Climate-smart agriculture: Mitigation of landslides and increasing of farmers' household food security

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Abstract. The application of the Climate Smart Agriculture (CSA) concept is an effort to improve food security as well as mitigate landslides in watershed areas. This study aims to determine the coefficient value of runoff that can cause landslides, risk criteria, and the level of vulnerability in the event of landslides as well as the criteria for household food security of farmers. The results showed that farmers who diversify tree crops (cacao) and food crops (cassava and sweet potato) can reduce the risk and vulnerability of landslides as well as improve the household food security conditions of farmers. Soil and water conservation through an agro-ecosystem approach can increase food production, farmer income, job opportunities, and the quality of community nutrition as well as the welfare and food security of farmer households around the forest.

1. Introduction
Indonesia has a relatively diverse climate and topography, both physical and chemical, resulting in fertile soil conditions. However, on the other hand, it can cause hydro-meteorological disasters such as floods, landslides, and drought. The development which has been based on the exploitation of natural resources, especially on a large scale, has resulted in the loss of the carrying capacity of the environment for people's lives. Forest resources in Indonesia are currently depleting which leads to increased risk of disasters, particularly landslides. Landslides occur due to high rainfall in mountainous areas which causes unstable soil structure. Landslides not only destroy agricultural land but also damage residential buildings, community settlements, and public facilities [1,2,3]. Based on data from the National Disaster Management Agency (BNPB), landslides rank 3rd according to the percentage of natural disasters that occurred in Indonesia in 2019-2020 [4], as shown in Figure 1.
Landslides are soil movements in geological processes that occur due to the interaction of several factors, including geomorphology, geological structure, hydrogeology, and land use. Several factors that influence the occurrence of landslides are soil conditions, rainfall levels, topography, vegetation, and the presence of earthquakes [5]. Landslides are likely to occur in areas that have active faults and can be monitored by seismographs. The earthquake that rocked Palu City, Sigi Regency, and Donggala (PASIGALA) on September 28 2018 have changed the landscape of Palolo District, Sigi Regency, Central Sulawesi to be prone to landslides.

Most of the villages in the Palolo Regency in the watershed area with unstable soil conditions because they are located in hills or mountains. The main factors that cause the Palolo area to be categorized as landslide-prone are natural (geology, hydrology, climatology, topography), land cover (vegetation), and human factors [6]. These factors can not only cause landslides but also cause drought, floods, and critical land due to land degradation and environmental damage. The phenomenon of landslides in recent years has also been one of the consequences of the conversion of forest land to non-forest (agriculture and settlements) in line with the increasing number of people living in watershed areas [7]. Several studies have shown that land management through crop diversification can have a significant effect on reducing the number of runoff losses [8,9].

Plant diversification technology in watershed areas can increase sustainably land productivity while preserving the environment and mitigating landslides [10]. This idea is packaged globally in the concept of Climate-Smart Agriculture (CSA), namely the concept of agricultural management in the world food system so that it can adapt to climate change conditions as well as become a mitigation actor [11]. A smart and wise strategy is needed so that agricultural development goals can be achieved amid the intensity of extreme climate events such as landslides which have an impact on decreasing agricultural productivity. Based on this, a study was conducted to determine the value of the runoff coefficient that could cause landslides, the criteria for risk and level of vulnerability in the event of landslides, and the criteria for household food security through crop diversification.
2. Methods

2.1. Design of research

2.2. Time and research location

The research was conducted in May-November 2019, in the Toranda watershed area, Palolo District, Sigi Regency which is the buffer zone of the Lore Lindu National Park (TNLL). Determination of the research location was carried out using a purposive method with the consideration that Palolo District is one of the centers for developing cocoa production with the largest planting area and is a leading plantation commodity in Sigi Regency [12]. The determination of respondents also used a purposive method, with respondents as many as 10 farmers who diversify cocoa + cassava + sweet potato. Determining the location of the research and respondents was carried out using a purposive method, namely the technique of determining the location and sample with certain considerations [13].

2.3. Data collection

Data collection to calculate runoff coefficients was carried out using rainfall data from the Palolo climatology station and land slope measurements using a clinometer. Meanwhile, the data to determine the criteria for food security were obtained by using a questionnaire to determine the financial statements of farming, non-farming, the value of rice food consumption, and the price of rice food in the research location.

2.4. Data analysis

Data analysis was carried out in stages using the following analysis:

2.4.1. Runoff coefficient analysis (C), is the difference between river water discharge, with the average rainfall in the catchment area based on the catchment area data at the study site (Sub-watershed), daily discharge [14], using the formula:

\[
C = \sum_{n=1}^{12} (d_n \times 86400) \times Q / (P \times A)
\]

(1)
C = runoff coefficient

\( d_n \) = number of days in the month \( i \)

86400 = number of seconds in 24 hours

Q = monthly average debit (m\(^3\) / sec)

P = yearly average rainfall (mm / year)

A = watershed area (m\(^2\))

The criteria used are:

a. \( C < 0.25 \), good watershed conditions
b. \( 0.25 < C < 0.50 \), moderate watershed conditions
c. \( 0.51 < C < 1 \), poor watershed conditions

2.4.2. Slides risk analysis, is carried out qualitatively by giving weight to each of the influencing variables based on how much influence these variables have on the occurrence of landslides. The greater the influence of these variables on the occurrence of landslides, the greater the weight value. While the determination of the level of vulnerability of landslides is carried out by making the class value of the vulnerability interval, using the formula:

\[
K_i = \frac{X_t - X_r}{K}
\]  

(2)

\( K_i \) = interval class

\( X_t \) = highest data

\( X_r \) = lowest data

\( K \) = number of classes desired

Interval class value:

Highest data = 60
Lowest data = 20
Number of classes = 3

\[
K_i = \frac{60 - 20}{3} = 13.3
\]  

(3)

2.4.3. The analysis of food security criteria (Z), is a calculation based on on-farm and non-farm income, the value of staple food consumption, and the price of staple food at the research location using descriptive-analytic methods based on calculations made by Balisacan (1996), Anderson and Roumasset (1996) in measuring food security [15] using the formula:

\[
Z = P (Q - C_m) + N
\]  

(4)

\( Z \) = food security index

\( P \) = price of staple food at the local level

\( Q \) = value of household food production (net of minus the inputs)

\( C_m \) = minimum food consumption needed

\( N \) = non-agricultural income

The criteria used are:

a. \( Z > 0 \), means that there is food security
b. \( Z < 0 \), means that there is food insecurity
3. Results and discussion

3.1. Surface runoff

The runoff coefficient (C) is a number that shows the ratio between the amount of runoff and the amount of rainfall. The surface runoff coefficient value is an indicator to determine whether a watershed area is experiencing physical disturbance and to control landslides in mountainous areas [16]. The value of C ranges from 0 to 1, C = 0 indicates that all rainwater enters the soil, while C = 1 indicates that rainwater flowing as surface runoff can cause landslides. Analysis of surface runoff is carried out on meteorological elements which include rainfall data, while physical properties include land use, soil types, and slope conditions. Physical elements can be categorized as static aspects, while meteorological elements are dynamic aspects that can change from time to time. Based on the analysis and calculations, the runoff coefficient (C) in the Toranda watershed area is 0.35, based on the annual runoff coefficient classification shown in Table 1 below.

Table 1. Classification of annual runoff coefficient (C).

| No. | C value | Score | Criteria |
|-----|---------|-------|----------|
| 1.  | <0.25   | 1     | Low      |
| 2.  | 0.25-0.50 | (0.35)| Moderate |
| 3.  | 0.51-1  | 3     | High     |

Table 1 shows that the surface runoff at the study location is in the moderate criteria (C = 0.35). This shows that watershed management through the use of agricultural land with a pattern of crop diversification is significant in reducing the danger of landslides that often occur in the study location. The amount of surface runoff that has the potential to cause landslides is highly dependent on soil texture, the amount and intensity of rainfall, slope, and land use through the selection of plant species as a vegetative form of soil and water conservation. Land use that does not apply conservation practices has resulted in more than 60% of the land area in the area classified as prone to moderate to very high erosion and has the potential to cause landslides [17]. Land use through plant diversification by planting root crops (cassava and sweet potato) has increased the amount of empty land cover in the monoculture cocoa cropping pattern. This can increase the surface runoff infiltration by 10-20% compared to without land cover vegetation.

3.2. Disaster risk criteria

Disaster risk is the possibility of a disaster and loss of life and/or physical infrastructure caused by a type of disaster in an area within a certain period. Disaster risk can be indicated by the results of a combination of risk-causing variables and possible risk criteria. The criteria for the risk of landslides at the study site and their causal variables are presented in table 2 below.

Table 2 shows that the research location has a high risk of landslides if there is rain with a volume of> 100 mm / day for more than 24 hours. Based on previous observations, landslides that have occurred in Palolo Regency in October 2018 occurred when the average volume of rainfall reached 150 mm / day for more than 3 consecutive days. Rainfall with high intensity in an area with a relatively steep and unstable slope can trigger landslides. The threshold value for rainfall that has the potential to cause landslides will be different in each region and will have a greater impact on areas prone to landslides than in areas that are not prone to landslides even with the same rainfall. Rainfall that needs to be watched out for in areas prone to landslides is> 300 mm / 3 days [18, 19]. Medium soil texture risk variables, 15-30% slope, and land use with a mixed pattern of cocoa and tubers can reduce the risk of landslides in the research location even though occasional high rainfall coupled with faults can cause a high risk of landslides. Furthermore, the vulnerability level of landslides based on the risk criteria at the location of research is presented in table 3 below.
Table 2. Landslide risk criteria based on the variable causes of slides.

| Variable of risk     | Weight | Value | Score | Criteria of risk |
|----------------------|--------|-------|-------|------------------|
| Soil Texture         |        |       |       |                  |
| Smooth               | 1      | 15    | 15    | Low              |
| Moderate             | 2      | 5     | 10    | Moderate         |
| Rough                | 3      | 0     | 0     | High             |
| Intensity of Rainfall (mm / day) |     |   | |                  |
| 0 - 50               | 1      | 0     | 0     | Low              |
| 51 - 100             | 2      | 4     | 6     | Moderate         |
| >100                 | 3      | 16    | 48    | High             |
| Slope                |        |       |       |                  |
| 0 - 14               | 1      | 0     | 0     | Low              |
| 15 - 30              | 2      | 20    | 40    | Moderate         |
| >30                  | 3      | 0     | 0     | High             |
| Land Use             |        |       |       |                  |
| Forest               | 1      | 0     | 0     | Low              |
| Mixed garden         | 2      | 20    | 40    | Moderate         |
| Rice fields          | 3      | 0     | 0     | High             |

Table 3. Vulnerability level of slides.

| No. | R value | Vulnerability rate |
|-----|---------|--------------------|
| 1.  | <23.3   | Low                |
| 2.  | 23.3-43.3 | (38.3) | Moderate         |
| 3.  | >43.3   | High               |

Table 3 shows that the research location has a moderate level of vulnerability. This is caused by natural risk factors such as soil texture and slope, which is in a tolerable condition. Besides, the reduced level of vulnerability is also due to the choice of cropping patterns in the form of crop diversification which can reduce the effect of high risk due to rainfall. Landslide vulnerability is caused by various determining factors, namely natural factors and management factors. Natural factors include cumulative daily rainfall for 3 consecutive days, slope, and soil type/texture. Meanwhile, management factors are caused by land-use patterns, infrastructure, and settlement density. Human factors, namely human activities on land digging the slopes also contribute to landslides [20].

3.3. Food security of household farmers

Watershed management for landslide mitigation is ideally done through a system that can increase land productivity, watershed sustainability, and household food security for farmers [21]. Land use patterns can be a risk factor for landslides and will affect land cover. Cultivating cocoa as a tree crop, which is generally carried out by farmers in the research location, is not only beneficial for economic interests but for reducing the danger of landslides because plant roots can bind soil aggregates. Diversification of plants in the form of multi-stratified plants by adding food crops (cassava and sweet potato) can form soil organic matter, improve soil structure and make soil with a slope relatively more stable [22]. Besides, these tubers can provide additional yields for farmers to improve the economy.
and ensure food security. The criteria for farmer household food security are presented in Table 4 below.

**Table 4. Criteria of farmer household food security (1 year)**

| No. | Indeks of security (IDR) | Criteria of security |
|-----|--------------------------|----------------------|
| 1.  | 13,707,000               | Tolerate             |
| 2.  | 29,448,000               | Tolerate             |
| 3.  | 8,091,000                | Tolerate             |
| 4.  | 12,402,000               | Tolerate             |
| 5.  | 12,789,000               | Tolerate             |
| 6.  | 10,773,000               | Tolerate             |
| 7.  | 28,916,000               | Tolerate             |
| 8.  | 11,556,000               | Tolerate             |
| 9.  | 29,484,000               | Tolerate             |
| 10. | 4,284,000                | Tolerate             |

Table 4 shows that farmers who apply a crop diversification pattern between cacao and root crops have higher household food security criteria. The food security criterion value that is greater than number 1 indicates that the household income of the farmer is greater than the expenditure to meet basic food needs even without income from non-agricultural businesses. This excess income can be used by farmers to meet other primary needs such as housing, clothing, education, and health, as well as savings or capital for farm management and development. The size of the farmer household food security index is not only influenced by farm income and the size of staple food consumption is also influenced by land area, many family dependents, and non-farm income [23]. Through crop diversification, while maintaining the existence of seasonal crops among tree crops, farmers can apply CSA as environmentally friendly and sustainable agriculture that takes into account climate variability and disaster factors [24,25].

4. Conclusion
The concept of CSA is an effort to empower farmers which aims to balance the environmental and socio-economic aspects of agriculture in an integrated manner by sustainably optimizing land productivity. Landslide disaster mitigation efforts and the application of the concept of sustainable agriculture can be carried out through the diversification of trees crops and food crops. Management of land with more than one plant species with varying ages makes farming safer from the risk of natural disasters and the consequences of climate change. The combination of trees crops and food crops can increase food production, farmers’ income, job opportunities, and the quality of community nutrition for the welfare of farmers around the forest.

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Acknowledgment

The authors would like to thanks Abdul Muis for his valuable discussion in developing the idea and earlier drafts of this paper. Special thank is going to the farmers who participated in the interview process. Further thanks to Abdur Rauf for his helps a lot in the process of collecting data and assisted in the processing of data and various parties that can't be mentioned one by one.