can be seen that the land cover of the pavement area (PUA) and paddy field (PF) classes is increasing. A significant decrease occurred in the shrubland (SL) class.

Table 7 shows the LULC that has occurred in the Jember Regency. In 1972, the land cover in the form of shrubland was 524.07 km^{2,} which then dropped drastically to 43.37 km^2. Many areas of scrubland have been converted into rice fields. As shown in Table 7, the paddy field cover (PF) in 1972 was 817.67 km^2 and then continued to increase until 2021 with an area of 1153.06 km^2.

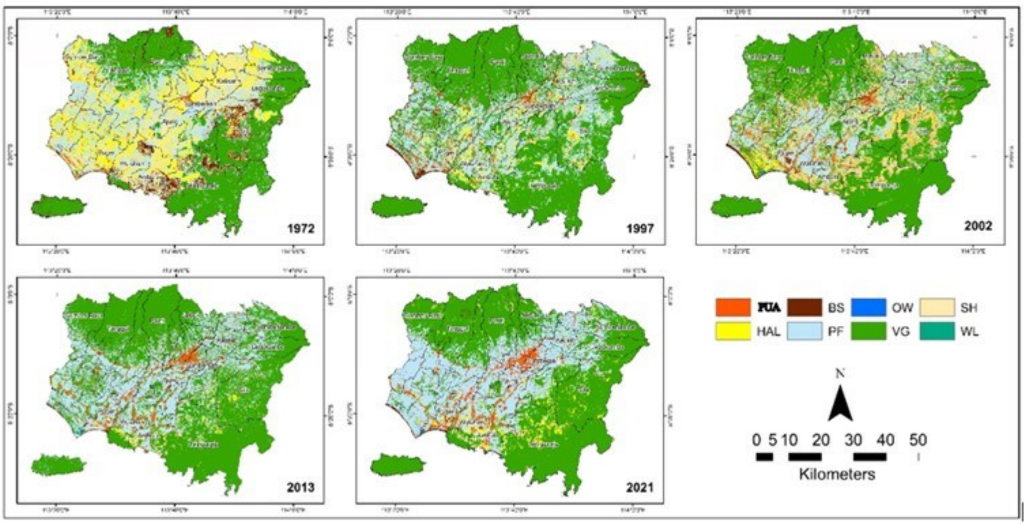

Figure 8. LULC in Agricultural areas.

Table 7. LULC change in subset C (Jember)

Class	1972		1997		2013		2021	
	km²	%	km²	%	km²	%	km²	%
PUA	53.28	1.61	123.63	3.74	184.46	5.57	170.96	5.17
HAL	598.22	18.08	170.10	5.14	34.86	1.05	130.60	3.95
BS	180.22	5.45	42.24	1.28	7.55	0.23	23.95	0.72
PF	**817.67**	**24.71**	**1015.50**	**30.68**	**1088.27**	**32.88**	**1153.06**	**34.84**
OWB	1.15	0.03	0.14	0.00	3.80	0.11	4.63	0.14
VG	1134.85	34.29	1907.42	57.63	1911.16	57.75	1804.88	54.54
SL	524.07	15.83	43.37	1.31	77.48	2.34	19.68	0.59
WL	0.14	0.00	7.19	0.22	2.03	0.06	1.63	0.05
Total	**3309.60**	**100.00**	**3309.60**	**100.00**	**3309.60**	**100.00**	**3309.39**	**100.00**

Table 8. Rate of Development of Rice Commodity in Jember Regency 2005 ± 2013

Year	Area	Land Use Change
2006	140.186	
2007	141.066	0,63
2008	143.597	1,79
2009	154.438	7,55
2010	153.696	-0,48
2011	155.126	0,93
2012	162.618	4,83
2013	158.568	-2,49
Average	151.162	1,82

Source : BPS Kabupaten Jember (2007-2014)

Based on BPS data for 2006-2014, paddy fields in Jember Regency increased by 1.82% per year (Table 8). The increase in paddy field area can be caused by efforts to improve agricultural management, such as improvement of facilities and infrastructure for support the agricultural sector, starting from the aid of superior seeds to farmers, farmer cooperation for carrying out pest control activities, many construction and requirement for irrigation facilities such as waterworks, water gates, and designated water channel to sufficiently irrigate paddy fields as well as improving management institutional. Furthermore, (Sunartomo, 2015) shows that in the coming period (2014-2028), the rice cultivation area shows an average growth rate of 6.83% per year.

4. CONCLUSION

Applying a series of Landsat images from 1972 to 2021 can significantly demonstrate the change in land use and land cover (LULC) in the eastern part of East Java. The development of the region from 1972 to 2021 propagated and changed the LULC, which tended to increase significantly: the pavement and urban area (PUA), paddy field (PF), vegetation (VG), open water body (OWB), and wetland (WL). Those classes have increased more than 100% during the last fifty years. The PUA increased from 2,05% in 1972 to 9,65% in 2021 (about 370% increase) in the total areas, while during the same period, PF increased from 16,1% to 35,8% (about 122% increase) in the total areas. Consequently, the occupation of space for the heterogeneous agricultural land (HAL), bare soil (BS), and shrubland (SL) is significantly decreased to balance this LLC change. This also means that more and more HAL, BS, and SL are converted to PUA, PF, VG, OWB, and WL.

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