Analysis of the Relationship Between the Percentage of Residential Density and the Built-Up Land Index in Community Environments

Rivi Yuliya Indriarti, Hamim Zaky Hadibasyir(✉), and Annisa Trisnia Sasmi

Faculty of Geography, Universitas Muhammadiyah Surakarta (UMS), Surakarta 57162, Central Java, Indonesia

hamim.zaky.h@ums.ac.id

Abstract. The city is the center of various activities, including those related to the economy, services, government, and education. Specifically, the development of Semarang City spurs the growth of buildings. However, population growth in Semarang City is only concentrated in a few sub-districts. Births, deaths, and migration are the main drivers of population growth. Thus, this study aims to determine the level of building density in Semarang City, the correlation and regression values of the built-up land index with the percentage of built-up land, and the estimation of the distribution of built-up land. Building density was seen using the built-up land index in the form of NDBI, UI, IBI, and EBBI. Image transformation was also performed utilizing the NDBI (Normalized Difference Built-up Index), UI (Urban Index), IBI (Index-based Built-up Index), and EBBI (Enhanced Built-up and Bareness Index) algorithms. The algorithm employed comprised channels or bands in the Landsat 8 OLI/TIRS imagery. A total of 30 samples were involved in building correlation and regression values. As a result, significant correlation and regression had a low relationship, with an R-square value of 0.282 on EBBI, while NDBI, UI, and IBI had a non-significant correlation, and the regression had a very low relationship, with an r-square value < 0.1. Besides, the estimated percentage of built-up land produced different estimation values, with the highest estimated value found in the EBBI built-up land index with a value of 85.29% to 99.66%. Moreover, the high density of buildings is due to the increasing population in Semarang City; after the decline in COVID-19 cases, the increase in living needs triggered urbanization.

Keywords: Population growth · built-up land index · building density · urbanization

1 Introduction

The city is the center of human activity, which usually starts with government, society, culture, economy, industry, security, and others. The city itself has high growth compared to other regions. On the other side, built-up land is an appearance of the earth's surface

H. Z. Hadibasyir and V. N. Fikriyah (Eds.): ICGDM 2022, ASSEHR 755, pp. 392–406, 2023.
https://doi.org/10.2991/978-2-38476-066-4_25

that has experienced human intervention and has certain functions in society in the form of built-up physical appearances, such as settlements, industry, and roads in the form of asphalt (Zahrotunisa, 2017). In a city, development and growth are caused by several factors, including human activities and movements. City development is directly proportional to population growth, where an increase in population will affect city development, which does not deny the increase in land use in the city (Trinufi and Rahayu, 2020). The increased need for built-up land is due to the high population growth; the more the population increases in certain areas, the more residential buildings will be. This development is also due to urbanization. This development can then trigger a growth in the number of buildings (Rosyadi and Azahra, 2020). Further, due to high urbanization, new problems arise in urban areas, such as high crime, unemployment, slum settlements, and other social problems (Harahap, 2013).

Moreover, the building is the most basic need of the population. The growth in the number of buildings is triggered by population growth in the form of births, deaths, and migration. Birth and death are natural factors in population growth, while the migration is a non-natural factor. Usually, the population in Indonesia tends to be clustered, and there are many of them in urban areas, which are centers of activity, making it easy to reach something. Urban development is also often associated with expanding agglomeration developments and increasing building land. In addition, changes in land development into uncontrolled development will impact various social and environmental (Ayu et al., 2021). Due to the increase in the urban population, the need for space also increases, causing changes in land use; it tends to reduce the proportion of the area, which was originally for agriculture, to become non-agriculture (Kusrini, Suharyadi, and Hardoyo, 2011).

Specifically, Semarang City is Central Java Province's capital, the largest metropolitan city in Indonesia after Jakarta, Surabaya, Bandung, and Medan. Semarang City is also very strategic and has a very rapid development. The impact of regional expansion in Semarang City is in the form of high population growth, resulting in an increasingly denser city center for government, trade, services, and attractiveness to local and regional communities. In addition, the increase in prices in the city center has resulted in the developing of services and trading activities, mostly in the suburbs (Arsandi, R, Ismiyati, and Hermawan, 2017). The Semarang City development is also marked by skyscrapers, which are currently dominating along with the development of this modern era. Semarang City also has the potential for rapid land use changes due to its attractiveness, so many newcomers are attracted to employment in industrial activities (Nahib, 2016). The Semarang City development is also followed by an increase in the need for built-up lands, such as settlements, road networks, facilities, and infrastructure. More specifically, 2021 is the year of transition from the pandemic to the endemic period. Many residents flocked to a certain area to recover their economy, which had collapsed during the 2020 COVID-19 pandemic. It is one of the factors in the increase in the number of buildings and the density of buildings.

Usually, building density mapping requires much effort related to building measurements and others. In this case, accessibility is crucial when taking measurements to make it easier to get data in densely populated and slum areas, where remote sensing is a simple and inexpensive elocutionary issue. With the development of science and methods, remote sensing is now increasingly advanced, allowing for more effective mapping of building densities. The advantage of using remote sensing is the easy processing that can be done with various mathematical algorithms to get new information. Information obtained from remote sensing can be combined with various other information to test its accuracy and interpretation (Mansouri, Feizi, Jafari Rad, and Arian, 2018). However, the main problem with this mapping is in the form of an assessment related to changes in land use from agriculture to housing. These changes are often due to increased urbanization and high housing developments (As-syakur, Adnyana, Arthana, and Nuarsa, 2012).

Identifying the density of buildings in the field also requires a lot of time, money, and effort to use the data obtained more effectively. As stated, the advantage of using remote sensing imagery is that data is easy to obtain and has reliable accuracy (Puspitasari and Suharyadi, 2016). In remote sensing, several land covers are available, such as area, mapping, and classification in the form of bodies of water and vegetation (Pranata and Kurniadin, 2021). For this reason, the most efficient method is to use remote sensing to obtain land cover characteristics at different scales of analysis (Saputra, Akbar, Permadi, and Pratama, 2018). The image obtained from remote sensing is obtained by using image interpretation. Recently, remote sensing imagery has also been used to calculate built-up areas and has become a popular tool in society.

Remote sensing imagery is data that can be used to monitor and map changes in built-up and vacant land in urban areas, which impact population growth and increased urbanization (Jia et al., 2014). Remote sensing is also an appropriate method for temporally monitoring the development of urban areas. The obtained data produces relatively high accuracy (Saputra et al., 2018). This remote sensing capability is supported by spatial resolution conditions and precise channels to monitor urban changes. The role of remote sensing data is vital for urban land use management. Visual extraction of urban land information is related to settlement quality (Farizki and Anurogo, 2017). In addition, the built-up land index can make processing easier since each index of built-up land has different values and information (Hidayati and Suharyadi, 2019).

Many studies using the NDBI, UI, IBI, and EBBI built-up land indices have been carried out in Indonesia. For this reason, this research was conducted to identify building density using sensing (Syahputra, Jatmiko, Hizbaron, and Fariz, 2021). The level of building density can be determined by using the NDBI, UI, IBI, and EBBI built-up land indices, which are methods involving a channel/band of remote sensing data that generates new images to show the level of building density in an area. The research location was in Semarang City. This study's purposes include determining the level of building density in Semarang City using the 2021 NDBI, UI, IBI, and EBBI image transformation results, correlation and regression of the built-up area index, the relationship and link between the built-up land index and the percentage of built-up land, and estimated percentage of built-up land with built-up land index.

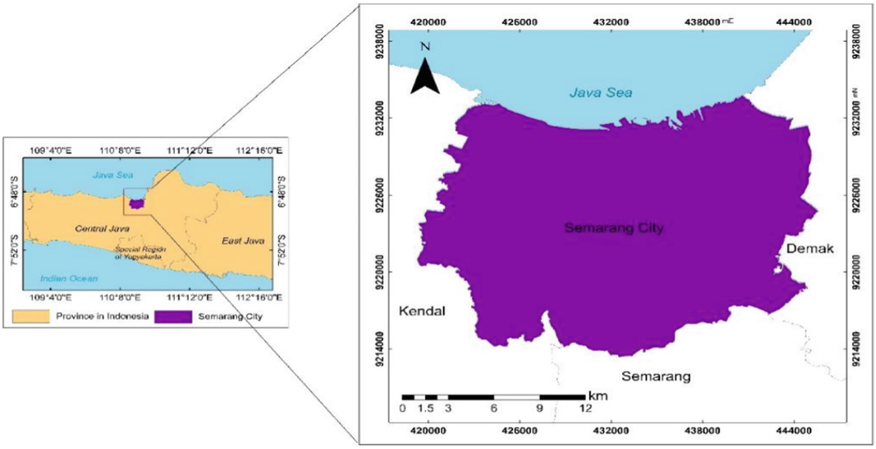

Fig. 1. Research Location

2 Research and Method

2.1 Study Location

The research location was the area of Semarang City, located at 109°35′–110°50′ East Longitude and 6°50′–7°10′ South Latitude. The administrative boundary of Semarang City is to the north by the Java Sea, to the south by Semarang Regency, to the east by Demak Regency, and to the west by Kendal Regency. Semarang City also has an area of 373.78 km^2, with a population of 1,656,546 people and a population growth rate of 0.25 in 2021. Figure 1 is a map of the research locations located in Semarang City.

2.2 Tools and Material

This study used tools and materials in the form of secondary data obtained from certain sources. The researchers also performed data processing on specific data. The data and equipment used can be seen in Table 1.

The equipment utilized in this research in the form of image processing support software included QGIS, ENVI, ArcGIS, and others. The equipment employed in the research can be seen in Table 2.

Table 1. Data Used for Research

No.	Data	Source	Year
	Citra Landsat 8 OLI/TIRS	USGS/Google	2021
	30 sample points	Data processing	2022
	Built-up land index value	Data processing	2022
	Percentage of built-up land	Data processing	2022
	Shapefile Central Java Province Administration Boundary	InaGeoportal	2019

Table 2. Software Used in Research

No.	Software	Uses
	USGS	Downloading imagery
	QGIS	Performing image corrections and base maps for sample digitization of each pixel
	ENVI	Image processing to obtain image transformation of the built-up land index
	ArcGIS	Performing image cutting, sample search, and map layouts processes
	SPSS 16	Conducting a process of correlation and regression of the percentage of built-up land with the index of built-up land

2.3 Processing and Analysis Techniques

The data processing carried out in this research was to obtain image transformation by downloading Landsat 8 OLI/TIRS images on path 120 and row 65, with a recording date of May 13, 2021, sourced from the USGS. The choice of image recording date used was to minimize the cloud cover present at the time of recording. Besides, radiometric and atmospheric correction of Landsat 8 OLI/TIRS images was performed on QGIS using the Semiautomatic Classification Plugins tool. Then, the atmospheric correction was carried out so that the reflectance in the image decreased. Image processing was continued using ENVI 5.3 to determine the image index transformation. Processing to obtain the image transformation of built-up land was then conducted by combining the bands using the built-up land index method (EBBI, IBI, NDBI, and UI).

1. Built-up Land Index

a. Enhanced Built-up and Bareness Index

The Enhanced Built-up and Bareness Index (EBBI) is an index of built-up land that uses the NIR band with a wavelength of 0.83 m, the SWIR band with a wavelength of 1.65 m, and the TIRS band with a wavelength of 11.45 m. The wavelength was calculated based on the reflection contrast and absorption range on built-up and non-built-up areas.

xxxxxxxx

$$\text{EBBI} = \frac{SWIR2 - NIR}{10\sqrt{SWIR + TIRS}} \quad (1)$$

Description:

EBBI : Enhanced Built-up and Bareness Index
NIR : Near Infrared Band
SWIR : Short Infrared Band 1
TIRS : Thermal Infrared Band 1

b. Index-based Built-up Index

Index-based Built-up Index (IBI) is an index whose changes combine land use in the form of built-up land, agriculture/vegetation, and water bodies as an equation.

$$\text{IBI} = \frac{\frac{2xSWIR1}{SWIR+NIR} - \left(\frac{NIR}{NIR+RED} - \frac{GREEN}{GREEN+SWIR1}\right)}{\frac{2xSWIR1}{SWIR+NIR} + \left(\frac{NIR}{NIR+RED} + \frac{GREEN}{GREEN+SWIR1}\right)} \tag{2}$$

Description:

IBI : Index-based Built-up Index
GREEN : Green Band
NIR : Near Infrared Band
RED : Red Band
SWIR1 : Short Infrared Band 1

c. Normalized Difference Built-up Index

The Normalized Difference Built-up Index (NDBI) is a built-up index that expresses the density of built-up land by displaying the most common changes when showing the results of the built-up area with sensitivity to large areas of land. In this built-up land index, the NIR and SWIR bands were used. The relatively higher reflectance is in the SWIR band (Pranata and Kurniadin, 2021).

$$\text{NDBI} = \frac{SWIR - NIR}{SWIR + NIR} \tag{3}$$

Description:

NDBI : Normalized Differential Built-up Index
NIR : Near Infrared Band
SWIR : Short infrared Band 1

Table 3 presents classifications of NDBI values based on the data processing results.

d. Urban Index

Table 3. Classification of NDBI Values

Class	NDBI Value	Classification of Building Density Level
1	- 1 up to 0	Non-Building
2	0 up to 0.1	Low
3	0.1 up to 0.2	Medium
4	0.2 up to 0.4	High

The Urban Index (UI) is an index of built-up land that can distinguish buildings from vegetation/bodies of water, usually using the NIR and SWIR bands. Both these indices are sensitive to built-up and non-developed land.

$$\mathrm{UI} = \frac{SWIR2 - NIR}{SWIR2 + NIR} \tag{4}$$

Description:

UI : Urban Index
NIR : Near Infrared Band
SWIR2 : Short Infrared Band 2

The transformed image was processed utilizing ArcGIS (Int (Spatial Analyst)) for each index and then *Create Random Point* to obtain the value of each index based on the pixels. Each pixel in the transformed image measured 30 m × 30 m. The number of samples that could be used was 30 to 500 for correlation and multiple regression, while 10 to 20 for correlation and simple linear regression (Sugiyono, 2019). The number of samples used to determine the correlation and regression in this study was 30 samples. The sample was digitized to obtain the percentage of built-up land value for each pixel in QGIS. This digitization was done according to the actual conditions for each pixel using the base map in QGIS. The percentage value was also obtained by calculating the area of the digitized per pixel and the area image.

Linear regression in this study was employed to see how much influence one variable had on other variables (Petrus Katemba and Koro, 2017). To find out the relationship between the percentage of built-up land and the index of built-up land, a sample test was conducted using SPSS 16, and the graphing also used SPSS 16. Regarding the relationship between the percentage of built-up land and the index of built-up land in a statistical approach, regression analysis was performed. The percentage of built-up land was the independent variable (X), and the indices of built-up land (EBBI, IBI, NDBI, and UI) were the dependent variables (Y) (Zahrotunisa, 2017). The formula that can be used is:

$$Y = a + bX \tag{5}$$

Description:

Y : Estimated value
a : The constant/intercept on the Y axis, i.e., the value of Y when X = 0
b : Regression coefficient
X : Independent variable.

3 Results and Discussion

The expansion of the area in Semarang City into 16 sub-districts has resulted in an increase and decrease in population each year. The sub-district with the highest population increase was the Tembalang Sub-district, which was caused by educational facilities in the form of a university. It became an attraction, so people flocked to the area to continue their education. It is due to the education center and growth center, a residential area. In addition, the population has increased due to births, deaths, and urbanization. An increase in population caused by land use in the form of settlements also occurred in Genuk Sub-district and Mijen Sub-district, whose spikes had a fairly wide scope (Arsandi et al., 2017). In this regard, population growth is a factor that cannot be controlled in a region's development. The speed of change and improvement leads to the importance of monitoring changes in urban areas through remote sensing data, which can provide comprehensive and efficient coverage of areas at different times (Rahman and Nugraha, 2021). Based on this, it can be seen that population growth has led to growth and changes in the number of buildings in Semarang City. When the population gets denser, the number of buildings in Semarang City is also getting denser. The purpose of settlement development is to support industrial, social, economic, and cultural development, which is an important factor in sustainable development (Rustianto and Saputra, 2021).

The number of buildings in Semarang City is also caused by the increasing primary need of its residents to get a comfortable, clean, and decent place to live. The density of these buildings is adjusted by the number of roof areas in the study area with the area per settlement block in units of settlement units, the results of which will show that the comparison between non-settlement land use and residential land in the study (Farizki and Anurogo, 2017). This increase in population is usually caused by urbanization, which in turn causes an increase in the need for built-up land for economic and social needs. It leads to uneven urban development and impacts inadequate facilities, infrastructure construction, and inappropriate land use (Satria and Rahayu, 2013). Semarang City also has charm related to the immigrant population, where many newcomers depend heavily on their lives in overseas cities, such as on economic and educational aspects. Moreover, the things that cause the high density of buildings in Semarang City are the population's high development, adequate facilities and infrastructure, educational areas' existence, rapid industrial development, and good accessibility (Aditiya, 2022). Conversely, a small residential area can lead to unsuitable habitation areas and not suitable land use (Arfiani and Priyono, 2016).

Data on Semarang City's building density were obtained from the Landsat 8 OLI/TIRS image processing results, which can be seen in Fig. 1. The image transformation at the index was constructed using bands 3, 4, 6, 7, and 10 in the Landsat 8 OLI/TIRS imagery. The image transformation results were indexes of built-up lands, such as EBBI, IBI, NDBI, and UI. For the results of the image transformation of the NDBI built-up land index in Semarang City, the highest value was 0.423, and the lowest value was -0.621. In addition, UI's built-up land index had the highest value of 0.432 and the lowest value of -0.807. Then, the highest value of the IBI built-up land index was 1.248, while the lowest value was -0.348. Meanwhile, the highest value of the EBBI built-up land index was 0.270, and the lowest value was -0.144. The highest value color is shown in red, and the lowest value is depicted in green. Based on the developed land index in the processing results, it can be seen that the highest built-up land index values were the NDBI and UI built-up land index, while the lowest value was the UI built-up land index value. NDBI and UI were based on high-speed mapping of open or built-up land areas. However, these two indices cannot verify the distribution of built versus vacant land (Zha, Gao, and Ni, 2003). This inability is caused by the high complexity of the spectral response pattern to vegetation, vacant land, and built-up areas, especially in pixel combinations in areas with heterogeneous objects (He, Shi, Xie, and Zhao, 2010).

Furthermore, the EBBI is a development of the NDBI index. The EBBI built-land index has more accurate results than the NDBI built-land index when the two built-up indexes differentiate built-up land from non-built-up land (empty land) (Putra, Suprayogi, and Sudarsono, 2019). In addition, the NDBI built-up land index has a weakness, i.e., it cannot distinguish built-up land from vacant land (Hidayati, Suharyadi, and Danoedoro, 2018). In this condition, it is necessary to have an even distribution of adequate facilities and infrastructure because the development of existing facilities and infrastructure in urban areas is not evenly distributed. These facilities and infrastructure are fundamentally intended to meet the community's needs in various daily activities. Besides, the density of settlements in urban areas results from limited urban land, which affects the government and society in socializing (Suhaeni, 2010). Figure 2 depicts the transformation results of the built-up land index in Semarang City in 2021.

The transformation results of the built-up index in the building density research tend to be centered on West Semarang Sub-district, East Semarang Sub-district, North Semarang Sub-district, South Semarang Sub-district, Ngaliyan Sub-district, Gayamsari Sub-district, Candisari Sub-district, Genuk Sub-district, and Pedurungan Sub-district. These districts have a dense population, industrial activity, and dense education. Changes to built-up land in Semarang City also tend to occur in sub-districts on the outskirts of Semarang City, with the highest development in Ngaliyan Sub-district (Ayu et al., 2021). Thus, management and evaluation related to the impact of land use change or

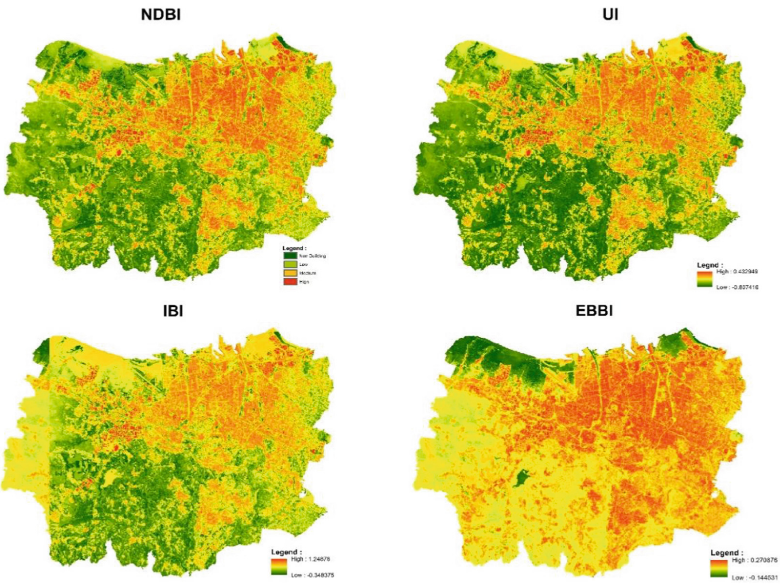

Fig. 2. Image Transformation Results to Built-up Land Index

use in Semarang City need to be carried out to make Semarang City a sustainable city (Hadibasyir, Fikriyah, and Taufiqurrahman, 2020).

Moreover, correlation is a discussion related to the closeness of the relationship between variables, expressed by the value of the correlation coefficient. The value of this correlation can be positive or negative based on the dependent and independent relationships. In addition, this correlation is intended to determine whether there is a relationship between the percentage of built-up land and built-up land index values. The correlation value obtained is analyzed concerning the closeness of the relationship between the percentage of built-up land and the built-up land index (Karisoh, Tondobala, and Syafriny, 2020). A variable is said to have a correlation if the significant value (2-tailed) is less than 0.05, whereas the variable has no correlation if the value is more than 0.05.

Regarding the correlation value obtained for the built-up land index and the percentage of built-up land, of the four developed land indices, only the EBBI built-land index had a significant correlation value of 0.03, with a Pearson Correlation of 0.531. The other three indices had a significant value above 0.05, where the NDBI built-land index had a correlation value of 0.637 with the percentage of built-up land, while the UI had a correlation value of 0.720, and IBI had a value of 0.560. The correlation value of the percentage of built-up land with the index of built-up land varied because the sample values were also different. This value corresponds to the pixel value in each built-up index (Table 4).

Table 4. Correlation Value of Built-up Land Index with Built-up Land Percentage

		PERSENLT	**NDBI**	**UI**	**IBI**	**EBBI**
PERSENLT	Pearson Correlation	1	0.090	0.068	0.111	0.531**
	Sig. (2-tailed)		0.637	0.720	0.560	0.003
	N	30	30	30	30	30
NDBI	Pearson Correlation	0.090	1	-0.076	-0.126	-0.037
	Sig. (2-tailed)	0.637		0.691	0.506	0.846
	N	30	30	30	30	30
UI	Pearson Correlation	0.068	-0.076	1	0.072	-0.086
	Sig. (2-tailed)	0.720	0.691		0.705	0.650
	N	30	30	30	30	30
IBI	Pearson Correlation	0.111	-0.126	0.072	1	-0.073
	Sig. (2-tailed)	0.560	0.506	0.705		0.701
	N	30	30	30	30	30
EBBI	Pearson Correlation	0.531**	-0.037	-0.086	-0.073	1
	Sig. (2-tailed)	0.003	0.846	0.650	0.701	
	N	30	30	30	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Linear regression is one of the methods used to see the relationship between one variable and another. In this case, the variable used was the percentage of built-up land with the built-up index. The percentage of built-up land used for each index differed based on the data processing results during the study. The value generated by this regression was employed to see how the relationship between the two variables was used. Figure 3 is a scatter plot regression graph of the percentage of built-up land with the built-up index.

The variable X, the dependent variable or the predicted variable, was the percentage value of built-up land, while the Y variable, or independent variable or the influencing variable, was the index of built-up land, i.e., NDBI, UI, IBI, and EBBI. The linear regression results of the NDBI built-up land index for the percentage of built-up land had an r-square value of 0.0008, while for the UI built-up land index, the r-square was 0.005. In addition, the r-square value of the IBI built-up land index was 0.012, whereas the r-square value of the EBBI built-up land index was 0.282. Based on this r-square value, the highest value was the EBBI built-up land index, which had a low relationship with the percentage of built-up land, while the other built-up land indices had a very low relationship. The relationship obtained from the regression of the percentage of built-up land with the index of built-up land was due to the comparison of the number of different

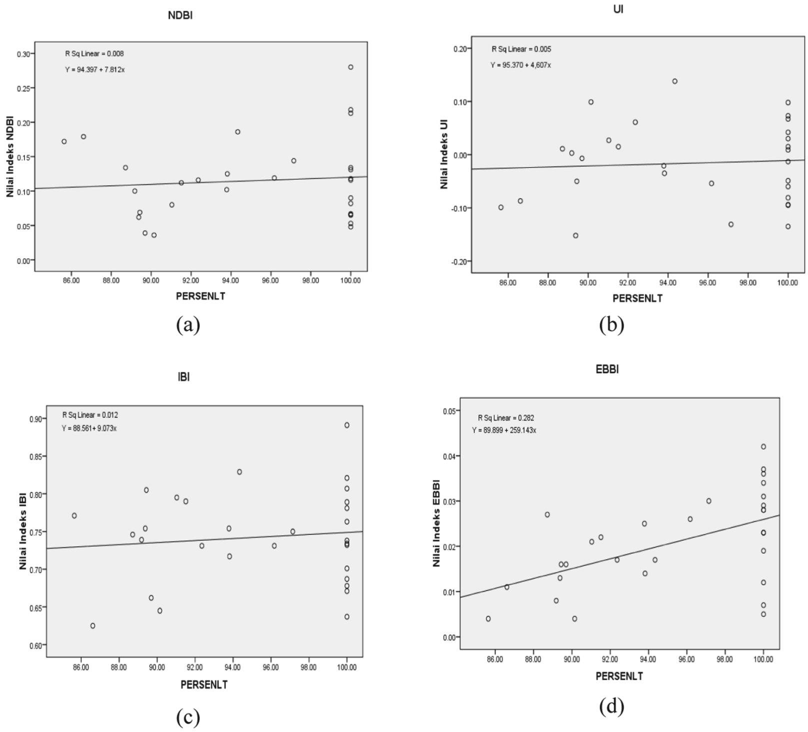

Fig. 3. Regression Scatter Plot Graph

numbers; while the percentage value of built-up land could reach 100%, the built-up land index value only reached 0.27.

Additionally, the estimated percentage of built-up land is a prediction of the percentage of built-up land in each index of built-up land. This estimation of the percentage of built-up land is intended to see how much the distribution of the percentage of built-up land is to the built-up land index. This estimated value was obtained from the regression equation $Y = a + bx$. The value of a was obtained from linear regression showing the coefficient value and significant value. To find out the estimated value of the percentage of built-up land from NDBI data, the formula $y = 94.397 + 7.812x$ was used, while UI data employed the formula $y = 95.370 + 4.607x$. Also, the IBI built-up land index utilized the formula $y = 88.561 + 9.073x$, and the EBBI built-up land index used the formula $y = 89.899 + 259.143x$.

This estimate produced different values for each index. The built-up land index showed that the UI built-up land index had a relatively smaller estimated value of the percentage of built-up land compared to the other indices. The built-up land index with the highest estimated percentage of built-up land was the EBBI built-up land index, with a value ranging from 85.29% to 99.65%. As with the building density level, the estimated value of the percentage of built-up land with a higher value was based on the EBBI built-up area index. Based on this estimated value, the EBBI built-land index had a higher value than other built-land index values. This value was due to the difference in each index of built-up land used.

4 Conclusions

The level of building density in Semarang City can be determined using image transformation in the form of built-up land indices, such as NDBI, UI, IBI, and EBBI. The existence of this built-up land index allows for much more efficient yields. Based on the built-up land index, visually, it can be seen that the EBBI built-up land index appeared to have clearer built-up land and fewer lowest values compared to the other built-up land indices. However, the EBBI built-up land index also included vacant land, which was not built-up land. In addition, a significant correlation value was only found in the correlation between the percentage of built-up land and the built-up land index of the EBBI, while the other built-up land indices did not correlate with the percentage of built-up land. Furthermore, the highest r-square value was uncovered in the EBBI built-up land index, with an r-square value of 0.282. This r-square value indicates that the percentage of built-up land and EBBI had a low level of relationship, whereas the index of other built-up land had a very low level of relationship. Lastly, the estimated percentage of built-up land with the highest built-up land index was found in the EBBI built-up land index.

Acknowledgement. The authors would like to thank Universitas Muhammadiyah Surakarta, which allowed the authors to write this article to completion. The authors also thank the reviewers and editors, who have provided many constructive comments. In addition, the authors would like to thank the supervisor and both parents for all forms of support, both morally and materially. The authors do not forget to thank the friends who contributed to this writing.

References

Aditiya, M. I. (2022). Hubungan perkembangan kawasan terbangun terhadap kekritisan lingkungan menggunakan citra landsat di kota semarang. *Naskah Publikasi*. Retrieved from http://eprints.ums.ac.id/101818/1/NASKAHPUBLIKASI.pdf

Arfiani, A., and Priyono, H. (2016). Analisis Hubungan Kualitas Permukiman Dengan Kondisi Kesehatan Masyarakat Di Kecamatan Kotagede Kota Yogyakarta Berdasarkan Sistem Informasi Geografis. *Naskah Publikasi*. Retrieved from http://eprints.ums.ac.id/id/eprint/47644%0A. http://eprints.ums.ac.id/47644/30/NASKAHPUBLIKASIarfiani-72.pdf

Arsandi, A. S., R, D. W., Ismiyati, and Hermawan, F. (2017). Dampak pertumbuhan penduduk terhadap infrastruktur di kota semarang. *Karya Teknik Sipil*, *6*, 1–14.

As-syakur, A. R., Adnyana, I. W. S., Arthana, I. W., and Nuarsa, I. W. (2012). Enhanced built-UP and bareness index (EBBI) for mapping built-UP and bare land in an urban area. *Remote Sensing*, *4*(10), 2957–2970. https://doi.org/10.3390/rs4102957

Ayu, P., Zahra, A., Yesiana, R., Anggraini, P., Harjanti, I. M., Studi, P., … Sipil, D. (2021). Analisis Perkembangan Dan Faktor-Faktor Yang Mempengaruhi Lahan Terbangun di Kota Semarang. *Jurnal RIPTEK*, *1*(1).

Farizki, M., and Anurogo, W. (2017). Pemetaan kualitas permukiman dengan menggunakan penginderaan jauh dan SIG di kecamatan Batam kota, Batam. *Majalah Geografi Indonesia*, *31*(1), 39. https://doi.org/10.22146/mgi.24231

Hadibasyir, H. Z., Fikriyah, V. N., and Taufiqurrahman, M. I. (2020). Microscale Urban Ecological Condition Mapping Using Landsat 8 Imagery in Semarang City. *La Geografia*, *18*(3), 209–220.

Harahap, F. R. (2013). Dampak Urbanisasi Bagi Perkembangan Kota di Indonesia. *Society, Jurnal*, *I*(1), 35–45.

He, C., Shi, P., Xie, D., and Zhao, Y. (2010). Improving the normalized difference built-up index to map urban built-up areas using a semiautomatic segmentation approach. *Remote Sensing Letters*, *1*(4), 213–221. https://doi.org/10.1080/01431161.2010.481681

Hidayati, I. N., and Suharyadi, R. (2019). A Comparative Study of various Indices for extraction urban impervious surface of Landsat 8 OLI. *Forum Geografi*, *33*(2), 162–172. https://doi.org/10.23917/forgeo.v33i2.9179

Hidayati, I. N., Suharyadi, R., and Danoedoro, P. (2018). Developing an Extraction Method of Urban Built-Up Area Based on Remote Sensing Imagery Transformation Index. *Forum Geografi*, *32*(1), 96–108. https://doi.org/10.23917/forgeo.v32i1.5907

Jia, K., Liang, S., Wei, X., Yao, Y., Su, Y., Jiang, B., and Wang, X. (2014). Land cover classification of landsat data with phenological features extracted from time series MODIS NDVI data. *Remote Sensing*, *6*(11), 11518–11532. https://doi.org/10.3390/rs61111518

Karisoh, S. D., Tondobala, L., and Syafriny, R. (2020). Pengaruh Kekumuhan Terhadap Kualitas Hdup Masyarakat Di Perkampungan Kota Manado. *Spasial*, *7*(1), 62–69.

Kusrini, Suharyadi, and Hardoyo, S. R. (2011). Perubahan Penggunaan Lahan dan Faktor yang Mempengaruhinya di Kecamatan Gunungpati Kota Semarang. *Majalah Geografi Indonesia*, *25*(1), 25–42.

Mansouri, E., Feizi, F., Jafari Rad, A., and Arian, M. (2018). Remote-sensing data processing with the multivariate regression analysis method for iron mineral resource potential mapping: A case study in the Sarvian area, central Iran. *Solid Earth*, *9*(2), 373–384. https://doi.org/10.5194/se-9-373-2018

Nahib, I. (2016). Prediksi Spasial Dinamika Areal Terbangun Kota Semarang Dengan Menggunakan Model Regresi Logistik (Spatial Dynamics Prediction of Built-Up Area at Semarang City using Logistic Regression Model). *Majalah Ilmiah Globë*, *18*(2), 95–104.

Petrus Katemba, and Koro, R. (2017). Prediksi Tingkat Produksi Kopi Menggunakan Regresi Linear. *Jurnal Ilmiah Flash*, *3*(1), 42–51.

Pranata, S., and Kurniadin, N. (2021). Identifikasi Perubahan Indeks Kerapatan Bangunan Pasca Likuifaksi Di Kota Palu. *Buletin Poltanesa*, *22*(1), 27–32. https://doi.org/10.51967/tanesa.v22i1.469

Puspitasari, S., and Suharyadi. (2016). Kajian Kepadatan Bangunan Menggunakan Interpretasi Hibrida Citra LANDSAT-8 OLI di Kota Semarang Tahun 2015. *Bumi Indonesia*, *15*(1), 165–175. Retrieved from https://core.ac.uk/download/pdf/196255896.pdf

Putra, D. B., Suprayogi, A., and Sudarsono, B. (2019). Analisis Kerawanan Banjir pada Kawasan Terbangun Berdasarkan Klasifikasi Indeks EBBI (Enhanced Built-Up and Bareness Index) Menggunakan SIG (Studi Kasus di Kabupaten Demak). *Jurnal Geodesi Undip*, *8*(1), 93–102. Retrieved from https://ejournal3.undip.ac.id/index.php/geodesi/article/view/22464

Rahman, M., and Nugraha, A. S. A. (2021). Normalized Dryness Built-up Index (NDBI) to Detect Settlement Change In Buleleng Sub-District. *Media Komunikasi FPIPS*, *20*(1), 46. https://doi.org/10.23887/mkfis.v20i1.30427

Rosyadi, A., and Azahra, M. F. (2020). Pemetaan Presentase Kepadatan Bangunan Menggunakan Model Regresi Berdasarkan Citra Landsat 8 (Studi Kasus Kota Bandung). *Jurnal Penginderaan Jauh Indonesia*, *02*(01), 7–12.

Rustianto, F. D., and Saputra, A. (2021). Analisis Kualitas Lingkungan Permukiman Menggunakan Citra Pleiades Dan Sistem Informasi Geografis Di Kecamatan Godean, Kabupaten Sleman. *Naskah Publikasi*. Retrieved from http://eprints.ums.ac.id/id/eprint/88169

Saputra, A., Akbar, M., Permadi, A. S., and Pratama, B. M. (2018). Pemetaan Tutupan Lahan Berbasis Drone di Daerah Perkotaan. *Prosiding Seminar Nasional Pendidikan Geografi FKIP UMP*, (30 m), 196–208.

Satria, M., and Rahayu, S. (2013). Evalauasi Kesesuaian Lahan Permukiman. *Teknik PWK*, *2*(1), 160–167.

Sugiyono. (2019). *Metode penelitian kuantitatif, kualitatif, dan r&d* (Sutopo, ed.). Bandung : Afabeta, 2021.

Suhaeni, H. (2010). Tipologi Kawasan Perumahan dengan Kepadatan Penduduk Tinggi dan Penanganannya. *Jurnal Permukiman*, *5*(3), 116. https://doi.org/10.31815/jp.2010.5.116-123

Syahputra, A., Jatmiko, R. H., Hizbaron, D. R., and Fariz, T. R. (2021). Perbandingan Indeks Lahan Terbangun NDBI dan Land Surface Temperature Dalam Memetakan Kepadatan Bangunan di Kota Medan. *Journal of Science, Technology, Dan Virtual Culture*, *1*, 16–22.

Trinufi, R. N., and Rahayu, S. (2020). Analisis Perubahan Kerapatan Vegetasi dan Bangunan di Kota Banda Aceh Pasca Bencana Tsunami Analysis of Vegetation and Building Density Changes in the Banda Aceh City Post-Tsunami Disaster. *Ruang*, *6*(1), 28–37.

Zahrotunisa, S. (2017). Prediksi Spasial Perkembangan Lahan Terbangun Melalui Pemanfaatan Citra Landsat Multitemporal di Kota Bogor. *Jurnal Online Informatika*, *2*(1), 30. https://doi.org/10.15575/join.v2i1.88

Zha, Y., Gao, J., and Ni, S. (2003). Use of normalized difference built-up index in automatically mapping urban areas from TM imagery. *International Journal of Remote Sensing*, *24*(3), 583–594. https://doi.org/10.1080/01431160304987