

# Sustainable Land Use Model In Garang Watershed

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# Sustainable Land Use Model In Garang Watershed

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**Abstract.** Land cover change is a phenomenon that often occurs along with population growth and economic activity. This phenomenon not only occurs in urban areas but also penetrates into suburban areas, which incidentally have an important role in the water flow system. The same condition occurs in the Garang Watershed, Semarang City, where changes in land cover have begun to penetrate the water catchment area. Land cover change in the Garang watershed system will certainly have consequences for potential water-related disasters, and it will get worse due to climate change. Climate change in many places has triggered a water-related disaster or hydrometeorological disaster. Land cover change and climate change are conditions that cannot be avoided but can be managed so that they do not have a negative impact on the community. To minimize the adverse impacts of land cover changes and climate change is to provide land use directions that can reduce the threat of hydrometeorological disasters so that the sustainability of the ecosystem in the Garang watershed can be maintained. One approach that can be used in the framework of sustainable land use modeling is the spatial regression method. The results of the analysis show that the role of vegetation and water reservoirs can significantly reduce the potential hazard of hydrometeorological disasters.

**Keywords:** environment, sustainable land use, reservoirs

## 1. Introduction

A watershed is an ecosystem unit that is limited by ridges that have the function of flowing water from upstream to downstream. The sustainability of the function of a watershed will be significantly influenced by land cover, land use, slope factors, and geomorphological characteristics. The condition of land cover will be greatly influenced by population growth and everything, but on the one hand, the availability of land is limited. Limited land makes changes in land cover and land use inevitable. Changes in land cover and changes in land use cause serious consequences for environmental quality in a watershed [1, 2, 3]. Research in Thailand [4,5], India [6,7], China [8], America [9], and Semarang [10] showed a significant effect of land cover change and land-use change causing an increase in the greenhouse gas effect which is characterized by an increase in the earth's surface temperature, and climate change that trigger hydrometeorological disasters in the form of landslides, droughts, and floods.

Changes in land cover also occur in the Garang River Basin, which is a functional hydrological area that crosses three autonomous regions, namely Semarang Regency (upstream), Semarang City, and Kendal Regency (middle and downstream). Based on Landsat 8 imagery, changes in land cover in the last eight years show that the built-up area is growing and the vegetated area is decreasing. Based on the comparison of land cover data in 2013 and land cover in 2021, the built-up area in the Garang river basin increased by 533.03 Ha. The increase in built-up land will certainly have an important influence on the environmental quality of the Garang River watershed, particularly related to water systems and

microclimate. The increase in built-up land will have an effect on increasing surface runoff and reducing the amount of water that is absorbed into the soil. The increase in built-up land will also affect the increase in the earth's surface temperature as a result of reduced vegetation that absorbs solar heat, so that heat radiation is reflected back and trapped in the atmosphere or what is known as the greenhouse gas effect [11].

Many research show empirical facts that land cover changes have a complex effect on natural environmental conditions, but research on the effects of land cover and land use changes in a watershed is still limited, so research on land effects is necessary cover changes in the natural environment in a watershed by modeling. The model of the effect of land cover changes on natural environmental conditions in a watershed will be the basis for directing more environmentally friendly land uses and can contribute to the sustainability of ecosystems in the watershed.

## 2. Methodes

Land cover has an important role in preserving the quality of the natural environment. Changes in land cover have caused various problems related to microclimate, runoff, erosion [12] water availability, and disasters. For this reason, an effort is needed to ensure that land cover changes do not put significant pressure on the natural physical environment. Naturally, the ideal land cover is a land cover composition that is able to keep the air temperature from increasing significantly, while at the same time ensuring the availability of water all the time.

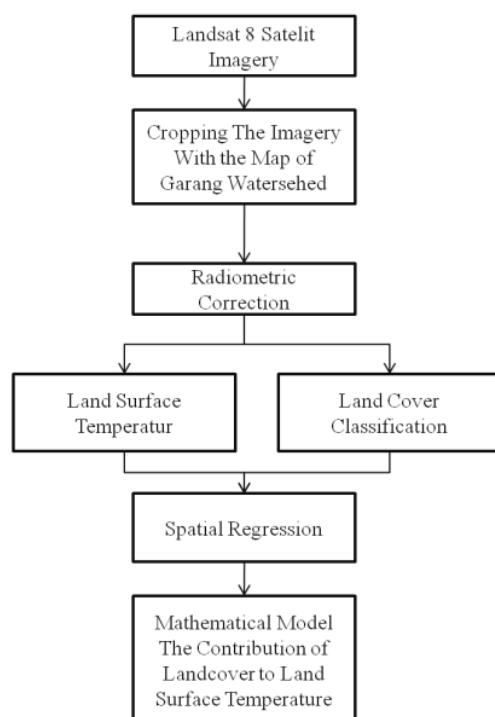
To answer the problem of ideal land cover composition, modeling can be a means to provide a simpler picture of the complexity of the influence of land cover on environmental conditions. This study uses a spatial regression model. The spatial regression model can describe the effect of land cover changes on each spatial unit in the Garang watershed and provide important information as a basis for consideration of land use planning.

Spatial regression can be applied to explore the relationship and the influence of land cover and environmental conditions. This relationship is indicated by the spatial correlation between land cover and environmental conditions. The use of spatial regression will provide a complete picture of the effect of land cover on environmental quality in the Garang watershed. Spatial regression in principle explores the contribution of each data unit in space to a particular problem [13], in this case, the effect of land cover on environmental conditions. Land cover as a variable that will affect the environmental conditions of the watershed is represented by the area of each land cover. Environmental conditions are represented by land surface temperature. Mathematically the influence of land cover on environmental conditions can be denoted as follows:

$$Y = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5 + C$$

Where Y is Environmental Condition (Land Surface Temperature)  $a_n$  is regression coefficient that shows the elasticity of the influence of each land cover on environmental conditions,  $x_n$  is Land cover type, C is Constants. The parameter of land cover in this research is the housing area (X1), the industrial area (X2), the vegetated area (X3), and the water bodies area (X4).

The data processing process in spatial regression analysis will use GIS to create land cover maps, land surface temperature maps, and make spatial regressions. Land cover data and land surface temperature were obtained using Landsat 8 satellite imagery. Schematically, the data processing and analysis process can be seen in Figure 1.



**Figure 1.** Data and Analysis Process of Modelling The Sustainable Land Use.

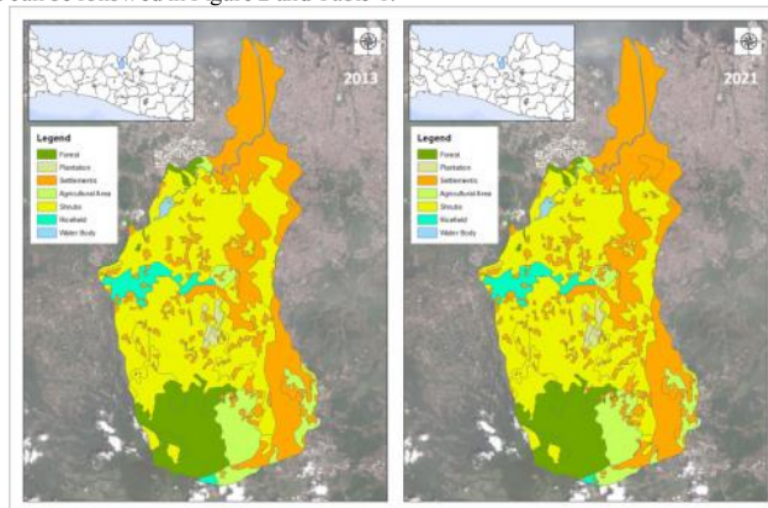
### 3. Results

The Garang River Basin is located in the central part of Central Java Province, which includes three autonomous regions, namely part of Semarang City, part of Semarang Regency, and part of Kendal Regency, which is the upstream part of the Garang River Basin. The Garang River Basin has an area of approximately 212.8 km<sup>2</sup> (see Figure 2). The Garang River Basin is one of the watersheds that have a strategic role in supporting regional development nationally. The existence of the Garang watershed provides important support for the function of the national urban area, namely the City of Semarang. The Garang River Basin provides support in providing raw water for the City of Semarang, on the one hand, the Garang River Basin also has a high potential for damage in the form of flash floods that will threaten the Semarang City area which is a downstream area of the Garang River Basin. There is an important infrastructure in order to ensure the availability of water, and reduce the threat of flooding for the city of Semarang, namely the Jatibarang Reservoir.



**Figure 2.** The Boundary of Garang Watershed.  
Source: Sentinel-2 Imagery, USGS, 2021.

The built-up areas in the Garang Watershed have increased significantly in the last ten years. The increasing number of the built-up area not only in the downstream area but also in the upstream area, especially in the West Ungaran and East Ungaran sub-districts. And it's growth tends to spread in the upstream part of the Garang River Basin. A brief description of the land cover growth in the Garang watershed can be followed in Figure 2 and Table 1.



**Figure 3.** Land Cover Changes of Garang Watershed Between 2013 and 2021.

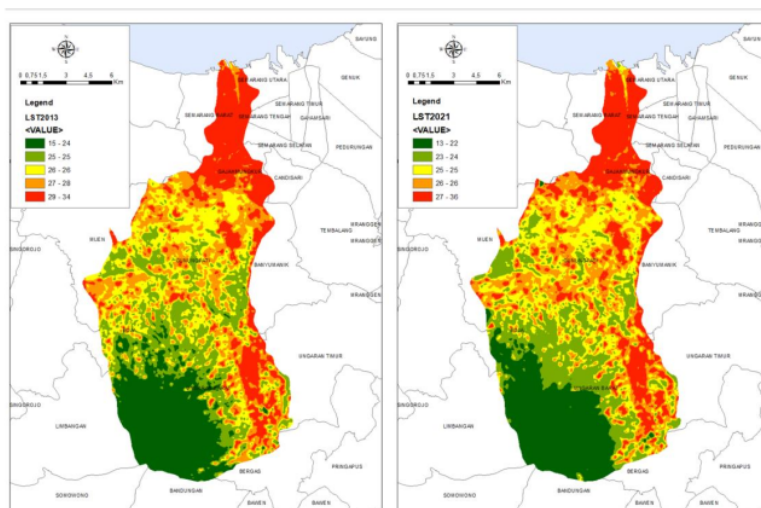


**Table 1.** Land Cover Change in Garang Watershed.

No	Land Cover	Area (Ha)		Total Change
		2013	2021	
1	Housing	6780,64	7257,83	+477,19
2	Industrial	65,72	121,56	+55,84
3	Vegetated Land	14.371,73	13.752,53	-619,2
4	Water Body	58,94	145,11	+86,17
	Total	21277,03	21277,03	

Changes in land cover in the river watershed are also followed by changes in land surface temperature. Based on the results of processing infrared thermal band satellite image data in 2013 and 2021, it is found that there is a significant difference in the value of the land surface temperature. In 2013 the average temperature of the earth's surface in the Garang river basin was 25.70C. Meanwhile, in 2021 the average air temperature in the Garang river basin is 26.60C, or an increase of 0.90C. This increase is inseparable from the development of built-up land, especially in the central area of the Garang river basin. A clearer picture of the temperature in the Garang river basin can be followed in Figure 4.

The consequences of land cover changes that occur will certainly have an impact on environmental sustainability in the Garang Watershed. The increase in the land surface temperature will continue along with the increase in built-up land. Without any regulatory effort, of course, this condition will clearly have an even worse impact in the future. The increase in the average temperature of the earth's surface in the Garang Watershed is 0.90C, especially in the downstream area which is the center of Semarang City, and the middle area in the Garang watershed shows clear evidence of the need for regulation of land use in the Garang watershed.

**Figure 4.** Spatial Pattern of Land Surface Temperature in the Garang Watershed.

The results of the spatial regression indicate that residential land and industrial land have an effect on increasing land surface temperature in the Garang Watershed, on the contrary, the presence of vegetated land and bodies of water play a significant role in reducing the increase of land surface temperature. The elasticity of the residential land aspect to the increase in land surface temperature is equal to. A brief description of the results of the spatial regression of the influence of land cover on the earth's surface temperature in the Garang river basin can be followed in Table 2.

**Table 2.** Output of Spatial Regression using Ordinary Least Square Methods.

Variable	Coefficient [a]	StdError	t-Statistic	Probability [b]	Robust_Pr [b]
Intercept	23,200721	0,010782	2151,709804	0,000000*	0,000000*
AREA_H (X1)	0,000579	0,000034	17,12363	0,000000*	0,000000*
AREA_VEG (X2)	-0,000589	0,000038	-15,675295	0,000000*	0,000000*
AREA_WAT (X3)	-0,002707	0,002882	-0,939297	0,347566	0,093725
AREA_IND (X4)	0,062205	0,020075	3,09866	0,001959*	0,000308*

Notes:

\* An asterisk next to a number indicates a statistically significant p-value ( $p < 0,01$ )

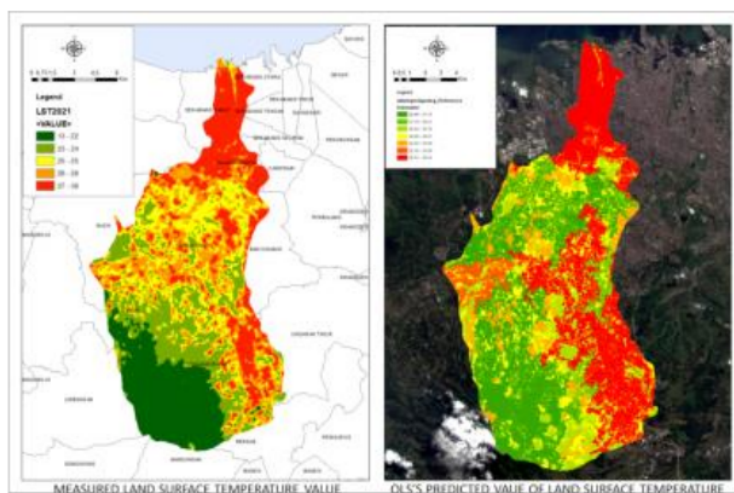
Based on the output of the spatial regression, the effect of land use on land surface temperature in Garang Watershed can be formulated mathematically as follows.  $LST = 23,2 + 0,000579X1 - 0,000589X2 - 0,002707X3 + 0,062205X4$  (2) It means that the change in the housing area and the industrial area will trigger the increase of land surface temperature in the Garang Watershed. If the industrial area is increased by 1 unit, and the area of other land cover does not change, then the air temperature has the potential to increase by 0.060C. Conversely, if the vegetated area is increased, it will have the potential to reduce air temperature by 0.00060C. The mathematical model generated from this research will be able to become an instrument that measures the maximum allowable limit so that the air temperature does not experience a significant increase in the future and has an impact on the potential effects of greenhouse gases that trigger climate change [14].

#### 4. Discussion

The effect of increasing the area of built-up land in the Garang Watershed indicates that the composition of land cover and the type of use will greatly affect environmental sustainability, in this case, indicated by a significant increase in land surface temperature in the Garang Watershed. The results of the research on the Garang Watershed provide empirical evidence from various previous studies conducted in various urban areas in the world which show a significant relationship and influence between land cover on environmental sustainability and triggers climate change [15,16]. The area dominated by vegetation has a significant role in controlling the increasing value of land surface temperature due to the capability of vegetation to produce oxygen and water vapor during the metabolism process. The presence of vegetation can reduce the heat emitted by activities on built-up land. The ability to reduce heat radiation is due to the ability of plants to produce oxygen during the metabolic process and produce water vapor during the evaporation process. The presence of oxygen and water vapor is an important element in reducing heat and on a large scale will be able to play a role in controlling the microclimate in the Garang Watershed [17].

The results of modeling the influence of land cover on the value of the land surface temperature in the Garang watershed indicate a tendency for an increase in surface temperature in the middle and upstream areas of the watershed. Changes in land cover and land use for residential and industrial activities are the main factors for the increase in land surface temperature. A clearer picture of air temperature forecasts in the Garang Watershed can be seen in Figure 5.





**Figure 5.** Comparison of Soil Surface Temperature Measurement Using TIRS and Prediction Results of Soil Surface Temperature Values In Garang Watershed.

## 5. Conclusion

Based on the analysis, it can be concluded that environmental sustainability will be significantly influenced by the land cover and land use composition. The higher built-up area especially industrial activities and housing, they will make decreasing the environmental sustainability due to the increasing value of air temperature in the Garang Watershed.

The growth of settlements and industry is a normal mechanism in line with economic growth in the city of Semarang, Kendal and Semarang Regency, and it has consequences for environmental sustainability. If the growth of built-up land is not controlled properly in terms of area and distribution of space, then the increase in the earth's surface temperature in the Garang river basin is unavoidable. So to reduce the impact of increased land surface temperature, which has the potential hazard that threatens environmental sustainability, controlling the development of built-up land towards the middle and downstream of the Garang Watershed must be controlled and limited. Control of the area of built-up land for residential areas can be done by encouraging vertical development efforts and limiting the horizontal development of settlements. This effort is important because the amount of land is fixed and the high demand for settlements will trigger land conversion. Lands that have vegetation as a means to reduce the increase in the earth's surface temperature will certainly decrease and have an impact on decreasing the quality of the living environment. The decline in environmental quality will affect human life in the future, and the sustainability of the environment will be threatened.

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