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Analysis of Community Adaptation Strategies Factors for Ecosystem-Based Disaster Risk Reduction in the Upper Merawu Watershed

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Abstract: The Merawu Watershed is one of the critical watersheds in Indonesia. This watershed is located in Banjarnegara Regency which has an altitude of 1000 meters above sea level with high rainfall intensity. The type of soil in Banjarnegara Regency is mostly ultisol and inceptisol soil, making the area vulnerable to landslides. Under these conditions, intensive agriculture is mostly carried out by the surrounding community, with the main commodity being planted is potatoes. Planting without paying attention to soil and water conservation techniques on steep land and spraying pesticides with high intensity can trigger erosion, landslides, and environmental pollution. The hamlets of Tamansari and Penanggungan are prone to erosion, landslides, and environmental pollution due to intensive agriculture. But, the adaptation strategy adopted by the community is still lacking. Therefore, it is necessary to research the factors that influence community adaptation strategies in ecosystem-based disaster risk reduction. This study aims to identify the factors that influence the adaptation strategy. The method used in this research is the logit model method. The respondents used in this study were 30 from the Tamansari Hamlet and the Penanggungan Hamlet. The results showed that the adaptation strategies factors for erosion are land area and household income, while landslides are assets and location. There are no variables that have a significant effect on the community's adaptation strategy to environmental pollution.

Keywords: a*daptation, disaster, watershed, factor*

Introduction

The Merawu Watershed is one of the critical watersheds in Indonesia. Factors that cause critical watersheds include topography, rainfall intensity, soil type, and land use. Merawu watershed is located in Banjarnegara Regency, where 24.4% of the sub-districts are located at an altitude of 1000 meters above sea level. According to [1] Banjarnegara Regency is dominated by hilly and mountainous topography. Based on BPS data in 2015, rainfall in Banjarnegara Regency averages 3000 mm/year. The high intensity of rainfall into the range of 2500-3000 mm/year is included in the high intensity [2].

The type of soil in Banjarnegara Regency is mostly ultisol and inceptisol, making the area vulnerable to landslides [3]. With high rainfall intensity and soil types prone to landslides, it can increase the potential for landslides in Banjarnegara Regency. Land use factors also affect the occurrence of landslides in Banjarnegara Regency. Using agricultural land without paying attention to proper conservation techniques will also cause the area to erode. Based on data from PT Indonesia Power (2009), the Merawu watershed contributes 10.41 mm/year of eroded sediment to the Mrica Reservoir, Banjarnegara Regency.

Penanggungan and Tamansari are hamlets in Banjarnegara Regency which are prone to erosion, landslides and environmental pollution. Most of the Tamansari and Penanggungan hamlets community practice intensive agriculture with the main commodity being planted is potato [4]. The potatoes and other products planted by the community without following the rules of soil and water conservation, the planting does not follow the contours. Planting does not follow the contours can increase the rate of soil erosion and trigger landslides. This is in line with what was said by [2] that planting in the direction of the contour is able to withstand the rate of erosion and landslides. The communities also use pesticides on their land to increase production yields. Planting carried out on steep slopes without paying attention to conservation techniques and spraying pesticides with high intensity makes the area vulnerable to disasters such as erosion, landslides, and environmental pollution [4].

Soil erosion, landslides, and environmental pollution (soil and water) often hit the Tamansari and Penanggungan hamlets in the upstream Merawu watershed area. However, the adaptation strategy undertaken in the context of risk reduction is still lacking, so it is important to conduct research related to "Analysis of Community Adaptation Strategies Factors for Ecosystem-Based Disaster Risk Reduction in the Upper Merawu Watershed". This research was also conducted because there have not been many studies on adaptation strategies factors in disaster risk reduction. This study aims to determine what factors influence the adaptation strategies carried out by the community in Tamansari and Penanggungan Hamlets in ecosystem-based disaster risk reduction.

Method

Location

The research was conducted in 2 hamlets in the Merawu watershed upstream, Banjarnegara Regency, namely Tamansari Hamlet, Karangkobar District and Penanggungan Hamlet, Wanayasa District. The location selection is based on the area's vulnerability to erosion, landslides, environmental pollution and the condition of the community, which is still low in carrying out adaptation strategies. Research location is shown in Figure 1.

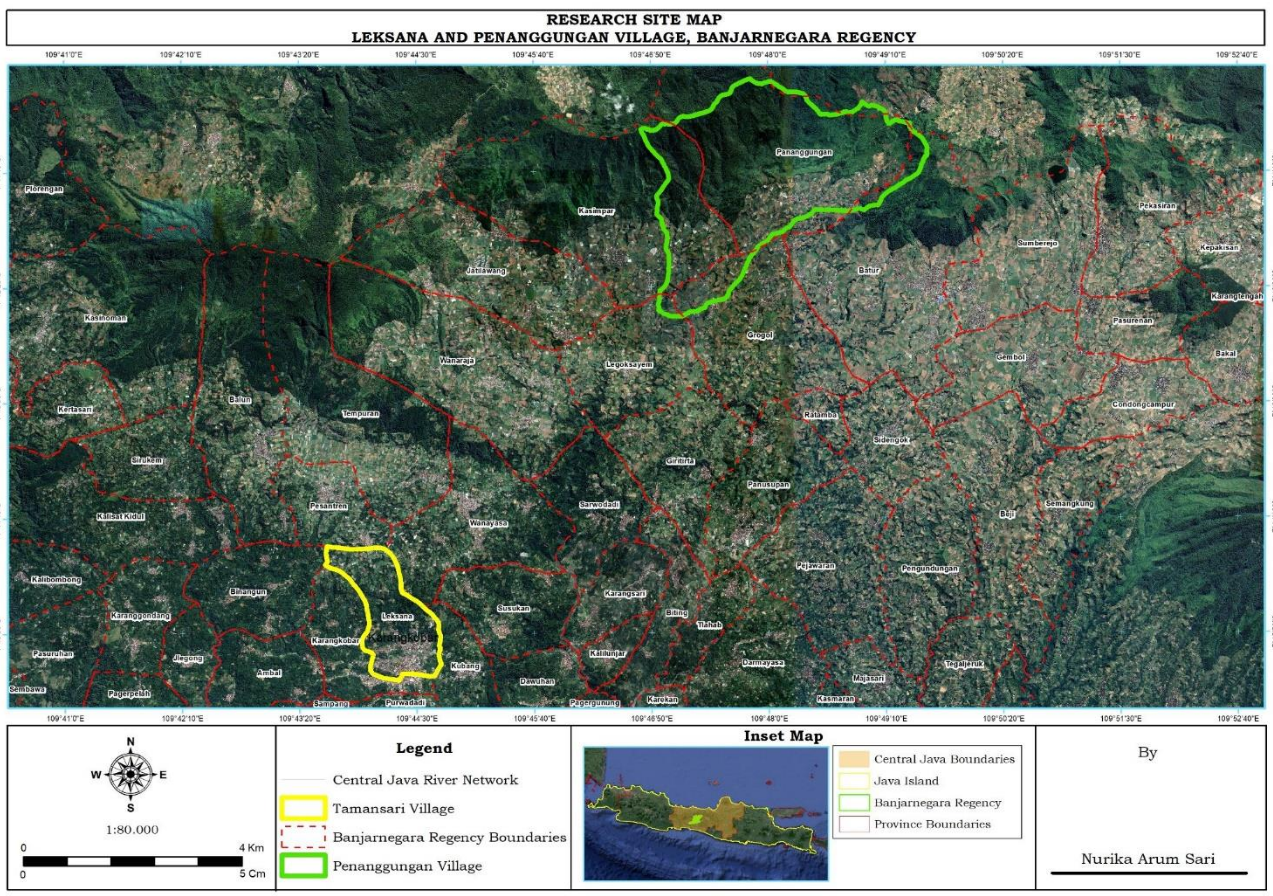

Figure 1. Research location

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Materials

The material used in this research is quantitative data on age, education, land area, household income, and assets. The data source used in this research is primary data obtained directly from the field. The primary data from the field in this research is questionnaire data related to the factors that influence adaptation strategies. These factors are shown in Table 1.

Table 1. Variable and Source of Data

Type of Data	Variable
Social and Economic Condition	• Age (year) • Education (year) • Land area (hectare) • Household income (tens of millions) • Assets (hundred million) • Dummy location

The variables used in this study were age, education, land area, household income, and assets. Based on research conducted by [5] entitled "Climate Change Adaptation Strategy: Influencing Factors and Benefits of Its Application", education and land area are independent variables that will influence farmers in carrying out adaptation strategies. Age and income also influence farmers' willingness to carry out adaptation strategies [6]. According to [7] one of the factors that determine a person's adaptive capacity is asset ownership. Household income is also one factor determining a person's adaptation strategy [8].

Data Collection Technique

The data collection method used is a survey method with a questionnaire as a tool. According to [9] the questionnaire is one of the collection tools in the survey method to obtain respondents' opinions. The questionnaires were distributed directly by the researchers. In this study, the questionnaire was closed-ended to determine the factors influencing the community's adaptation strategy in disaster risk reduction. The sampling technique was carried out randomly using the Simple Random Sampling method on 30 communities consisting of 15 residents of Dusun Tamansari and 15 people of Dusun Penanggungan. According to [10], the minimum sample size limit in research using statistical data analysis is 30.

Data Analysis

Factors influencing adaptation strategy were analyzed by binary logistic regression. The model used to determine the factors that influence the community's adaptation strategy in the Tamansari and Penanggungan hamlets is the logistic regression method. One of the reasons for using logistic regression analysis is its ability to determine whether there is an influence of factors that are thought to have a relationship with adaptation strategies. The logistic regression model is able to eliminate factors that have no relationship and measure how much the relationship between the dependent variable and the independent variable is [11]. This model is also able to predict the size of the community's opportunity to adapt because this model can determine the linear function of the factors that are thought to have a relationship with the adaptation strategy.

The logistic regression method is one of the regression analysis methods with a response variable, namely a binary variable. Binary variables are data in the form of a nominal scale (dichotomous), which only consists of two possibilities, namely yes (1) and no (0) [12]. The functional form of the logistics model is:

$$\ln\left[\frac{P}{1-P}\right] = \alpha + \beta x + \mu \quad \textbf{(1)}$$

where P is the probability value of the dependent variable whose binary values are 0 and 1. The P value is obtained from:

$$Y = \text{Prob}(Y = 1) = \left[\frac{1}{1+e^{-(\alpha=\beta x+\mu)}}\right] \quad \textbf{(2)}$$

The probability distribution used in the logit function is a logistic distribution, so that the conditional expected value of Y if X is known as:

$$E(Y|X) = \pi(X) = -\frac{e^{g(x)}}{1+e^{g(x)}} \quad \textbf{(3)}$$

where,

$$g(X) = \ln\frac{\pi(x)}{1-\pi(x)} \quad \textbf{(4)}$$

The response variable is the community adaptation to erosion, landslides and environmental pollution which is divided into two categories: the community adapts (1) and the community does not adapt (0). The independent variables that affect the community's adaptation in this study are age, education, land area, assets, household income and the dummy location of the community's residence. The logistic regression model to determine the factors that influence community adaptation are:

$$P = \frac{1}{1+e^{-(\beta 0+\beta 1X1+\beta 2X2+.....+\beta 6X6)}} \quad \textbf{(5)}$$

and transformed into logit to be:

Logit (P)

= Ln[P/(1-P)]

= βo+ β1X1+ β2X2+ β3X3+ β4X4+ β5X5+ β6X6

= βo+ β1Age+ β2Education+ β3Land Area+ β4Household Income + β5Assets+ β6Dummy location

where,

P = Community adaptation (1:Yes, 0: No)

βo = Intercept

β1-6 = Coefficient of independent variables or parameters to be estimated (logits)

X1 = Age (year)

X2 = Education (year)

X3 = Land area (hectare)

X4 = Household income (tens of millions)

X5 = Assets (hundred million)

X6 = Dummy location (Tamansari Hamlet: 0, Penanggungan Hamlet: 1)

From six mentioned variables, two data are categorized as nominal and ordinal data, namely education and location dummy. Parameter testing is conducted to determine whether the independent variables contained in the model have a significant relationship with the dependent variable.

Test the significance of the Alleged Logistics Regression Model

In concluding the significance of the model, it is carried out through statistical hypothesis testing, which is stated as follows:

• Ho : $\beta 1=\beta 2=...=\beta j=...=\beta k=0$

(Alleged model is not significant)

• H1 : At least one $\beta j \neq 0$

(Significant alleged model)

the hypothesis was proved by using the probability ratio test statistic as follows:

$$G = -2\text{Ln}\left(\frac{\text{Likehood model under Ho}}{\text{Likehood model under H1}}\right) \quad \textbf{(6)}$$

Where Ln is a logarithm based on natural numbers (e). The G test statistic follows the X2 distribution, so the test is carried out by comparing the G statistic value with the X2 table value with n degrees of freedom at α significant level (0.05). If the probability value > 0.05, Ho is accepted, and vice versa; if the probability value is 0.05, then Ho is rejected.

Odds Ratio

The measure was used to see the relationship between independent and dependent variables in logistic regression. The logistic regression is the value of the odds ratio (ψ). The odds ratio value starts from zero to infinity with the following categories:

- If bj is positive, then the odds ratio will be more than one (Xj has a positive effect on the success response variable)
- If bj is negative, then the odds ratio will be between one and zero (Xj has a negative effect on the success response variable)
- If bj is zero, then the odds ratio will be one (Xj has no effect on the success response variable).

The formula for finding the odds ratio value is:

$$\text{Odds ratio for Xj} = \frac{\left(\frac{(pi)}{1-pi}\right)Xj=1}{\left(\frac{(pi)}{1-pi}\right)Xj=0} = \frac{e^{b0+b1x1+\cdots+bj(1)+\cdots+bkXki}}{e^{b0+b1x1+\cdots+bj(0)+\cdots+bkXki}} = e^{bj}$$

The probability of success in the Xj=1 category is e^{bj} times greater than Xj=0.

Results And Discussion

Adaptation is an adjustment strategy that humans use during their lives to respond to environmental and social changes [13]. Adaptation aims to adjust to changes, environmental pressures, disaster hazards, and risks, and opportunities [14]. Environmental changes experienced by a community will lead to further action and handling by previously knowing widely about information, knowledge, and experience in dealing with changes that occur. Environmental changes that occur will cause two actions for the people who are in it. First, the community will move because they cannot accept the changes. Second, they survive in the environment by making various kinds of adjustments.

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Tamansari and Penanggungan Hamlets are vulnerable areas to erosion, landslides and environmental pollution. Based on research conducted [4], the adaptation strategy carried out by the Tamansari Hamlet community against erosion is to clean waterways before the rainy season. In contrast, the community does not take adaptation actions for landslides and environmental pollution. The community of Penanggungan Hamlet did not take good adaptation actions to the disasters of erosion, landslides and environmental pollution. Based on these results, it can be concluded that the adaptation actions taken by the Tamansari and Penanggungan Hamlets community are still low, so it is necessary to analyze the factors that influence the less adaptation strategy.

Logistic regression model analyzed factors influencing adaptation strategy with the following stages:

1. Model Feasibility Test

The feasibility test of the model or goodness of fit is carried out using the Hosmer and Lemeshow (H-L test) principle. The null hypothesis in this test is that the model has sufficiently explained the data. If the H-L test value is equal to or less than the specified significance level (5%) it means that the null hypothesis is rejected or in other words, there is a significant difference between the model and the observed value. This shows that the feasibility of the model is not good because the model cannot predict the value of the observations. Vice versa, if the H-L value is greater than 5%, it means that the null hypothesis is accepted, in other words the model is able to predict the value of its observations with 95% confidence. The results of the H-L test and omnibus test are presented in the following table:

Table 2. Results of H-L and Omnibus Test

H-L test	**Chi-square**	**Sig.**
Erosion	8.593	0.378
Landslide	4.607	0.799
Environmental Pollution	6.362	0.607
Uji omnibus	**Chi-square**	**Sig.**
Erosion	11.110	0.085
Landslide	12.405	0.054
Environmental Pollution	4.106	0.662

The significance value based on the H-L test for erosion is 0.378; landslides of 0.799, and environmental pollution of 0.607. Based on these values, it can be concluded that the logistic regression model for erosion, landslides and ecological pollution is sufficient to explain the data because the significance value is greater than 0.05. Therefore, the logistic regression model in this study is suitable for further analysis.

2. Overall Model Fit Test

Overall Fit/Omnibus Model Testing is also conducted to determine whether all independent variables in the logistic regression simultaneously affected the dependent variable, such as the F test in linear regression. Based on the results of the omnibus test presented in **Table 2**, it can be seen that the significance values for erosion and landslides are 0.085 and 0.054 so it can be concluded that there are independent variables that jointly affect the model because the significance value is less than 0.1. The significance value for environmental pollution is 0.662, so it can be concluded that there are no independent variables that jointly affect the model because the significance value is more than 0.1. In other words, the erosion and landslide models can be used. In contrast, the environmental pollution model cannot be used because the variables of age, education, land area, household income, assets, and location do not affect the adaptation strategy.

3. Nagelkerke R Square

Nagelkerke R Square is a modification of the Cox&Snell R Square coefficient, which tries to imitate the size of R in multiple regression with a value between 0 to 1. The closer the value to 1 means, the ability of the independent variables to explain the dependent variable is getting better. The results of the Nagelkerke R Square test are presented in **Table 3** as follows:

Table 3. Results of Nagelkerke R Square

	Nagelkerke R Square
Erosion	0.415
Landslide	0.480
Environmental Pollution	0.268

Based on the results of Nagelkerke R Square, the logistic regression coefficient of determination (R^2) is 0.415 for erosion, 0.480 for landslides, and 0.268 for environmental pollution, so it can be said that the contribution of the independent variable to the dependent variable for erosion is 41.5%, for landslides is 48.0% and 26.8% for environmental pollution. In other words, the dependent variable variations that can be explained by the independent variables on erosion, landslides and environmental pollution are 41.5%, 48% and 26.8% and the remaining 58.5%, 52% and 73.2% are explained by other variables outside this research model.

4. Model Building

Factors that are thought to have a relationship with community adaptation strategies are age (X1), education (X2), land area (X3), household income (X4), assets (X5), and the location of the community's residence (X6). The model is obtained from the results of data processing using SPSS 24. The output of the logistic regression results for factors that affect adaptation strategies are presented in the table as follows:

Based on the test of factors that influence the community's adaptation strategy with binary logistic regression against erosion, landslides, and environmental pollution, it can be seen that:

- The variables that significantly influence the community's adaptation strategy on erosion are land area and household income, which are 0.073 and 0.044.
- The variables that significantly influence the community's adaptation strategy on landslide are assets and location, which are 0.068 and 0.046.
- There are no variables that have a significant effect on the community's adaptation strategy on environmental pollution.

The variable significantly influences the community adaptation strategy if the significance value is less than (5% and 10%) and is said to have no significant effect if the significance value is more than α. The coefficient values in **Table 4** are positive and negative, indicating the influence of the independent variable on the dependent variable. Based on the test results, the erosion variables that positively affect the adaptation strategy are age, education, and assets. In contrast, the landslide variables positively affect education, land area, household income, and assets. The odds ratio is the ratio of the odds that it doesn't happen, and this value indicates a person's tendency to carry out an adaptation strategy.

Based on the results of the erosion test, the odds ratio of the variable land area and household income were 0.252 and 0.871, respectively, indicating that land area has a greater chance of adapting to erosion by 0.252 times and household income has a greater chance of adapting to erosion by 0.871 times. The odds ratio value on the asset and location variable landslide test results is 1.707 and 0.082, respectively. It indicated that assets have a greater chance of adapting to landslides by 1.707 times and locations have a greater chance of adapting to landslides by 0.082 times.

Table 4. Results of Adaptation Strategies Factor

Variable	Coefficient	Sig.	Odds Ratio
Erosion			
Age	0,096	0,195	1,101
Education	0,248	0,555	1,281
Land area	-1,378	0,073*	0,252
Household income	-0,138	0,044**	0,871
Assets	0,061	0,673	1,062
Location	-0,437	0,643	0,646
Constant	-2,301	0,603	0,100
Landslide			
Age	-0,026	0,725	0,974
Education	0,125	0,777	1,133
Land area	0,322	0,649	1,379
Household income	0,090	0,255	1,094
Assets	0,535	0,068*	1,707
Location	-2,497	0,046**	0,082
Constant	-1,051	0,826	0,350
Environmental Pollution			
Age	-0,014	0,896	0,986
Education	-0,231	0,703	0,794
Land area	-0,891	0,488	0,410
Household income	-0,132	0,318	0,876
Assets	-0,059	0,846	0,942
Location	1,325	0,393	3,763
Constant	1,296	0,845	3,656

Adaptations made to erosion are influenced by land area and household income. By referring to the odds ratio value, land area and household income have a negative influence on erosion adaptation, so it can be concluded that the smaller the land and household incomes owned by a person, the adaptation made by the community to erosion is getting better. This is different from the results of research conducted by [15], which states that the wider the land owned by farmers, the greater the risks faced by farmers, so the willingness to adapt is also greater. It can be said that the study carried out is inversely proportional to the study conducted by [15]. This is because the characteristics of the community in the research location are different from the study location conducted by [15].

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Based on the conditions in the field, people who own smaller land areas are more aware of the threat of erosion. The community will tend to pay more attention to the condition of the land so that the adaptation is carried out better. This is because people who have large and many lands tend not to worry about the results of their land production being affected by erosion. After all, they feel they can still get results from other lands, so the adaptation carried out will be lower. In addition, people who have large areas of land tend to have less monitoring of erosion on their land.

Household income also affects the community in adapting to erosion. Based on the conditions in the field, the higher the household income, the lower the community's adaptation strategy against erosion. People with large household incomes tend to not pay attention to land affected by erosion. This is because household income is a combination of farm and non-farm income, so this income does not only come from farming [16]. People who feel that their income outside of farming is higher will have lower adaptation to erosion. In addition, based on interviews that have been conducted, people with high farming incomes are increasingly intensive in purchasing seeds, so money that should be used for making terraces, mounds, and others is allocated to purchase seeds.

Adaptations made to landslides are influenced by the assets owned by each individual and location. Assets consist of houses, land, savings, livestock, jewelry, transportation equipment, electronic devices and trees in the house's yard. Assets have a positive influence on landslide adaptation actions. The more assets an individual has, the better the adaptation to landslides will be. People who have a lot of assets will tend to take adaptation actions by taking their assets to improve and work on their land to avoid landslides. In addition, people with a lot of assets will reduce their dependence on land to reduce the threat of landslides. It can also affect the diversification of livelihoods because people's jobs become diverse.

Location differences have a negative effect on the community's adaptation strategy to landslides, so it can be concluded that the adaptation action to landslides carried out by the Tamansari Hamlet community is better than Penanggungan Hamlet. This is influenced by the different types of land use in the two hamlets. Tamansari Hamlet has an agroforestry land use type and Penanggungan Hamlet has an intensive agricultural land use type.

According to [17], agroforestry is a planting pattern that by combining agricultural and forestry crops. Agroforestry is one of the adaptation strategies carried out by the Tamansari Hamlet community to reduce the risk of landslides. This is in line with [18] that agroforestry practices reduced runoff and erosion and can improve soil infiltration rates. Based on research conducted by [19], agroforestry techniques are also able to reduce environmental pollution due to pesticides by an average of 49%.

The agroforestry system in Tamansari Hamlet is planting the plant of coffee, sengon, and several other fruit crops. In contrast to the people of Penanggungan Hamlet, where the land is processed in such a way for potato production, it will trigger landslides. Therefore, the difference in location affects the community's adaptation strategy to landslides.

Based on the results of the partial test, the logistic regression model for erosion and landslides is as follows:

Logit (Erosion adaptation) =

-2.301 + 0.096Age + 0.248Education 1,378 Land area 0.138 Household income + 0.061 Assets 0.437 Dummy location

Logit (adaptation of landslides) =

-1.051 0.026Age + 0.125Education 0.322Land area - 0.090Household income 0.535Assets 2,497Dummy location

Conclusions

Factors that influence the community's adaptation strategy to erosion disasters are land area and household income. The lower the land area and household income owned by the community, the better the adaptation actions taken against erosion will be. Landslide adaptation strategies are influenced by assets and location differences. The greater the assets owned by the community, the better the adaptation actions taken against landslides. Location differences have a negative effect on the community's adaptation strategy to landslides. The community adaptation strategy of Tamansari Hamlet is better than Penanggungan Hamlet because Tamansari Hamlet has an agroforestry land use type while Penanggungan Hamlet has an intensive agricultural land use type.

Conflicts of interest

There are no conflicts to declare.

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