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Utilization of Current Data for the Geospatial Analysis on the Suitability of Apple Plantation Land Based on Fuzzy Inference Systems

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Abstract. Apples are one of the high-value imported commodities for Indonesia. One of the apple production centers in the country is Batu City; however, its production capacity tends to be declining year by year. To fulfill the demand of the domestic apple industry, opening new plantations seem to be promising, yet it requires comprehensive observations related to the spatial factors. Experts and direct field reviews are needed to perform the land suitability analysis and this will take much time and effort. Therefore, a smart system that can conduct the geospatial analysis independently by using a fuzzy inference system is developed. The data was obtained by using satellite imagery and data interpolation, and the data was then digitized and analyzed to provide the information needed. The analysis was performed on each pixel with six variable inputs including altitude, rainfall, humidity, air temperature, soil type, and sunshine intensity. In addition, the use of the five-clustering output makes the results more accurate. The tests show 92.86% accuracy proven through comparison of the results of the spatial analysis using the fuzzy inference system with direct reviews on the field.
Keywords: apple plantation, geospatial analysis, fuzzy inference systems

1 Introduction

The extraordinary growth of international markets over the past few decades has been the primary cause of globalization [1]. According to [2], empirically, there has been no consensus about the definition of globalization. However, it seems clear that globalization is taking place in all areas, including agriculture and horticulture. The world has been globalizing the market of fresh fruits and vegetables in line with the high demand from developing countries as to meet the needs of fresh fruits and vegetables that can be complied by domestic production [3]. From the report [3], Indonesia is facing a challenge in providing fresh fruits, especially the domestic ones, for its population to prevent the high value of imported fruits.

The challenge for the provision of fresh fruits in Indonesia in recent years has been anticipated by [4], by launching new production centers as to encourage an increase in the output and quality of the domestic fruits. This program is expected to help to expand plantation areas that the production capacity and quality of the domestic fresh fruits increase as well.

According to the data [5], apples represent one kind of fruits of high dependence on the import industry. The population seems to like to consume apples much seen from the number of imported apples compared to other imported fruits like mandarin orange, pear, grape, orange, durian, and others [5]. In line with the program and demand of the population [4], it is necessary to open up new apple production centers.

From the data [6], the main apple production center in Indonesia is Malang (Poncokusumo), Batu City, and Pasuruan (Nongkojajar); all are located in East Java. The selection of the centers is by emphasizing the apple growing factors [6]. Based on the data [7], the apple production in Batu City is the largest in East Java that the fruit has long become the icon of the city. There have been approximately 2.1 million apple trees in Batu City producing 708.43 tons of apples in 2014. However, apple production has dropped by 15% compared to 2013. If no efforts are taken, Batu City will lose its title as the largest apple producer in Indonesia.

Many studies have been conducted to examine the decline of apple production; one of the factors affecting the decline is climate change [8]. In addition to climate change, the growing media and geographic factors also play a significant role in the decline. Therefore, a feasibility study needs to be performed on the apple plantation [9]. One of the studies [9] has an analysis of climate. Another study [10] has its focus on the spatial factor for the suitability of apple plantation in Batu City, but the result has not been satisfying as it is only a map showing level changes between the striking points and no algorithms are used. The research [11] on the use of AHP for the land suitability analysis provides no spatial analysis. Furthermore, other studies by [10] and [11] show that a synergistic is needed for the analysis of apple plantation suitability by using a decision support system.

In this present study, the decision support system used is the fuzzy logic system. There are six variable inputs including altitude, average annual rainfall, humidity, average temperatures, sunshine, and soil type. Based on the statement [12], there are five classes of land suitability, i.e. S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable), N1 (currently not suitable), and N2 (permanently not suitable).

In comparison with other logic systems, the fuzzy logic system can make more equitable and humane decisions. [13] and [14] have been doing some research on the prediction of rainfall from climate data and they performed the prediction by using the fuzzy inference system with an accuracy of more than 90%. Based on the analysis of [15], the fuzzy logic system describes the feelings or intuitions by changing the crisp value into the linguistic value through fuzzification and classifies it in a rule based on knowledge. The input for the spatial analysis consists of six variables and the results will be collected using algorithms that comply with the judgment of the experts. The selection of the inference system must be appropriate to each case, e.g. Mamdani is usually suitable for intuitive problems while Sugeno is usually suitable for control issues [15].

The fuzzy logic system used in this study is the inference system of Tsukamoto because it uses the land suitability that tends to be predictive and clustering. The purpose of this study is to determine the relevance of apple plantation by utilizing the Fuzzy Inference System and expert assessment with a geospatial approach. The incorporation of geospatial and fuzzy interference system for a decision support system will help to produce more accurate and compatible results, just like the ones in the actual field. Therefore, by having this framework, the land suitability analysis can be done faster as well as more effective and efficient, and the results will be in line with the assessment of experts.

2 Previous Studies

There have been some studies related to the topic done in the last few years, and these studies become references for the present study. The study by Aditiyas *et al*. [10] focuses on the spatial analysis for the suitability of apple plantations in Batu City, but the result is only a map showing level changes between the striking points and no algorithms are used.

In contrast, Reshmidevi *et al.* [16] have found a combined Geographic Information System with the Fuzzy Inference System for evaluation of agricultural land suitability in a watershed with old data as its reference; in other words, the data used is not an up to date. The use of agricultural land is continuous that the use of current data is very influential towards the results of the analysis.

Meanwhile, Sun *et al.* [17] have performed mapping and evaluation for settlement by using AHP Algorithm, but the weighting and indexing are determined by using the assumptions of authors—this is somewhat bias as weighting and indexing should be done by experts.

Recent studies by Zhang *et al.* [18] have implemented a conformity assessment of tobacco land by using AHP and Fuzzy Systems; the combination has made the analysis more effective and efficient. The assessment turned out to be good and significant by using the combined algorithm in Shandong Province of China whose topography tends to be flat.

Research from Sri Hartati and Imam S. Sitanggang [23], is a similar study which is a decision support system based on the fuzzy logic. But in research [23] focuses on building applications to determine the suitability of the land to be planted by certain plants. While in this research focuses on spatial analysis so that the results form a map of land suitability on apple plants. In addition to the study [23] determine the plant according to the analysis of land conformity.

3 Study Area and Material

The study took place in Batu City, East Java, Indonesia (Fig. 1) because Batu is the largest apple producer in the country. Batu City is very much suitability for apples, but a feasibility study is needed for apple plantations.

The material used was physical data and remote sensing satellite imagery. The satellite imagery used was the ASTER Global Digital Elevation Model (GDEM). In addition, climate data were obtained from BMKG with six stations in East Java. The soil type data referred to the data from the Department of Agriculture of the East Java Province.

Apples have different characteristics with other horticulture crops. They are suitable to be grown in a subtropical climate. There are some important requirements to cultivate apples as shown in Table 1.

Table 1. Crop Requirement of Apple Plantations

No.	Variable	Apple Crop Needs
1	Elevation/Altitude	800 – 1200 metres
2.	Annual Rainfall	1000 – 2600 mm^3
3.	Humidity	50 – 85
4.	Temperature	16 - 22 ^{o} C
5.	Sunshine Intensity	40 – 70%
6.	Soil Type	Latosol, Andosol, Litosol

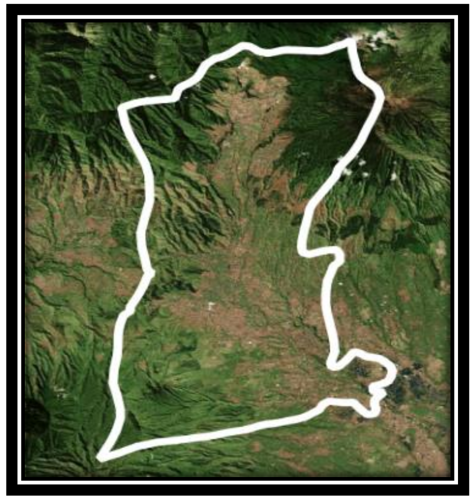


Figure.1 Study Area

4 Methodology and Proposed Method

The research methodology is described in Fig. 2:

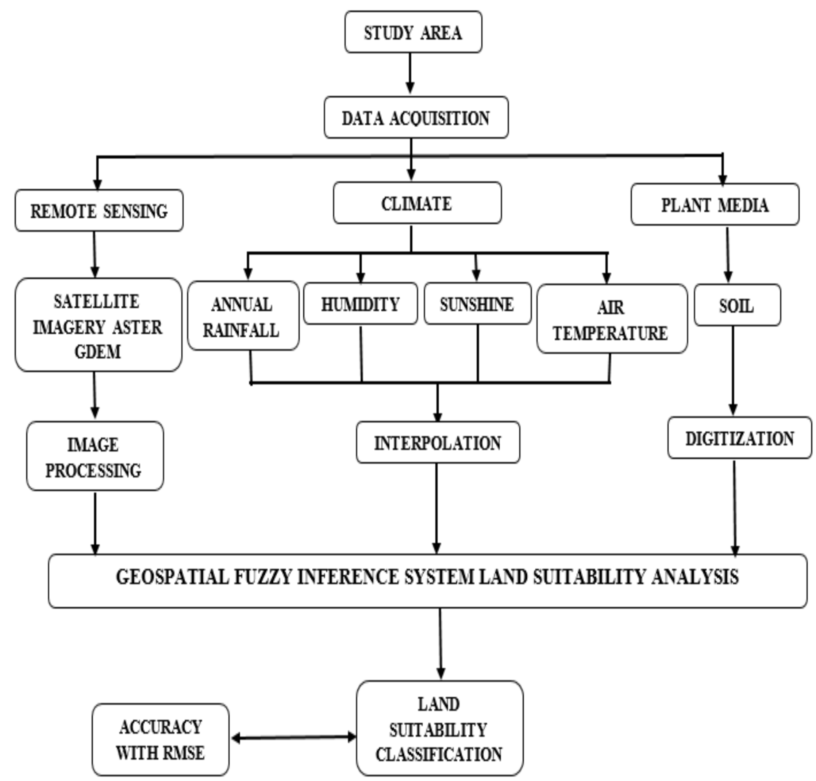


Figure.2 Research Methodology

The data acquisition used three parameters. The first parameter was the remote sensing by using Aster GDEM acquired on November 25, 2015, from www.earthexplorer.usgs.gov [19]. The satellite data provided information about altitude. The pixel resolution of this satellite image was 30 meters.

The second parameter was the climate data from BMKG with six stations in East Java. The weather data was acquired from 1 January 1990 to 31 December 2015, as shown in Table 2.

Table 2. Climate Data from the Six Stations

Station No.	**Station Name**	**Location**
96935	Juanda Meteorology Station	Sidoarjo Regency
96943	Karang Ploso Climatology Station	Malang Regency
96945	Tretes Geophysics Station	Pasuruan City
96949	Karang Kates Geophysics Station	Malang Regency
96975	Sawahan Geophysics Station	Nganjuk Regency
96987	Banyuwangi Meteorology Station	Banyuwangi Regency

The research [20] performs a spatial interpolation with the emphasis on Data Elevation Models (DEM). This study used spatial interpolation of the Inverse Distance Weight (IDW). The method of Inverse Distance Weight (IDW) assumes that each input point of influence is local and decreases towards distances. IDW interpolation methods are affected by the inverse of the distance obtained from the mathematical equation. The general IDW formula is as follows:

$$z_0 = \frac{\sum_{i=1}^{n} w_i z_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

where z_0 is the value of the suspected group and z_i is the value of the estimation. The weighted value in the IDW technique is calculated using the following formula:

$$w_i = \frac{1}{d_{i0}^2} \quad (2)$$

where d^2_{i0} is the distance between the observation $\underline{i}$ with the suspected point. Weighting the values by involving the square of the distance is not an absolute statute.

The third parameter was the plantation media using the data of the Agriculture Department of East Java Province. The data was presented in the form of a picture that needed data digitization to be processed. Digitization was done to make the image data processed spatially and naturally for the analysis. Researchers [22] have already introduced digitization with the use of open source software or Quantum GIS software (freeware).

The Geospatial Fuzzy Inference System proceeds through several stages. The input variable identification is required to know the influential inputs on later regimes. For the variable of altitude, rainfall, humidity, temperature, and sunshine, the identification was done by employing the following fuzzy equation:

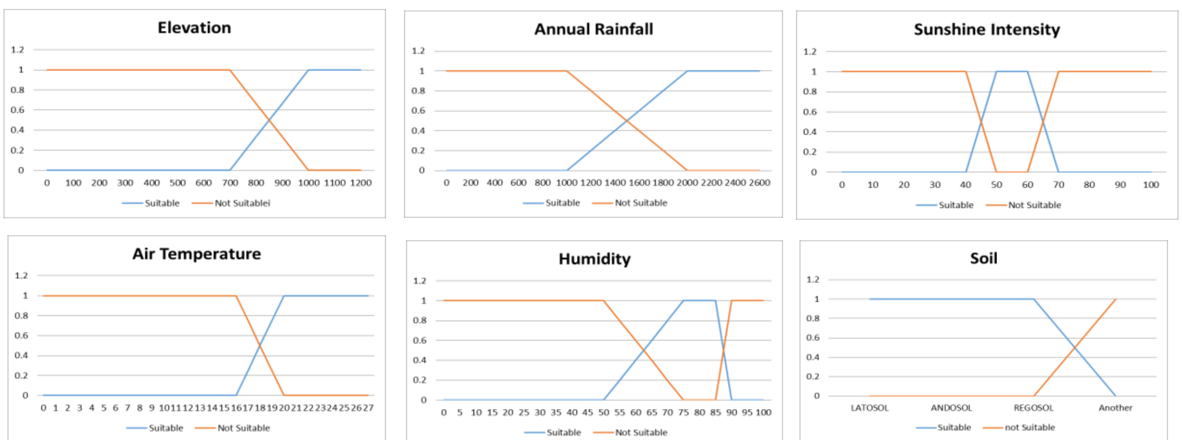
$$\mu[x,a,b,c,d]\begin{cases} 0: & x \le a \\ \frac{x-a}{b-a}; & a \le x \le b \\ 1; & b \le x \le c \\ \frac{d-x}{d-c}; & c \le x \le d \\ 0; & x \ge d \end{cases} \quad (3)$$

As for the soil type, the equation looks like the following:

$$\mu[x,a,b]\begin{cases} 0; & x \le a \\ \frac{x-a}{b-a} & a \le x \le b \\ 1; & x \ge b \end{cases} \quad (4)$$

where $\mu[x,a,b,c,d]$ in the Eq. (3) represent three numbers of a low, medium, and high fuzzy value. In the Eq. (4), $\mu[x,a,b]$ is a reference with low and high value.

After the fuzzy equation is made, the next step is the creation of a membership function of each input variable. This paper uses six variables input for the suitability analysis of apple plantation as shown in Fig. 3 and the output membership function of the existing five variables are presented in Fig. 4.



(e)

Figure.3 Input Variable Membership Function: (a) Elevation (b) Annual Rainfall (c) Sunshine Intensity, (d) Air Temperature (e) Humidity and (f) Soil Type

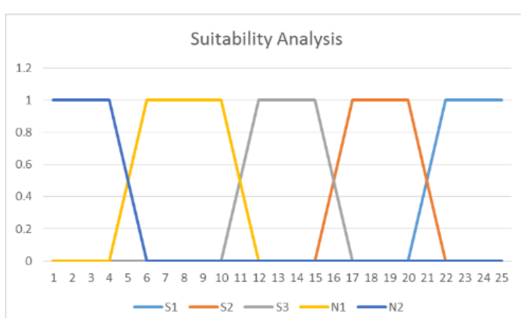


Figure 4. Output Variable Membership Function

After performing the membership functions, the next step was the creation of rules. The decision had to be stated from the variable entry and exit, and it was 2.178, meaning that the selected state was ten extremes rule. The selection was done using the AND rules and THEN rules. Experts held the establishment of the rules by weighting each criterion.

The next stage is defuzzification employing the Tsukamoto method, known as the average centered (Center Average Defuzzier) as shown in the following equation:

$$Z = \sum_{i=1}^{n} \propto izi \quad \frac{\sum_{i=1}^{n} \propto izi}{\sum_{i=1}^{n} \propto i} \quad \ldots\ldots\ldots\ldots(5)$$

In the Eq. (5), Z is the result of defuzzification, whereas the $\propto i$ is the value of the membership antecedent, and zi is the product of each of the inference rules.

Accuracy of the analysis results must be ensured to enhance public confidence. One method of evaluation is RMSE (Root Means Square Error). RMSE was done by comparing the analysis in the field directly. The RMSE equation is as follows:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (X_{obs,i} - X_{model,i})^2}{n}} \quad (6)$$

where X_{obs} is observed values, and X_{model} is modeled values at time/place i.

5 Preliminary Result and Spatial Analysis

Data acquisition was organized by using satellite imagery. The following results were obtained:

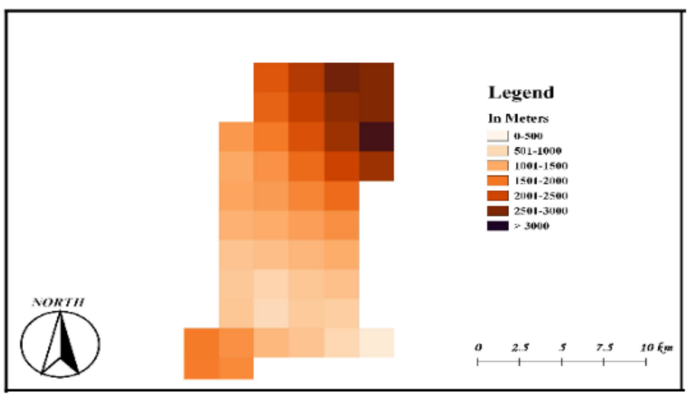


Figure 5. Elevation from Satellite Imagery

From the spatial data, most areas of Batu City are 600 meters above the sea level (Fig. 5) or have an altitude of 800-1200 meters above the sea level, which is an important requirement for apple plantations.

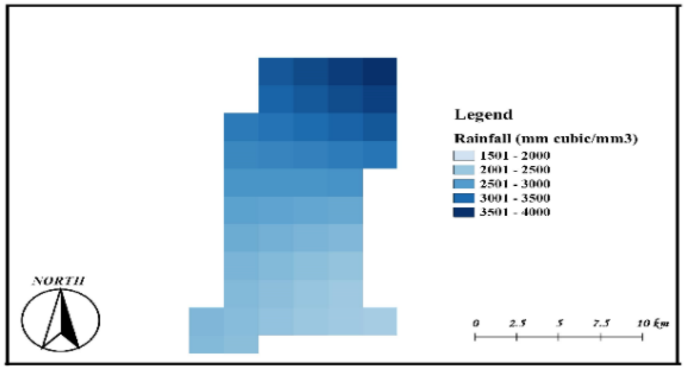


Figure 6. Annual Rainfall Interpolation from BMKG

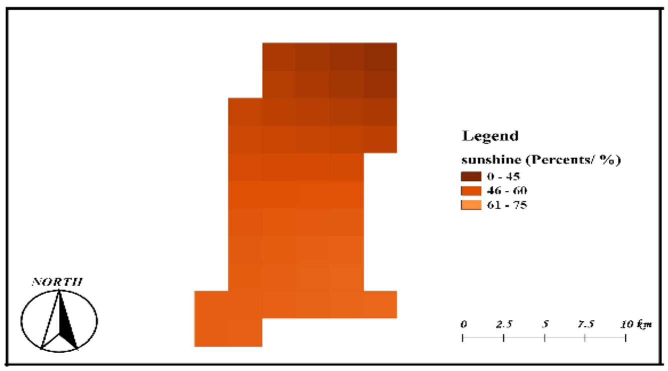


Figure 7. Sunshine Intensity Interpolation from BMKG

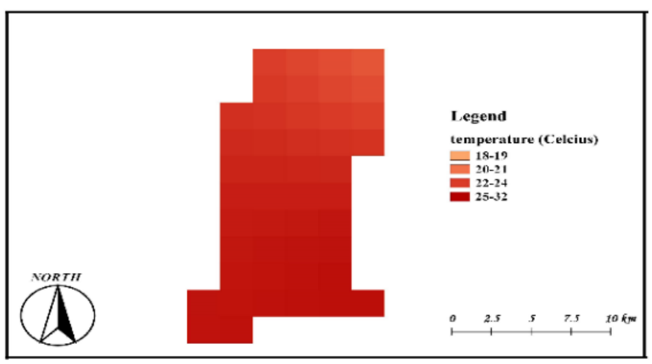


Figure 8. Air Temperature Interpolation from BMKG

Figure 9. Annual Humidity Interpolation from BMKG

Because Batu City is located in the plateau area, it has a very cool climate. Fig. 6 describes that the annual precipitation in the north area is higher than in the south area. The temperature in Fig. 8, humidity in Fig. 9, and sunshine intensity in Fig. 7 seems very balanced and almost the same. Fig. 10 describes the results of map digitization on soil types for suitability of apple plantations.

From the results of the acquisition, the data were modeled in the form of an image map with the techniques of remote sensing, interpolation, and digitization. Then it was analyzed spatially by using a fuzzy inference system by experts.

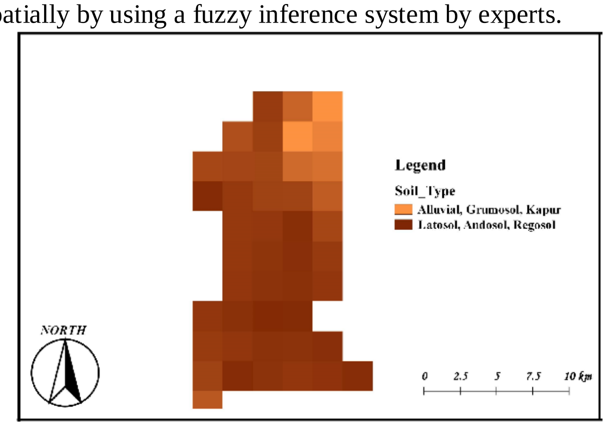


Figure 10. Soil Type with Digitization from Related Department

The spatial analysis needed many supporting data and fuzzy rules so it required smart computing utilization. The analysis on the suitability of the apple plantation area can be simulated with the fuzzy inference system. The system accelerates the process and provides a similar result.

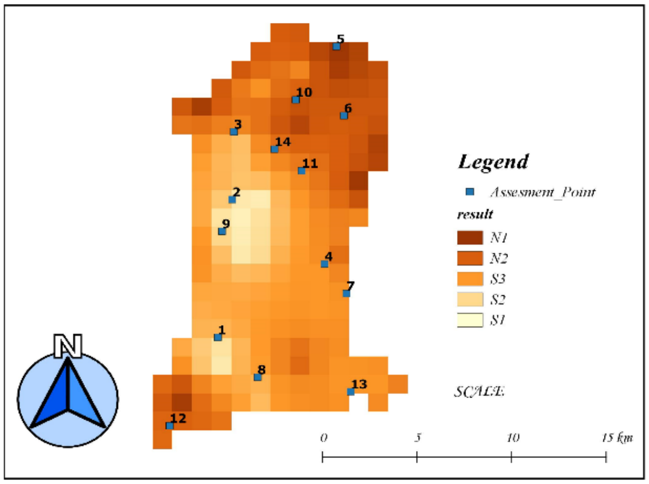


Figure 11. Final Suitability Maps with the Fuzzy Inference System from the Expert

6 Testing and Accuracy

After the spatial analysis using the fuzzy inference system was completed, the next stage was to conduct a test and assess the accuracy of the analysis. The test was carried out by using fieldwork to a certain area. Results were compared with the results of the previous spatial analysis.

The level of accuracy was determined by comparing the spatial analysis results with the fuzzy inference system and the fieldwork analysis to assess the suitability of apple plantations. The comparison was organized by using the equation of Root Means Square Error (RMSE).

Samples for RMSE were taken randomly and 14 random points were chosen. The expert analysis was also considered to determine the suitability of apple plantation. For coordinate recording, handheld GPS with high resolution was used (Fig. 11).

After the results of the 14 points came out, comparison, as shown in Table 4, was performed. Data of Table 4 helped to perform the accuracy calculation of the spatial analysis by using the fuzzy inference system. The accuracy analysis produced a figure of 92.85%.

Table 4. Data Comparison for Accuracy

No	Location		Data		Accuracy
	Longitude	Latitude	Spatial Analysis	Field Work	
1	112.5165	-7.8816	S1	S1	1
2	112.5233	-7.8121	S1	S1	1
3	112.5241	-7.7779	S1	S1	1
4	112.5672	-7.8446	S3	S3	0
5	112.5728	-77.7349	N2	N2	1
6	112.5764	-7.7698	N1	N1	1
7	112.5776	-7.8595	S3	S3	1
8	112.5354	-7.9017	S2	S2	1

No	Location		Data		Accuracy
	Longitude	Latitude	Spatial Analysis	Field Work	
9	112.5185	-7.8281	S2	S2	1
10	112.5535	-7.7618	N2	N2	1
11	112.5563	-7.7976	S3	S3	1
12	112.4936	-7.7962	N1	N1	1
13	112.5796	-7.909	S3	S3	1
14	112.5434	-7.7867	S3	S3	1

7 Conclusion and Discussion

A spatial analysis is needed for land clearings preceding an opening of apple plantations. Using direct analyses by experts will cost much. In consequence, a framework is introduced for the spatial analysis by using fuzzy algorithms and equations for the interpolation and digitization. Thus, the space analysis is done in pixel-based.

The pixel-based spatial analysis produces 92.85% level of accuracy when compared with the manual analysis. With such high accuracy, it becomes a benchmark and breakthrough technology of using an artificially intelligent system for spatial analysis compared with the manual one. If compared with [16], [17], and [18], this paper has proven that Batu City is very suitable for apple plantations since all variables are highly related. The results will be even more comprehensive and accurate if some other variables, such as slope and acidity, are added into the spatial analysis.

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