Spatial Dynamics Model of Land Availability and Mount Merapi Disaster-Prone Areas in Sleman Regency, Yogyakarta Special Region Province

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Abstract. The existence of Mount Merapi in Sleman Regency makes the agricultural land in the area fertile and that becomes the attraction for humans to occupy the region. A high population growth will lead to the residents demand of the availability built-up land higher, that makes the environmental carrying capacity in Sleman Regency decrease. However, the volcanic activity of Mount Merapi becomes a threat to the people who live in the area of Disaster Prone Areas of Mount Merapi. Predictions on the availability of land as well as the relation to the disaster-prone areas, and the carrying capacity of the environment needs to be done. 2007 – 2017 population data and Landsat 7 ETM + 2007, 2012, and Landsat 8 OLI 2017 imagery will be used in this research as variable in the spatial dynamics model. Meanwhile, physical and accessibility data such as slope, distance from the river, distance from protected area, distance from road, and distance from the center of economic growth will be used as limiting factor of built-up land. Environmental carrying capacity can be observed through a dynamic system model of the relationship between population growth and land availability within the period of 2007 - 2100, then made into the spatial dynamics model to know it’s spatial stance. The results of this model show that built-up land increasing every year, packed areas that are suitable for built-up land first, then encroach on areas which not suitable for built-up land and Mount-Merapi Disaster-Prone Areas.

1. Introduction
One of the regencies in Indonesia with high percentage of population growth is Sleman Regency. During the years 1995 - 2005 population growth in Sleman District reached 2.7% which is much higher than the national population growth [1]. The rapid growth of the population will cause the need for land as a space for their activities to increase and will lead to a kind of competition to get a suitable space in accordance with various interests and human needs. The increase in the number of population affect the process of development and development activities of a region and the increasing need for space or land [2]. Population density often creates problems in spatial planning due to large population pressure on land. In densely populated areas and uneven distribution will face problems such as housing problems, employment issues, educational issues, food problems, security issues and can have an impact on environmental damage[3].

The higher the population growth, will cause the higher need for land, while the existing land area is fixed. Ultimately, this will degrade the environmental carrying capacity [4]. Carrying capacity will
achieve good quality if the size of land for the area is between 30 - 70% of the total usable land [5]. The existence of a disaster-prone area became one of the factors in the selection of the area that will be used as the settlement, which of course the settlements should not be built in that area or the existence of settlements built minimized in that area to avoid the high risk of disaster. Based on this, it is necessary to predict the availability of land for constructed land control which can be done with spatial dynamics model.

This spatial dynamics model is based on a system dynamics model. The system dynamics model describes the behavior of the relationship between the variable of population growth with the variable of land availability. Spatial dynamics model is made in the form of developed region development, and can show when the land supporting capacity in Sleman District no longer able to meet the needs of its population. The development of the built-up land will be associated with the disaster prone areas of Mount Merapi in Sleman regency.

2. Methods
Spatial dynamics is the result of a spatial model (GIS) and system dynamics. System dynamics GIS-based is the right method to describe the relationship and dependence between the population, built-up area and land carrying capacity in the future [6]. The variables used in the system dynamics, such as population, built-up area, land needs, land availability. Data processing and analysis using the system dynamics software, whereas the spatial with its GIS using ArcGIS 10.3 software. The variable in spatial analysis is settlement development variable and settlement suitability variable that consist of variables such as slope, distance from the river, distance from road, distance from the center of economic growth elevation, and Mount Merapi disaster-prone area.

According to the explanation above, it seem that the model showed a causality relation into the causal loop diagram. Causal loop diagram is a connected arrow, where the upper arrow is the causes and the bottom arrow is the effects [7]. The system dynamics step create the causal loop diagram is determined by former with model used and assumption variable. The system dynamics can predict population growth within the research area which its limited land. This method can be simulated with spatial concept, by looking at to time and direction of built-up area development. The GIS analysis used overlay analysis with its result such as suitable area, less suitable area, and not suitable area for built-up area (settlement) [8]. This spatial analysis combined with system dynamics analysis result on the development of built-up area (settlement) with the existing availability land.

3. Result and Discussions
3.1 System Dynamics Model
System Thinking, System Practice (STSP) can be used for system dynamics as an attempt to simplifying the rules of natural science, and the results were successsfully simplifying the existing system of natural phenomena (Checkland, 1999), also system dynamics can be defined as a method that is used for learning the system (Soesilo dan Karuniasa, 2014). According to the background on modelling issues as a story, a model variable and an assumption, then made a Causal Loop Diagram (CLD) from the model of land availability and built-up area that showed on figure 1. According to Causal Loop Diagram (CLD), system dynamics model for land availability and built-up area, then the next is made Stock and Flow Diagram (SFD), that is showed by figure 2.

3.2 Assumptions in the model
According to the model variable, there are several assumptions that is used in the model, as follows:
1) Emigration pressure factor (population out), assumed as one of impact from the population pressure in an area. In this model made non-linier functional approach from the population pressure. The assumption scale is 0-1 (Rina and Rika, 2012), where if the population pressures is high, then emigration pressures factor are also high.
2) Emigration is the movement of people/populations/communities from an origin area to the outside with purpose to work/stay (BPS, 2012). On this model, emigration factor assumed as an impact from the factor of emigration pressures, then do the approach of non-linier function from the factor
of emigration pressures. The assumption scale is 0-5, where if the factor of emigration pressures is high, then the occurred emigration is also high.

Figure 1. The Causal Loop Diagram of the Land Availability and Built-up Land Model [6]

Figure 2. Stock and Flow Diagram (SFD) System Dynamics Model for Land Availability and Built-up Land

3.3 Simulation Result
On the figure 3a and figure 3b, It can be seen that the amount of population have a unique pattern with the exponential growth pattern (behavior). The variable of built-up area also have a unique pattern then horizontal, therefore It has the feature of sigmoid pattern (behavior).
3.4 Model Validation

The validity of model performance to gain confidence that the model performance appropriate with the performance of real system are to compare between the model output and the empirical data, then do the statistical test to see the deviation with Average Mean Error (AME) that is the deviation accepted is <30%, due to many factors that cannot be controled on the model [9].

The result of validation test for the amount of population variable in 2007-2017 on this model showing that the AME value is 3% and the model is valid. The average of the amount of population actually in 2007-2017 on Sleman Regency are 1.115.082 inhabitants, while the average of the population amount from the simulation result at the same years are 1.149.895 inhabitants. Model validation for variable of built-up area in the model of land availability and the development of population amount from 2007-2017 showing that the AME value is 6.3% and the model is valid. The average of built-up area actually in 2007-2017 on Sleman Regency are 17.589 ha, while the average of built-up area from the simulation result at the same years are 16.478 ha.

3.5 Model Simulation

From the model simulation, the development of built-up area on Sleman Regency is tend to rise, while the land availability is tend to fall. The encounter of development line of built-up area and land availability (50% from the extensive of research area) will occur in 2035. Then the comparison between the built-up area and the land availability reach the ratio of 70:30 in the years among 2056 and ratio of 80:20 in 2070.

3.6 Built-Up Land and Mount Merapi Disaster-Prone Areas 2017

The disaster-prone area of Mount Merapi in Sleman Regency has the following area, Zone III are 4.869 Ha, Zone II are 3.288 Ha, Zone I are 1.357 Ha, and Non-Disaster Prone Area are 48.099 Ha. The area that was built in the disaster prone areas of Mount Merapi in 2017 as follows, the built-up land in Zone I Disaster Prone Area are 246 Ha, the built-up land in Zone II Disaster Risk Area are 820 Ha, and the built-up land located in Disaster Prone Areas Zone III are 400 Ha.

Based on the result from data processing, researcher know that Ngemplak is a district with the highest built-up land that located in Zone I Disaster Prone Area, which is equal to 64 Ha. Then, in Zone II Disaster Prone Area, Pakem becomes the subdistrict with the highest built-up land in the area are 266 Ha, followed by Cangkringan 252 Ha and Turi 242 Ha. In Zona III Disaster Prone Area, Cangkringan becomes the highest number of constructed areas that occupy the area, which is 262 Ha.

3.7 Suitability Landscape Area for Settlement

Intervention result between built-up area and population was implemented in space which have spatial pattern, that is to find the suitable area to be built. Suitability of built-up area (settlement) with limiting
factors rules was made with 3 classification that is suitable, less suitable, and not suitable which consist of variables are: slope (0-2%, 2-15%, 15-25%, 25-40%, and >40%), terrain, distance from the river (>100 meter), distance from road (<100 meter), distance from center of economic growth (<2000 meter), and Mount Merapi Disaster-Prone Areas. Most of suitability area is located in south of Sleman Regency, meanwhile most of not-suitability area is located on the north that have steep slope and hilly. The suitability area was based on variables which considering physical data and accessibility data. The number of suitable area reach about 52,883 ha, meanwhile the less suitable area about 4,581 ha, and not-suitable area reach about 149 ha.

3.8. Discussions
By 2035, the simulation results generally show a total population of 1,764,344 people and an upgraded land area of 28,872 ha, which has a proportion of 50% of the research area. The predicted developments occurred this year, indicating the area of each sub-district is getting denser by the built-up land. The area built this year lies on the slope of 8%, the terrain from flat to the plateau, the distance from the river > 50 meters, the distance from the road < 100 meters, the distance from the center of economic activity 2001 - 2500 m. In 2035 the built-up land will be in Zone I of 300 Ha, Zone II of 820 Ha, and Zone III of 400 Ha.

Figure 4. Built-Up Land Prediction 2035 Map
Figure 5. Built-Up Land Prediction and Mount Merapi Disaster Prone Areas 2035 Map
Figure 6. Built-Up Land Prediction 2056 Map
Figure 7. Built-Up Land Prediction and Mount Merapi Disaster Prone Areas 2056 Map
The prediction of spatial dynamics model in 2060 shows that the development of built-up land has become denser and uncontrollable, based on the simulation result, this year, the environmental supporting capacity has reached its maximum capability, with 40,252 ha of built land area which gives proportion of 70% research area. The current population based on the simulation result is 2,486,268 inhabitants. The development of the area built in 2056 occurs on the slope <15%, the terrain from flat up to the hilly, the distance from the river <50 meters, the distance from the road 101 - 750 meters, and the distance from the center of economic activity> 2500 meters. In 2056 there was an addition of built-up land in Zone I become 888 Ha, Zone II become 1,235 Ha, and no addition to Zone III.

4. Conclusion
Population growth occurring in the research area has affected the availability of land for constructed land in the study area. The occurrence of population increase causes the need for land is increasing as well, thus, increasing the built-up land. The increasingly widened land area in the research area resulted in the decreasing availability of land. Based on the simulation results, population growth with land availability has an inverse relationship, as the number increases, so the availability of land decreases. Decreased availability of land also decreases the carrying capacity of the environment. In this study, the research area is predicted to reach maximum supportability in 2056.

Spatial dynamics models show that built-up land are increasing year by year, packing areas suitable for built-up land, and then developing in areas less suitable for built-up land. In the end, in 2056 it is predicted that the area of built-up land has reached 70% of the research area, which means the ability of land to meet the needs of the population optimally has been optimized by this year. Increasing the growth of the built-up land in the Disaster Prone Areas of Mount Merapi need to be considered for the security of the population in the event of a disaster caused by Mount Merapi.

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