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Prediction of Peri-Urban Land Use in Sleman Regency and Its Suitability Towards Spatial Planning

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ABSTRACT: The development of Yogyakarta city as the growth center in the Yogyakarta urban area has resulted in significant land use changes in its peri-urban, especially in Sleman Regency. This changes needs to be understood to anticipate uncontrolled land use changes in the future. Therefore, this study seeks to simulate land use changes in the peri-urban area of Sleman Regency in 2041 using Land Change Modeler. The variables used in this study consisted of driving factors (distance to roads and settlements, and population density) and limiting factors (distance to rivers, environmental physical conditions, and determination of protected areas). Based on the simulation results, there will be a significant increase in residential areas from agricultural areas. On the contrary, green areas experience a decrease. By knowing future land use, this study can be beneficial for land use control policies for sustainable land use.

Keywords: Peri-Urban, Land Change Modeler, Land Use Change.

ABSTRAK: *Berkembangnya kota Yogyakarta sebagai pusat pertumbuhan di kawasan perkotaan Yogyakarta telah mengakibatkan perubahan penggunaan lahan yang signifikan pada kawasan peri-urbannya, khususnya di Kabupaten Sleman.. Perubahan penggunaan lahan ini perlu dipahami untuk mengantisipasi perubahan penggunaan lahan yang tidak terkendali di masa mendatang. Oleh karena itu, penelitian ini berupaya mensimulasikan perubahan penggunaan lahan di kawasan peri-urban Kabupaten Sleman tahun 2041 dengan menggunakan Land Change Modeler. Variabel yang digunakan dalam penelitian ini terdiri dari faktor pendorong (jarak ke jalan dan pemukiman, dan kepadatan penduduk) dan faktor pembatas (jarak ke sungai, kondisi fisik lingkungan, penetapan kawasan lindung). Berdasarkan hasil simulasi, terjadi peningkatan yang signifikan pada lahan pemukiman dari lahan pertanian. Sedangkan penggunaan lahan tidak terbangun mengalami penurunan luas. Dengan mengetahui kondisi penggunaan lahan di masa mendatang, hasil penelitian ini dapat menjadi masukan bagi kebijakan pengendalian pemanfaatan lahan untuk penggunaan lahan yang berkelanjutan.*

Kata Kunci: *Peri-Urban, Land Change Modeler, Perubahan Penggunaan Lahan*

INTRODUCTION

Continuous urban growth could encourage physical expansion to its surrounding areas (Ahani & Dadashpoor, 2021), exceeding the administrative boundaries of the city itself (Woltjer, 2014). As happened in Jakarta, the expansion reached 40-50 km towards its satellite cities such as Depok, Bekasi, Tangerang, and Bogor (Winarso et al., 2015). This is possible because urban growth correlates with an increase in land demand, which the main city could no longer fulfill as the availability of land is limited. As a result, cities will grow horizontally toward rural areas near them, causing those areas to change. The process of changing rural areas into more urbanized areas is called peri-urbanization (Mondal & Banerjee, 2021), which gives rise to transitional areas known as peri-urban.

The peri-urban area is the area around the main city boundary (Winarso et al., 2015), located in the transition area between urban and rural, as the result of the interaction between urban and rural development (Shaw et al., 2020). Peri-urban areas emerge gradually at the edge of the urban area, and within a certain period of time, there will be a spatial transformation in that area, which was originally rural to urban areas, due to a shift in land use (Aguilar et al., 2022). This process represents progressive urban growth that leads to the increase of built-up areas (Mondal & Banerjee, 2021). Therefore, areas that are becoming peri-urban today, will become part of urban areas one day, thus posing a serious challenge for policymakers in managing peri-urban growth areas (Mortoja et al., 2020).

The peri-urban area has several unique characteristics. First, this area is heterogeneous (Ahani & Dadashpoor, 2021) has a combination of urban and rural characteristics (Shaw et al., 2020). To illustrate, peri-urban villages are characterized by increased activity in trade (Pratiwi et al., 2022), modern housing, services, and parks (Hardiyanti et al., 2018). In peri-urban, sometimes the land use tends to be fragmented as a result of a dynamic and integrated social economic process (Roast, 2019). Secondly, the peri-urban area develops unplanned or sporadic (Mortoja et al., 2020). Based on (Azzizi & Ariastita, 2016), sporadic development in peri-urban areas can be influenced by several factors, including the availability of infrastructure, accessibility, public facilities, and people's purchasing power. This will lead to confusion in regional governance between more than one authorized government institution due to unclear physical boundaries (Hedblom et al., 2017). Thirdly, another character is dynamic (Ahani & Dadashpoor, 2021). It could be seen by continuous changes in its spatial structure and features. In other words, a spatial transformation could occur, which can be in the form of reducing or increasing the area of a land function. In other words, changing its dominant activities (Mahendra & Pradoto, 2016).

Due to the pressure from its main city, there is a high probability of land conversion in peri-urban. Based on a study conducted by (Czekajlo et al., 2021), 41% or 2,700 km^2 of peri-urban in Canada experienced land use change. Abass et al (2018) assessed the impact of peri-urbanization in the Kumasi Metropolis, Ghana, showing 54.6% increase in built-up areas during 1986-2016, causing a decrease in food production. Still in the agricultural context, urban growth in the Global South has an impact on Urban peri-urban Agriculture (UPA), especially on all factors of agricultural production, including land and farmers (Follmann et al., 2021). Furthermore, other challenges for the growth of peri-urban areas are reduced biodiversity (McKinney, 2002), ecosystem degradation (Sutton et al., 2016), impacts on physical and mental health due to reduced access to green spaces (van den Bosch & Bird, 2018).

The city of Yogyakarta, as the center of Yogyakarta Urban Area, has experienced an immense physical development and population growth in the last decades. This has an impact on the increasing need for land. In addition, these developments pushed the area around the city of Yogyakarta to experience urbanization, especially in Sleman Regency. Purba et al (2016) stated that villages in the peri-urban area of Yogyakarta City had experienced spatial urbanization, as indicated by land conversion of >60% from agricultural area to non-agricultural area. In another research conducted by Selang et al. (2018), in a period of only five years (2012-2016), there has been a fall in agricultural land up to 37.77% in Bimomartani Village, Ngemplak District, Sleman Regency. The land conversion in the peri-urban area of Sleman Regency occurs to meet the housing needs of the community, including migrants. In the Sleman Regency alone, the growth in the number of housing units reaches 1,500 units annually (Fajriyanto, 2011). However, the increase in built-up land often violates the established spatial plan policy. Based on the results of the spatial use audit, several indications of violations of spatial use were found in the Jogjakarta Urban Area; one location in Yogyakarta, nine locations in Sleman Regency, and two locations in Bantul Regency. This number increased quite significantly in just one year to 23 points in Yogyakarta City, 22 points in Sleman, and 14 points in Bantul (Danar, 2020). This violation has the potential to continue to occur if land use only follows market forces.

In Indonesia research regarding the peri-urban development was mainly conducted in larger urban areas such as Jakarta Metropolitan Area (JMA), Bandung, and Yogyakarta City. Most of them show the challenge regarding peri-urbanization. Peri-urbanization can have negative impacts in the future, both on carrying capacity and environmental capacity. Based on (Widodo et al., 2015), the carrying capacity of the Yogyakarta Urban Area that has exceeded the safe limit is in 11 villages, meanwhile, the carrying capacity of water availability which has exceeded the limit occurs in 7 villages. If massive peri-urbanization happens, it may put more pressure on the capacity. In the Bandung Metropolitan Areas, the transformation in the peri-urban areas has increased the risk of flooding as well as decreased the groundwater level (Legates & Hudalah, 2014). This happens due to the rise of the built-up areas in catchment areas for residential and recreational areas. Based on BNPB (n.d.), 5,753 Hectares of land in Sleman Regency is exposed to flood hazard. This should also be a consideration so that the development will not increase disaster risk. On the other hand, the conversion of agricultural land which mostly occurs in peri-urban areas can have an impact on the issue of food sustainability. The risk of a food crisis will increase if the conversion of agricultural areas is not followed by the provision of new agricultural areas or an increase in food production. A research conducted by (Pribadi & Pauleit, 2015) investigated the interaction between urbanization and peri-urban agriculture in the Jakarta Metropolitan Areas. In the region, agricultural and farmland have fallen significantly, replaced by high-rises buildings, shopping malls, hotels and residential, etc., making a decrease in the share of agricultural sector in their GDP. In the Yogyakarta Urban Area itself, the pattern of peri-urbanization occurs as results of urban activities, physical form, and rural features. This further leads to an inequal growth rate among districts, causing a fragmented development (Wibisono & Sulistya, 2022). In 2021, Nurcahyani & Marwasta (2021) examined peri-urbanization in Yogyakarta Province and its impact on the protected agricultural field using overlay analysis. Even though land conversion in the province has correlation with the economic growth rate, especially in one of its regencies, Sleman, it still poses many challenges. The growth rate has sacrificed the existence of agricultural areas, and it mostly appears in fertile land. Besides, land prices have been increasing, and housing is no longer affordable.

To respond to these problems, the need to track changes in land use consistently is very important to do in spatial planning, including supporting evidence-based solutions, and understanding the implications of a policy (Wellmann et al., 2020). Collaboration among parties is also urgent to manage scattered land use in peri-urban areas (Abass et al., 2018). Based on this background, the purpose of this research is to simulate land use in peri-urban areas in Sleman Regency. Modeling land use change is expected to answer questions about the location of land conversion to support regional planning (Gomes et al., 2020). By knowing the potential locations of land use incompatibility in the future, it will be able to become input for decision-making and the preparation of land use control policies to achieve sustainable land use.

METHODS

Study Area

This study uses a deductive approach to suitability assessment and spatial modeling. The deductive approach begins with developing research hypotheses based on previous theories. The hypothesis of this study is that the need for land in peri-urban areas due to urbanization and population growth, will lead to physical growth in built-up areas. This is as explained by Woltjer (2014), that global investments, increasing population in rural areas, as well as the development of residential areas are driving factors for land conversion in peri-urban areas. The hypothesis will be explained through an analysis of land use change predictions, to gain conclusions. This research was conducted in a peri-urban area in Sleman Regency, which consists of villages in Godean, Mlati, Ngemplak, Seyegan, Sleman, Gamping, and Ngaglik subdistrict (Figure 1).

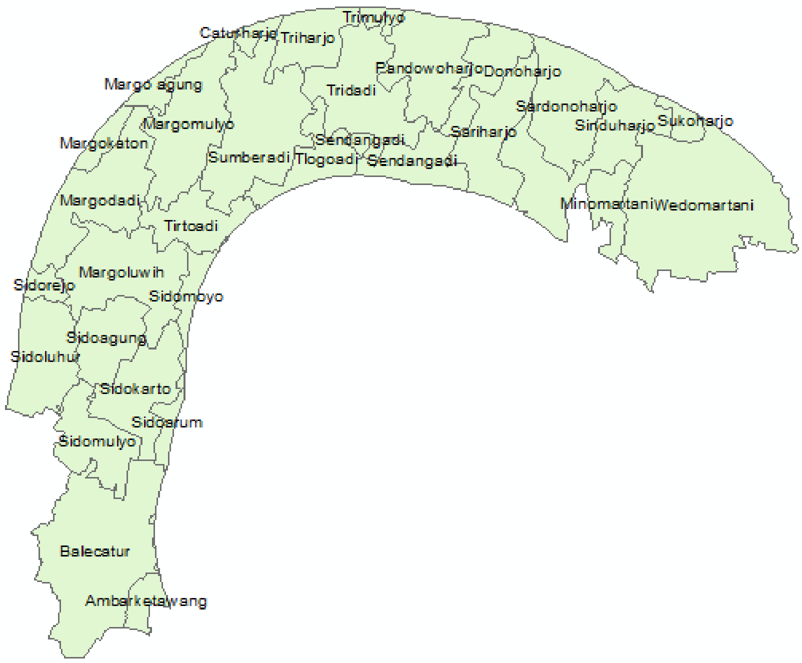


Figure 1 Study Area
Source: Authors (2022

The determination of villages that is included in this area is based on the distance from the City of Yogyakarta as the growth center that mainly influences growth in Sleman Regency. It is determined based on buffer analysis in ArcGIS. The result is as follows:

Table 1. Study Area

District	Village
Ngaglik	Sariharjo, Sardonoharjo, Minomartani, Sukoharjo, Sinduharjo
Godean	Sidomulyo, Sidoarum, Sidokarto, Sidholuhur, Sidoagung, Sidomulyo, Sidorejo
Mlati	Tirtoadi, Sumberadi, Tlogoadi, Sendangadi
Seyegan	Margoluwih, Margodadi, Margokaton, Margomulyo, Margoagung
Sleman	Caturharjo, Triharjo, Tridadi, Pendowoharjo, Trimulyo
Gamping	Ambarketawang, Balecatur
Ngemplak	Wedomartani

Source: Authors (2022)

Variable and Data

The development of peri-urban areas can be influenced by various things. In general, the expansion of peri-urban is influenced by an increase in population migration caused by socioeconomic factors such as poverty and limited employment opportunities in the city center (Saxena & Sharma, 2015) . Peri-urban areas are also considered to be able to accommodate the needs of the lower middle class to obtain affordable housing or to obtain jobs so it is certain that the growth of built-up areas in peri-urban areas will continue to rise (Mortoja et al., 2020). Based on Pramana & Efendi (2019), there are several factors that led to an increase in the use of built-up land in peri-urban areas:

1) Counterurbanisation. Overpopulation in areas with higher hierarchies results in urban expansion to peri-urban. Migrants choose peri-urban areas because they want a place to live with rural characteristics but still have similarities with urban areas.

2) Population retention. The economic structure in peri-urban areas that no longer relies on the agricultural sector has succeeded in attracting productive groups from the outside of the region to work as well as settle.
3) Centripetal migration. Migrants prefer living in peri-urban due to good accessibility to the city center.

In this study, several variables were used, consisting of driving variables and limiting variables as shown in Table 2. Driving variables are variables that can affect the increase in built-up area. On the contrary, limiting variables are variables that can inhibit the increase of built-up area.

Table 2. Variable Used in Research

No	Factors	Variable	Explanation
1	Driving factors	Distance to road	Good accessibility is the main attraction for built areas.
		Distance to existing settlements	The distance to current settlements will have a positive effect on built-up land use because existing settlements often have the necessary facilities and infrastructure available.
		Population density	Population density has a positive effect on the use of built-up land related to the increased demand for land due to an increase in population.
2	Limiting factors	Distance to river	Proximity to the river may limit the change due to low suitability for the built-up area.
		Contour	Steep contours will limit changes in non-built-up land use.
		Designation of protected areas	Designation of protected areas will limit changes in non-built-up land use because of the relatively strict policy of land conversion

Source: Authors (2022)

Data for each variable were collected through secondary data surveys including a base map, thematic map, and land use map from the Spatial Planning Office, population density from the Central Bureau of Statistics, and Google Earth satellite imagery for three years (2021, 2018 and 2015). These data are analyzed with ArcGIS and IDRISI Terrset software.

Table 3. Data

No	Sub-Objective	Data	Source	Explanation
1	Preparation of land use maps of 2015, 2018, and 2021	Google Earth image of 2015, 2018, dan 2021 (Raster)	Google Earth	Land use maps are created using the image classification feature on ArcGIS. Classification is carried out on several land use types: water bodies, open space, agriculture, shrubs, settlements, and forests.
		Administrative map (shapefile)	Spatial Planning Office	The administrative boundary map is used to create a map of the boundaries of the study area, which is then superimposed on the land use map.
2	Preparation of driving factor maps	Road map (shapefile)	Spatial Planning Office	The preparation of the distance to the road map is carried out by using basic data, the location of the existing road. The euclidean distance method in ArcGIS is used to make the distance to road map.

No	Sub-Objective	Data	Source	Explanation
		Existing settlement map (shapefile)	Google Earth	Based on the results of the image classification, a distance map of the existing settlements was created using the Euclidean distance method in ArcGIS.
		The number of populations	Central Bureau of Statistics	The population density map was created by integrating the administrative boundary map with population density data published by the Central Bureau of Statistics.
3	Preparation of limiting factor maps	River Map (shapefile)	Spatial Planning Office	Making a map of the distance to the river is carried out using the euclidean distance feature in ArcGIS.
		Contour Map (Shapefile)	Spatial Planning Office	Contour map is created based on the contour maps of Sleman Regency, then clipped with the study area map.
		Protected Area Map (shapefile)	Spatial Planning Office	The protected area map was obtained from the selection of areas designated as protected areas in the Sleman District Spatial Planning.
4	Predicting land use map	Land use map 2021 and all maps resulted from step 2 and 3	Result of previous processes	Prediction map is done based on sub-objective outputs 1,2, and 3, using Land Change Modeler in Terrset. The format of the output is raster.
5	Overlay between land use prediction and land use plan	Land use prediction map (shapefile) Land use plan map (shapefile)	Result of analysis Spatial Planning Office	Land use prediction map is converted to a shapefile, then overlaid with the land use plan map to develop the suitability map.

Source. Authors (2022)

Analysis Method

This study uses Land change modeler (LCM). It is a tool in the IDRISI Terrset software for investigating land use change and modeling future land use. LCM uses historical land cover data to model land-use transition relationships with independent variables and uses this for future land use prediction (Eastman & Toledano, 2018). Historical data used in this study are land use data for 2015, 2018, and 2021 obtained from the Google Earth satellite imagery. It has the same interval of three years. The 2015 and 2018 land use maps are used as initial and final data, respectively, then used for modeling the 2041 land use map. The year of 2041 is chosen as the predicted year to adjust to the period of the Sleman Regency Spatial Plan which ends in 2041. Then, the map for 2021 is compared with the map resulting from the google earth classification in 2021. If the results are good, the 2021 prediction map will be used as the basis for the 2041 map prediction by determining six iterations.

In conducting LCM analysis, there are several steps that are carried out, namely (1) Change Analysis, (2) Transition Potential, and (3) Change Prediction (Clark Lab, 2020). The first stage, c*hange analysis* assesses the change from one land cover to another over a certain period of time (Eastman, 2016). It is to determine the land change that occurred in 2015-2018, both the increase and the decrease. The second stage, *transition potential* aims to make land use transitions possible using available methods, as well as determining explanatory variables. In this study, the Multi-Layer Perceptron (MLP) Neural Network is used. This stage will regulate the possibility of transitioning land use from one land use to another. In determining the transition potential, it is also possible to determine the transition sub-model. However, if it has the same driving factors, it can be made into one sub-model (Eastman, 2016). This stage also determines which land use is allowed and not allowed to change to another land use. For example, bushes or open space are permitted to turn into settlements, but water body is not allowed to turn into them. The third stage, c*hange prediction,* aims to regulate the land use prediction process based on land use change trends and a map of potential transitions in the previous stage (Eastman, 2016). Setting the prediction year is also done at this stage. Prediction modeling by default uses Markov Chain. This model will then determine the effect of the variables above on changes in future land use (2041).

Furthermore, to determine the validity of the results, the kappa coefficient is used by comparing the predicted results in 2021 with the existing map resulting from the Google Earth image classification in 2021. In a qualitative analysis, the kappa coefficient measures the level of agreement between two experts in assessing something (Priyadi et al., 2020). In land use prediction, the kappa coefficient is used to measure the accuracy of the resulting prediction results (Nabila, 2023). The formula for calculating the kappa coefficient is as follows (Roseana et al., 2019):

$$Kappa\ Accuracy\ (\hat{K}) = \frac{N\ \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \times\ x_{+i})}{N^2 -\ \sum_{i=1}^{r}(x_{i+} \times x_{+i})}$$

x_{ii} : The number of observations in row i and column i (the number of observations in land use type i of simulation result that corresponds to the area of land use type i based on observation or Google Earth)

x_{+i} : The marginal total for column i (the number of observations in land use type i, based on the observation or Google Earth)

x_{i+} : The marginal totals for row i (the number of observations in land use type i, based on the simulation/prediction)

i : Row and column

r : The number of rows (land use type) in the matrix

N : The total number of observations (Total area of all land use types)

The calculation of the kappa coefficient is done automatically using the IDRISI Terrset. There will be four types of kappa coefficients; (1) Kappa standard (KStandard) measures the simulation ability to gain perfect classification, (2) Kappa for no information (Kno) measures the overall agreement between the simulated and reference map, (3) Kappa for location (Klocation) indicates the success of the simulation in terms of the ability of the model to detect the correct location of the changed pixels, and (4) Kappa for stratum-level location (KlocationStrata) indicates how well the grid cells are located within the strata (Christensen & Arsanjani, 2020). The combination of the four kappa will bring comprehensive assessment in measuring accuracy of location and quantity.

The interpretation of all four kappa coefficients is as follows (Küchenhoff et al., 2012):

Table 4. Kappa Coefficient

Variable	Explanation
< 0.20	Poor
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Good
> 0.80	Very good

Source: Authors (2022)

The final stage of this research is to do an overlay analysis. The overlay was carried out by comparing the prediction map for 2041 with the spatial pattern plan for Sleman Regency. This analysis uses ArcGIS software to find locations that have the potential for spatial planning violations to occur.

RESULTS AND DISCUSSIONS

Land Use Change Analysis in Peri-Urban Sleman

The first step of LCM is change analysis, assesses the change from one land cover to another over a certain period of time. Change analysis was carried out using land use data of 2015 and 2018 as initial and final data. Land use data was obtained from Google Earth images which was further processed using the maximum likelihood classification (MLC). Compared to the minimum distance method approach, the MLC produces a more accurate classification (Patil et al., 2012). This analysis uses more than thirty samples of each land use type. The classification results consist of land use for open space, water bodies, agriculture, shrubs, settlements, and forests.

Based on the calculation, there has been a significant decrease in the agricultural area and an increase in the settlement area. Figure 2 shows the net change of each land use in the period 2015-2018. There is an increase of more than 600 hectares in the settlement area. On the contrary, the agricultural area experiences a significant decrease of nearly 1,200 hectares. The largest contributor to the net change in settlement area is open field and agriculture area. This is in accordance with research conducted by Valent et al. (2021), from 2013 to 2020 in the Jogjakarta agglomeration area, the agricultural area decreased by 586.59 hectares, where the highest conversion occurred in settlements of 471.52 hectares. Moreover, the Sleman Regency has an average growth rate of 1.70% (high) so it will potentially increase the occurrence of land conversion for settlements (Selang et al., 2018).

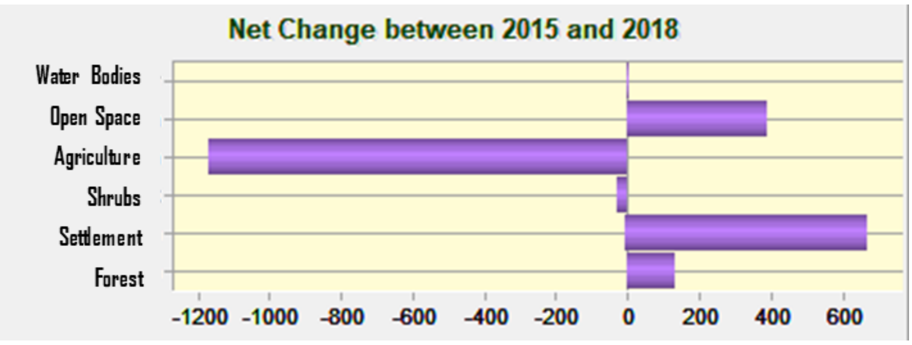


Figure 2 Net Change between 2015 and 2018
Source. Authors (2022)

The growth of Sleman Regency as a satellite area of Yogyakarta City has indeed occurred quite rapidly. The construction of the ring road in Yogyakarta has triggered the development of settlements in the surrounding area (Amri et al., 2019), including Sleman itself. Furthermore, Yogyakarta also upgrade its accessibility by providing Trans Jogja in 2008. The development of Trans Jogja is also one of the factors in land conversion. Currently, there are 129 Trans Jogja available as public transportation services whose service routes cover peri-urban areas of Sleman Regency, Yogyakarta City, and Bantul Regency so that urban physical development occurs that converts agricultural land into housing and shops following this route (Amri et al., 2019). Other factors that also greatly affect the demand for residential development so that land conversion occurs in Sleman Regency, is the existence of Adi Sucipto Airport, universities, and schools, as well as the establishment of industrial shopping centers (Habibatussolikhah, et al., 2016). This can be seen from the sale of houses which are often close to these facilities.

Transition Potential Modelling

The transition potential model is the second stage of analysis to set the possibility of a potential transition from one land use to another. During this stage, all the driving and limiting variables are used in the input model. There are six variables used in this model: distance to road, distance to settlements, distance to river, contour, population density, and protected areas. In LCM modeling, iterations are determined based on the range of initial and final data to obtain a prediction for 2041. There are 10,000 iterations with 0.01 acceptable RMS (root mean square) used as system default. The result of this stage is the Cramer's coefficient of each variable.

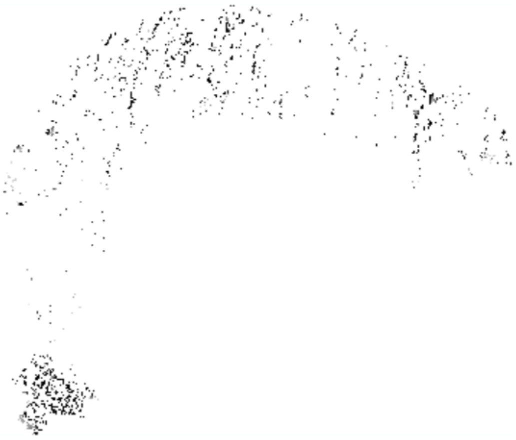
Table 5. Cramer's coefficient

Variable	Cramer's coefficient
Distance to settlement	0.4319
Contour	0.1198
Population density	0.1063
Distance to river	0.1161
Protected area	0.0813
Distance to road	0.0645

Source. Authors (2022)

The Cramer's coefficient indicates how strong two variables are associated. The model gives quick estimates of the ability of each variable to predict the land use in the future, using the coefficient that ranges from 0-1. Values between 0.4 – 1 are considered enough for predictions, meanwhile values less than 0.15 are considered weak (Mehrabi et al., 2019). Based on Table 5, the most influential variable is distance to settlement. This means that historically in the study area, land conversion happens next to the existing settlement. It is surprising that the distance to road has low association to land conversion, meanwhile in fact that the built-up areas mostly occur near to road. The other variables also have low associations with the land use conversion; however, it does not necessarily ensure the excellence of the model because of the complexity of associations between variables and the possibility of other factors that may influence the model (Mehrabi et al., 2019).

In this study, all land uses are assumed to be converted into settlements, except for water bodies. For example, bushes or open space are permitted to turn into settlements, but water bodies are not allowed to turn into them. Figure 3 shows the potential transitions from one land use to settlement. It is developed based on historical land conversion and based on the variables. As discussed earlier, MLP is used in this stage for determining the location and the amount area of change, which further be used in predicting future land use. Figure 3a is the potential transitions from forest to settlement, 3b is from shrubs to settlement, 3c is from agricultural field to settlement, and 3d is from open space to settlement. The black dots represent the area who have high possibility to change. Agricultural fields and open space are more likely to change into built-up areas or settlements. On the other hand, forests and shrubs are less likely to change.



(a) From forest to settlement

(b) From shrubs to settlement

(c) From agricultural field to settlement

(d) From open space to settlement

Figure 3 Potential Transitions
Source. Authors (2022)

Change Prediction

The prediction results can be seen in Figure 4. Figure 4 (left) shows land use in 2021, while Figure 4 (right) shows changes in land use in 2041. Based on these two figures, there is a significant change, especially in the settlement area (in orange colour). In 2041, the simulation shows that the peri-urban area of Sleman Regency is dominated by settlement areas, while the agricultural area (green colour) has decreased significantly. The calculation results predict that there will be an increase in the settlement area of 2,935 hectares. Meanwhile, the agricultural land is predicted to decrease by more than 2,110 hectares. Other than that, open fields, bushes, and forest also decreased by 394 hectares, 253 hectares, and 178 hectares, respectively.

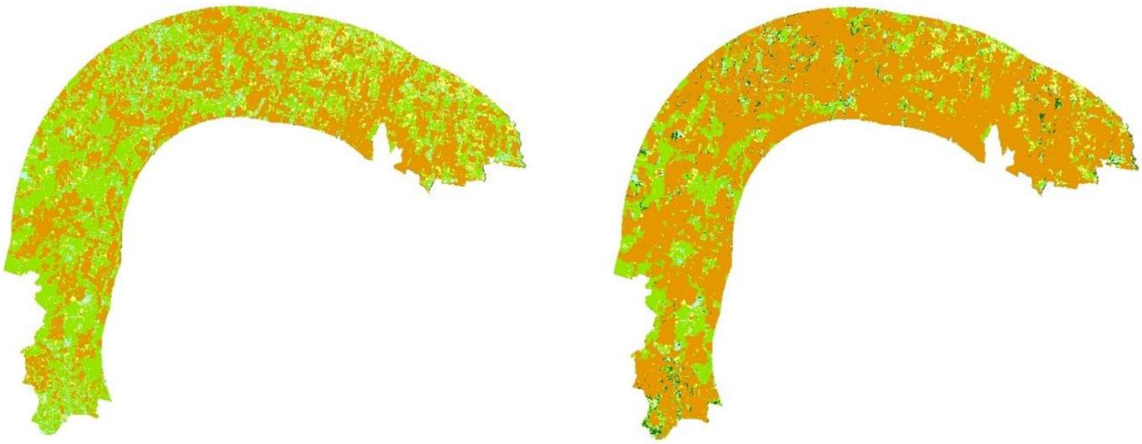


Figure 4 Land Use Prediction 2021 (left) and Land Use Prediction 2022 (right)
Source: Author (2022)

Future land conversion can occur due to various possibilities. Population growth and the need for residential areas will also increase along with plans to build three toll roads that will be connected to, (i) Cilacap - Jogja Toll Road, (ii) Solo - Jogja - YIA Kulon Progo Toll Road, (iii) Jogja Toll Road – Bawen. The construction of this toll road aims to support connectivity in 3 major cities, Yogyakarta-Solo-Semarang or the so-called 'Joglosemar Golden Triangle' area. This development is included in the National Strategic Project and will be connected to the Trans Java Toll Road, namely the Semarang - Solo Toll Road. This development is considered to have a significant impact on improving the community's economy, especially in the golden triangle of the *Joglosemar* (Jogjakarta – Solo – Semarang) tourism sector (Ministry of Public Works and Public Housing, 2020)**.** The increase in the economy can simultaneously form interrelated patterns between economic improvement, increased employment, increased settlements, and increased land conversion.

Validity of Prediction

The results of the 2021 prediction are compared to the results of the existing land use map made from image classification in the same year to determine the level of accuracy. The two maps were then analyzed with kappa calculation in the IDRISI TerrSet. The calculation results have four kappa coefficients, including Kappa Standard and Kappa Location. Klocation measures the ability of the model to predict correct location of pixels that change (Nasiri et al., 2019). Terrset calculation results show a kappa location coefficient of 0.80. This means that the model has a good ability to detect the correct location of the changed pixels. Meanwhile, the standard kappa calculation of 0.75 also shows the model has good accuracy in gaining perfect classification.

Kstandard	= 0.7591
Kno	= 0.8551
Klocation	= 0.8061
KlocationStrata	= 0.8061

Figure 5 Kappa Calculation Result
Source. Authors (2022)

Prediction of Future Land Use Suitability

Land suitability prediction was made by comparing the spatial pattern map of Sleman Regency with the prediction map for 2041. However, the overlay analysis was only carried out on residential land use, bearing in mind that this land use will continue to rise in the future. Figure 3 shows the result of the overlay. The green color shows the map of residential area in 2041, while the orange color shows the use of settlement land use in the Sleman Regency Spatial Plan. This means that there are several locations that are not suitable, namely the green color which is located beyond the permitted locations or can be seen in transparent. Several locations that have the potential for land use violations mainly occur in Sidomulyo, Balecatur, Sidoagung, Sidorejo, Margoluwih, Margodadi, Tridadi, Wedomartani, and so on. Although there are some locations that potentially violate the spatial plan, the interesting part is the spatial plan of Sleman Regency is mostly still in accordance with the future development.

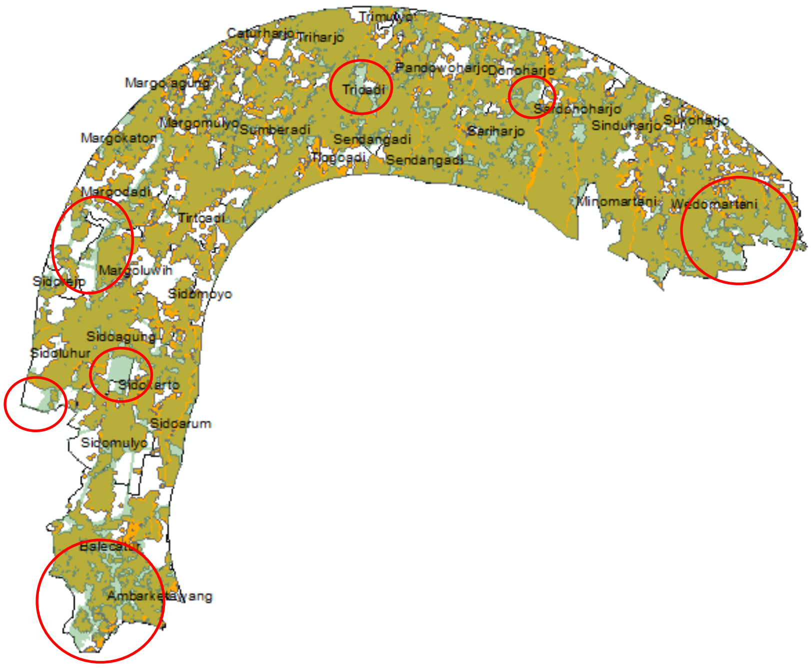


Figure 6 Prediction of Settlement Suitability toward Spatial Planning
Source: Authors (2022) and Spatial Planning Office

CONCLUSIONS

Conclusion and Further Research

The simulation results show that there will be changes in land use from agriculture to settlements. The accuracy of this prediction is good enough based on the kappa coefficient. The settlement area in 2041 is predicted to grow to 2,935 hectares. However, in 2041, the suitability of residential land use to the regional spatial plan (*Rencana Tata Ruang Wilayah)* is still quite high, although there is some potential for violations of residential land use. It should be considered that there are several limitations of the research; this research does not use a detailed classification of land use according to the classification in the regional spatial plan. It causes the suitability maps to not capture a more detailed picture of the suitability location when compared to the regional spatial plan. Another limitation of this study is that most driving and limiting variables do not have strong correlations with land use expansion. In addition, this research also does not consider the variable of community perception which is quite an important variable in choosing a location to settle. Furthermore, this modeling scenario does not consider the implementation of sustainable food agriculture land policy. These limitations should be considered by conducting other research in the future.

Policy Recommendation

Formal and informal settlements in peri-urban areas will develop together with growth in peri-urban areas. These developments need to be anticipated through strict policies. Unfortunately, control of built-up land in peri-urban areas is often responded to only by normative planning mechanisms such as planning flexibility. Silva (2019) argues that this is ambiguous and leads to policy violations by the community resulting in an increase in irregularly built-up land in peri-urban areas. Land management policies that are highly normative are also seen as an indication of the inability of local governments to decide on urban expansion patterns, thereby compromising the rural environment and risking social conflict (Dizdaroglu et al., 2012). Based on the result of the study, the author suggest:

1) Strong enforcement in the implementation of Sustainable Food Agricultural Land Policies, considering that agricultural areas in all villages will likely to change into settlements in 2041. The policy enacts agricultural field that should be protected to support food self-sufficiency and security. Increasing need of housing may be challenging in preserving agricultural fields in those villages, but with a strong enforcement may reduce the land conversion rate.
2) Land conversion that may not be suitable with the land use planning will likely happen in Sidomulyo, Balecatur, Sidoagung, Sidorejo, Margoluwih, Margodadi, Tridadi, Wedomartani, and so on. Disincentives may be applied for new developments taking place in areas that are not in accordance with the spatial plan.
3) A more comprehensive research on predicting the land use conversion in the Yogyakarta peri-urban as a tool for spatial planning.

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REFERENCES

Abass, K., Adanu, S. K., & Agyemang, S. (2018). Peri-urbanisation and loss of arable land in Kumasi Metropolis in three decades: Evidence from remote sensing image analysis. *Land Use Policy*, *72*. https://doi.org/10.1016/j.landusepol.2018.01.013

Aguilar, A. G., Flores, M. A., & Lara, L. F. (2022). Peri-Urbanization and Land Use Fragmentation in Mexico City. Informality, Environmental Deterioration, and Ineffective Urban Policy. *Frontiers in Sustainable Cities*, *4*. https://doi.org/10.3389/FRSC.2022.790474/FULL

Ahani, S., & Dadashpoor, H. (2021). A review of domains, approaches, methods and indicators in peri-urbanization literature. *Habitat International*, *114*, 102387. https://doi.org/10.1016/j.habitatint.2021.102387

Amri, I., Deka, M., & Yuliyana, P. D. (2019). Urban Sprawl : Perubahan PL dan Implikasinya Terhadap Tekanan Penduduk dan Daya Dukung Lahan pada Daerah Urban dan Peri-Urban di Sebagian Daerah Istimewa Yogyakarta. *Researchgate*. https://doi.org/10.13140/RG.2.2.21145.06241

AZZIZI, V. T., & ARIASTITA, P. G. (2016). Faktor-Faktor yang Mempengaruhi Terbentuknya Pola Perumahan Leapfrog di Kawasan Peri Urban Kota Malang. *Jurnal Teknik ITS*, *5*(2), C156–C159. https://doi.org/10.12962/J23373539.V5I2.18611

BNPB. (n.d.). *inaRISK*. Retrieved September 24, 2021, from https://inarisk.bnpb.go.id/

Christensen, M., & Arsanjani, J. J. (2020). Stimulating Implementation of Sustainable Development Goals and Conservation Action: Predicting Future Land Use/Cover Change in Virunga National Park, Congo. *Computers, Environment and Urban Systems*, *12*(4). https://doi.org/10.3390/su12041570

Clark Lab. (2020). *TerrSet Geospatial Monitoring and Modeling Software*. https://clarklabs.org/terrset/

Czekajlo, A., Coops, N. C., Wulder, M. A., Hermosilla, T., White, J. C., & van den Bosch, M. (2021). Mapping dynamic peri-urban land use transitions across Canada using Landsat time series: Spatial and temporal trends and associations with socio-demographic factors. *Computers, Environment and Urban Systems*, *88*. https://doi.org/10.1016/j.compenvurbsys.2021.101653

Danar. (2020). *Indikasi Pelanggaran Tata Ruang Cenderung Naik - Krjogja*. https://www.krjogja.com/yogyakarta/1242505063/indikasi-pelanggaran-tata-ruang-cenderung-naik

Dizdaroglu, D., Yigitcanlar, T., & Dawes, L. (2012). A micro-level indexing model for assessing urban ecosystem sustainability. *Smart and Sustainable Built Environment*, *1*(3), 291–315. https://doi.org/10.1108/20466091211287155

Eastman, J. R. (2016). *TerrSet Geospatial Monitoring and Modeling System. Manual.*

Eastman, J. R., & Toledano, J. (2018). A Short Presentation of the Land Change Modeler (LCM). In M. T. Camacho Olmedo, M. Paegelow, J.-F. Mas, & F. Escobar (Eds.), *Geomatic Approaches for Modeling Land Change Scenarios* (pp. 499–505). Springer International Publishing. https://doi.org/10.1007/978-3-319-60801-3_36

Fajriyanto. (2011). Konversi Lahan Pertanian Dan Trend Pembangunan Perumahan. *Seminar Nasional SCAN#2 : 2011 Life Style and Architecture*.

Follmann, A., Willkomm, M., & Dannenberg, P. (2021). As the city grows, what do farmers do? A systematic review of urban and peri-urban agriculture under rapid urban growth across the Global South. *Landscape and Urban Planning*, *215*, 104186. https://doi.org/10.1016/J.LANDURBPLAN.2021.104186

Gomes, E., Banos, A., Abrantes, P., Rocha, J., & Schläpfer, M. (2020). Future land use changes in a peri-urban context: Local stakeholder views. *Science of The Total Environment*, *718*, 137381. https://doi.org/10.1016/j.scitotenv.2020.137381

Hardiyanti, P., Soewarni, I., & Imaduddina, A. H. (2018). *Tipologi Wilayah Peri Urban Kabupaten Malang (Typologies Peri Urban Of Malang Regency)*. http://eprints.itn.ac.id/125/

Hedblom, M., Andersson, E., & Borgström, S. (2017). Flexible land-use and undefined governance: From threats to potentials in peri-urban landscape planning. *Land Use Policy*, *63*. https://doi.org/10.1016/j.landusepol.2017.02.022

Küchenhoff, H., Augustin, T., & Kunz, A. (2012). Partially identified prevalence estimation under misclassification using the kappa coefficient. *International Journal of Approximate Reasoning*, *53*(8). https://doi.org/10.1016/j.ijar.2012.06.013

Legates, R., & Hudalah, D. (2014). Peri-urban planning for developing east asia: Learning from chengdu, china and yogyakarta/kartamantul, indonesia. *Journal of Urban Affairs*, *36*(S1). https://doi.org/10.1111/juaf.12106

Mahendra, Y. I., & Pradoto, W. (2016). Transformasi Spasial di Kawasan Peri Urban Kota Malang. *JURNAL PEMBANGUNAN WILAYAH & KOTA*, *12*(1). https://doi.org/10.14710/pwk.v12i1.11462

McKinney, M. L. (2002). Urbanization, biodiversity, and conservation. *BioScience*, *52*(10). https://doi.org/10.1641/0006-3568(2002)052[0883:UBAC]2.0.CO;2

Mehrabi, A., Khabazi, M., Almodaresi, S. A., Nohesara, M., & Derakhshani, R. (2019). Land Use Changes Monitoring Over 30 Years And Prediction Of Future Changes Using Multi-Temporal Landsat Imagery And The Land Change Modeler Tools In Rafsanjan City (Iran). *Sustainable Development Of Mountain Territories*. https://doi.org/10.21177/1998-4502-2019

Ministry of Public Works and Public Housing. (2020). *Badan Pengatur Jalan Tol Kementerian Pekerjaan Umum dan Perumahan Rakyat*. https://bpjt.pu.go.id/berita/dimulainya-pembangunan-jalan-tol-solo-yogyakarta-nyia-kulon-progo

Mondal, D., & Banerjee, A. (2021). *Exploring peri-urban dynamism in India: Evidence from Kolkata Metropolis*. https://doi.org/10.1016/j.jum.2021.06.004

Mortoja, M. G., Yigitcanlar, T., & Mayere, S. (2020). What is the most suitable methodological approach to demarcate peri-urban areas? A systematic review of the literature. *Land Use Policy*, *95*. https://doi.org/10.1016/j.landusepol.2020.104601

Nabila, D. A. (2023). Pemodelan prediksi dan kesesuaian perubahan penggunaan lahan menggunakan Cellular Automata-Artificial Neural Network (CA-ANN). *Tunas Agraria*, *6*(1), 41–55. https://doi.org/10.31292/jta.v6i1.203

Nasiri, V., Darvishsefat, A. A., Rafiee, R., Shirvany, A., & Hemat, M. A. (2019). Land use change modeling through an integrated Multi-Layer Perceptron Neural Network and Markov Chain analysis (case study: Arasbaran region, Iran). *Journal of Forestry Research*, *30*(3). https://doi.org/10.1007/s11676-018-0659-9

Nurcahyani, T. T., & Marwasta, D. (2021). Peri-Urbanization in DIY and Its Relationship to Sustainable Agricultural Lands Protection Program. *E3S Web of Conferences*, *325*. https://doi.org/10.1051/e3sconf/202132507005

Patil, M. B., Desai, C. G., & Umrikar, B. N. (2012). Image Classification Tool for Land Use / Land Cover Analysis : A Comparative Study of Maximum Likelihood. *International Journal of Geology, Earth, and Environmental Sciences*, *2*(3).

Pramana, A. Y. E., & Efendi, H. (2019). Tingkat Aksesibilitas Transportasi Publik di Wilayah Peri-Urban Kawasan Perkotaan Yogyakarta. *REKA RUANG*, *2*(1). https://doi.org/10.33579/rkr.v2i1.1128

Pratiwi, W. D., Shekar Rani, M., Kusuma Nagari, B., & Dwi Pratiwi, W. (2022). Dwelling and Housing Transformation in Southern Bandung Forest Tourism Area. *Jurnal Permukiman*, *17*(2), 93–108.

Pribadi, D. O., & Pauleit, S. (2015). The dynamics of peri-urban agriculture during rapid urbanization of Jabodetabek Metropolitan Area. *Land Use Policy*, *48*. https://doi.org/10.1016/j.landusepol.2015.05.009

Priyadi, P., Sediyono, E., & Prasetyo, S. Y. J. (2020). Penataan Ruang Kawasan Agropolitan di Kabupaten Semarang dengan Metode Artificial Neural Network. *Jurnal Transformatika*, *17*(2). https://doi.org/10.26623/transformatika.v17i2.1615

Roast, A. (2019). Peri-Urban China. Land use, growth, and integrated urban-rural development. *Eurasian Geography and Economics*, *60*(5). https://doi.org/10.1080/15387216.2019.1669475

Roseana, B., Subiyanto, S., & Sudarsono, B. (2019). Analisis Spasial Perkembangan Fisik Wilayah Kabupaten Klaten Menggunakan Sistem Informasi Geografis Dan Prediksinya Tahun 2025 Dengan Ca Markov Model. *Jurnal Geodesi Undip*, *8*(4).

Saxena, A. M., & Sharma, A. S. (2015). Periurban Area: A Review of Problems and Resolutions. *International Journal of Engineering Research & Technology (IJERT)*, *4*(9). www.ijert.org

Selang, M. A., Iskandar, D. A., & Widodo, R. (2018). Tingkat Perkembangan Urbanisasi Spasial Di Pinggiran Kpy (Kawasan Perkotaan Yogyakarta) Tahun 2012-2016. *Kota Layak Huni "Urbanisasi Dan Pengembangan Perkotaan*.

Shaw, B. J., van Vliet, J., & Verburg, P. H. (2020). The peri-urbanization of Europe: A systematic review of a multifaceted process. In *Landscape and Urban Planning* (Vol. 196). https://doi.org/10.1016/j.landurbplan.2019.103733

Silva, C. (2019). Auckland's Urban Sprawl, Policy Ambiguities and the Peri-Urbanisation to Pukekohe. *Urban Science*, *3*(1). https://doi.org/10.3390/urbansci3010001

Sutton, P. C., Anderson, S. J., Costanza, R., & Kubiszewski, I. (2016). The ecological economics of land degradation: Impacts on ecosystem service values. *Ecological Economics*, *129*. https://doi.org/10.1016/j.ecolecon.2016.06.016

Habibatussolikhah, A. T., Darsono, & Susi, W. A. (2016). Analisis Faktor Yang Mempengaruhi Alih Fungsi Lahan Sawah Ke Non Sawah Di Kabupaten Sleman Daerah Istimewa Yogyakarta. *SEPA*, *13*(1), 22–27.

Valent, C. G., Subiyanto, S., & Wahyuddin, Y. (2021). Analisis Pola Dan Arah Perkembangan Permukiman Di Wilayah Aglomerasi Perkotaan Yogyakarta (APY)(Studi Kasus: Kabupaten Sleman). *Jurnal Geodesi Undip*, *10*(2).

van den Bosch, M., & Bird, W. (2018). Oxford Textbook of Nature and Public Health: The Role of Nature in Improving the health of a population. In *Oxford University Press*. Oxford University Press. https://books.google.co.id/books?id=pAJCDwAAQBAJ&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

Wellmann, T., Lausch, A., Andersson, E., Knapp, S., Cortinovis, C., Jache, J., Scheuer, S., Kremer, P., Mascarenhas, A., Kraemer, R., Haase, A., Schug, F., & Haase, D. (2020). Remote sensing in urban planning: Contributions towards ecologically sound policies? In *Landscape and Urban Planning* (Vol. 204). https://doi.org/10.1016/j.landurbplan.2020.103921

Wibisono, B. H., & Sulistya, A. Y. (2022). Contemporary urban development of Yogyakarta municipality's peri-urban areas. *World Review of Science, Technology and Sustainable Development*, *18*(2). https://doi.org/10.1504/WRSTSD.2022.121305

Widodo, B., Lupyanto, R., Sulistiono, B., Harjito, D. A., Hamidin, J., Hapsari, E., Yasin, M., & Ellinda, C. (2015). Analysis of Environmental Carrying Capacity for the Development of Sustainable Settlement in Yogyakarta Urban Area. *Procedia Environmental Sciences*, *28*. https://doi.org/10.1016/j.proenv.2015.07.062

Winarso, H., Hudalah, D., & Firman, T. (2015). Peri-urban transformation in the Jakarta metropolitan area. *Habitat International*, *49*. https://doi.org/10.1016/j.habitatint.2015.05.024

Woltjer, J. (2014). A Global Review on Peri-Urban Development and Planning. *Jurnal Perencanaan Wilayah Dan Kota*, *25*(1).