

ENVIRONMENTAL MANAGEMENT STRATEGIES FOR ECONOMIC LOSSES DUE TO LANDSLIDES ON THE DIENG PLATEAU FOREST AREA

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ENVIRONMENTAL MANAGEMENT STRATEGIES FOR ECONOMIC LOSSES DUE TO LANDSLIDES ON THE DIENG PLATEAU FOREST AREA. The Dieng Plateau is an area known for its agricultural cultivation. However, excessive use of land for agriculture increases the potential for landslides that disrupt community activities. This research aims to determine the potential losses due to landslides on agricultural land and determine strategies for managing environmental damage due to landslides in the Dieng Plateau. Determination of sample locations was carried out using the purposive sampling method, while data collection used the accidental sampling method. Data analysis uses quantitative techniques and SWOT analysis is used to formulate environmental damage management strategies. The research results show that the greatest losses due to landslides occur during the harvest period. The observation location that has the greatest potential for loss is location 1 which is Dieng Kulon Village. As the years go by, the resulting losses will be greater. The appropriate environmental management strategy to implement is Planting of vegetation types that are beneficial for the environment, tourism and agriculture to improve environmental quality and improve community welfare, stricter monitoring of agricultural activities, and the formation of a disaster response team.

Keywords: Dieng, environment, economic losses, landslide, management strategies

STRATEGI MANAJEMEN LINGKUNGAN TERHADAP KERUGIAN EKONOMI AKIBAT BENCANA LONGSOR DI KAWASAN HUTAN DATARAN TINGGI DIENG. Dataran Tinggi Dieng merupakan salah satu kawasan yang dikenal dengan hasil budidaya pertanian. Akan tetapi pemanfaatan lahan untuk pertanian yang berlebihan meningkatkan potensi terjadinya bencana longsor yang mengganggu aktivitas masyarakat. Penelitian ini bertujuan untuk mengetahui potensi kerugian akibat bencana longsor pada lahan yang mengalami alih guna dan mengetahui strategi manajemen lingkungan akibat bencana longsor di Dataran Tinggi Dieng. Penentuan lokasi sampel dilakukan menggunakan metode purposive sampling, sementara pengumpulan data menggunakan metode accidental sampling. Analisis data menggunakan teknik kuantitatif dan analisis SWOT yang digunakan untuk merumuskan strategi manajemen lingkungan. Hasil penelitian menunjukkan bahwa kerugian terbesar akibat bencana longsor terjadi pada masa panen. Lokasi pengamatan yang memiliki potensi kerugian terbesar adalah lokasi pengamatan 1 yaitu Desa Dieng Kulon. Semakin bertambah tahun maka nilai kerugian yang dihasilkan akan semakin besar. Strategi manajemen lingkungan yang tepat dilakukan adalah pemanfaatan jenis-jenis vegetasi yang bermanfaat bagi lingkungan, wisata, dan pertanian untuk memperbaiki kualitas lingkungan dan meningkatkan kesejahteraan masyarakat, memantau aktivitas pertanian yang lebih ketat, serta membentuk tim tanggap bencana.

Kata kunci: Dieng, kerugian ekonomi, lingkungan, longsor, dan strategi pengelolaan

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I. INTRODUCTION

The Dieng Plateau is situated in two administrative regions: Wonosobo Regency and Banjarnegara Regency. It has an average elevation of 1,600 to 2,000 m above sea level, with daytime temperatures ranging from 15 to 20 °C and nighttime temperatures around 10 °C. The plateau is characterized by undulating to sloping topography. In Wonosobo Regency, the protected forest area spans approximately 4,598 ha, of which about 50 to 60% has been converted to agricultural land (Haty et al., 2021; Maya, 2022; Santosa, 2023; Wijaya et al., 2024). The Dieng Plateau is well known for its agricultural use due to its fertile soil and scenic landscape. However, excessive agricultural activities have a negative impact on the environment such as soil fertility loss, water pollution, deforestation, climate change, and pesticide pollution (Candan Demirkol, 2022; Rey-Romero et al., 2022; Waithaka, 2023). Forest encroachment by local communities for agriculture has disrupted the ecological balance of the region (Maesaroh & Suwarno, 2022). This will certainly have an impact on the balance of the ecosystem in the area. The forest area in the area is intended to protect the ecosystem from damage and potential natural disasters, because encroachment will eliminate the function of the forest as an ecosystem buffer.

The history of natural disasters caused by volcanoes and landslides in the Dieng area is still often found. Dieng, situated at an altitude of 2000–2500 m above sea level, is an active volcanic region, as evidenced by the continuous emission of sulfuric smoke from the Si Kidang crater (Rahayuningsih & Wati, 2023). The condition of the Dieng area which is vulnerable to disasters is still often found today. It was proven in previous research that the area prone to landslides with high potential reached 46.90% (Krisnandi et al., 2021). Whereas once the charm of the Dieng ecosystem was a protected forest. Land use then changed when residents' agricultural patterns switched to potato cultivation as a staple crop for Dieng farmers (Sahara et al., 2023).

Pradana et al. (2015) state that the Dieng Plateau has been dominated by potato farming. Mountainous areas with a slope of more than 40%, have been heavily exploited for potato plantation. Even more than 900 ha of protected forest in Wonosobo have been cleared (Swarnawati, 2018). Potato cultivation continues to increase every year. While this land-use change supports farmers' incomes, it significantly harms the environment. The area with a slope of more than 40% has been widely used for potato cultivation, resulting in the clearing of more than 900 ha of protected forest area (Santosa, 2022). Central Java potato production 2020 reached 269.476 thousand tons, 58% of which came from agriculture in Dieng (Badan Pusat Statistik Jawa Tengah, 2021). Besides potatoes, the most common vegetable crops grown by farmers as inter-crops are carrots (*Daucus carota*) and cabbage (*Brassica oleracea*) (Pujiwinarko et al., 2024). The dry land yield, in average per annum, tea 149.48 tons, coffee 689.00 tons, fruits 106,925 tons, varieties of cassava, peanuts, bean, and corn, 195,812, and varieties of vegetables including potatoes, 191,238 tons (Wahono & Puspitawati, 2021).

Tree species that are identical to productive plants that are usually planted in state forests managed by Perhutani, such as *Pinus merkusii* Jungh. & de Vriese, *Eucalyptus* sp., *Cupressus sempervirens* L. and *Schima wallichii* (DC.) Korth (Pujiwinarko et al., 2024). Potato farming is particularly vulnerable in the rainy season as potato plants wither quickly and are prone to landslides (Akmalia, 2022).

The utilization of forest areas as agricultural land certainly has a negative impact on the environment. For example, deforestation due to agricultural land expansion has occurred greatly in Vietnam, with a high proportion of forests being converted into agriculture, leading to a negative impact on the hydrologic regime in the large basin (Truong et al., 2022). Clear-cutting and other forestry practices inflict intense disturbances on forests, global warming, causing dramatic changes in the habitat available to support biodiversity, and

degradation of physical and rheological soil properties (Galindo et al., 2022; Lawrence & Vandecar, 2015; Tolimir et al., 2020; Wahyuni & Suranto, 2021). One of the impacts felt by the community is the frequent landslides on the Dieng Plateau that disrupt community activities. Massive agricultural activities accompanied by continuous tillage increase the potential for landslides due to land degradation. If landslides occur on the agricultural land itself, it will certainly cause greater losses than the income that the community earns from these activities.

Previous research indicates that the losses due to landslide events on agricultural land in Clapar Village, Banjarnegara, amount to 4 billion IDR (Mutia et al., 2018). Meanwhile, Retnowati (2014) reported that landslide occurrences on agricultural land in Kokap District, Special Region of Yogyakarta, resulted in estimated economic losses ranging from IDR 60,900,000.00 to IDR 220,460,000.00. Another study conducted by Dewangga (2018) on agricultural land in Girimulyo District, Kulonprogo, Yogyakarta, demonstrated that the potential economic losses incurred include: i) IDR 1,958,600 per hectare per year after the processing period, ii) IDR 2,288,700 per hectare per year after the planting period, iii) IDR 5,683,000 per hectare per year after the growing period, and iv) IDR 19,361,400 per hectare per year at the time of harvest. Predictions for economic losses in 2028 include: i) IDR 5,662,300 per hectare per year after the processing period, ii) IDR 6,616,600 per hectare per year after the planting period, iii) IDR 16,429,700 per hectare per year after the growth period, and iv) IDR 55,973,700 per hectare per year at the time of harvest.

Estimating economic losses from landslides in agricultural land located within or adjacent to protected forest zones is critical, as these areas exhibit higher environmental vulnerability and contribute significantly to disaster-induced degradation. Global landslide-related economic losses have risen sharply from approximately USD 50 billion annually in the 1980s to over

USD 200 billion in recent years, with the majority occurring in developing countries characterized by fragile infrastructure and weak disaster governance, causing both direct and indirect economic losses (Zhang et al., 2021; Marín-Rodríguez et al., 2024). Although numerous studies have focused on technical aspects such as susceptibility mapping and loss estimation (Elkhrachy et al., 2023; Shano et al., 2020; Zhao et al., 2023), most remain sectorally isolated and rarely integrate comprehensive environmental management frameworks. Estrella et al. (2016) and Renaud et al. (2016) emphasize that conventional engineering-based approaches often fail to deliver sustainable outcomes in mountain ecosystems because they neglect ecosystem functions and services. Consequently, systemic strategies rooted in Ecosystem-based Disaster Risk Reduction (Eco-DRR) and Adaptive Environmental Management—such as vegetative engineering, watershed restoration, and risk-informed land-use planning—are still underrepresented in landslide economic mitigation frameworks (Sneddon, 2022; Hossain et al., 2024).

This study adopts the Ecosystem-based Disaster Risk Reduction (Eco-DRR) framework (UNDRR, 2020; Sneddon, 2022) combined with Adaptive Environmental Management (Estrella et al., 2016; Renaud et al., 2016) as the core conceptual foundation. Eco-DRR explicitly recognizes healthy ecosystems (particularly forest and agroforestry systems) as cost-effective natural infrastructure that reduces landslide hazard, exposure, and vulnerability simultaneously, while adaptive management ensures continuous learning and adjustment of strategies in response to changing socio-ecological conditions. By integrating quantitative economic valuation, time-value-of-money projections, and SWOT-based strategy formulation within this dual framework, the research addresses the identified gap and provides a replicable model for highland tropical regions. Specifically, this study (1) quantifies current and future economic

losses due to landslides on the Dieng Plateau, (2) evaluates environmental damage linked to forest-to-agriculture conversion, and (3) formulates locally appropriate environmental management strategies to minimize long-term losses and enhance community resilience.

II. MATERIAL AND METHOD

A. Study Site

The research was conducted in the Dieng Plateau Protection Forest area which is located in two areas, namely Wonosobo Regency and Banjarnegara Regency. This research was conducted in Dieng Wetan Village and Sikunang Village, Kejajar District, Wonosobo Regency, and Dieng Kulon Village, Karangtengah Village, and Bakal Village, Batur District, Banjarnegara Regency. The area of Dieng Wetan is 282 ha, Sikunang 373.9 ha, Dieng Kulon 197 ha, Bakal 485 ha, and Karangtengah 48900 ha. Dieng Plateau has a rough topography in the form of hills and valleys with a slope of 87.5-92.4%. The area is at an altitude of $\pm 2,100$ m above sea level. The study site was selected

based on the research objective, namely forest areas that have undergone land-use conversion into agricultural land. The selection of the location was based on the bio-physical and administrative characteristics of the region to increase area diversity, thereby enabling the collection of comprehensive and representative data for spatial and ecological analyses. The selected research site is a forest area located on the Dieng Plateau. The research location is shown in Figure 1.

B. Methods

The tools used in this study were a camera, tally sheet, GPS, laptop, and writing materials. The materials used were administrative maps, forest area maps, land use maps, slope maps, and soil type maps. These maps were used to determine the observation locations by spatially analyzing the maps and determining the observation locations according to the specified characteristics. The characteristics of the observation location are forest areas that have been converted to agricultural land.

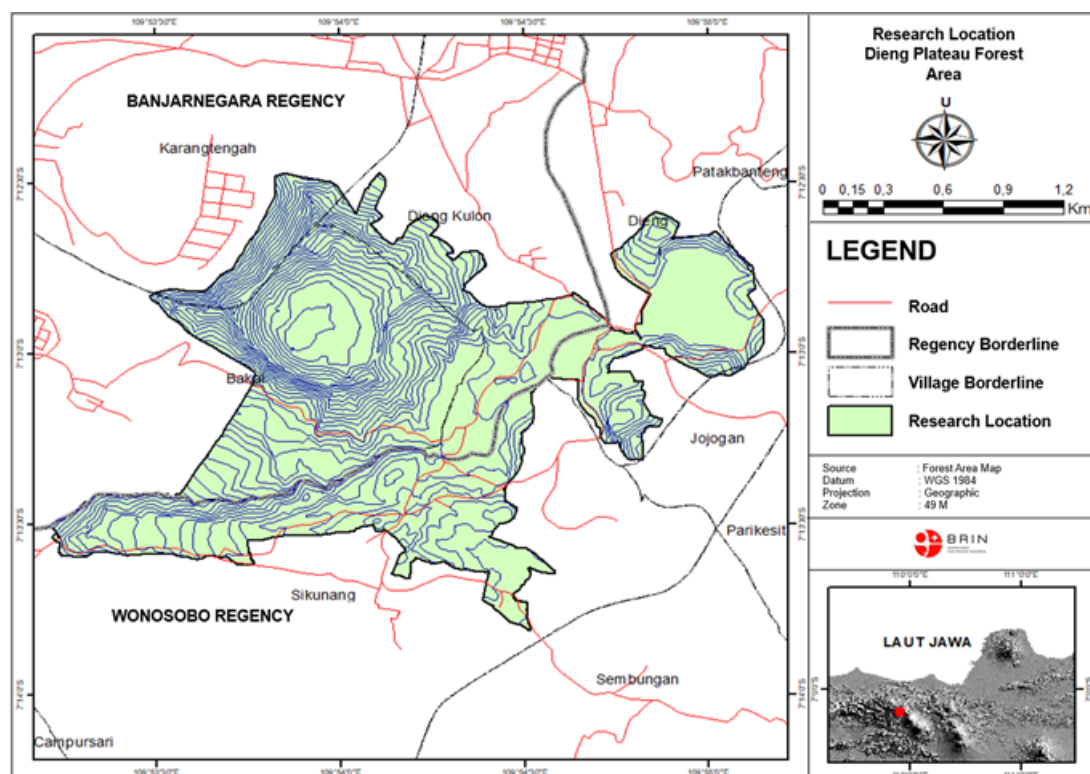


Figure 1. Research location in the Dieng Plateau Protection Forest area

The determination of study site selection used the purposive sampling method, which involved selecting locations with the condition that the forest area had undergone land conversion to agricultural land. The samples were determined using a spatial analysis method by applying an overlay technique to four types of maps: soil type maps, forest area maps, slope maps, and land use maps. Spatial analysis using the overlay technique was conducted to generate new information. The results of this spatial analysis produced 9 analytical units with different variations and characteristics. The sampling locations are the observation or data collection sites, which are divided into nine sampling locations with different characteristics. These nine sampling locations are distributed across five villages located within two administrative regions. The research location refers to the general study area, namely the forest area of the Dieng Plateau. The results of the spatial analysis of the research locations can be seen in Figure 2.

Data collection that used is accidental sampling technique. The selection of accidental sampling was based on field conditions and the characteristics of the research object. Agricultural lands resulting from forest land-use conversion are generally unevenly distributed, not formally documented, and difficult to identify spatially in advance. Therefore, accidental sampling was considered the most appropriate approach, as it allows respondents to be selected based on locations that are accessible and directly encountered in the field during the research period. Furthermore, this approach is relevant because the study aims to describe existing conditions rather than to achieve statistical generalization across the entire population. Accidental sampling enables efficient data collection under constraints of time, access, and limited preliminary information, while still capturing real variations in biophysical conditions and land management practices. Thus, this method is suitable for exploratory and descriptive studies.

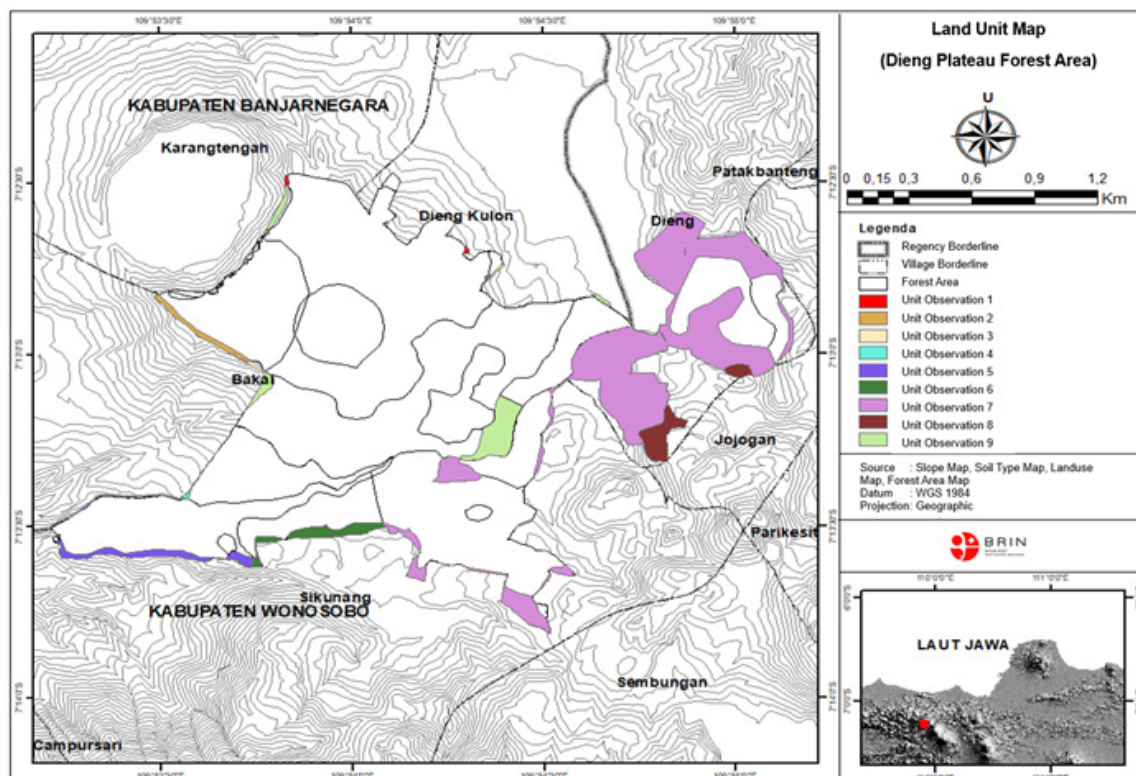


Figure 2. Land units map in the Dieng Plateau Protection Forest area

Samples were taken based on justifiable considerations, as long as they met the requirements. Requirements respondents were farmers and were on farm activities in the forest area. The respondents interviewed were those who were met accidentally at the sampling location, but the respondents selected were not just anyone, but rather those who were related to the research, namely farmers who were carrying out agricultural activities at the location. Before the interview was conducted, a validation was carried out on the respondents, following the steps for determining the respondents. First, to ensure that the respondent is a farmer. Second, to ensure that the respondent is carrying out agricultural activities in the forest area. Third, to ensure that the respondent is a cultivator or owner of the land. Fourth, to ensure how the respondent opens up the forest area. The number of respondents was not clearly determined beforehand. The number of respondents was determined by how many respondents could be met in the field during the data collection period. The total number of respondents was 22. Respondents are farmers who actively carry out agricultural activities in converted forest areas and 9.1% of respondents have experienced a landslides. Data collection conducted to respondents aims to collect information on land area, land ownership, land clearing techniques, land management, land management capital, and income obtained from crop production. The data was analyzed to determine the income and economic loss if landslide occurs on the land.

C. Analysis

1. Economic Valuation of Agriculture

The analysis of economic valuation of agriculture is conducted to determine the amount of income generated by the community from agricultural activities carried out in the Dieng Plateau forest area. The results of the economic valuation will show the amount of income obtained and its changes each year. Continuous land cultivation will result in a

decrease in land productivity due to erosion and a decrease in the ability of the land to provide nutrients for plants, so that there is a decrease in crop yields over time. The economic valuation of agriculture is calculated based on the income of agricultural businesses. Farm income is calculated by multiplying the crop yield per hectare by the average selling price and then subtracting the total production costs. The following formula is used to calculate farm income (Jarwinto et al., 2015).

1.1 Farm income

$$FI = SI - FE \dots\dots\dots(1)$$

where:

FI = farm income (IDR/year/hectare)

SI = sales income (IDR/year/hectare)

FE = farm expenses (IDR/year/hectare)

1.2 Sales income

$$SI = Y \times P \dots\dots\dots(2)$$

where:

SI = sales income

Y = production yield (kg/year/hectare)

P = average selling price (IDR/kg)

1.3 Farming expense

$$FE = Cs + Cf + Cp + Cl + Ct \dots\dots\dots(3)$$

where:

FE = farming expense

Cs = cost of seeds (IDR/year/hectare)

Cf = cost of fertilizer (IDR/year/hectare)

Cp = cost of pesticides (IDR/year/hectare)

Cl = labor cost (IDR/year/hectare)

Ct = cost of tools (IDR/year/hectare)

2. Estimation of Economic Losses Due to Landslides in Conversion Areas

The estimation of economic losses is carried out to determine the losses due to landslides so that the estimated losses can be obtained if a landslide occurs in the period 2019-2024. Due to the difference in time dimensions, the following formula is used to predict the economic losses due to landslides for the next 6 years (Kumalawati, 2005):

$$Fv = Po \times (1+i)^n$$

$$FI = SI - FE \dots\dots\dots(4)$$

where:

Fv = future value of money

Po = present value of money

i = interest rate

n = year n

Ct = cost of tools (IDR/year/hectare)

In this calculation, the current interest rate of 5.75% is used, based on the Bank Indonesia Rate. To assess the economic losses due to landslides, it is assumed that landslides occur at several times during the planting, growing, and harvesting seasons (Garcia-Chevesich et al., 2021; Kimura et al., 2023; Zhang et al., 2019). The assumed level of occurrence is total damage. This assumption is applied because of landslides on the slope like the Dieng Plateau usually causes severe physical damage to land structures, including landslides, which make land permanently unusable for agricultural production. The components calculated in analyzing each period differ according to the treatment required in that period. The results of this calculation can be used as a recommendation that forest areas should not be converted into agricultural land and should be better maintained as forest areas.

3. Analysis of Environmental Management Strategies on Economic Losses Due to Landslides

Economic assessment and estimate of lost use as inserting key in environmental management strategy analysis. SWOT analysis is a form of situational analysis that systematically identifies the strengths, weaknesses, opportunities, and

threats of an organization and its environment in order to formulate organizational strategies (Istiqomah & Andriyanto, 2017). The analysis is carried out by identifying problems in the form of a matrix to determine the strategy that is appropriate for the existing factors. The analytical approach using the SWOT analysis matrix can be seen in Table 1 (Sarsby, 2012)

III. RESULT AND DISCUSSION

A. Result

1. Agricultural Economic Valuation of Forest Area Conversion as Agricultural Land

Agriculture activities provide economic benefits for farmers so that they are considered economically feasible. The calculation of farm income can be seen in Table 2. Farm income is calculated by calculating the difference between total farm income per year in one hectare and the farming costs incurred per hectare in one year. Commodities developed by each farm include potatoes, carrots, cabbage, broccoli, leeks, and chilies. Potatoes have a harvest season of 3 times per year, carrots 2 times per year, leeks 4 times per year, cabbage 3 times per year, and chili 12 times per year. Chili peppers and leeks were chosen to be inter-crops planted between the main crops.

It can be seen in Table 2 that within one year and one hectare area, farming costs amounted to IDR 155,930,842.00. From the costs incurred, labor and seed costs are the largest cost components that need to be optimized to improve efficiency and profitability. The total revenue obtained from the sale of crops amounted to IDR 259,230,545.00. The profit from farming amounted to IDR 103,299,704.00

Table 1. SWOT analysis matrix

Internal External	Strength	Weaknesses
	Combining strengths and opportunities	Turning weaknesses into strengths
Opportunities	Using strengths to turn threats into opportunities	Eliminating both aspects of weaknesses and threats
Threats		

per year per hectare or, with a profit margin of 39.84%, this farming business is quite profitable. These results show that farming or activities carried out provide economic benefits for farmers. However, environmentally there are many impacts that arise both in the short and long term.

Table 2. Costs, revenue, and income of farming businesses

Cost	Cost per year per hectare
Seeds	IDR 63,991,136
Fertilizer	IDR 18,7448,33
Pesticides	IDR 10,418,706
Labor	IDR 51,152,574
Tools	IDR 11,623,592
Amount	IDR 155,930,842
<i>Revenue</i>	Revenue and income per year per ha
Sales income	IDR 259,230,545
Farm income	IDR 103,299,704

2. Estimation of Economic Losses Due to Landslides in the Utilized Area

The economic losses prediction due to landslides at observation location can be seen in Table 3. Table 3 presents estimates of losses (per hectare) due to landslides during each period at each observation locations. Table 3 shows that the largest losses occurred in observation locations 1, 2, and 6 amounting to IDR 219,180,000.00, IDR 125,128,571.00, and IDR 72,000,000, respectively.

Observation location 1 is located near Telaga Merdada, the occurrence of landslides will certainly cause greater losses if it damages the surrounding land and disrupts activities in the lake. Observation location 2 is in the vicinity of community agricultural land, landslides that occur can harm other community-owned agricultural land which of course will cause greater economic losses. Observation location 6 is located around the Steam Power Plant (PLTU) area, not a few community agricultural lands are located adjacent to the pipeline and PLTU area. If a landslide occurs, of course the losses incurred are very large, especially if

Table 3. Economic loss prediction due to landslides at observation locations

Obeservation location	Planting period (per ha)	Growing period (per ha)	Harvesting period (per ha)
1	IDR 219,180,000	IDR 352,900,000	IDR 1,192,377,381
2	IDR 125,128,571	IDR 234,954,762	IDR 1,192,377,381
3	IDR 17,312,500	IDR 65,680,556	IDR 131,454,167
4	IDR 15,800,000	IDR 20,200,000	IDR 51,400,000
5	IDR 21,992,000	IDR 30,397,333	IDR 74,188,000
6	IDR 72,000,000	IDR 131,450,000	IDR 355,893,333
7	IDR 61,708,333	IDR 118,425,000	IDR 290,425,000
8	IDR 30,416,456	IDR 58,026,697	IDR 160,154,955
9	IDR 56,500,000	IDR 94,000,000	IDR 254,000,000

the landslide damages the pipes belonging to the PLTU. In addition to economic losses, the danger that will occur as a result of damaged pipes will threaten the community. The losses that occur above are economic losses that occur during the planting period. The more the period increases, the greater the losses will be. The losses incurred at observation locations 3, 7, and 8 amounted to IDR 17,312,500.00 - IDR 61,708,333.00. Observation locations 7 and

8 are located in tourist areas where landslides will disrupt tourist activities. While observation location 3 is located around agricultural land with a very steep slope. If a landslide occurs at that location, it will have an effect on the livelihood of the community. Based on the results in Table 3, the average estimated economic loss for all agricultural land in the study area (per hectare) was calculated, as shown in Table 4.

Table 4. Estimation of economic losses due to landslides on agricultural land

Period	Component	Economic losses (per ha)
Planting period	Seeds	IDR 49,950,336
	Fertilizer	IDR 6,248,278
	Labor	IDR 3,920,243
Total		IDR 60,118,857
Growing period	Fertilizer	IDR 6,248,278
	Pesticides	IDR 3,472,902
	Labor	IDR 43,432,311
	Tools	IDR 11,623,592
	Number of planting period	IDR 60,118,857
Total		IDR 124,895,940
Harvesting period	Labor	IDR 3,800,021
	Harvest results	IDR 260,056,111
	Number of growing period	IDR 124,895,940
Total		IDR 388,752,071

Table 5. Estimation of economic losses due to landslides in 2019-2024

Year	Planting period (per ha)	Growing period (per ha)	Harvesting period (per ha)
2019	IDR 69,834,635	IDR 152,988,214	IDR 830,912,064
2020	IDR 73,850,127	IDR 161,785,036	IDR 878,689,507
2021	IDR 78,096,509	IDR 171,087,676	IDR 929,214,154
2022	IDR 82,587,058	IDR 180,925,217	IDR 982,643,968
2023	IDR 87,335,814	IDR 191,328,417	IDR 1,039,145,996
2024	IDR 92,357,624	IDR 202,329,801	IDR 1,098,896,891

Estimating economic losses at each time of the event gave different results. During the planting period the components needed are seeds, fertilizers, and labor. During the growing period, the calculation includes fertilizers, pesticides, labor, tools, and planting period total losses. Losses from the planting period are carried over and counted as part of the growing period losses. During the harvest period, the calculated components are labor, the harvest itself, and the total loss during the growing period. Of the three times of the incident, risk of landest loss occurred during the harvest period, which amounted to IDR 388,752,071.00. The loss during the harvest period was the largest because it was an accumulation of losses in the previous period. During the growing period, the loss amounted to IDR 124,895,940.00. While in the planting period the least loss was IDR 60,118,857.00. Losses during this period are small because the costs incurred or components calculated are still small. Economic losses due to landslides are calculated based on units per season per hectare. More details of the estimation of

economic losses incurred when landslides occur at the observed sample locations are shown in Table 4.

Estimation of economic losses due to landslides needs to be done for the next few years so that it can be a consideration for forest area managers and local governments in determining more appropriate policies and regulations. Table 5 shows the calculation of economic loss estimation in the year of the study, which is 2019. The estimation of economic losses in the following 6 years is calculated using the concept of time preference due to time differences that affect the value of money. The estimation of economic loss due to landslide in 2019-2024 can be seen in Table 5 below.

3. Environmental Management Strategy for Potential Landslide Disaster in Dieng Plateau Forest Area

The utilization of forest areas into agricultural land further triggers the potential for landslides. For this reason, an appropriate environmental management strategy is needed

Table 6. Matrix of environmental management strategies in Dieng Plateau

	Internal	Strength	Weakness
		- Soil fertility - High land productivity - Superior quality of agricultural products	- Lack of availability of agricultural land - Continuous tillage system - Disaster prone areas
External	Opportunity	- Cultivation of superior commodities - Utilization of certain types of trees to support agroforestry based tourism or landscape based tourism - Implementing mixed cropping systems on agricultural land	- Planting plants that can improve soil quality - Training and socialization to optimize the potential of nature tourism as employment for local communities - Intensive monitoring of land and resource utilization
	Threats	- Rehabilitation of damaged land - Educate farmers on better tillage	- Establishment of a disaster response team - Monitoring of agricultural activities around forest areas

to deal with these problems. The environmental management strategy is determined through SWOT analysis. The results of the SWOT analysis can be seen in Table 6.

B. Discussion

1. Agricultural Economic Valuation of Forest Area Conversion as Agricultural Land

Agricultural valuation analysis aims to determine the income of the community from the results of farming carried out in forest areas (Artani et al., 2019). Based on the Central Java Statistics Agency's report, this crop contributes 58% to the total potato production in Central Java. Agricultural activities have caused severe environmental degradation, leading to declining crop productivity in both quality and quantity over time. Additionally, intensive agricultural activities can lead to a decrease in the availability of nutrients for plants, such as nitrogen, phosphorus, and potassium, which are necessary for growth. Consequently, this can result in declining crop yields over time. Furthermore, land use changes from agriculture to non-agriculture can also reduce the available agricultural land area, thereby affecting agricultural productivity. We identified land hunger and land grabbing of forest conversion as a key threat. For example (Curtis et al., 2019), highlight how deforestation due to population pressures increases landslide activity and the role of land use changes, such as plantation development, in amplifying landslide risks in forested regions. In addition to the decline in land productivity, the threat of landslides that would cause economic losses for farmers should also be a concern. This is due to the loss of business capital due to crop failure (Arrogante-Funes et al., 2021; Kasno, 2020; Mandal et al., 2023; Woniala & Nyombi, 2014; Zhang et al., 2021; Zhang et al., 2021).

Variables that can be seen for the success of agricultural production include fertilizers, pesticides, and also labor. Fertilizers are used during the land preparation period, during land preparation the fertilizer used is organic fertilizer, while during the planting period

the fertilizer used is inorganic fertilizer. The fertilizer needs of each farmer are different. Pesticides used by farmers in the dry and rainy seasons are different. In the rainy season farmers need a lot of pesticides because of the increase in pests during the season, while in the dry season, farmers only use half of the pesticides needed in the rainy season. Pesticides are mixed with water and sprayed for 5 days a week using a suction device connected to a pipe to collect water from water sources or ponds. The tools used in agricultural activities are hoes, sickles, and water suction equipment from the lake. The total cost incurred by farmers for the provision of tools averaged IDR 3,000,000.00, the provision of tools is done at the beginning of land clearing or assumed to be the beginning of the planting season, at the beginning of the year. The labor required in one hectare varies in number according to what is needed by the landowner.

Similar research conducted on agricultural land in Bandung showed that the most costs were incurred in the cost of seeds, where potato seeds are a commodity that requires large capital. In addition, labor costs are also mostly incurred in land processing, planting, fertilizing, maintenance, watering, and harvesting activities. This is because the labor used is outside the family and requires wages (Rahmah & Wulandari, 2021). Economically, agricultural activities are feasible because they provide economic benefits for farmers. Income from farming plays a role in increasing the country's foreign exchange, is able to play a role in the absorption of labor for a growing population, and at the same time encourages regional development and regional economic growth and the national economy (Mangatas, 2021). On the one hand, agriculture in the Dieng Plateau is able to raise the dignity of farmers economically, but on the other hand it also creates a real socio-economic gap. Wealthy farmers who have large capital are able to become potato masters by planting the commodity on a very large area, while small farmers are increasingly alienated (Turasih, 2019).

2. Estimation of Economic Losses Due to Landslides in the Utilized Area

Areas utilized for activities are protected forest areas that have important functions in maintaining the balance of ecosystems and the environment (Saidah et al., 2021). The loss of protected areas causes an increase in erosion, landslides, and increases the volume of nutrients discharged into the lake due to high fertilizer use in agriculture (Noywuli, 2023; Soeprbowati et al., 2021). For this reason, an estimation of economic losses borne by farmers if landslides occur in the area is carried out. In estimating the amount of losses incurred due to landslides, the assumption of landslide occurrence time is used, namely during the planting period, growing period, and harvest period.

This research shows that as the year increases, the economic loss due to landslide on agricultural land increases, this is due to the increasing time of money. Landslides are one of the factors that cause economic losses in agricultural land, including direct losses such as partial or complete destruction of agricultural production and loss of land and/or reduction in land value (Bhandari et al., 2021; Perera et al., 2018). This event shows that the economic costs incurred due to landslides are increasing over time, particularly due to the conversion of agricultural land into less land and the greater losses experienced as a result of landslides (Shakya et al., 2023; Zumpano et al., 2018).

Disaster-related losses are estimated both retrospectively and through projections of potential future impact. (Zumpano et al., 2018). Estimation of economic losses due to landslides using the concept of time value of money. Time Value of money means that money has a time value. The value of money changes over time; hence, its future value differs from its present value. The method of valuing money in the future is the calculation of money owned today and invested with the determination of interest so that it undergoes a process of interest (compounding) so that the value will change in the future (Oktavia et

al., 2023). Table 5 shows that the losses Due to Landslides in the Utilized Area incurred would be different based on the time of landslide. The prediction of losses due to landslides is done for 6 years. The difference in time dimension will certainly lead to differences in the calculated value of money so that interest rates are used to predict the value of money according to the estimated period.

The Dieng Plateau has a height and slope that can potentially cause erosion and runoff. The phenomenon of erosion can also trigger various forms of threats to living things, ranging from property and infrastructure losses (Soeprbowati et al., 2021; Soeprbowati et al., 2021). The occurrence of erosion on a large area scale can cause landslides. According to previous studies, the erosion rate on the Dieng Plateau is generally very high, exceeding 480 tons/ha/year and is exacerbated by high intensity rainfall in the rainy season (Sari et al., 2021). High erosion rates result in significant economic losses, particularly in agricultural areas, where soil fertility declines and crop yields are reduced (Shakya et al., 2023). Landslides are one form of advanced erosion that is often overlooked by the community in Dieng, who generally lack resilience to land degradation processes, thus endangering livelihood sustainability (Rudiarto et al., 2020). This disaster has negative impacts, including decreased land productivity due to environmental imbalance and have led to slope instability (Advenia & Rahayu, 2023; Perera et al., 2018).

The inability to manage land degradation exacerbates the economic burden, as agricultural productivity continues to decline, leading to further livelihood insecurity for the community (Nguyen et al., 2023; Tadesse & Hailu, 2024). The most common erosion is furrow erosion which occurs up to 50%. While the average incidence of landslides in the rainy season is 38%. Besides affecting agricultural areas, landslides also have the potential to hit residential areas (Shabbir et al., 2023). Based on historical data, the Dieng area has at least three potential natural disasters, namely earthquakes,

landslides, and toxic gas disasters (Sumotarto et al., 2023; Wardoyo et al., 2021). These potential disasters have been proven to have a detrimental impact on the community including material losses, disruption of people's daily activities and even loss of life (Indrayati, 2013; Maesaroh & Suwarno, 2022; Zumpano et al., 2018).

A study conducted in Cibanteng Village, Cianjur showed that indirect economic losses due to landslides on agricultural land reached IDR 352,811,700 and IDR 1,205,152,300 for indirect losses in 2.5 years (Abidin et al., 2019). Other research with other types of natural disasters such as flooding showed that economic losses resulted in a reduction in crop yields of IDR 1,639,666.00/ha/year (Hanifah & Putri, 2022). Predicted losses of farmers due to landslides experienced by residents of Hargotirto Village, Kulonprogo Regency reached the highest value of IDR 220,460,000, - due to the relatively large agricultural land so that it can produce relatively many agricultural products. For the lowest value reached a value of IDR 60,900,000, - because the agricultural land is not so extensive so that the agricultural production produced is relatively small (Retnowati, 2104). The larger the farm, the greater the loss. This study shows that the longer the duration of the landslide, the higher the losses incurred. Losses during the planting season are lower than during the harvest season due to capital accumulation.

Moreover, maintaining the ecological integrity of forests has been identified as a cost-effective strategy for preventing soil erosion and reducing the economic risks associated with landslides (Soeprbowati et al., 2021; Suprpto et al., 2022). Sustainable forest management and reforestation efforts, especially in areas prone to landslides like Dieng Plateau, are crucial for safeguarding both the environment and local economies (Sari et al., 2021; Soeprbowati et al., 2021).

The prediction of economic loss due to landslides can be used as a consideration for farmers not to conduct activities in forest areas because it damages the function of the

forest as a protected area. If the forest area is maintained, the protection function and prevention of landslides can continue so that large economic losses to farmers due to landslides can be avoided (Pathak et al., 2025; Tarolli & Straffelini, 2020).

3. Environmental Management Strategy for Potential Landslide Disaster in Dieng Plateau Forest Area

Good environmental management is needed to manage forest areas that have been converted into agricultural land (Cahyani, 2020). The purpose of environmental management is to control and prevent greater impacts. Currently, landslides have often occurred on the Dieng Plateau. This suggests a decline in the area's environmental quality. The strategies that can be formulated based on the analysis that has been carried out are as follows:

SO (Strength & Opportunity) Strategy

The SO (Strength & Opportunity) strategy was created to maximize the strengths and opportunities. The high soil fertility in the area can be utilized to plant species that have many advantages. Planting superior commodities can increase farmers' income because the price offered is high according to the quality (Dabutar & Husein, 2022). The Dieng Plateau has high land productivity so that superior commodity cultivation has high potential to be developed in the area. The cultivation of superior commodities such as potatoes and vegetables in highland areas has been proven to increase farmers' income due to higher selling prices that correspond to product quality. Studies in the highlands of Himachal Pradesh, India, have shown that the use of improved potato varieties increases productivity and harvest quality, resulting in a significant increase in farmers' income (Roy et al., 2021).

Moreover, research in the Andes highlands of Peru reports that the development of local vegetable varieties resistant to cold climates has enhanced both the economic value and welfare of farmers (Aguilar-Luis et al., 2024). These superior commodities

not only provide economic benefits but also support the sustainability of agricultural systems in environmentally vulnerable areas. These superior commodities not only provide economic benefits but also support the sustainability of agricultural systems in these environmentally vulnerable areas. However, it is important to consider that potato plants require a substantial amount of water and are typically cultivated using a contour-cutting planting system (Abebe & Temam, 2024; Arifin et al., 2021). For this reason, the development of other superior commodity cultivation is recommended.

In addition to planting superior commodities, improvement of the mixed planting system is also recommended, in addition to providing additional benefits for farmers, trees planted around agricultural land have a positive impact on the environment, the smallest impact is to provide coolness which is now starting to be felt less (Yu et al., 2025). One type of plant that can be considered to prevent landslide and improve soil quality are *Schima wallichii* and *Ficus* spp. *Schima wallichii* is a high-altitude tree species whose roots and litter reduce surface erosion and enrich the soil, improving its structure and fertility (Fardhani, 2021). *Ficus* spp. offer effective solutions to restore soil fertility and ecosystem functions (Hendrayana, 2025).

The Dieng Plateau is also known as a beautiful natural tourist attraction, the utilization of certain types of vegetation to support natural tourism around is highly recommended. The creation of lodging that offers a natural atmosphere surrounded by trees is currently in great demand, this is a potential to increase the income of the government and local communities. Tree planting in the Dieng Plateau area certainly has a positive impact on the biotic, abiotic and cultural environment.

WO (Weakness & Opportunity) Strategy

This strategy is made to provide solutions to weaknesses so that they become strengths through existing opportunities. As we know that tillage on agricultural land is carried out

massively, by cultivating the soil continuously from the preparation period to post-harvest (Liu et al., 2022). This activity has a negative impact on soil quality, due to the reduction of aggregates, loss of organic matter, and increased sedimentation of the chemicals used (Bonifacio et al., 2024; Lal, 2016). Improving soil quality is essential to prevent land degradation through planting crops that can improve soil quality.

Training and socialization are also important to provide knowledge to the community about the tourism potential that exists and can be utilized as community employment (Noviyanti & Nuruddin, 2020). The natural beauty of the Dieng Plateau has a lot of potential to be developed as a natural tourist attraction to enjoy the scenery and coolness. The opening of new jobs in the tourism sector will reduce the possibility of opening new land for agriculture so that deforestation can be suppressed. Optimization of existing tourism objects also needs to be done, to increase visitor interest and regional income from the tourism sector.

Abundant natural resources attract many investors and communities to exploit them. This is very threatening to the environment on the Dieng Plateau, so it needs intensive monitoring by responsible parties so that the utilization of existing resources and land remains in accordance with applicable regulations.

ST (Strength & Threats) Strategy

Frequent landslides in the Dieng Plateau area have long been complained about by the community. This shows that the environmental quality in the area has declined. Frequent landslides not only cause material losses but also disrupt people's daily activities. Rehabilitation of degraded land is very important to do before greater impacts occur (UNDP, 2019). Some sites have experienced land degradation due to the lack of rehabilitation, such as Nepal, which has similar conditions where forest conversion to agricultural land has caused decreased soil fertility and increased erosion (Thapa & Paudel, 2002). According to farmers' testimonies, some unproductive lands have been abandoned, and

these lands need to be rehabilitated to improve the quality of the land, especially to strengthen soil aggregates so that they are not prone to landslides when it rains. Improving the quality of the environment in terms of biotic and abiotic will also affect the quality of the cultural environment on the Dieng Plateau.

WT (Weakness & Threats) Strategy

The threat of landslides that occur frequently and are difficult to predict is very troubling to the community. For this reason, a possible strategy is the establishment of a local disaster response team. We recommend that the team have a clearer institutional framework with strong multi-stakeholder engagement. The team still will operate under the local disaster management agency (BPBD), with coordination involving forestry, agriculture, and community stakeholders. Authorization will align with Indonesia's national disaster management regulations (e.g., *Peraturan Pemerintah* No. 21/2008). This structure is supported by practices outlined in Geo-environmental Disasters for multi-stakeholder disaster response coordination. The funding source we proposed was from local government budgets, national disaster management funds (e.g., through Indonesia's BNPB), and partnerships with NGOs or international programs focused on disaster risk reduction. Community-based crowdfunding will also be explored to enhance local ownership, as suggested by Perera et al. (2018) in their study on community-level disaster recovery in Sri Lanka. This aims to provide ease of evacuation to the community if a landslide occurs. Establishing a community-based team can enhance local awareness and understanding of landslide risks. The formation of a team from the community is easier because of the bonds of care and communication that have been established. The formation of evacuation teams also provides employment for people who do not have jobs or agricultural land as the main livelihood on the Dieng Plateau. The existence of a disaster evacuation team is also able to attract tourists to visit because there is

a sense of security when traveling to the Dieng Plateau.

Given the high risk of landslides, effective oversight by local authorities is essential to prevent illegal forest clearing for agriculture. Clear regulation is needed, especially to improve land use systems and align spatial plans for effective landslide risk management. We need alignment between national spatial planning (RTRW Nasional) and regional spatial planning (RTRW Daerah) policies to ensure cohesive land use management in landslide-prone areas. This aligns with findings from Varkkey et al. (2018), who emphasize the role of policy coherence in mitigating environmental degradation in forested regions. Specific recommendations for stricter zoning regulations, incorporation of landslide susceptibility maps, and capacity-building for local authorities to enhance compliance. These measures are supported by Bottaro et al. (2022), who highlight the importance of spatial planning in mitigating hydrogeological hazards in mountain forests. Law enforcement and strict sanctions on perpetrators of illegal encroachment of forest areas must also be enforced. Supervision aims to maintain the forest ecosystem so that the quality of the environment on the Dieng Plateau does not decline, because the decline in environmental quality can increase the potential for natural disasters due to human activities.

Conversion of forest areas into agricultural land in the Highlands has significant impacts on environmental degradation, particularly through increased landslide risks, declining land productivity, and soil degradation. Intensive agricultural practices, such as excessive use of fertilizers and pesticides as well as contour-cutting planting patterns, exacerbate erosion levels and threaten the sustainability of the agricultural system in this region. Economic loss estimations indicate that the highest financial impact occurs when landslides take place during the harvest period. The apparent increase in loss values over time does not reflect an escalation in landslide frequency or magnitude, but is solely the result of the time value of money, in

which future losses are valued higher under the applied economic projection model. Therefore, the increasing trend should be interpreted as an economic effect rather than a physical increase in landslide risk. Therefore, appropriate and sustainable environmental management strategies are necessary to minimize these risks.

IV. CONCLUSION

Agricultural activities in the Dieng Plateau Forest Area provide profits or income from farming of IDR 103,299,704.00 per year per hectare. The negative impact of these activities is the risk of landslides on agricultural land which causes different losses during the planting, growing, and harvesting periods. Of the three times of occurrence, the highest loss occurred during the harvest period which amounted to IDR 388,752,071.00. Losses during the growing period amounted to IDR 124,895,940.00. While during the planting period the least loss was IDR 60,118,857.00. The frequency of landslides is directly correlated with increased economic losses. Based on the SWOT analysis, several strategies can be implemented to support sustainable community development. Planting superior and mixed crops can increase farmers' income while improving soil quality. Community training and socialization play an important role in raising awareness of tourism potential and creating local jobs. Land rehabilitation efforts are needed to prevent further degradation, supported by community-based teams that strengthen awareness and preparedness for landslide risks. Finally, clear and consistent regulations are essential to optimize land use and ensure effective landslide risk management.

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