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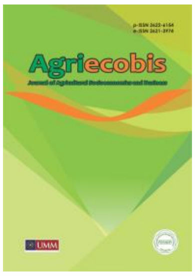

Research Article

The Effect of Land Slope Level on Productivity of Pujon Agroforestry

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ABSTRACT

The slope of the land can influence accessibility, water movement, and soil characteristics, thereby affecting the productivity of agroforestry plants. This study aims to analyze the effect of land slope on agroforestry productivity. The methods employed included field observations and questionnaires to collect data. A total of 100 farmers from various locations participated as respondents in this study. Regression analysis was conducted to determine and compare the influence of land slope on the productivity of agroforestry crops. The results of the analysis indicated that land slope does not significantly affect land productivity. The highest net income for farmers on slopes of 15-30% was from chili crops, amounting to Rp 76,987,600 per year with a B/C Ratio of 2.97, while the lowest was from cauliflower crops, with an income of Rp 31,586,800 per year and a B/C ratio of 1.74. The distribution of plant species across different slope levels was relatively uniform. Thus, the slope of the land does not have a significant effect on the success and productivity of the agroforestry system.

INTRODUCTION

Studying the level of land slope in relation to agroforestry productivity is essential for understanding the relationship between land topography and the success of agroforestry systems. Optimal utilization of forest land at varying slope levels for the production of agroforestry, wood, non-timber forest products, and environmental services is crucial for improving community welfare while ensuring sustainability. The productivity of agroforestry on different slopes varies according to their shape and characteristics. Slope shape significantly impacts the rate of erosion and soil loss (Abhishek et al., 2019). Research indicates that concave and complex slopes experience less soil loss compared to equivalent uniform slopes, whereas convex and complex slopes exhibit higher erosion rates (Alice, 2016; Alice et al., 2018). Agroforestry, which involves the combined and/or sequential use of forest land for agricultural and forestry activities, aims to maintain forest and environmental functions (Doe & Johnson, 2018).

The implementation of agroforestry is anticipated to enhance farmers' welfare while addressing global warming, environmental degradation, and poverty (Debashis et al., 2017). The agroforestry system is designed to provide economic and social benefits, thereby improving community welfare. Additionally, agroforestry ensures sufficient food availability, supplies raw materials for biofuels, and fulfills ecological functions for the community (Tamrin et al., 2017). Primarily, agroforestry is expected to optimize sustainable land use, guaranteeing and enhancing community needs, and increasing the ecological carrying capacity, particularly in rural areas (Khofifah et al., 2017).

The level of land slope can affect agroforestry productivity by influencing several crucial factors related to plant growth and production. On steep land, water tends to flow more quickly and does not absorb into the soil properly, leading to dryness in plants and reduced productivity (Brown, 2021; Sedigheh et al., 2023). Plants on steep land also face challenges in accessing water, necessitating the use of proper irrigation techniques. Additionally, steep land is prone to erosion, which can strip away the fertile topsoil layer and diminish nutrient availability, thereby affecting plant productivity (Bautista & Garcia, 2019; Abisola et al., 2021). When studying the impact of land slope on agroforestry productivity, it is important to consider factors such as the types of plants cultivated, planting patterns, water management, and suitable management techniques for steep land conditions.

In general, plants suitable for planting on land with a slope greater than 15 degrees are those resistant to erosion, such as woody plants with strong root systems. Additionally, land management techniques, such as terracing and contour cropping, are employed to minimize erosion and maintain soil fertility (Farooq et al., 2019; Duraisamy et al., 2020). Examples of forestry plants include pine trees (Pinus merkusii Jungh. et de Vriese), while agricultural plants include chicory, chayote, cucumber, taro, ginger, banana, durian, and jackfruit. Agroforestry-based land patterns aim to enhance farmers' abilities in cultivating various plant species, thereby increasing their income. The role of agroforestry extends beyond providing income; it also serves an ecological function in mitigating flooding and landslides (Claire et al., 2018; Garcia & Lee, 2023).

To study the effect of land slope on agroforestry productivity, it is essential to directly measure parameters such as erosion rate, soil fertility, water availability, and plant productivity. This approach enables the assessment of land suitability for agroforestry systems and the identification of appropriate techniques and plant species for the terrain (Ickowitz et al., 2019; Chukwuebuka et al., 2020). Understanding these relationships can provide more effective land management recommendations. The purpose of this study is to examine agroforestry farming and the relationship between land slope and agroforestry crop productivity, with the goal of determining the impact of slope on agroforestry production.

METHOD

Sampling among agroforestry farmers was conducted using a non-probability sampling method, indicating that not every member of the population had an equal chance of being selected. This approach was necessary because the total population of research respondents was unknown. The Slovin method was employed to determine the appropriate sample size, ensuring that the sample could adequately represent the entire population. For this research, a tolerance limit of 10% was adopted, corresponding to an accuracy level of 90%. Slovin's formula is as follows (Wythoff, 2018):

$$n = \frac{N}{1+N(a)^2}$$

$$n = \frac{6148}{1+6148(0.1)^2}$$

$$n = 98,399$$

Respondents were rounded up to 100 farmers.
Where:
n = sample
N = population
e = standard error value (10%)

Data collection in the Pujon Malang District, East Java, Indonesia, utilized a non-probability sampling method (Vehovar et al., 2016). This approach implies that each member of the population did not have an equal chance of being selected as a sample because the exact number of respondents available to complete the research questionnaire was unknown. According to Sugiyono (2018), a questionnaire is a data collection technique that involves asking respondents questions to obtain relevant information that meets the research needs. Data was collected directly from the research location, and field surveys included measurements of land slope levels, topographic data, and plant productivity data, providing a more in-depth understanding of the interaction between land topography and agroforestry productivity.

Data analysis was conducted using both descriptive and quantitative methods. Descriptive analysis provided an overview of the background for selecting plant types, general respondent data, and data on farmers' income and expenditure in forest use. Quantitative analysis was used to quantify these aspects and identify patterns or correlations. The following equation was employed for the analysis (Edy et al., 2023; Sutarni & Fitri, 2023):

$$TR = P \times Q$$

Where:
TR = (Total Revenue)/total revenue
P = (Price) Selling price on site or in the market
Q = (Quanty) Production amount

To calculate farmer profits, use the formula:

$$\Pi = TR - TC$$

Where:
TC = (Total Cost) costs of planting, maintenance, labor, etc.
Π = Profit from food and non-timber crops.
TR = (Total Revenue) total revenue.

To find out how much correlation and influence the independent or independent variables have on the level of land slope on agroforestry productivity (Y), namely: land (X1), erosion (X2), sustainability (X3), on productivity (Y).

$$Y= a + B1X1 + B2X2 + B3X3 + e$$

Information:
Y = Productivity
a = constant
B1-3 = regression coefficient X1-X3
X1 = Land
X2 = Erosion
X3 = Sustainability

RESULTS AND DISCUSSION

Observation results table, the number of male respondents was 79 people and 21 female respondents, a total of 100 respondents were sampled in this study.

Table 1. Characteristics of Respondents

No	Characteristics	Number of Farmers	Presentation
Gender			
1	Man	79	79.00 %
2	Woman	21	21.00 %
	Total	**100**	
Age			
1	15 – 64	91	91.00 %
2	>64	9	9.00 %
	Total	**100**	

Source: processed data

Based on the data presented in the table, 91 respondents (91% of the total) fall into the productive working age category, whereas 9 respondents (9% of the total) belong to the non-productive working age category. This indicates that the majority of farmers possess strong physical capabilities, enabling them to effectively manage forests and thereby enhance their agricultural income. This finding aligns with Nurfatriani et al. (2023) and Wulandari et al. (2023), who assert that farmers' physical strength aids in forest management and has the potential to increase agricultural revenue.

Agroforestry Commodities at Land Slope Level

Farmers implement an agroforestry system, where each cultivates multiple or different types of plants on a single plot of land. The agroforestry crops planted on slopes ranging from 0-45˚ include chilies, carrots, cabbage, cauliflower, mustard greens, tomatoes, and ginger. Additionally, the land supports tree species such as sengon (*Albizia chinensis*), mahogany (*Swietenia mahagoni*), suren (*Toona spp.*), jackfruit (*Artocarpus heterophyllus*), and avocado (*Persea americana*). Annual plants like various vegetables, such as cabbage, mustard greens, chilies, and carrots, are grown during the rainy season. Farmers prefer vegetable cultivation due to the presence of a central vegetable trading market, which facilitates easier marketing of their produce.

Agroforestry Farmer Income

The farming analysis in this study was conducted on three land models for various agricultural commodities. The analysis included assessments of revenue, total costs, income, and the benefit-cost (B/C) ratio as measures of feasibility. Table 2 presents the farmer income at different land slope levels using the agroforestry pattern.

Table 2. Agroforestry Farmer Income

Plant Type	Total revenue (TR)	Total cost (TC)	Income ha/year (µ)	B/C Ratio
Slope 15-30%				
Chili	116,067,600	39,080,000	76,987,600	2.97
Carrot	91,708,200	37,740,000	53,968,200	2.43
Cauliflower	74,166,800	42,580,000	31,586,800	1.74
Tomato	76,114,132	43,246,668	32,867,468	1.76
Mustard	67,204,444	23,780,000	43,424,444	2.83
Cabbage	91,034,000	39,580,000	51,454,000	2.30
Average	**86,049,196**	**37,667,778**	**48,381,419**	**2.34**
Slope 30-45%				
Chili	89,499,310	32,471,000	57,028,310	2.76
Ginger	79,611,520	32,851,000	46,760,520	2.42
Tomato	66,758,632	25,483,222	41,275,410	2.62
Cabbage	49,647,570	27,309,000	32,338,570	1.82
Carrot	94,989,360	39,691,000	55,298,360	2.39
Average	**76,101,278**	**31,561,044**	**46,540,234**	**2.41**
Moisture >45%				
Carrot	82,104,400	29,180,000	52,924,400	2.81
Ginger	89,971,800	40,580,000	49,391,800	2.22
Cauliflower	77,931,400	39,380,000	38,551,400	1.98
Mustard	75,991,200	32,580,000	43,411,200	2.33
Tomato	50,476,600	18,046,668	32,429,932	2.80
Average	**75,295,080**	**33,153,334**	**43,341,746**	**2.28**

Source: processed data

In Table 2, the highest average net income of farmers on a slope of 15-30% was obtained from the chili commodity, amounting to IDR 76,987,600 per year, while the lowest was from the cauliflower commodity, at IDR 31,586,800 per year. The limited number of cauliflower farmers, small land areas, and high maintenance costs contribute to this lower income. Conversely, many farmers cultivate chilies on this slope, resulting in high productivity and substantial yields, reflected in a benefit-cost (B/C) ratio greater than one, indicating the profitability of the agroforestry pattern at various slope levels. According to Adityas et al. (2018) and Zahroh (2022), chili farming is more profitable and economically viable than cauliflower farming due to supportive revenue analysis, technological advancements, and sustainable agricultural practices. This is related to erosion, productivity, and sustainability of agroforestry, as presented in Table 3.

Table 3. Correlation of Land Slope Level on Productivity and Sustainability

		Land Slope	Erosion	Continuity	Productivity
Land Slope	Pearson Correlation	1	0,854	0,797	0,128
	Sig. (2-tailed)		0,000	0,000	0,242
	N	86	86	86	85
Erosion	Pearson Correlation	0,854	1	0,771	0,152
	Sig. (2-tailed)	0,000		0,000	0,164
	N	86	86	86	85
Sustainability	Pearson Correlation	0.797	0,771	1	0,294
	Sig. (2-tailed)	0.000	0.000		0,064
	N	86	86	86	85
Productivity	Pearson Correlation	0.128	0,152	.294	1
	Sig. (2-tailed)	0.242	0,164	,064	
	N	85	85	85	85

Source: processed data

The basis for decision-making is that if the significant value is <0.05, it is considered correlated; if the significant value is >0.05, it is not considered correlated (Wu et al., 2020). According to the table above, it can be concluded that land slope and productivity are not correlated. This is confirmed by the Pearson correlation result of 0.128, indicating a low degree of relationship (0.00 to 0.20). Additionally, the significant value for the relationship between agroforestry composition and profits is 0.2, which is greater than 0.05, thus indicating no correlation. This lack of correlation is attributed to the similarity in plant types across different land slope classifications at the research location. Consequently, the income remains consistent because the crops and market prices are similar. Therefore, it can be concluded that land slope has no relationship with land productivity. In contrast, Aninda et al. (2022) and Cavassin Diniz et al. (2018) found a relationship between productivity and land slope in their research.

Table 4. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0,591 [a]	0,349	0,325	5,577

Source: processed data

Based on the coefficient of determination test results, the R Square value is 0.349, indicating that 34.9% of the variations in productivity are explained by the existing variables. These results demonstrate that land slope, erosion, and sustainability account for only 34.9% of the influence on productivity, while the remaining 65.1% is influenced by other variables, as presented in Table 4.

Table 5. t-test Analysis

Variable	Productivity			Information
	B	t	Sig	
Constant	10.513	4.263	0.000	
Land	0.250	1.544	0.125	Not Significant
Erosion	-0,134	-0.544	0.587	Not Significant
Sustainability	0.209	2.526	0.013	Significant

Source: processed data

Based on the results of the equation in the table above, the following equation can be obtained:

$$Y = 10.153 + 0.25X1 – 1.34X2+ 0.209X3$$

Where:
Y = Productivity
X1 = Land
X2 = Erosion
X3 = Sustainability

The analysis of the multiple linear regression equation revealed that the constant value is 10.153. This result indicates that when land slope, erosion, and sustainability are zero, the company value changes by 10.153%. The regression coefficient analysis shows that the land slope (X1) has a positive regression coefficient value of 0.25 for the productivity variable. This means that an increase of 1 unit in the land slope, with other independent variables held constant, will increase the company value by 0.25. The erosion regression coefficient (X2) has a negative value of -4.020, indicating that an increase of 1 unit in the erosion variable, with other independent variables held constant, will decrease the company value by 4.020. For the sustainability regression coefficient (X3), a positive value of 0.29 was found. This suggests that an increase of 1 unit in the sustainability variable, with other independent variables held constant, will increase the company value by 0.29. Based on the significance levels, erosion and land slope variables do not have a significant effect on productivity. However, Bhandari et al. (2021) and Pierce & Lal (2017) assert that the degree of erosion and other land-related factors significantly impact agricultural production. The sustainability variable does have a significant effect on productivity, as its significance value is smaller than 0.05.

Slopes in agroforestry exhibit varying productivity based on their shape and characteristics. Concave and complex slopes experience less soil loss but higher erosion rates compared to equivalent uniform slopes (Minsuk et al., 2020; Evgenia, 2022). Agroforestry has been shown to reduce energy expenditure and increase productivity during wood harvesting (Nyanchi, 2019; Pawel et al., 2022). Implementing agroforestry systems on slopes can control erosion and landslides by strategically arranging trees and plants according to the morphological units formed by previous landslides (Madaline et al., 2021; Mengistu et al., 2021). Despite the significant impact of slope on agroforestry productivity, some studies suggest that slope does not have a significant effect on productivity. However, using agroforestry on slopes to control erosion and landslides by arranging vegetation based on past morphological units remains beneficial (Rasu et al., 2021). Overall, integrated agroforestry systems and effective soil fertility management play crucial roles in maintaining soil fertility and promoting sustainable crop production.

CONCLUSION

Agroforestry crop commodities planted on slopes ranging from 0-45˚ in Pujon include chilies, carrots, cabbage, cauliflower, mustard greens, tomatoes, and ginger. These crops grow under a canopy of multiple tree species (MPTS) such as sengon (Albizia chinensis), mahogany (Swietenia mahagoni), suren (Toona spp.), jackfruit (Artocarpus heterophyllus), and avocado (Persea americana). Vegetable plants on slopes of 15-30% have a B/C ratio of 2.34, on slopes of 30-45% a B/C ratio of 2.41, and on slopes above 45% a B/C ratio of 2.28. The finding that the slope of the land does not significantly affect productivity provides valuable new insights for the development of sustainable agroforestry practices. Understanding the relationship between land slope and agroforestry productivity can help in developing strategies to optimize agroforestry systems across various topographies.

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