Analysis of Changes in Agricultural Land Use to non-Agricultural Around The Semarang - Solo Toll Point, Boyolali District

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Abstract: The construction of a toll gate in Kragilan Village, Mojosongo District, Boyolali Regency is expected to spur regional development because of its strategic location between Yogyakarta and Solo. This research aims to analyze the impact of toll road construction on changes in agricultural land use around the toll gate with two main focuses: changes in land use and the spatial pattern of these changes. The main data was taken from Sentinel imagery and analyzed to identify land changes between 2019 and 2023. The research results show that the largest land conversion is from fields to settlements, with a linear pattern of change following the highway route. The classification accuracy test shows high accuracy. Suggestions for future research include extending the analysis period and adding socio-economic impact studies.

<u>Keywords</u>: land use; land use change; Boyolali Regency.

1. Introduction

The government continues to develop infrastructure, including toll roads, to meet public needs and support national objectives as outlined in the 1945 Constitution. Toll roads, regulated under Law No. 38/2004, are part of the road network that requires toll payment. The purpose of building toll roads is to ensure equitable regional growth, enhance community mobility, and accelerate the distribution of goods and services, thereby reducing congestion and increasing efficiency.

Toll road infrastructure not only improves mobility and interregional connectivity but also has significant economic, social, and environmental impacts, such as creating job opportunities and encouraging investment in surrounding areas. Besides boosting economic growth in the regions it traverses, toll roads also lead to changes in land use, such as the conversion of agricultural land to non-agricultural uses. This study focuses on the Boyolali toll gate in Kragilan Village, Mojosongo Subdistrict, Boyolali Regency, part of the Semarang-Solo toll road section, which has been under construction since 2009 and opened in 2021, facilitating access to Boyolali city.

Boyolali, located in Central Java Province, Indonesia, occupies a strategic position approximately 30 kilometers east of Semarang and lies between Solo and Semarang. Its location along the main route of Central Java provides excellent connectivity, facilitating the mobility of residents and goods. Boyolali is also characterized by diverse natural features, including mountains to the south and several rivers, such as the Bengawan Solo River, along with abundant natural resources.

Boyolali's geography supports the agricultural sector with fertile soil suitable for rice, sugarcane, and horticulture, as well as a tropical climate that allows year-round production. Local rivers also provide water for irrigation. The inauguration of the Boyolali toll exit has created new job opportunities in the construction and operation of toll roads. Regional development around the toll road is expected to improve access to local trade and industry, leading to shifts in land use from agriculture to residential and other commercial activities.

Good urban planning is essential to direct regional development positively and minimize negative impacts. Observing and analyzing land use changes, such as the transition from vegetation to non-vegetation caused by toll road construction in Boyolali, can be conducted using remote sensing.

Remote sensing is an art and science field that focuses on collecting data and information about objects on the Earth's surface using tools that do not directly interact with the studied objects (Lillesand and Kiefer, 1979). This method uses specialized sensors and instruments mounted on aircraft, satellites, or drones to collect data from a distance. Remote sensing has a wide range of applications, from environmental monitoring and geological mapping to weather forecasting and natural resource management. The visual representation of data obtained from these sensors and instruments is commonly referred to as imagery.

Imagery is information presented visually, derived from the capture of light energy reflected by objects, known as images or pictures (Kiefer et al., 1993). Remote sensing imagery represents visual data collected by satellites, aircraft, or drones of the Earth's surface. These images depict the Earth's surface and can be used for various purposes, from geographic mapping to environmental monitoring and understanding climate change. Satellite imagery is typically produced from measurements of different electromagnetic spectrum ranges, including visible and infrared light, which are translated into various colors and brightness levels in the images. With global coverage and the ability to capture images from high altitudes, satellite imagery is invaluable for helping scientists, stakeholders, and researchers understand and manage our planet and make data-driven decisions across various fields.

This study uses Sentinel imagery from a satellite developed by the European Space Agency (ESA), which provides high-resolution data for detailed environmental monitoring. These images are valuable for monitoring climate, forest fires, floods, and agriculture and are well-suited for analyzing changes in small areas like Kragilan Village, Boyolali.

This research aims to provide information to the government for regional planning and to the community regarding developments around the Boyolali toll gate. The study also seeks to identify the impact of toll road construction on changes in agricultural land use in Kragilan Village, Mojosongo, Boyolali.

2. Methodology

This study utilizes Sentinel Remote Sensing Imagery as the primary data source. On-screen digitization of Sentinel imagery is performed, followed by visual interpretation to obtain information on land use in Kragilan Village, Mojosongo Subdistrict, Boyolali Regency. A subsequent analysis is conducted to gather information about the spatial patterns of agricultural land-use changes in the study area, which will then be presented descriptively. The selection of the study location is based on the research focus, which is the land-use changes occurring in the area surrounding the Boyolali toll gate. Therefore, Kragilan Village, located in the toll gate area, is chosen as the study site.

3. Results and Discussion

The land use classification process in Kragilan Village is carried out by visual interpretation of sentinel 2A imagery with a distance of 10 meters. This process is carried out by considering the interpretation aspects, namely Hue, Texture, Size, Shape, Height, Pattern, Shadow, Site, and Association.

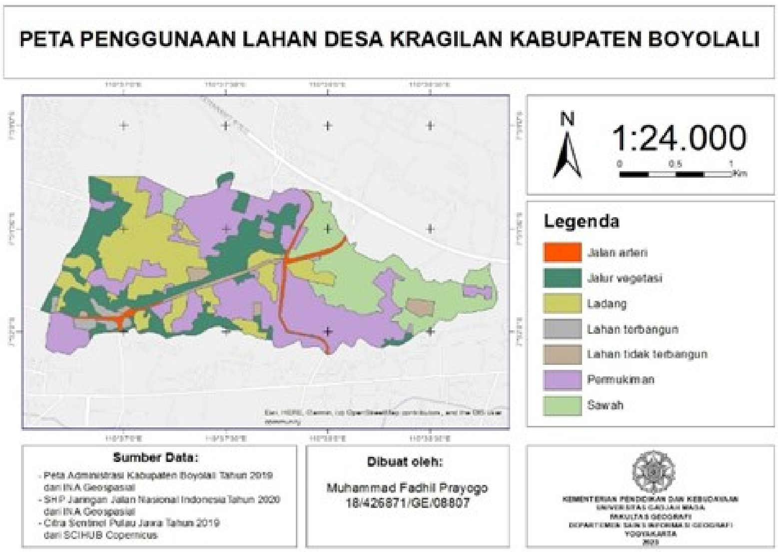

Figure 1: Land Use Map of Kragilan Village in 2019

Table 1: Area of Land Use of Kragilan Village in 2019

Class	Area		%
	Meter2	Ha	
Rice Fields	785094	78,5094	19%
Fields	849559	84,9559	21%
Settlements	1438639	143,8639	35%
Vegetation Strips	772288	77,228778	19%
Built-up Land	67859	6,78592	2%
Unbuilt Land	113651	11,365142	3%
Highways	81060	8,106032	2%

Source: Research Data Processing 2019.

The results of the 2019 Sentinel image classification show that land use in Kragilan Village is divided into 7 main classes: settlements (35%), fields (21%), rice fields (19%), and vegetation paths (19%). Other classes include built-up land (2%), unbuilt land (3%), and highways (2%).

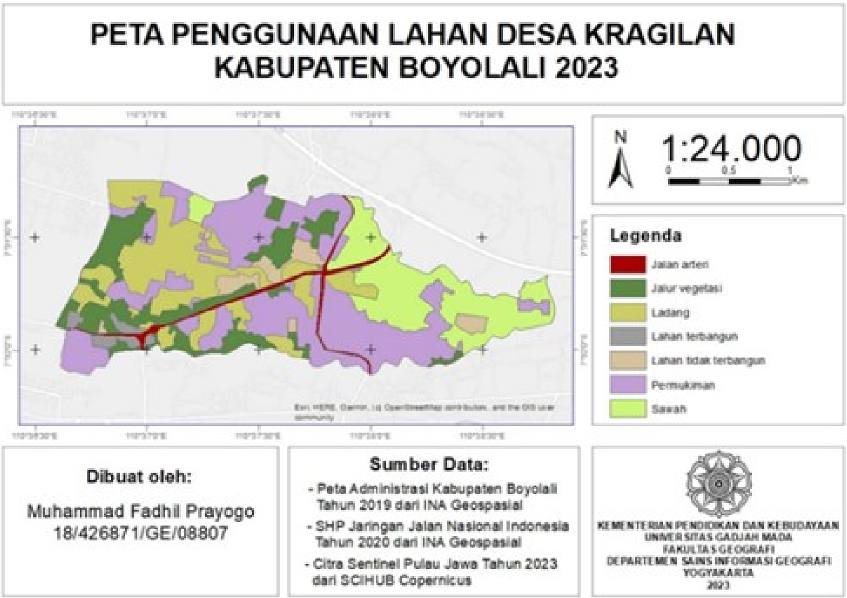

Figure 2: Land Use Map of Kragilan Village in 2023

Table 2: Area of Land Use of Kragilan Village in 2023

Class	Area		%
	Meter2	Ha	
Rice Fields	785094,4405	78,5094	19%
Fields	870479,45	87,0479	21%
Settlements	1470943,171	147,0943	36%
Vegetation Strips	631766,3516	63,1766	15%
Built-up Land	75119,96854	7,5119	2%
Unbuilt Land	161681,425	16,1681	4%
Highways	113165,9668	12,7566	3%

Source: Research Data Processing 2023.

The results of the 2023 Sentinel image classification show that land use in Kragilan Village remains divided into 7 main classes. Settlements dominate with an area increasing to 147.09 Ha (36%), followed by fields (87.04 Ha or 21%), rice fields (78.5 Ha or 19%), and vegetation paths decreasing to 15% (63.17 Ha). Other classes include built-up land (7.51 Ha or 2%), unbuilt land (16.16 Ha or 4%), and highways (12.75 Ha or 3%).

Field testing of land use classification results was carried out with the aim of obtaining information regarding the truth or accuracy of the classification results that had been carried out, and this study used the simple random sampling method. This method takes samples randomly and evenly throughout the Kragilan Village area without paying attention to certain strata or groups. The sample model form in this study is in the form of pixels of 15 x 15 meters and the area of the field being checked is 30 x 30 meters, the number of samples itself is determined by the Stephen Isaac and William B. Michael sampling method with a selected error tolerance of 5% so that 51 samples are obtained. The location of the sample points is the same in the 2019 and 2023 land use classifications so that differences in the field are visible, and for 2019 field checks were carried out with the help of high-resolution imagery, namely Google Earth Pro Historical Imagery. The results of this field check will then be entered into the confusion matrix table.

Figure 3: Field sample point of Kragilan Village
Source: Research Data Processing

The calculation of the accuracy value of the land use classification results is carried out using the confusion matrix method, this method is carried out by entering the data from the field test checklist into the confusion matrix table and then calculating the accuracy by seeing how much land use in the classification matches its appearance in the field.

Table 3: Confusion Matrix Calculation 2019

2019	lapangan							
	class	sawah	ladang	lahan tidak terbangun	lahan terbangun	permukiman	jalur vegetasi	JUMLAH
interpretasi	sawah	9	0	0	0	0	1	10
	ladang	0	10	1	0	0	0	11
	lahan tidak terbangun	0	0	2	0	0	0	2
	lahan terbangun	0	0	0	1	0	0	1
	permukiman	0	1	1	0	15	1	18
	jalur vegetasi	0	2	0	0	0	7	9
	TOTAL	9	13	4	1	15	9	51
	BENAR							44
	OVERALL ACC							86

Source: Research Data Processing

The 2019 classification results showed that out of 51 field test samples, 44 samples were classified correctly and 7 samples were incorrect. The correct classifications included rice fields (9 samples), fields (10 samples), undeveloped land (2 samples), developed land (1 sample), settlements (15 samples), and vegetation lines (7 samples). The overall accuracy of the 2019 classification was 86%, with an error of 14%.

Table 3: Confusion Matrix Calculation 2023.

2023	lapangan							
interpretasi	class	sawah	ladang	lahan tidak terbangun	lahan terbangun	permukiman	jalur vegetasi	JUMLAH
	sawah	9	0	0	0	1	0	10
	ladang	0	12	0	0	0	0	12
	lahan tidak terbangun	0	0	2	0	0	0	2
	lahan terbangun	0	0	0	1	0	0	1
	permukiman	0	2	1	0	18	0	21
	jalur vegetasi	0	1	1	0	0	3	5
	TOTAL	9	15	4	1	19	3	51
	BENAR							45
	OVERALL ACC							88

Source: Research Data Processing

In the 2023 classification results, out of 51 field test samples, 45 samples were classified correctly and 6 samples were incorrect. The correct classifications include rice fields (9 samples), fields (12 samples), unbuilt land (2 samples), built-up land (1 sample), settlements (18 samples), and vegetation paths (3 samples). The overall accuracy of the 2023 classification was 88%, with an error of 12%.

The accuracy test aims to determine the accuracy value when classifying land use. Image classification is considered correct if the result of the confusion matrix calculation is more than 80% (Short, 1982). Therefore, the total accuracy of the classification results (Total Accuracy) of 86% in 2019 and 88% in 2023 is considered correct.

After the accuracy test of the land use classification was carried out, an analysis of changes in land use that occurred in the period 2019-2023 was carried out. The method used in this process is to overlay the 2019 and 2023 land use maps, the results of the overlay are in the form of a land use change map for 2019-2023.

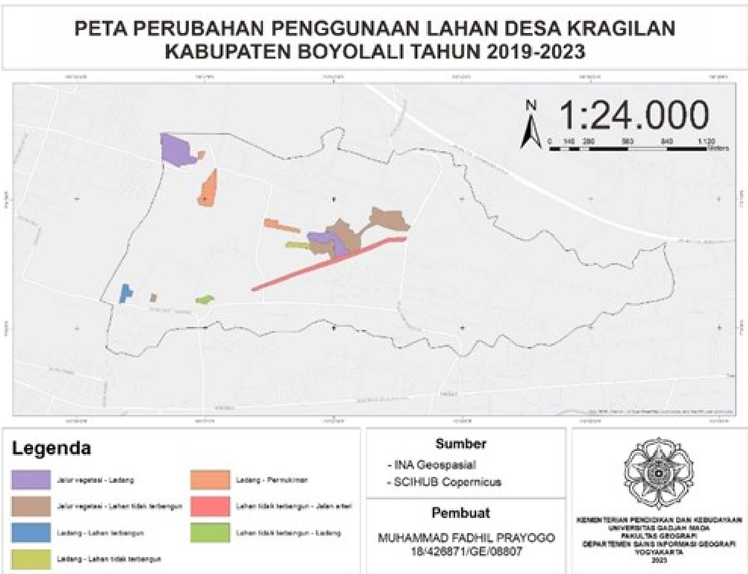

Figure 4: Land Use Change Map of Kragilan Village, Boyolali Regency 2019-2023
Source: Research Data Processing

In the period 2019-2023, there were 7 changes in land use, namely: vegetation paths to fields, vegetation paths to undeveloped land, fields to built-up land, fields to undeveloped land, fields to settlements, undeveloped land to highways, and undeveloped land to fields.

Analysis of spatial patterns of land use changes was carried out by identifying and examining geographic trends related to these changes in Kragilan Village between 2019-2023. The results of the analysis show that the detected spatial pattern is a linear pattern, where land changes, especially from agriculture to non-agriculture, occur along corridors such as highways, railroads, or rivers. All of these land changes are located near highways.

4. Conclusions

In the period 2019–2023, there were 5 locations of changes from agricultural to non-agricultural land in Kragilan Village, Boyolali Regency. These changes include: fields to built-up land, fields to unbuilt land, and fields to settlements. The largest change was fields to settlements, with a total area of 3.23 Ha in 3 locations, all of which are in the highlands. The results of the analysis of the land use change map of Kragilan Village 2019–2023 show a linear spatial pattern, where changes from agricultural to non-agricultural land occur along the highway.

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