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## Prediction and location suitability of settlement growth at The BWK II of Semarang City

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**Abstract:** Population growth in urban areas leads to the increasing demand for settlement areas and the expansion of settlement growth in inappropriate locations. Semarang is one of the important metropolitan cities in Indonesia which has problems with the supply of settlement areas. The main focus of this research is to understand the problem, including the aspects of settlement growth, forecasting, and proposing recommendations for expansion of the settlement areas. The study area is BWK II of Semarang City which consists of two Districts, Candisari and Gajahmungkur. The study area is a very potential area for settlement growth. The aim of the research was to predict the settlement growth and assess the location suitability of settlement growth based on the Master Plan document of Semarang City. The primary data for the study is obtained from QuickBird data image, and the spatial analysis was conducted by utilizing Remote Sensing, Geographic Information System, and LanduseSim as the software for prediction simulation. Accessibility and existing settlement location are considered as the driving factor while the river is considered as the constraint factor. The result of the study shows that the prediction of settlement growth is mostly consistent with the Master Plan of Semarang City. The study provides evidence that settlement growth was also observed in the conservation area and flood-prone area which are restricted for further development. The findings are beneficial for planners to reformulate the policies and strategies for future settlement growth.

### 1. Introduction

The increase of urban population due to natural growth and urbanization has several implications for the increasing demand for space for activities and settlements. Urbanization is considered as a spatio-social process that triggers land conversion causing changes to the landscape of the city and the surrounding area. [1,2]. The needs for settlement needs has increased from year to year. Over 30 years, housing stock in Shanghai, the largest city in China, has increased by 58%, [3].

Currently, many urban problems in Indonesia are caused by the high population growth resulted in the increasing demand for housing. The increasing demand for urban settlements is not supported by the availability of land [4]. The establishment of urban settlements is not the main problem, yet the main issue is the fact that those settlements are not controlled and grow in areas that are not suitable for residential areas. Weak law enforcement and low public awareness of the spatial plan result in the improper use of space. The development of urban settlements is usually controlled through policy instruments such as master (spatial) plan, development plan and zoning regulation. Those policies are designed to manage urban development, with the aim of creating cities that are able to fulfil people's needs [5–8].

The settlement system consists of the composition of various elements, namely Nature, Man, Society, Shells and Network, which are interconnected [9]. Residence is generally called as a settlement and is specifically referred to as a house. [10,11]. Settlements around the world may change spatially, yet the



patterns of changes might vary as well as the driving factors of its spatial changes [12,13]. The settlements have a dynamic structure, are able to change at any time and each change is accompanied by growth.

Uncontrolled urban settlement is a manifestation of normal urban growth processes under historically unprecedented conditions. [14]. Many urban settlements are results of a spatially distributed, decentralized building process. [15]. The contributing to the growth of settlements are natural physical, social and geographical factors [16,17]. Monitoring growth trends is important for land management and decision making [18], and supports infrastructure planning to be effective in urban areas [19].

Completeness of facilities and infrastructure is an attraction for the community to decide the location of their residence. The contributing factors to the decision are accessibility, space and land availability, availability of residential facilities and infrastructure, and basic physical and environmental condition [20]. The trend of choosing a location for housing and the direction of urban expansion in Iraq are influenced by spatial, topographic, and social factors (population density, income, regional protection, the same ethnic area) [21]. The decision to choose the location for settlements also are based on physical characteristics of residential environment, availability of facilities and services, social environment, ethnic and demographic factors, and characteristics of the housing [22].

In keeping with the development of Semarang City as a Metropolitan City, the settlement growth in Semarang also increases rapidly. Candisari District and Gajahmungkur District which are included in BWK II of Semarang has a high potential for settlement growth. Settlement growth in Candisari District might cause a decrease in water resources [23]. At present, settlement growth in the study area is still ongoing. Policy makers must find solutions for conflicts between settlement growth, ecological conservation, and environmental carrying capacity.

Constant settlement growth might result in settlement development in non-residential areas. Prediction on the growth of settlement area is necessary to determine future settlement location and distribution, to anticipate negative effects of settlement development in non-residential areas. Based on the issue, the aim of the study was to predict the settlement growth and settlement development in BWK II of Semarang in 2031 and its suitability to Master Plan Document of Semarang City Year 2011-2031. Location suitability between Master Plan Document and existing condition is the benchmark to determine if the spatial plan documents are suitable with the development of each area. This study used descriptive quantitative method with a spatial approach utilizing Geographic Information System and Remote Sensing (GIS/RS) technology in most of the analysis. LanduseSim was used as software spatial planning model to predict the growth of land use/settlements area.

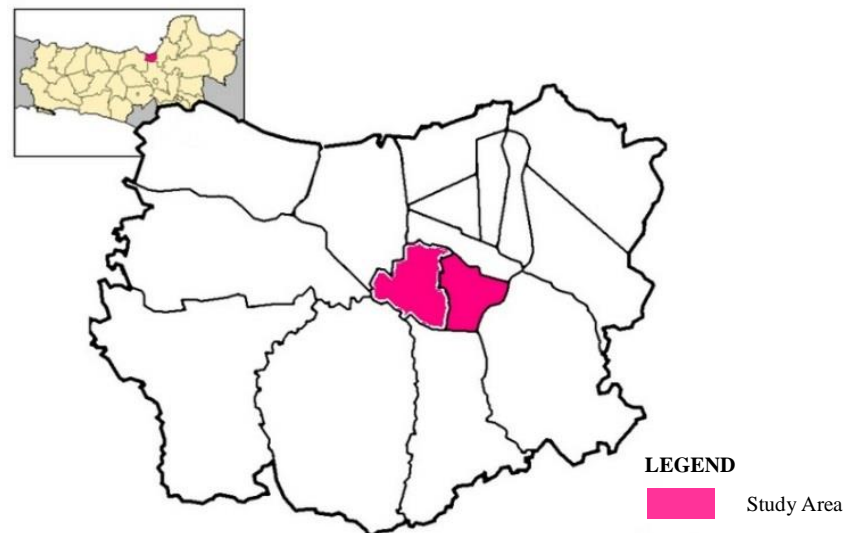
LanduseSim is a GIS tool for land use/ land cover (LULC) modelling and simulation. LanduseSim able to deal with land dynamic simulation. LanduseSim as land use modeling software becomes an appropriate software to do simulation such as predict of land-use change. LanduseSim was designed to be a stand-alone software however several initial operations require GIS software in order to prepare input data for LanduseSim. LanduseSim is targeted for urban & regional planner, real estate planner. To ensure the valid modelling, LanduseSim was designed by implementing Enhanced Cellular Automata Model Algorithm, a cutting-edge of methodology for land scape simulation. LanduseSim also equipped by user-friendly GUI (Graphic User Interface). LanduseSim as a software for spatial planning model provides solutions for planners to predict information regarding Land Use Change in the future. LanduseSim is a GIS-based application for spatial land use modelling and simulation in urban and regional planning[24].

## 2. Research Location

The study area is Bagian Wilayah Kota (BWK) II of Semarang covering two District (*kecamatan*), i.e., Candisari District and Gajahmungkur District. Candisari District consists of 8 villages and

Gajahmungkur District consists of 7 villages. BWK II of Semarang covers an area of 1.320 Ha and its population density is 116 – 66 person / Ha [25].

Bagian Wilayah Kota (BWK) is part of Semarang city area which is a functional area or area that has similar space functions. In the scale of neighborhood, the settlement area in BWK II is categorized as highdensity settlement. High density settlement development plan includes improving the quality of settlement environmental infrastructure and providing green and non-green open space and improving the quality of housing through vertical housing development. [26]. Figure 1 shows the study area.



**Figure 1.** The Study Area

### 3. Methods

The aim of the research was to analyze the Prediction and Location Suitability of Settlement Growth at The BWK II of Semarang. This study used descriptive quantitative method with a spatial approach utilizing Geographic Information System and Remote Sensing (GIS/RS) technology in most of the analysis and LanduseSim as a modelling software for land use prediction. The main data source was Quickbird images. The primary data for the analysis were the results of supervised classification Quickbird images using maximum likelihood method.

The process of analysis was conducted as follows:

- Analysis of Settlement Growth Prediction based on the land use development trends year 2015, 2020, 2025, and 2031, using the variable of accessibility as the driving factor and the variable of river as constraint. The location of existing settlement was also included in the prediction analysis
- Analysis of settlement growth based on the percentage of the increase of settlement area between Year 2015 and 2031
- Analysis of location suitability of settlement growth Year 2031 (prediction) compared to the Master Plan of Semarang City Year 2011-2031.

### 4. Result and Discussion

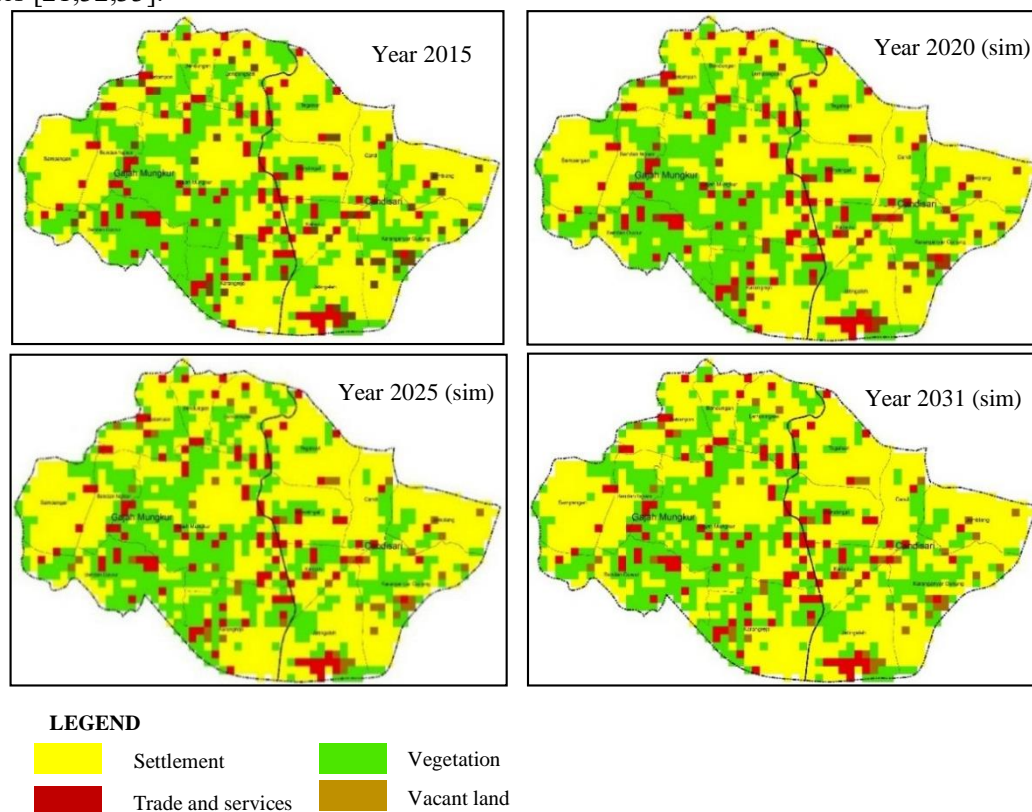
#### 4.1. Prediction of Settlements Growth

Settlements are part of a residential environment which consists of more than one housing unit that has infrastructure, facilities, public utilities and is a tangible form of fulfillment of human needs for space. [27]. Settlement area is a process of functional placement based on patterns of human activities and

direct physical as well as non-physical impacts [28]. To be able to gain information about future condition, a planner need a prediction tools for the dynamics of land use change. Future land use predictions include predicting changes of land use that occur as a result of a spatial planning scenario. One of the applications to predict the development of an area using land use simulation is LanduseSim. LanduseSim, as a land use change modelling software to predict the future of land use, has specific framework on spatial modelling process. [29].Based on computation method, LanduseSim is an option to perform spatial simulation

The study contains the land use prediction for Year 2031 based on the growth trend without taking into account any policy interventions. The classification of land use is based on Anderson's classification. The land use and cover is classified according to the level II classification scheme described by Anderson et al [30]. Classification of land use is grouping objects into categories based on the similarity in nature, or the relationship between objects [31].

LanduseSim modelling depicts the transition of land use based on certain variable. The variable used in the study is accessibility as the driving factor and river as the constrain. The location of existing settlements is also considered in this prediction. The variable of variable was chosen because several previous studies shows that accessibility affected land growth. Land and settlement growth are significantly affected by accessibility, facilities, infrastructure, environmental interactions and spatial policies [21,32,33].

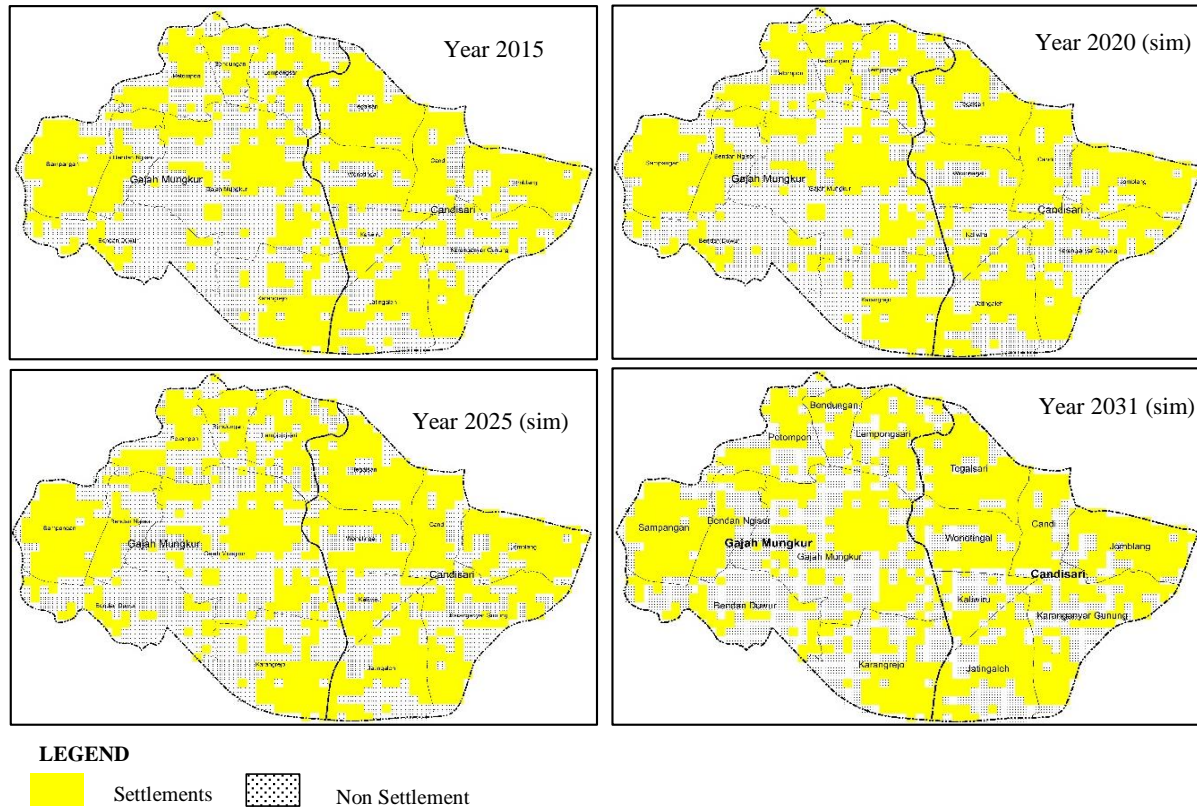


**Figure 2.** Land use Prediction for Year 2020, 2025, 2031.

Figure 2 shows the prediction of settlement growth for Year 2020, 2025, and 2031. There are three areas which are dominant for settlement area, namely Jomblang Village, Sampangan Village and Tegalsari Village. Those areas are conveniently located, supported by good access to various facilities of the city. While Bendan Duwur Village is the area with the least settlement area (see Table 1). Bendan Duwur Village is an area with wavy and hilly topography and located on a fault line. Although road lanes are in good conditions, the accessible is low. Figure 3 shows the land use for settlement area and non-



settlement area in Semarang in 2015 and the model of land use prediction for Year 2010, 2025, and 2031 are the result of LanduseSim modelling.



**Figure 3.** Prediction of Settlement Area for Year 2000, 2025, 2031

**Table 1.** Settlement Area Year 2031

No.	Village	Settlements		Non Settlements		Total	
		(ha)	%	(ha)	%	(ha)	%
1	Bendan Duwur	38.18	29.63	90.67	70.37	128.85	100
2	Bendan Ngisor	35.46	58.79	24.86	41.21	60.32	100
3	Bendungan	29.52	63.85	16.71	36.15	46.23	100
4	Candi	48.42	71.26	19.53	28.74	67.95	100
5	Gajah Mungkur	125.97	43.85	161.31	56.15	287.28	100
6	Jatingaleh	71.35	59.67	48.22	40.33	119.57	100
7	Jomblang	71.14	75.41	23.20	24.59	94.34	100
8	Kaliwiro	24.58	46.34	28.46	53.66	53.04	100
9	Karanganyar Gunung	80.12	56.55	61.57	43.45	141.69	100
10	Karangrejo	69.95	48.10	75.47	51.90	145.42	100
11	Lempongsari	49.57	58.84	34.67	41.16	84.24	100
12	Petompon	43.98	51.06	42.15	48.94	86.13	100

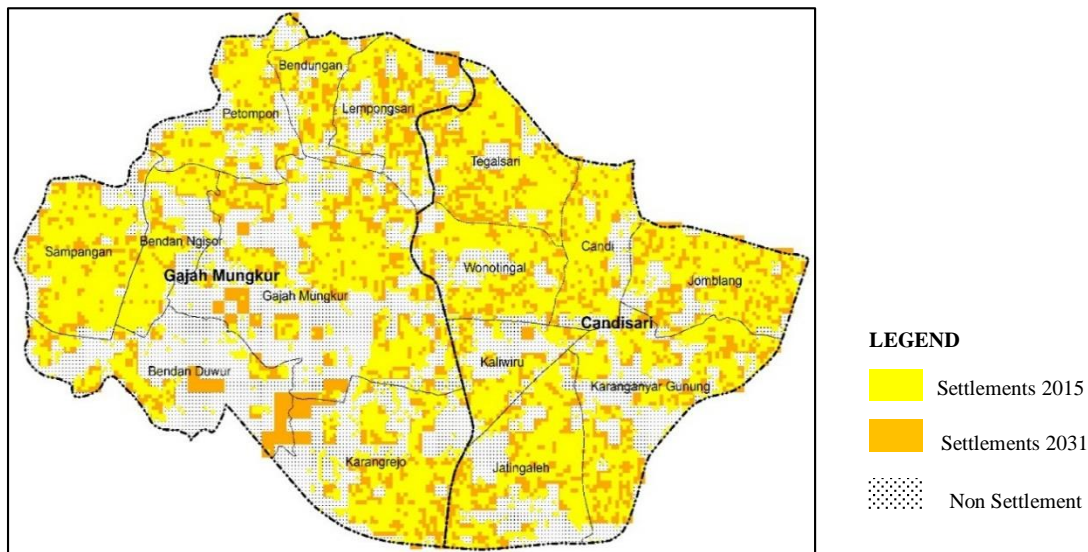
13	Sampang	76.60	74.41	26.35	25.59	102.95	100
14	Tegalsari	80.87	78.47	22.19	21.53	103.06	100
15	Wonotingal	53.36	65.34	28.30	34.66	81.66	100
Total		899.06	56.10	703.65	43.90	1602.71	100

#### 4.2. The Settlement Growth Year 2015-2031

The settlement growth is determined based on the percentage of the increase of settlement area in 2015 and 2031. Table 2 shows the increase of settlement area in the study area. Bendan Duwur Village has the highest (59.42 %), which is possible since Bendan Duwur Village is a developing education area supported with many facilities. Figure 4 shows the area distribution of settlement growth in the study area. The dominant expansion of settlement area is observed in Gajahmungkur Village for 28.58 ha. Gajahmungkur Village has the potential to be the object of settlement development because of its non-built up area.

**Table 2.** Settlements Growth 2015-2031

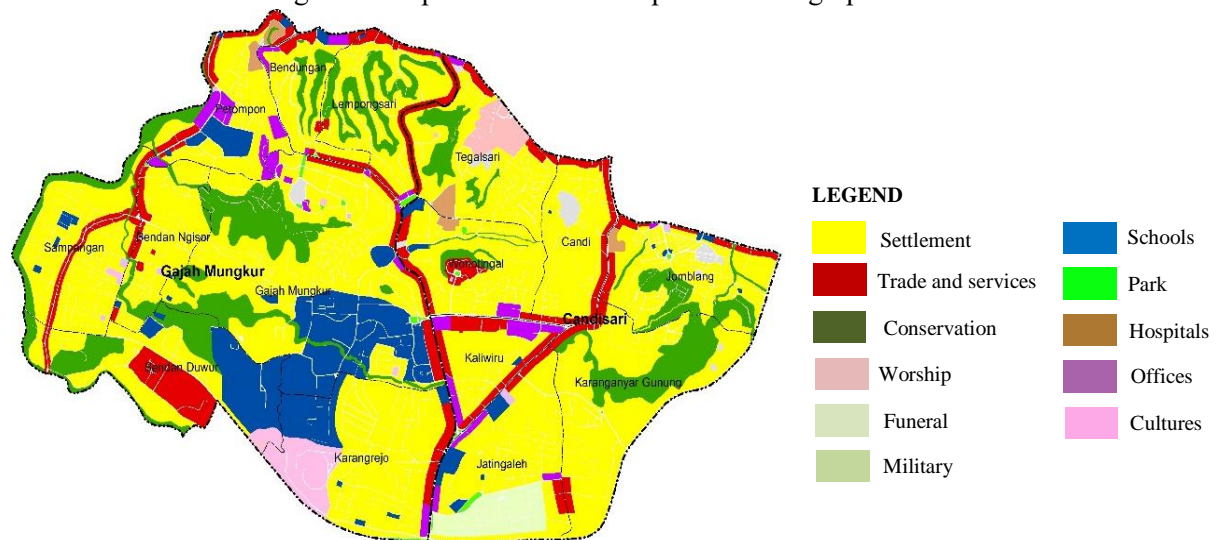
No.	Village	Settlements	Settlements 2031	$\Delta$ 2015-2031	
		2015		(ha)	(%)
		(ha)	(ha)	(ha)	(%)
1	Bendan Duwur	23.95	38.18	14.23	59.42
2	Bendan Ngisor	33.71	35.46	1.75	5.18
3	Bendungan	23.19	29.52	6.33	27.29
4	Candi	42.26	48.42	6.16	14.57
5	Gajah Mungkur	97.39	125.97	28.58	29.35
6	Jatingaleh	56.79	71.35	14.56	25.63
7	Jomblang	55.90	71.14	15.24	27.27
8	Kaliwiru	21.77	24.58	2.81	12.90
9	Karanganyar Gunung	64.71	80.12	15.41	23.81
10	Karangrejo	56.75	69.95	13.20	23.25
11	Lempongsari	34.84	49.57	14.73	42.27
12	Petompon	41.11	43.98	2.87	6.97
13	Sampang	64.67	76.60	11.93	18.44
14	Tegalsari	62.68	80.87	18.19	29.03
15	Wonotingal	44.51	53.36	8.85	19.88
Total		724.25	899.07	174.82	24.14



**Figure 4.** Settlements Growth 2015-2031.

*4.3. Suitability of Settlement growth with Spatial Planning Document*

Analysis of Suitability of Settlement growth with Spatial Planning Document were conducted by comparing the predicted settlement growth area for Year 2031 to the Master Plan of Semarang City. The Master Plan of Semarang City (RTRW) is the result of the spatial planning in a region which is considered as a geographical unit including all related elements whose boundaries and systems are determined based on administrative aspects [34]. The Master Plan is designed due to the limitation of the space; therefore, policies are needed to control the use of space and conduct spatial planning so that it can be effective. The products of spatial plan are established as documents known as The Master Plan Maps. Spatial planning documents as the product of spatial planning process has the role not only to make effective use of space and prevent conflicts between functions in the process of spatial use, but also aims to protect the community as the inhabitants of the space from environmental hazards that may arise due to the non-suitable development of spatial functions in locations. Space pattern is the distribution of space designation in a particular area [35]. The space pattern is one of main products in the process of spatial planning document preparation. The space pattern is one of the essential foundations to establish zoning policies in the future. Figure 5 shows the land use as established in the Master Plan of Semarang which is presented as the map of Semarang Space Pattern.

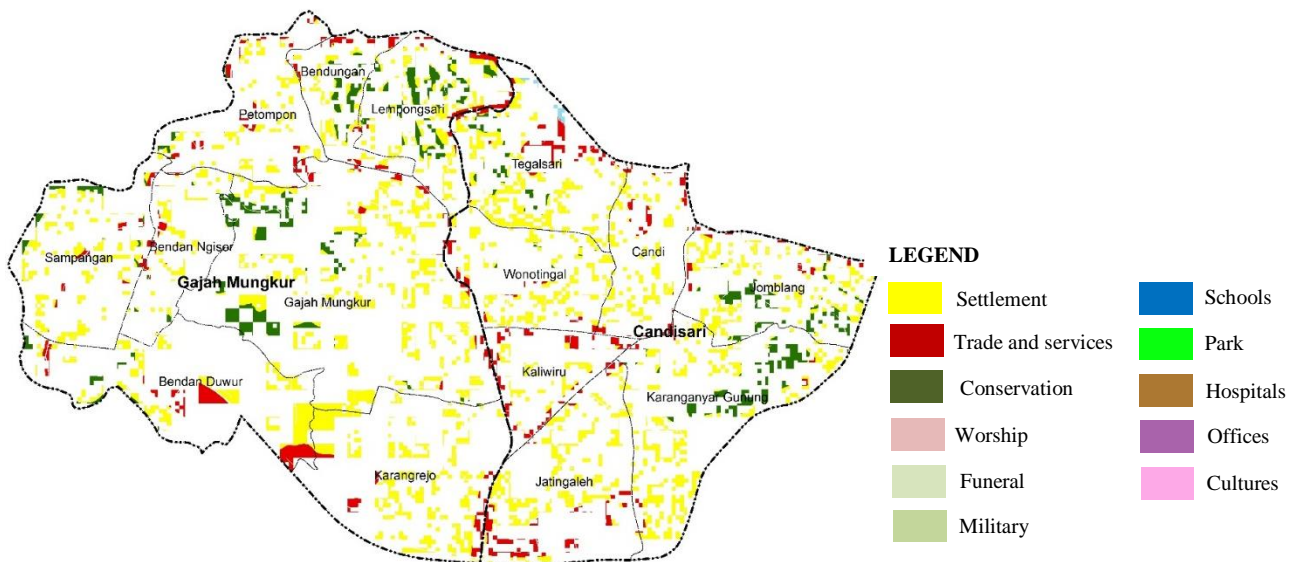


**Figure 5.** Map of Semarang City Space Pattern Year 2011-2031





15	Wonotingal	44.38	3.32	1.38	49.08
Total		641.75	100.58	95.48	837.81
%		76.60	12.01	11.40	100.00



**Figure 7.** Map of Suitability of Semarang City Space Pattern Year 2011-2031 to Settlement Growth

Figure 7 shows the distribution of suitability between the growth of settlement area in 2031 to the Master Plan of Semarang City. The result of suitability analysis of settlement growth area between the prediction for Year 2031 and the Master Plan Year 2011-2031 is presented in Table 4. The settlement area that is suitable to the Master Plan is 198.74 Ha (71.32%), which is mostly located in Gajahmungkur District (35.00 Ha). While the area that is not suitable to the Master Plan covers 79.92 Ha (28.68 %). The area that is not suitable serves as trade and service area which covers 39.79 Ha (14.28 %), conservation area 39.35 Ha (14.12%) and flood prone area 0.78 Ha (0.28%).

**Table 4.** Suitability of Predicted Settlement Area Year 2031 to Space Pattern Year 2011-2031

No	Village	Suitable	Un Suitable			Total
		Settlements	Trade and Services	Conservation	Flood Prone	
1	Bendan Duwur	13.42	6.25	1.71		21.38
2	Bendan Ngisor	4.95	0.69	0.78		6.42
3	Bendungan	4.90	2.07	2.56		9.53
4	Candi	8.56	2.15			10.71
5	Gajah Mungkur	35.00	2.60	10.78		48.38
6	Jatingaleh	15.73	4.76			20.49
7	Jomblang	12.54	1.64	5.18		19.35
8	Kaliwuru	3.97	3.89			7.87
9	Karanganyar Gunung	19.48	0.80	6.56		26.84
10	Karangrejo	21.57	2.67			24.24

11	Lemponsari	10.92	2.59	7.17		20.68
12	Petompon	7.91	2.39	0.59		10.88
13	Sampangan	11.66	1.54	1.87		15.07
14	Tegalsari	16.30	4.31	1.95	0.78	23.33
15	Wonotingal	11.83	1.45	0.20		13.48
Total		198.74	39.79	39.35	0.78	278.66
%		71.32	14.28	14.12	0.28	100.00

## 5. Conclusion

The prediction of settlement growth at BWK II of Semarang City shows an increase of settlement growth at 24.14% during the period of Year 2015-2031. The area with the highest settlement growth is Bendan Duwur Village. The condition is likely to take place since Bendan Duwur Village is a developing education area supported with various facilities. The area that is not suitable to Master Plan is 28.68% of settlement area, because it is functioned as trade and service area, conservation area, and flood prone area.

Based on its potential, the settlement area in the study area can be developed in trade and service in Jatingaleh Village and Sampangan Village because those area are equipped with good accessibility to other area. Yet, the development of settlement area in Jatingaleh Village and Sampangan Village cannot be implemented since it is against the Master Plan of Semarang City. The Policy related to land use in settlement area is explicitly stated in Spatial Plan of Semarang City by regulating its location and distribution based on the carrying capacity of its environment and the areas are not to be converted.

The results of the LanduseSim analysis can be used as consideration by planners. In particular in Indonesia, some planning is done not based on a direct analysis approach to land use. Planners do a partial analysis of other aspects with an intuitive approach to produce proposed spatial plans. Mechanisms like this, the results are not optimal because they do not have a picture / information on the composition of land use in the future. The use of LanduseSim as a GIS-based application for spatial planning and modelling for land use changes is effective to support urban and regional planning, especially in BWK II of Semarang as the study area because the application provides spatial planning similar to the document of Semarang City Master Plan, showing the degree of suitability at > 70%.

## 6. Acknowledgements

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