International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-4, February 2020

Spatial Monitoring of Urban Development Direction using Landsat 7 ETM+ and Landsat 8 OLI/TIRS in Balikpapan City, Indonesia

Bayu Elwantyo Bagus Dewantoro, Pavita Almira Natani, Zumrotul Islamiah

Abstract: ***The development of urban areas in the city of Balikpapan increases over time and is characterized by increasing population. The growth and development of urban areas needs to be monitored so that the control function on area spatial can be implemented. This research aims to determine the direction of urban areas and measure the density of the built-up as a leading indicator of the development of urban areas in Balikpapan. The method used in this study is the multispasio-temporal analysis of remote sensing data of Landsat 7 ETM+ and Landsat 8 OLI/TIRS which contain a combination of spectral transformation, classification supervised Maximum Likelihood, accuracy assessment and statistical analysis. The results showed the trend of urban development from 2001 to 2019 towards east and northeast with the highest built-up density located in the sub-district of Balikpapan Tengah by 82.07% and followed by the sub-district of Balikpapan Kota by 76.94%. The largest land conversion took place on the bare soil with low vegetation density class to be vegetation with the converted area of 7095.91 ha or approximately 14.10% followed by the bare soil with low vegetation density class to be built-up with the converted area of 5826.86 ha or about 11.58% of the total area of Balikpapan city during the period from 2001 to 2019. The accuracy of urban development map in 2001 reaches 92.39 % and the year 2019 reaches 95.69 %, while the accuracy of land cover map in 2001 reaches 85.57% and the year 2019 reaches 87.28 %.***

Keywords: ***Land Cover Change, Remote Sensing, Urban Development***

I. INTRODUCTION

Land is a limited resource and cannot be increased. Inversely proportional to the condition, human needs will continue to increase land. The increasing demands of land demand resulted in complex problems and related to community activities.

Revised Manuscript Received on February 28, 2020.
* Correspondence Author

Bayu Elwantyo Bagus Dewantoro*, Department of Geographic Information Science, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, Indonesia. Email: bayuelwantyo@mail.ugm.ac.id

Pavita Almira Natani, Departement of Civil Engineering and Planning, Institut Teknologi Kalimantan, Balikpapan, Indonesia. Email: 08171059@student.itk.ac.id

Zumrotul Islamiah, Departement of Civil Engineering and Planning, Institut Teknologi Kalimantan, Balikpapan, Indonesia. Email: 08171086@student.itk.ac.id

Land conversion is a problem that is formed from the needs of growing land. Land conversion can be interpreted as a change both in part and overall land function from being planned to other functions and can negatively impact the environment and resources of the land [1].

Land conversion is a consequence of the growing number of people aimed at both the development agenda and other anthropogenic activities. Although it is a natural thing, a fixed land conversion should be limited to its growth. When land conservation occurs in large magnitude can cause spatial problems. The existing spatial plan cannot run properly and can impede the development of both the economy, as well as the facilities and infrastructure of a region. In addition, the height of land conservation also complicate evaluation of spatial plan implementation.

The city of Balikpapan is one of the cities that experience the conversion of land is quite massive. Land conversion does not wake up to waking land increases annually. The increase of land area was developed due to the development of urban areas of Balikpapan. The development of the city can have a good impact on the community economy, but it still requires a strict monitor as a control effort related to its expansion so that protected areas and buffer areas can be maintained and the functions Ecological or environmental services.

The development of remote sensing technology is capable of being used as one of the main techniques in performing the monitoring function of urban area development. The availability of good multitemporal data and extensive area coverage and the ability to detect using various digital image processing methods makes remote sensing techniques widely applied for urban studies, Especially the development of urban areas and spatial distribution. Integration of remote sensing techniques and geographic information systems is able to improve effectiveness and efficiency in the analysis of the direction of urban areas [2].

An urban study, particularly related to the development of urban areas, urban sprawl, urban growth, urban planning and similar research has been conducted by many researchers. Reference [2] has researched spatio-temporal monitoring on urban areas in India using statistical methods on the data extraction per radius buffer with the Normalized Built-up Index (NDBI) index transformation. Almost similar research has been done as in [3] in Romania, but the research is more focused on future built-up modelling.

The study of the direction of urban areas in the city of Balikpapan using the integration of remote sensing techniques and geographic information systems that have not been carried out and the dynamic pace of development makes the authors feel the need to raise the topic contribute to the monitoring function in the control of urban area development.

The purpose of this research is to know the direction of the urban development and measure the density of the built-up area as a leading indicator of the development of urban areas in Balikpapan.

II. LOCATION AREA

The city of Balikpapan is one of the cities in East Kalimantan province which is located at coordinates 1° 00’ 00" to 1°30’00’’Southern Latitude and 116 ° 30 ′ 00" to 117°00’00’’ Eastern Longitude. The city of Balikpapan is at an altitude of 0-100 meters above sea level with an average rainfall of 10.23 mm/day and an average temperature of 27.68 ° C [4]. The city of Balikpapan has 6 sub-districts with a population of more than 645000 people in 2018 and a total area of 50330.57 ha [5].

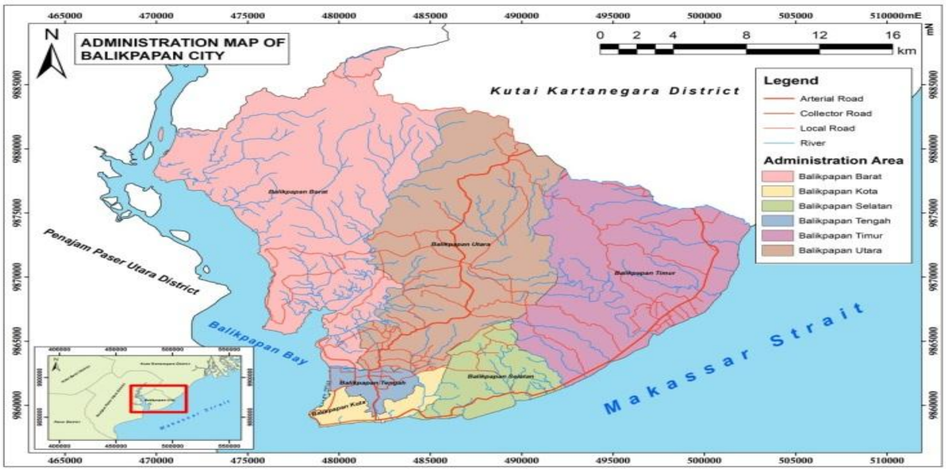

Fig. 1. Map of Study Area

III. RETRIEVAL DATA SOURCE

Extraction of built-up information areas obtained from the image processing Landsat 7 ETM+ and Landsat 8 OLI/TIRS recording years 2001, 2003, 2005, 2012, 2014, and 2019. The imagery is obtained from the United States Geological Survey (USGS) which is stored on the cloud computing platform of Google Earth Engine. The imagery used is based on the parameters of cloud cover conditions, data availability, minimum stripped error in Landsat 7 ETM+ because of Scan Line Corrector (SLC) failure, spectral resolution and spatial resolution. Landsat 7 ETM+ and Landsat 8 OLI/TIRS have different spectral resolution that can be seen in (**Table- I**) so it is necessary to integrate the extraction method to normalize the output of both images. The built-up extraction area is carried out using a variety of spectral transformation methods, including Normalized Difference Built-up Index (NDBI), Normalized Difference Vegetation Index (NDVI), and Modified Normalized Difference Water Index (MNDWI). Statistical Data of the number and density of the population, the number of vehicles, and land use obtained from the publication of the city of Balikpapan in numbers and official site of the central Statistic Agency of Balikpapan.

Table-I. Specification of Landsat 7 ETM+ and Landsat-8 (OLI/TIRS) imagery.

		Landsat 7 ETM+		Landsat 8 OLI/TIRS		
Sensing Time	Electromagnetic Area	Band	Wavelength (μm)	Band	Wavelength (μm)	Spatial Resolution
16-Apr-01	Coastal Aerosol	NA	NA	1	0.43 - 0.451	
24-May-03	Blue	1	0.441 - 0.514	2	0.452 - 0.512	30
05-Jun-05	Green	2	0.519 - 0.601	3	0.533 - 0.590	30
28-Sep-12	Red	3	0.631 - 0.692	4	0.636 - 0.673	30
25-Aug-14	Near Infrared	4	0.772 - 0.898	5	0.851 - 0.879	30
28-Feb-19	Short Wave Infrared (SWIR 1)	5	1.547 - 1.749	6	1.566 - 1.651	30
	Short Wave Infrared (SWIR 2)	7	2.064 - 2.345	7	2.107 - 2.294	30
	Panchromatic	8	0.515 - 0.896	8	0.503 - 0.676	15
	Cirrus	NA	NA	9	1.363 - 1.384	30
	Thermal Infrared (TIR 1)	6	10.31 - 12.36	10	10.60 - 11.19	TIRS (100) ETM+ (60)
	Thermal Infrared (TIR 2)	NA	NA	11	11.50 -12.51	100

Retrieval Number: D1893029420/2020©BEIESP
DOI: 10.35940/ijitee.D1893.029420
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

IV. RADIOMETRIC CORRECTION

The radiometric correction is performed on the Landsat 7 ETM^+ and Landsat 8 OLI/TIRS imagery to the surface reflectance level. Radiometric correction should be performed because the spectral reflection of the object on the Earth's surface is still affected by the interaction of electromagnetic waves with the atmosphere so that the spectral reflection of the recorded object may not be the actual spectral value [6]. The radiometric correction is performed using the following formula [7]:

$$L\lambda\left(Landsat\text{–}7ETM^{+}\right)=\left(\frac{(LMax\lambda-LMin\lambda)}{(QCalMax-QCalMin)}\right)\times(QCal-QCalMin)+LMin\lambda$$

(1)

Where $L\lambda$ = Top of Atmosphere (TOA) Spectral Radiance, QCal = Quantized calibrated pixel value in DN, Lmin = Spectral radiance scaled to QcalMax, QcalMin = Minimum quantized calibrated pixel value in DN. The Lmin, Lmax, QcalMax, and QcalMin can be found on the image metadata.

$$L\lambda(Landsat-8OLI/TIRS)=(ML\times QCal)+AL$$

(2)

Where $L\lambda$ = Top of Atmosphere (TOA) Spectral Radiance, ML = Band spesific multiplication factor rescaling from metadata, AL = Band spesific additive factor rescaling from metadata, QCal = Quantized calibrated pixel value in DN [8].

The TOA radiance to TOA reflectance conversion uses the following formula [8]:

$$p\lambda(Landsat-8OLI/TIRS)=\frac{p\lambda'}{\cos\theta sz}=\frac{p\lambda'}{\cos\theta se}$$

(3)

Where $p\lambda$ = TOA reflectance, θsz =angle of sun elevation, θse = angle of sun azimuth.

V. GEOMETRIC CORRECTION

A geometric correction is performed to ensure the object is in its actual location on the Earth's surface [9]. The reference used for geometric correction is the topographical map or the map of Rupabumi Indonesia. Map of Rupabumi Indonesia is transmitted to the image used, then the object that is felt statically measured the difference in distance between the map of Rupabumi Indonesia with the imagery. When the difference of the distance is < 25 meters, the image is considered feasible for use [10].

VI. TECHNIQUES FOR EXTRACTION AND ANALYSIS OF NDBI, NDVI, MNDWI, AND LAND COVER MAP

Extraction and analysis of built-up areas as a leading indicator of urban development is carried out using techniques and methods of spectral transformation in the form of NDBI, NDVI, and MNDWI. NDBI is a spectral transformation that is often used for the detection of built-up area [11], NDVI is required for the detection of vegetation and its density as a land cover indicator and MNDWI used to reduce detection errors due to the resemblance of spectral response to the built-up area and bare soil [12]. The integration of NDBI, NDVI, and MNDWI resulted in a new index called Built-up Area Index (BUI). Its image processing and analysis was conducted using Google Earth Engine cloud computing and software ENVI 5.2, ArcGIS 10.3, Microsoft Office Excel 2010, and IBM SPSS®.

VII. SPECTRAL TRANSFORMATION OF LANDSAT 7 ETM^+ AND LANDSAT 8 OLI/TIRS

Detection of built-up areas using Normalized Difference Built-up Index (NDBI) with the following formula [13]:

$$\text{NDBI}=\frac{SWIRBand-NIRBand}{SWIRBand+NIRBand} \quad (4)$$

Vegetation density was detected using a Normalized Difference Vegetation Index with the following formula [14]:

$$\text{NDVI}=\frac{NIRBand-\text{Re}dBand}{SWIRBand+\text{Re}dBand} \quad (5)$$

Reduction in surface moisture effect is carried out using the Modified Normalized Difference Water Index (MNDWI) with the following formula [15]:

$$\text{MNDWI}=\frac{GreenBand-SWIR2Band}{GreenBand+SWIR2Band} \quad (6)$$

The built-up extraction area uses a combination of NDBI, NDVI, and MNDWI to produce a more sharp and clear built-up area with subtraction methods in the following formulas [16]:

$$\text{BUI}=NDBI-NDVI-MNDWI \quad (7)$$

VIII. LAND COVER CLASSIFICATION AND ACCURACY ASSESSMENT METHOD

The land cover map was created using the supervised Maximum Likelihood classification method at Landsat 7 ETM^+ year 2001 and Landsat 8 OLI/TIRS year 2019 recording in consideration that this method is ideal to be applied to various types of data [6]. The land cover map is classified into 4 classes, namely built-up, bare soil with low vegetation density, vegetation, and water body. Sampling area retrieval is done on every class except built-up. This is because the built-up class has been extracted using the index transformation method so that when sampling is carried out in the built-up class, the built-up information on the map of urban development and the land cover map will be confusing and generating chaotic data structures that have an effect on erroneous analysis.

The accuracy test was carried out on the urban development map of the 2001 and 2019 areas and on the land cover map in 2019 using the confusion matrix method. The accuracy test is intended to know the percentage accuracy of the resulting map. The number of samples calculated using the Slovin formula and distributed using the stratified random sampling method with the purpose of each class on the classification scheme got an accuracy test sample.

IX. RESULT AND DISCUSSION

The distribution of urban areas and dynamism is influenced by land conversion phenomena that always occur in each region as the need for varying land functions increases.

The Land Cover map classification produces 4 classes of land cover, which are built-up, vegetation, water body, and bare soil with low vegetation density. The distribution of land covers in the city of Balikpapan can visually be identified on **Fig. 2**. The class of vegetation in the years 2001 and 2019 relative has a similar distribution in the west and northwest of the city of Balikpapan, while the class of bare soil with low vegetation density of relatively random spread, water body class is spread sporadic on coastal areas And partly a lake, as well as built-up classes scattered from the southern part of the city of Balikpapan to the east and northeast.

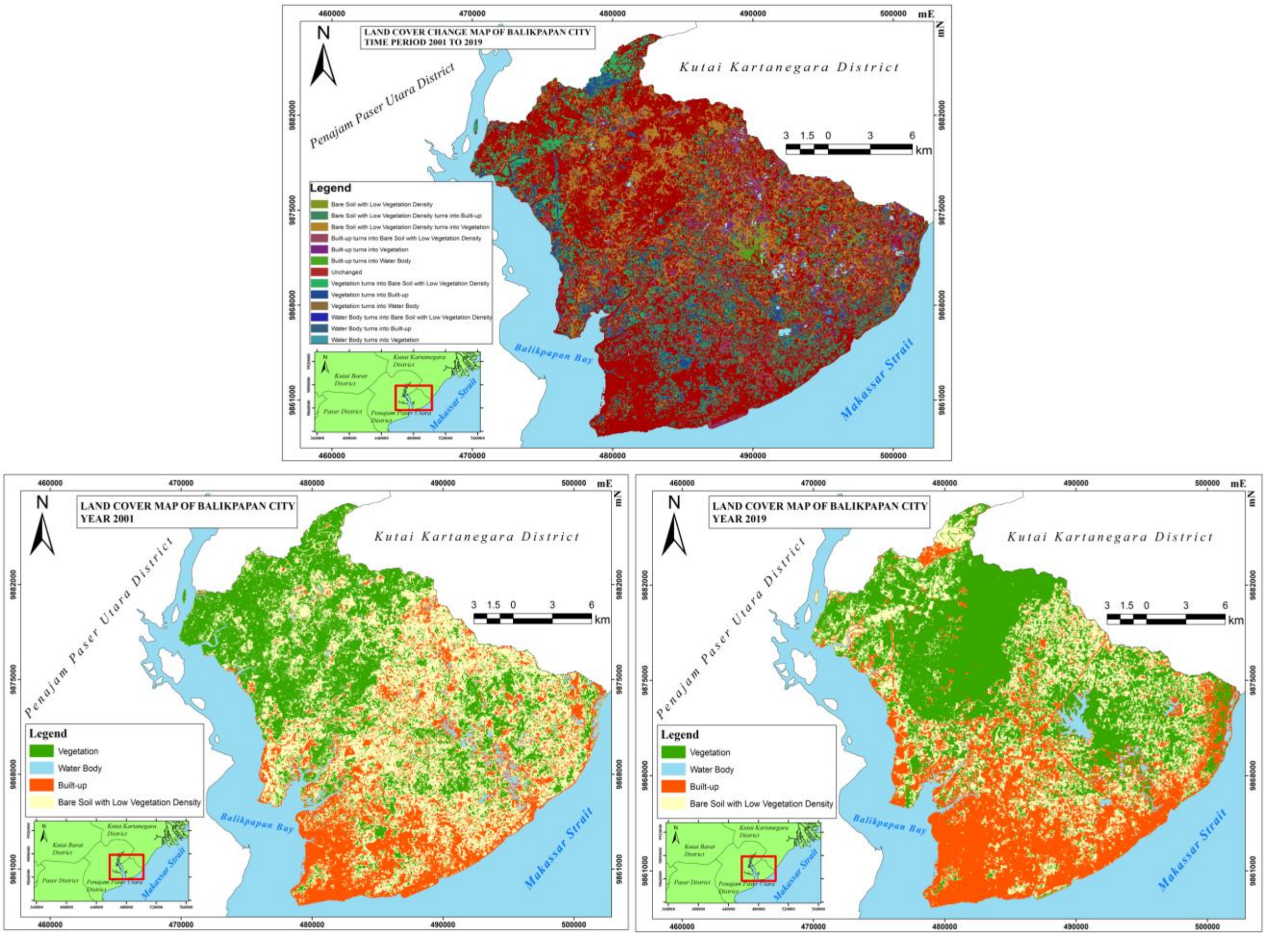

Fig. 2. Various land cover map and its changes in Balikpapan City

The results of the processing show that land conversion occurred in the 4 class cover of the land. The largest land conversion took place on the bare soil with low vegetation density class to be vegetation with the converted area of 7095.91 ha or approximately 14.10% followed by the bare soil with low vegetation density class to be built-up with the converted area of 5826.86 ha or about 11.58% of the total region of the city of Balikpapan (see **Table-II**). It shows that the land conversion to a built-up area takes a considerable portion. A systematic and structured monitoring mechanism is required to control a reasonably massive land conversion phenomenon, in particular the built-up area.

Table- I: Land Cover Change Matrix in Balikpapan City

	Built-up	Vegetation	Water Body	Bare Soil with Low Vegetation Density
Built-up	7346.81	1505.57	291.77	2059.36
Vegetation	2241.20	11509.30	91.81	4322.96
Water Body	421.27	184.69	483.25	81.63
Bare Soil with Low Vegetation Density	5826.86	7095.91	177.10	6691.09

The results of the processing on Landsat 7 ETM$^+$ and Landsat 8 OLI/TIRS imagery showed the spatial distribution in the built-up area in the period of 2001, 2003, 2005, 2012, 2014, and 2019. The data retrieval time of each time period is determined based on the main parameters of the cloud cover state of < 5% and the minimum stripped error in Landsat 7 ETM$^+$. Some of the the processed Landsat 7 ETM$^+$ images indicate stripped errors caused by sensor failure in satellites. This makes the classification process on imagery less disrupted and affects the analysis. It was seen on the image of Landsat 7 ETM$^+$ in the years 2001, 2003, and 2005 with white spots (see **Fig. 3.**) so that it affects the broad estimation of each class. Spatial distribution of built-up area from the years 2001, 2003, 2005, 2012, 2014, to 2019 looks consistent. The distribution pattern is relatively orderly with the increasing densities of built-up area geographically visible towards the east and northeast.

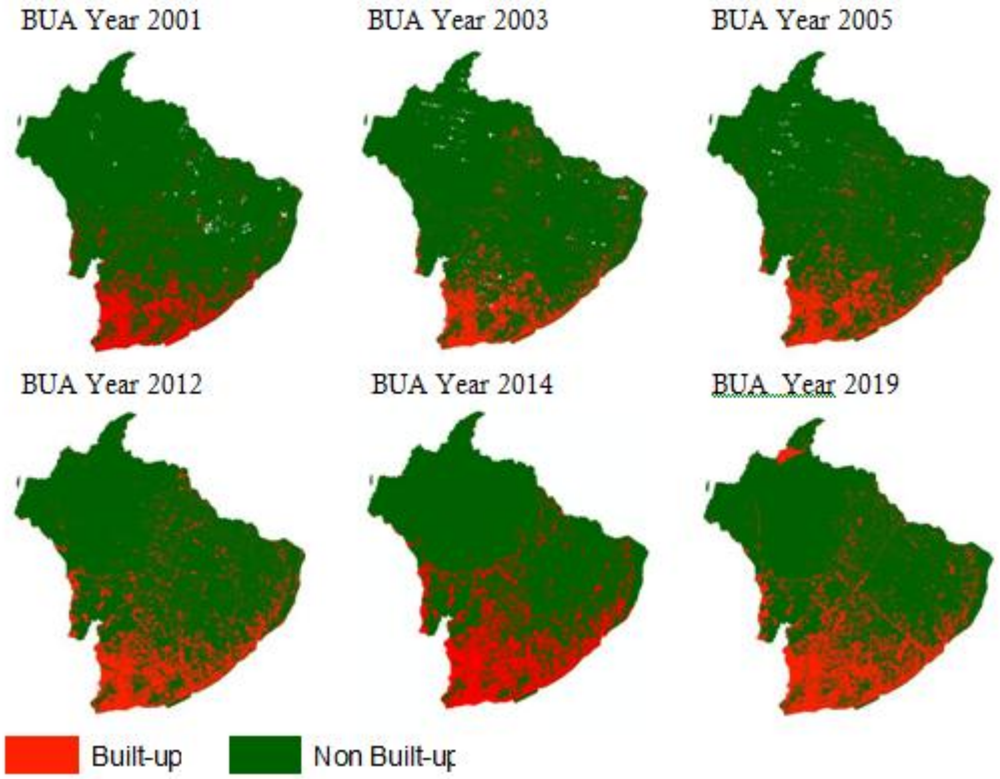

Fig. 3. Built-up Area (BUA) Dynamics of Balikpapan City

An built-up area extraction requires a threshold value as a reference for determining binary classification on a map. Specifying a threshold value is determined manually using the mean value in the image stats. Summary of statistical data obtained is an extraction from the built-up area that is homogeneous so that it can be a reference to the determination of threshold value. The trend of threshold values per year is relatively varied (see **Table-III**), especially in the period of 2001 – 2012 and the Year 2014 – 2019 due to differences in the spectral resolution of the ETM$^+$ sensors on Landsat 7 and OLI/TIRS on Landsat 8. The determination of the built-up class is based on the value of the digital number (DN) of the image higher than the mean value on the image statistics, while classes other than the built-up are extracted from the value of a digital number (DN) lower or equal to the mean value on the image statistics.

Table-III: Statistical data summary of Built-up Area Index

	Built-up Area Index (BUA)			
Year	Min	Max	Mean	St.Dev
2001	-1.321	0.328	-0.186	0.256
2003	-1.162	0.445	-0.23	0.237
2005	-1.105	0.408	-0.157	0.241
2012	-1.167	0.536	-0.077	0.247
2014	-1.087	0.566	-0.068	0.27
2019	-1.243	0.666	-0.012	0.336

The increase of built-up area was developed in the city of Balikpapan as a major indicator of urban growth in line with the increasing population and population density (see **Fig. 4.**). The estimated increase in built-up area from 2001 to 2019 reached 5420.32 ha with an increase in population reaching 162794 people from the period 2002 to 2018 [5].

This makes the city of Balikpapan need to control the expansion of the built-up because the land conversion trend does not awakened land to an built-up is increasing about 10.76% per year, mainly in the buffer and protected area so that the formulation of policies related to conservation and preventive measures related to land expansion should be encouraged because it concerns the sustainability of the environmental ecosystem [17].

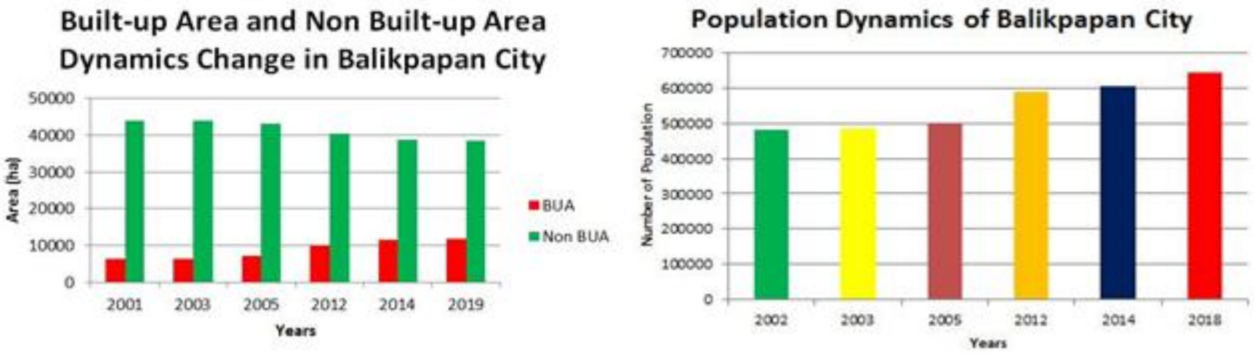

Fig. 4. Built-up, non built-up, and population dynamics of Balikpapan City

The direction of the development of urban areas is more precise, identified using a buffer analysis with a radius of 5 km, 10 km, 15 km, 20 km, and 25 km (see **Fig. 5.**) with a midpoint in the center of the city. Spatial distribution of built-up area has a trend leading to the east and northeast of the city of Balikpapan with the highest land density up to the lowest is at a radius of 5 km to 25 km to the outside of the city center. The direction of the development is assumed to occur due to the development of infrastructure, especially the construction of the Balikpapan-Samarinda toll road that provides opportunities to the movement of economic wheels in the city of Balikpapan more effective and efficient.

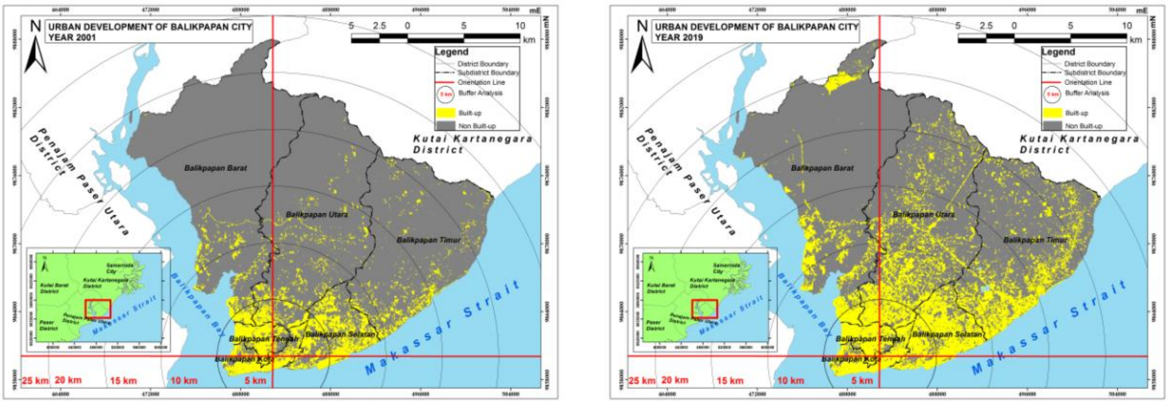

Fig. 5. Urban Development Map of Balikpapan City year 2001 and 2019

The increased built-up area highest from 2001 to 2019 in Balikpapan Utara sub-district reached 2168.34 ha, while Balikpapan Tengah became a sub-district with the lowest rise in land area. It is inversely proportional to the built-up density that turns Balikpapan Tengah into a sub-district with the highest overcrowding land compared to other districts in the city of Balikpapan (see **Fig. 6.**). It was influenced by the area per sub-district and radius distance from the city center. Balikpapan Tengah and Balikpapan Kota are included in the sub-district with a radius closest to the city center, making two of them become two sub-districts with the highest built-up density in the city of Balikpapan which reaches 82.07% and 76.94%, so that the trend of urban area development in sub-district of Balikpapan Tengah and Balikpapan Kota should no longer be oriented to the expansion of built-up area, but rather quality improvement on various public and private services.

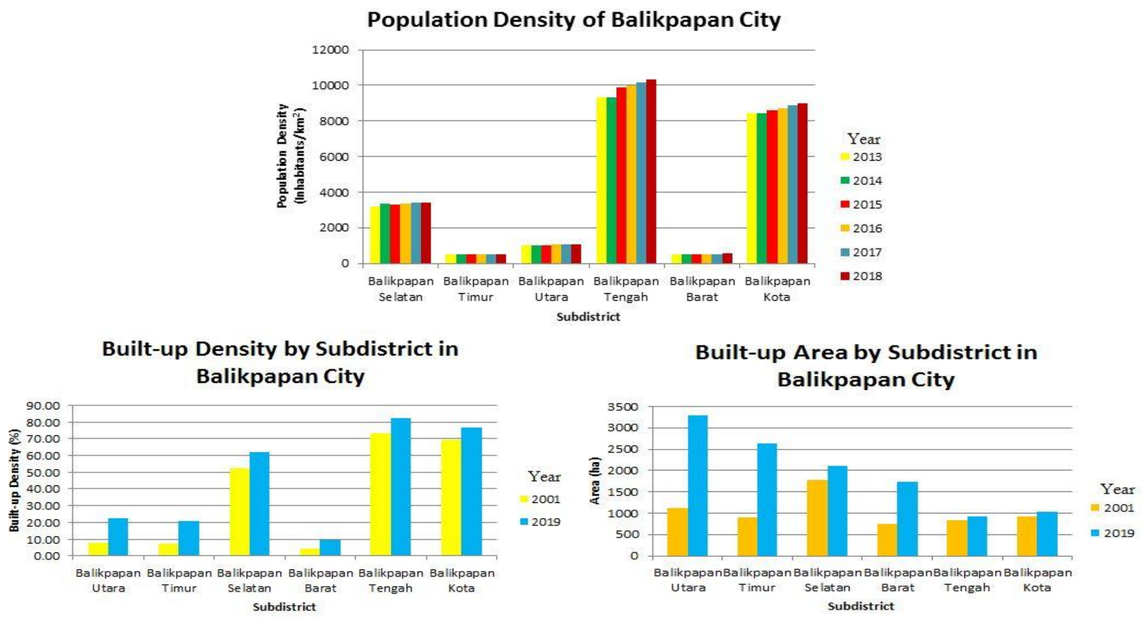

Fig. 6. Population and built-up dynamics graph of Balikpapan City

The development of urban areas is also represented by the increase in the number of motor vehicles, especially private vehicles such as private cars and private motorcycles. The increase in the number of vehicles from 2006 to 2018 reaches 331143 units (see **Fig. 7.**) with the highest number of 533842 units in the year 2018 period [5]. More motor vehicles are causing changes and the dynamics of air quality.

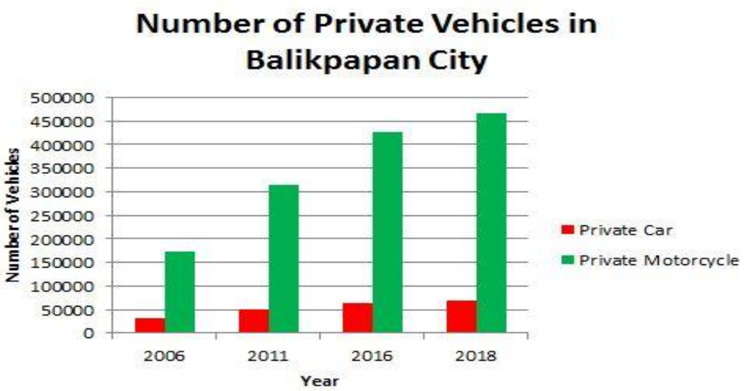

Fig. 7. Graph of private vehicle number in Balikpapan City

Measurement of air quality has been done in 2011 to 2018 consistently in 5 sample areas located in settlement (around Kampung Bar Ujung), roadside (Simpang Plaza Balikpapan, around Rapak roundabout, and around Simpang Gunung Malang), as well as public service (around Semayang port) with parameters of concentration SO_2, NO_2, CO, and PM 10 (see **Table-IV**). The highest concentration averages in the SO_2, NO_2 and CO parameters are on the roadside sample area (Simpang Plaza Balikpapan, around the Rapak roundabout, and around Simpang Gunung Malang) with a SO_2 concentration of 0.061 µg/Nm³, NO_2 at 0.040 µg/Nm³, and CO of 3.544 µg/Nm ³, while the highest PM 10 concentration was in the sample area around the Semayang port of 0.065 µg/Nm ³ [5].

Table-IV: Air Quality of Balikpapan City

	Air Quality Parameter (µg/Nm³)			
	SO_2	NO_2	CO	PM 10
Settlement	0.029	0.027	2.142	0.038
Roadside	0.061	0.040	3.544	0.052
Public Service	0.033	0.031	3.308	0.065

The accuracy test is done to determine the performance of map accuracy generated using confusion matrix. The accuracy test is carried out against the 4 maps produced, namely the map of the urban development year 2001 and 2019 and the map of land cover year 2001 and 2019. Field surveys on samples take quite a long time due to the number of sample polygons on the 4 maps more than 200 samples so that field surveys require supporting data in the form of high resolution imagery to minimize field work which is pretty much. Imagery on the Google Earth platform is selected as supporting data due to ease of access, data availability, and high resolution. The 2001 maps in the test used the map of Rupabumi Indonesia as a reference to the basic map that is officially used in Indonesia, compiled from 2000 to 2001.

Table-V: Confusion Matrix of Urban Development Map Year 2019

		Field Survey			
		Built-up	Non Built-up	Total Row	User Accuracy (%)
Tentative Map	Built-up	40	7	47	85.11
	Non Built-up	1	184	185	99.46
	Total Column	41	191	232	
	Producer Accuracy (%)	97.56	96.34		
	Overall Accuracy (%)	95.69			

Table-VI. Confusion Matrix of Urban Development Map Year 2001

		Field Survey			
		Built-up	Non Built-up	Total Row	User Accuracy (%)
Tentative Map	Built-up	44	17	61	72.13
	Non Built-up	5	223	228	97.81
	Total Column	49	240	289	
	Producer Accuracy (%)	89.80	92.92		
	Overall Accuracy (%)	92.39			

Table-VII. Confusion Matrix of Land Cover Map Year 2019

		Field Survey					
		Built-up	Vegetation	Bare Soil with Low Vegetation Density	Water Body	Total Row	User Accuracy (%)
Tentative Map	Built-up	101	7	3	0	111	90.99
	Vegetation	2	86	6	3	97	88.66
	Bare Soil with Low Vegetation Density	8	4	33	1	46	71.74
	Water Body	0	2	0	27	29	93.10
	Total Column	111	99	42	31	283	
	Producer Accuracy (%)	90.99	86.87	78.57	87.10		
	Overall Accuracy (%)	87.28					

Table-VIII. Confusion Matrix of Land Cover Map Year 2001

		Field Survey					
		Built-up	Vegetation	Bare Soil with Low Vegetation Density	Water Body	Total Row	User Accuracy (%)
Tentative Map	Built-up	98	1	11	0	110	89.09
	Vegetation	2	79	9	3	93	84.95
	Bare Soil with Low Vegetation Density	7	4	47	0	58	81.03
	Water Body	0	5	1	31	37	83.78
	Total Column	107	89	68	34	298	
	Producer Accuracy (%)	91.59	88.76	69.12	91.18		
	Overall Accuracy (%)	85.57					

Based on the accuracy test that has been done, the overall performance of the map includes good with an average of > 85% accuracy. It shows that the method of integrating the transformation indexes used in the extraction of built-up and non built-up produces good accuracy. The most classification fault on the land cover map is on the built-up class and bare soil with low vegetation density. This is because the sample training taken on both classes is quite similar visually, resulting in a classification error. Classification fault can be minimized by using supporting data such as composite image that is able to bring out the difference in the built-up and bare soil with low vegetation density.

X. CONCLUSION

Result showed a tendency towards the development of urban areas in the city of balikpapan during the period from 2001 to 2019 towards the east and northeast of the city center of Balikpapan. The direction of developments is supported by an increase in built-up area that reaches 5420.32 Ha density is in the sub-distric of Balikpapan Tengah and Balikpapan Kota reaches 82.07% and 76.94% by 85.57% and 87.28%, while the accuracy of map developments in urban areas of 2001 and 2019 by 92.39 % and 95.69%. The largest land conversion took place on the bare soil with low vegetation density class to be vegetation with the converted area of 7097.91 Ha or approximately 14.10% followed by the bare soil with low vegetation density class to be built-up with the converted area pf 5826.86 Ha or about 11.58% of the total area of Balikpapan City during the period from 2001 to 2019.

ACKNOWLEGDMENT

The authors would like to express our gratitude to The Remote Sensing Laboratory and Geographic Information System Laboratory, Department of Geographic Information Science, Universitas Gadjah Mada (UGM). We also would like to thank United States Geological Survey for providing free remote sensing data.

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AUTHORS PROFILE

Bayu Elwantyo Bagus Dewantoro is a college student of the Departement of Geographic Information Science, Faculty of Geography, Gadjah Mada University. Ever contributed to the National Seminar III of Geography, Gadjah Mada University and National Seminar on Fisheries Management Lombok, West Nusa Tenggara. Intrested in the areas of urban research, vegetation, athmosphere, and spatial modeling using the integration of remote sensing technique and geographic information systems.

Pavita Almira Natani is a college student of the Departement of Civil Engineering and Planning, Kalimantan Institute of Technology. Ever contributed to Science Writing Competition of Economy, Muhammadiyah University of Surakarta. Interested in city planning and transportation.

Zumrotul Islamiah is a college student of the Departemment of Civil Engineering and Planing, Kalimantan Institute of Technology. Ever contributed to writing competition on Kalimantan Institute of Technology and Muhammadiyah University of Surakarta. Interested on Environtment Management, Coastal Management and Urban Infrastructure