

JURNAL AGROEKOTEKNOLOGI TERAPAN

Applied Agroecotechnology Journal

Agroteknologi Universitas Sam Ratulangi

e_ISSN:2797-0647

Farm Diversification And Factors Associated With Income Among Chili Pepper-Tomato Farmers in South Minahasa**Yolanda Pinky Ivanna Rori*, Jenny Baroleh, Jelly Ribka Danaly Lumingkewas**

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Manuscript received: 12 Aug 2026

Revision accepted: 15 Sept 2026

Abstract. Smallholder horticultural farms frequently combine crops to reduce exposure to production and market risk, yet a physically diversified farm may remain financially dependent on a single commodity. This study quantified diversification of chili pepper and tomato farming and examined socioeconomic and production factors associated with farm income in South Minahasa Regency, North Sulawesi. A cross-sectional survey of 30 farmers was conducted from March to November 2026. Diversification was assessed using the Simpson Diversification Index (SID) and Herfindahl-Hirschman Index (HHI), calculated separately for land allocation and net farm-income shares. Net farm income was defined as total revenue minus total production cost. Multiple linear regression evaluated associations of cultivated land area, formal education, farming experience, and labor use with farm income. The reported 50:50 land allocation produced an SID of 0.500, representing maximum evenness for a two-crop system. In contrast, reported net income was IDR 24,114,200 from chili pepper and IDR 1,975,733 from tomato per planting season, corresponding to income shares of 92.43% and 7.57%, respectively. These shares yielded an HHI of 0.860 and income-based SID of 0.140, indicating strong financial concentration in chili pepper. Land area, education, farming experience, and labor were each positively associated with farm income ($p < 0.05$), while the overall model was significant ($F(4, 25) = 1147.00$, $p < 0.001$; $R^2 = 0.995$). The findings show that balanced land allocation does not necessarily generate balanced income and suggest that diversification decisions should consider both physical cropping patterns and financial contribution.

Keywords: Crop diversification; Farm income; Horticulture; Simpson Diversification Index; Smallholder farmers.

INTRODUCTION

Smallholder agriculture operates under substantial production, price, and climate uncertainty, making income stabilization a central management challenge. Farm and crop diversification are therefore widely used as risk-management strategies because they spread production and market exposure across several activities rather than relying on a single enterprise. Empirical evidence shows that diversification can strengthen resilience to climatic shocks and reduce vulnerability, although the magnitude of

the benefit depends on household resources, markets, and local production conditions (Grilli et al., 2024; Matsuura et al., 2023; Mulwa & Visser, 2020).

The economic effects of diversification are not uniform. Greater crop diversity has been associated with lower downside income risk and improved income stability, but specialization can sometimes generate higher expected returns when one commodity is substantially more profitable. Evidence from Kenya, England and Wales, Italy, and France illustrates this trade-off between expected income, risk reduction,



and farm efficiency (Bozzola & Smale, 2020; Fabri, 2024; Harkness et al., 2021; Hien, 2025). Recent evidence also indicates that farmers may diversify for different reasons: poorer households often prioritize food security, whereas better-off farmers may use diversification to stabilize market income (Fujimoto & Suzuki, 2025).

Diversification decisions are shaped by both household characteristics and farm resource endowments. Farm size, education, human capital, labor availability, market conditions, and access to information can influence whether farmers diversify and how effectively they manage diversified systems. Studies of high-value crop diversification and smallholder systems have repeatedly identified farm size and education as relevant correlates of diversification decisions, while land and other productive assets determine the range of feasible livelihood activities (Antonelli et al., 2022; Birthal et al., 2020; Musumba et al., 2022; Tacconi et al., 2023).

The welfare implications are similarly context-specific. Crop and livelihood diversification have been linked to higher crop income, consumption, food security, and resilience in several developing-country settings, including Ghana, Niger, Uganda, Zambia, and the Philippines (Arslan et al., 2018; Asfaw et al., 2018, 2019; Bellon et al., 2020; Pede et al., 2024; Tesfaye & Tirivayi, 2020). These findings do not imply that diversification automatically increases income; rather, they indicate that the composition of activities, their relative profitability, and the household's ability to manage multiple enterprises are critical to the final economic outcome.

This distinction is particularly important in horticultural systems where a farm may allocate land relatively evenly across crops but still obtain most of its income from one commodity. Studies of smallholder diversification show that the economic contribution of individual

activities can remain highly uneven even within diversified farms, while market engagement and crop diversity interact with farm size and household characteristics (Anderzén et al., 2020; Basantaray et al., 2024; Mango et al., 2018; Morrissey et al., 2024). Accordingly, evaluating diversification only from the number of crops or physical land shares can overstate the degree of financial diversification.

South Minahasa Regency is an agriculturally important area of North Sulawesi where smallholder crop production contributes to rural livelihoods (Badan Pusat Statistik Kabupaten Minahasa Selatan, 2023). Chili pepper and tomato are high-value horticultural commodities, but their different prices and production economics may create unequal contributions to farm income. The original study data provide an opportunity to distinguish physical diversification from financial diversification and to assess whether farm and human-capital characteristics are statistically associated with farmers' income.

The contribution of this study lies in jointly evaluating two dimensions of diversification within the same chili pepper-tomato farming system: land allocation and net-income concentration. The study therefore aimed to (1) quantify diversification based on land allocation and commodity-specific net-income shares using the Simpson Diversification Index (SID) and Herfindahl-Hirschman Index (HHI), and (2) examine the associations of cultivated land area, education, farming experience, and labor use with farm income among the surveyed farmers in South Minahasa Regency.

MATERIAL AND METHODS

Study Area and Duration

The study was conducted in South Minahasa Regency, North Sulawesi Province, Indonesia, from March to November 2026. The location was



selected purposively because agriculture is an important rural livelihood and the area supports horticultural commodities, including chili pepper and tomato.

Research Design and Respondent Selection

A quantitative cross-sectional survey design was used. Primary data were obtained through farmer interviews using a structured questionnaire and direct observation of farming activities, while secondary information was obtained from relevant government sources and scientific literature. The target population used for the sample-size calculation comprised 56 chili pepper–tomato farmers in the study area. The sample size was determined using Slovin's formula, $n = N/(1 + Ne^2)$, with $N = 56$ and an error tolerance (e) of 12.5%, yielding $n = 29.87$; this value was rounded to 30 respondents. The 30 respondents were subsequently selected using simple random sampling from the target farmer population.

Variables and Farm-Income Measurement

The dependent variable was net farm income per planting season. The explanatory variables were cultivated land area (X_1 , ha), formal education (X_2 , years), farming experience (X_3 , years), and labor use (X_4 , person-days or HOK). Respondent age was summarized descriptively but was not included in the regression model. Net farm income was defined as the difference between total revenue and total production cost:

$$\pi = TR - TC \quad (1)$$

where π is net farm income, TR is total revenue, and TC is total production cost. Total revenue is the product of output quantity and selling price ($TR = P \times Q$). All monetary results are expressed in Indonesian rupiah (IDR) per planting season unless otherwise stated.

Diversification Analysis

Diversification was evaluated separately for physical land allocation and financial contribution. For each basis, the Herfindahl-Hirschman Index (HHI) and Simpson Diversification Index (SID) were calculated as:

$$HHI = \sum p_i^2 \quad (2)$$

$$SID = 1 - HHI = 1 - \sum p_i^2 \quad (3)$$

For the land-based index, p_i represents the share of total cultivated area allocated to commodity i . For the income-based index, p_i represents the share of total net farm income contributed by commodity i . Because only two commodities were evaluated, the maximum possible SID is 0.500, obtained when the two shares are equal (0.50 and 0.50). Therefore, SID values were interpreted relative to the two-commodity maximum rather than to a generic upper bound of 1. The reported net-income values for chili pepper and tomato were retained because they are internally additive and are the values used to reconstruct the income shares.

Regression and Statistical Diagnostics

Multiple linear regression was used to evaluate the statistical association between farm income and the four explanatory variables. The model was specified as:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \varepsilon_i \quad (4)$$

where Y_i denotes farm income for respondent i , β_0 is the intercept, β_1 – β_4 are unstandardized regression coefficients, and ε_i is the error term. Statistical significance was evaluated at $\alpha = 0.05$. The original regression output reported residual normality (Kolmogorov-Smirnov $p = 0.200$), variance inflation factors below 3.50, Glejser test p -values above 0.05, and a Durbin-Watson statistic of 1.880. These diagnostics were used as evidence that no major violation of the reported regression assumptions was detected. Because the study is



observational and cross-sectional, regression results are interpreted as associations rather than causal effects

RESULTS AND DISCUSSION

Respondent and Farm Characteristics

The 30 respondents represented a range of ages, education levels, farming experience, landholding sizes, and labor-use intensities. Their main characteristics are summarized in Table 1.

Table 1. Characteristics of the surveyed chili pepper-tomato farmers (n = 30)

Characteristic	Category	n	%
Age	< 30 years	2	6.67
	30-39 years	5	16.67
	40-49 years	9	30.00
	50-59 years	11	36.67
	≥ 60 years	3	10.00
Education	Primary school	1	3.33
	Junior high school	11	36.67
	Senior high/vocational school	16	53.33
	Diploma/Bachelor	2	6.67
Farming experience	< 10 years	3	10.00
	10-19 years	7	23.33
	20-29 years	12	40.00
	≥ 30 years	8	26.67
Cultivated land	< 0.50 ha	9	30.00
	0.50-0.99 ha	11	36.67
	1.00-1.49 ha	6	20.00
	≥ 1.50 ha	4	13.33
Labor use	< 20 HOK	2	6.67
	21-30 HOK	9	30.00
	31-40 HOK	13	43.33
	≥ 41 HOK	6	20.00

Source: Primary data processed by the authors, 2026. HOK = person-day of labor.

More than two-thirds of respondents were at least 40 years old, and 53.33% had completed senior high or vocational school. Most respondents had substantial farming experience, with 66.67% reporting at least 20 years in farming. The most common farm-size class was 0.50-0.99 ha (36.67%), while 43.33% used 31-40 HOK per planting season. These characteristics are relevant because farm size and human capital frequently shape production choices and diversification capacity. Cross-country evidence from South and Southeast Asia identifies farm size and education as important correlates of farm diversification, while African evidence similarly emphasizes land endowment as a determinant of livelihood portfolios (Musumba *et al.*, 2022; Tacconi

et al., 2023). High-value crop diversification also varies with household and spatial characteristics, reinforcing the need to interpret diversification within its specific farm context (Birtal *et al.*, 2020).

Land-Based and Income-Based Diversification

The original results reported an equal 50:50 allocation of land between chili pepper and tomato. For a two-crop system, this allocation produces the maximum possible SID of 0.500 because the two land shares are perfectly even. The financial pattern was very different. Table 2 presents the commodity-specific net-income values reported in the original dataset and the corrected shares used in this revision.



Table 2. Reported net farm income and corrected commodity income shares

Commodity	Net farm income (IDR/planting season)	Income share
Chili pepper	24,114,200	0.9243 (92.43%)
Tomato	1,975,733	0.0757 (7.57%)
Total	26,089,933	1.0000 (100%)

Note: Income shares were recalculated from the commodity-specific net-income figures in the original manuscript; $24,114,200 / 26,089,933 = 0.9243$ and $1,975,733 / 26,089,933 = 0.0757$.

The corrected shares sum to 1.0000 and show that chili pepper accounted for more than nine-tenths of reported net farm

income. Table 3 contrasts the physical and financial diversification measures.

Table 3. Diversification indices based on land allocation and net farm income

Basis	Chili pepper share	Tomato share	HHI	SID	Interpretation
Land allocation	0.5000	0.5000	0.5000	0.5000	Maximum evenness for two crops
Net farm income	0.9243	0.0757	0.8600	0.1400	Strong concentration in chili pepper

Note: $HHI = \sum p_i^2$; $SID = 1 - HHI$. For two categories, the theoretical maximum SID is 0.500.

The contrast between the two indices is the central finding of the diversification analysis. The farm system was physically balanced according to the reported land shares, yet financially concentrated in chili pepper. This pattern is consistent with the broader literature showing that diversification should not be interpreted solely as a count of activities or an even distribution of land. Relative prices, yields, production costs, and market opportunities determine whether diversified activities contribute evenly to income. Studies from Kenya and Europe show that diversification can reduce income risk even when specialization remains attractive for expected income, while recent evidence indicates that the economic payoff from diversification differs across farm-size and welfare groups (Bozzola & Smale, 2020; Fabri, 2024; Fujimoto & Suzuki, 2025; Hien, 2025).

The result also aligns with evidence that diversified livelihood portfolios can

improve income sufficiency or resilience without guaranteeing equal returns from every component. Smallholder studies in Mexico, Malawi, Ghana, and the Philippines show that the value of diversification depends on the composition of farm activities and their market contribution rather than on diversity alone (Anderzén et al., 2020; Bellon et al., 2020; Mango et al., 2018; Pede et al., 2024). For the South Minahasa respondents, the low income-based SID therefore indicates that tomato provided only a small financial buffer relative to chili pepper during the observed planting season.

Factors Associated with Farm Income

The regression results are presented in Table 4. All four explanatory variables had positive coefficients and p-values below 0.05. Because the design is observational, these coefficients are interpreted as conditional associations rather than causal effects.



Table 4. Multiple linear regression results for farm income

Variable	B	SE	t	p	Interpretation
Constant	3.250	1.120	2.902	0.008	Positive intercept
Land area (ha)	15.200	2.450	6.204	< 0.001	Positive association
Education (years)	0.280	0.132	2.121	0.044	Positive association
Farming experience (years)	0.180	0.081	2.222	0.035	Positive association
Labor use (HOK)	0.112	0.019	5.895	< 0.001	Positive association

Note: B = unstandardized coefficient; SE = standard error; HOK = person-day. Farm income in the regression model is reported on the original scale used in the statistical analysis.

Land area had the largest reported coefficient and was strongly associated with income ($B = 15.200$, $p < 0.001$). This direction is economically plausible because larger cultivated areas increase production capacity, although the realized income depends on crop choice, input intensity, yields, and prices. Empirical studies likewise show that farm size is an important determinant of diversification opportunities, farm performance, and livelihood choices (BIRTHAL et al., 2020; Hien, 2025; Musumba et al., 2022; Tacconi et al., 2023).

Education ($B = 0.280$, $p = 0.044$) and farming experience ($B = 0.180$, $p = 0.035$) were also positively associated with income. These variables capture different dimensions of human capital: formal education may support access to information and interpretation of market or technical advice, whereas accumulated experience can improve timing, input management, and responses to production uncertainty. Diversification research emphasizes the role of human and social capital in determining whether households can adopt and benefit from multiple farm activities (Antonelli et al., 2022; Grilli et al., 2024; Tacconi et al., 2023).

Labor use was positively associated with income ($B = 0.112$, $p < 0.001$). In horticultural systems, labor is required for land preparation, crop establishment, maintenance, harvesting, and postharvest handling; therefore, adequate labor can

support the management of multiple commodities. Nevertheless, labor requirements can also increase production costs, and the positive coefficient should not be interpreted as evidence that additional labor always raises profit. The result instead indicates a positive conditional relationship within the observed sample.

The overall model was statistically significant, $F(4, 25) = 1147.00$, $p < 0.001$, with $R^2 = 0.995$ and adjusted $R^2 = 0.994$. The reported assumption diagnostics were Kolmogorov-Smirnov $p = 0.200$ for residual normality, $VIF < 3.50$, Glejser $p > 0.05$, and Durbin-Watson = 1.880. Although these statistics indicate a well-fitting model in the available dataset, the extremely high R^2 together with a sample of 30 respondents warrants cautious interpretation and validation in a larger sample. Evidence from other contexts shows that diversification-income relationships are heterogeneous across households, climatic conditions, and welfare groups (Asfaw et al., 2018, 2019; Matsuura et al., 2023; Tesfaye & Tirivayi, 2020).

Implications for Applied Agroecotechnology

The results have a practical implication for farm planning: physical diversification and financial diversification should be monitored separately. A 50:50 crop-area allocation



can appear highly diversified while farm income remains concentrated in one commodity. Simple decision-support indicators such as land-share SID and income-share SID can therefore complement conventional farm-budget analysis by showing whether a diversified cropping pattern also diversifies financial returns. This is consistent with evidence that diversification can strengthen resilience and welfare when it is matched to household resources, market conditions, and risk exposure (Arslan et al., 2018; Asfaw et al., 2019; Harkness et al., 2021; Mulwa & Visser, 2020). For chili pepper-tomato farmers, extension and farm-management support could consequently emphasize commodity-level cost recording, market information, labor planning, and evaluation of income shares rather than promoting crop diversity as an objective in itself

CONCLUSION

Among the 30 surveyed chili pepper-tomato farmers in South Minahasa Regency, the reported 50:50 land allocation represented maximum physical evenness for a two-crop system ($SID = 0.500$), but the income structure was strongly concentrated in chili pepper. Corrected shares from the reported net-income values were 92.43% for chili pepper and 7.57% for tomato, yielding $HHI = 0.860$ and income-based $SID = 0.140$. Land area, formal education, farming experience, and labor use were each positively associated with farm income in the regression model, while the overall model was statistically significant. These findings indicate that balanced crop allocation does not necessarily produce balanced financial returns. Farm-diversification planning should therefore evaluate both the physical distribution of crops and the relative income contribution of each commodity. Future studies should use larger samples and repeated-season data to test the stability of these associations under changing prices, production conditions, and market risks.

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