Livelihood Diversity and the Impact on Farming Household Income in the Karst Region of Indonesia

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Abstract. Indonesia consist of diverse agroecosystems, including karst landscapes and it shapes household livelihood strategies and contribute to rural income inequality. Livelihood diversification serves as an adaptive mechanism to reduce vulnerability and enhance resilience. Currently the study about livelihood diversity in Indonesian karst agroecosystems remain limited. This research analyzes livelihood diversity patterns among farming households in the karst regions of Daerah Istimewa Yogyakarta and examines their relationship with household income. Data were collected from 72 households through a census using semi-structured interviews. The results revealed that most household heads were men, with more than half being of productive age. The household heads mostly had low educational attainment. Agriculture was the main occupation (91.7%), with 77.7% of households receiving remittances. The Simpson Index indicated moderate livelihood diversification by scoring 0.48, dominated by agriculture and remittance income. Regression analysis revealed that livelihood diversity, land size, and age of household head significantly influence income generating. Livelihood diversity and land size had positive effects, while age had a negative effect. Gender, education, and remittance showed no significant effects. The study underscores the importance of enhancing livelihood diversity and integrated income strategies to strengthen household resilience and promote sustainable rural development in karst regions.

1 Introduction

Indonesia is characterized by diverse landscapes, among which karst regions dominated by limestone formations stand out due to their fragile ecological conditions. These landscapes present unique challenges for agriculture and rural livelihoods, such as shallow soils, porous substrates, irregular water availability, and high susceptibility to drought mark them. Such

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biophysical limitations create marginal agroecosystems that are difficult to cultivate using intensive farming practices [1]. Therefore, the consequences of these conditions extend beyond agricultural production, defining socioeconomic structures, restricting livelihood choices, and contributing to rural poverty.

Gunungkidul Regency in Daerah Istimewa Yogyakarta (DIY) is the most prominent karst area. Unlike other regions in DIY, which are supported by relatively fertile soils or sandy coastal lands, Gunungkidul is primarily dominated by marginal karst formations that pose significant constraints to agricultural intensification [2]. Farmers in this region rely primarily on rainfed land, cultivating crops such as *gogo* rice (rainfed rice), secondary crops, and maintaining livestock [3]. However, agricultural yields are often unstable due to high rainfall variability and karst soils' limited water storage capacity. Consequently, farming households frequently diversify their activities by engaging in migration, nonfarm employment, or small-scale enterprises as alternative income sources. These strategies thus highlight the importance of livelihood diversification to sustain household welfare under environmental and economic uncertainty.

Livelihood diversification has been widely recognized as an adaptive strategy in rural areas. It is defined as the process through which households expand their range of economic activities and build social capacity to secure and improve their living standards [4]. Diversification serves as a buffer against agricultural risks such as crop failures, price fluctuations, and droughts, all of which are particularly acute in karst agroecosystems [5]. For farming households in Gunungkidul, the need to diversify is not merely a strategy for additional income but a necessity to mitigate vulnerabilities associated with the fragility of their natural capital, since some research reports that household expenditures are still dominated by consumption [6,7]. Furthermore, migration to urban areas has become a common livelihood strategy, with remittances essential in sustaining rural household economies and supporting poverty alleviation.

Several studies related to livelihood diversity have been conducted in the region, such as that by Haryono et al. [7], which describes various household adaptation activities in Gunungkidul, including seasonal planting, agroforestry, livestock rearing, migration, and underground river tourism. These activities are undertaken specifically to adapt to existing environmental challenges [7], and participation in diverse *off-farm* activities is crucial for increasing household income [6]. However, while diversification has been studied in various rural areas, research focusing specifically on marginal karst areas remains limited. Previous studies in DIY have shown variations in farming systems across agroecosystems, yet most analyses remain concentrated on fertile lowlands or sandy coastal lands. Moreover, existing studies on livelihood diversity tend to be purely descriptive and primarily focus on the diversification of crop types. As a result, this previous research fails to quantify the diversity level or empirically analyze the relationship between livelihood diversity and household income in marginal karst agroecosystems.

Consequently, this study addresses this critical gap and positions itself among the few to focus on livelihood diversity specifically in karst regions. Building on these considerations, the present research aims to: (1) identify livelihood activity patterns among farming households in the karst regions of Gunungkidul Regency; (2) measure livelihood diversity through the Simpson Index of Diversity, Shannon-Wiener Index, and Herfindahl-Hirschman Index; and (3) analyze the factors that determine the household income. By focusing on karst regions, this study provides empirical evidence essential for addressing the livelihood challenges of marginalized rural households and informing policies that support sustainable and inclusive rural development.

2 Research Methods

The study was conducted in Gunungkidul Regency, Daerah Istimewa Yogyakarta (DIY). This regency was selected purposively because it comprises the largest karst agroecosystem in DIY, covering an area of 807 km^2 [8]. The research was concentrated explicitly on Wotawati Hamlet, Girisubo, Gunungkidul, a location chosen based on particular criteria relevant to the research objectives. The purposive selection of Wotawati was considered due to its unique geographical and ecological characteristics. The hamlet is in the Bengawan Solo Purba River valley, bordered by karst hills, contributing to its remote location. Furthermore, ponors (sinkholes) emphasize the distinct karst topography, which directly impacts surface water availability and dictates local agricultural practices.

The livelihood profile of the households further supported the site selection. The household's reliance on agriculture within marginal, rainfed karst lands renders them highly susceptible to environmental shocks, providing a critical context for investigating adaptation strategies. Moreover, preliminary survey data indicating a substantial show of out-migration as the alternative income strategy then positioned Wotawati as an optimal case study for examining livelihood resilience.

The study population consisted of all farming households cultivating karst rainfed land within isolated village. Given the finite population size of 72 households, the entire population was included in the study using the census method. This approach ensured the most comprehensive and accurate representation of the existing livelihood diversity within the defined research area. Primary data were gathered through face-to-face interviews utilizing a semi-structured questionnaire, while secondary data were acquired from official sources, primarily the village administrative office. The collected data were subsequently tabulated and analyzed using quantitative and qualitative methods.

2.1 Measurement of Livelihood Diversity

Livelihood diversity was assessed using three indices: the Simpson Index of Diversity (SID), the Shannon-Wiener Diversity Index (H'), and the Herfindahl-Hirschman Index (HHI). SID ranges between 0–1; values close to 1 indicate higher diversity. HHI also ranges between 0–1, but higher values indicate stronger concentration (i.e., lower diversification). H' typically ranges from 1.5–3.5; higher values suggest greater diversity. The general formulation for each index is presented in Table 1.

Table 1. The Formulation of the Simpsons Index Diversity, Shannon-Wiener Diversity Index, and Herfindahl-Hirschman Index

Simpsons Index Diversity	Shannon-Wiener Diversity Index	Herfindahl-Hirschman Index
$SID = 1 - \sum_{i=1}^{n} P_i^2$	$H' = -\sum p \ln p$	$HHI = \sum_{i=1}^{n} p_i^2$

where, SID was Simpson index diversity; H' was Shannon-Wiener Diversity Index; HHI was Herfindahl-Hirschman Index; P_i was the proportion of income from source i; n was the number of income sources; and p was probability of each source of income, calculated from the total income of each source (n) divided by the total income of each individual (N)

2.2 Classical Assumption Tests

Prior to conducting regression analysis, classical assumption tests were executed, encompassing normality, multicollinearity, heteroscedasticity, and linearity tests [9]. These

tests ensured that residuals were normally distributed, the variance of errors was constant, and no collinearity existed among independent variables.

2.3 Measurement of the Impact of Livelihood Diversity on Household Income

The impact of livelihood diversity on household income was examined using multiple linear regression models. The general model of this regression model was:

$$Log\ Y = \beta_0 + \beta_1 Livdiv + \beta_2\ l\_size + \beta_3\ gender + \beta_4\ age + \beta_5\ edu + \beta_6\ Remit + \varepsilon$$

Where, *Y* represented the household income (IDR); β_0 was the constant term; β_1–β_6 were the regression coefficients; *Livdiv* denoted the livelihood diversity index score (*SID, H', or HHI*); *l_size* was the size of cultivated agricultural land (m²); *gender* indicated the gender of the household head (dummy variable: 1 for male and 0 for female); *age* was the age of the household head (years); *edu* referred to the formal education level of the household head (categorical variable); *remit* represented presence of remittance (dummy variable: 1 received and 0 for not received); and ε was the error term.

3 Results and Discussion

3.1 The Characteristics and Livelihood Activities of Farming Households in Karst Agroecosystem

Table 2 shows the socioeconomic characteristics of 72 farming households in Gunungkidul Regency. The analysis shows that most farming households still rely on men as heads of households and are of productive age. The educational attainment indicates that farming households in the research area predominantly exhibit low levels of education. This condition can be seen in the fact that more than 80% of heads of households did not attend school and only graduated from elementary school. Agriculture remains the main occupation for 91.67% of households, with 77.7% dependent on remittances.

Table 2. The Characteristics of Farming Households in the Karst Agroecosystem of Gunungkidul (n = 72)

Characteristic	Category	Number of persons	Percentage (%)
Age	Productive	45	62.5
	Non-productive	27	37.5
Gender of household head	Male	59	81.94
	Female	13	18.06
Education	Did not complete elementary school	20	27.78
	Elementary school	39	54.17
	Junior high school	12	16.67
	Senior high school	1	1.39
Main occupation	Farmer	66	91.67
	Non-farmer	6	8.33
Number of income sources	1	6	8.33
	2–3	42	58.33
	4–5	21	29.17
	>5	3	4.17
Remittance recipients	Yes	56	77.7
	No	16	22.22

The primary occupation the households head was farmers. Most of the households also were the remittance recipients. The limited educational attainment constrains the ability of rural households to access non-agricultural employment opportunities, thereby reinforcing their dependence on farming as the primary source of livelihood [10].

Analyzing the number of income sources reveals a relatively narrow income base. Approximately 8.33% of households reported reliance on a single income source, exclusively from farming. The majority (58.33%) had two to three income sources, typically combining crops, livestock, and remittances from migrating household members. A further 29.17% engaged in four to five livelihood sources, including agricultural wage labor or non-agricultural freelance work. Merely 4.17% of households reported more than five income sources, occasionally including small-scale food processing or employment as village officials. Notably, household as the remittance recipient was particularly high, with 77.7% of respondents. Table 3 depicts the livelihood profile of farming households in the karst agroecosystem, which was still mostly dominated by three primary livelihood sources.

Table 3. The livelihood activities of farming households in the Karst region, Gunungkidul

Livelihood Activity	**Number of people**	**Percentage (%) ***
Farming	72	100
Migration	56	78
Livestock	48	67
Employee	16	22
Farm laborer	11	15
Retail	4	6
Food Business	4	6
Service	3	4
Meuble	4	6
Fisheries	2	3
Trader	5	7

Note: The percentage of the number of respondents (n= 72)

Table 3 shows the various livelihood activities carried out by households in Gunungkidul. These findings suggest that farming households in Gunungkidul remain heavily reliant on agriculture, both through on-farm and off-farm activities. This pattern is consistent with the observations of Gautam and Andersen [11], who argue that rural households typically continue to rely on agriculture as their livelihood activities. However, this case differs from other karst regions such as Maros in Sulawesi Selatan, where local communities have successfully leveraged karst landscapes for tourism development. In Gunungkidul, although initiatives such as the promotion of Pindul Cave as a tourist destination exist, agricultural activities continue to dominate household livelihood. While tourism is gradually expanding through the integration of cave exploration, farming activities, and coastal attractions, its economic contribution at the household level remains marginal and not yet measurable.

The high percentage of dependence on remittances underscores the importance of migration as a livelihood strategy for rural households, particularly in areas where agricultural land is of low fertility [12]. Remittances not only strengthen local economies by improving purchasing power but also play a role in reducing poverty. Nevertheless, excessive reliance on remittances can increase household vulnerability to external shocks, especially when migrants are no longer able to provide financial support [13]. This phenomenon is consistent with evidence from other regions and developing countries, where migration has become a widespread and critical livelihood strategy to sustain rural household economies [14]. While employees, farm labor, and retail contribute more than 15% to livelihood sources from farming households, others only contribute a lack of 10%.

3.2 Livelihood Diversity of Farming Household in Karst Agroecosystem

The results of the livelihood diversity indices indicated that the level of livelihood diversity among rural households remains within a very low to moderate range. The Simpson diversity index yielded a score of 0.48, categorized as moderate, while the Shannon (0.84) and Herfindahl (0.52) indices revealed a very low level of diversity. The variation in these values reflects the methodological sensitivity of each index. The Shannon index captures the richness and evenness of livelihood activity [15], whereas the Herfindahl index emphasizes income concentration within a few dominant sources. A moderate Simpson value thus suggested that most households engage in several livelihood activities; however, the lower Shannon and Herfindahl scores indicated that income distribution across these activities is uneven and tends to be concentrated in one or two primary sources.

Rural households in the study area mostly relied on livestock production and remittances. Such limited diversification increases their vulnerability to agricultural production risks, seasonal fluctuations, and market uncertainties. This evidence thus highlights a structural constraint in rural livelihood strategies, where diversification opportunities to non-agriculture sectors remain unexplored. This condition may be associated with the relatively low human capital in this region, thereby limiting access to alternative livelihood sources, particularly those requiring high qualifications. Higher education enhances employment competitiveness and productive capacity, leading to increased income. Nonetheless, the inadequate educational attainment in the research area was attributed to the perception that migration constitutes a more viable means of survival. Consequently, children in this region typically complete their education at the high school level and then directly migrate. This situation demonstrates that livelihood diversity in Gunungkidul is not only constrained by limited resources but also reinforced by the migration-oriented mindset of the households. As a result, the region consistently exhibits significant reliance on remittances.

3.3 The Impact of Livelihood Diversity on Farming Households Income in the Karst Agroecosystem

Prior to conducting regression estimation, classical assumption tests were executed to ensure the models' robustness (Table 4).

Table 4. Results of Classical Assumption Tests for Regression Models

Test Type	**Indicator / Statistic**	**Result**	**Decision Criteria**
Normality Test	Kolmogorov–Smirnov Sig. = 0.666	Sig. > 0.05	Residuals are normally distributed
Multicollinearity Test	VIF = 1.082–1.206	VIF < 10 and Tolerance > 0.10	No multicollinearity detected
Heteroskedasticity Test	Glejser= All Sig. > 0.05	Sig. > 0.05	No heteroskedasticity detected

The normality test of residuals indicates standardized residuals of 0.666, which lie within the acceptable significancy that should be more than 0.05, implying that the residuals are normally distributed. The multicollinearity test indicates that all Variance Inflation Factor (VIF) values are between 1.082–1.206, significantly below the critical threshold of 10, thereby confirming the absence of multicollinearity. The Glejser test for heteroscedasticity indicates significance values exceeding 0.05, suggesting that the variance of residuals

remains constant. The diagnostic results collectively affirm that the regression models adhere to classical assumptions, thereby ensuring reliable statistical inferences.

In this research, the dependent variable income was transformed into logarithmic form (Log_Inc) before conducting regression analysis. This transformation was performed to fulfil the normality assumption test [16]. The original income data typically displays a right-skewed distribution owing to the existence of a limited number of households with comparatively high incomes. This skewness may result in violations of the normality assumption, an essential rule in classical linear regression. The application of a logarithmic transformation makes the income data distribution more normal, thereby enhancing the validity of the regression estimates. The log transformation reduces the impact of outliers and allows for the interpretation of regression coefficients in proportional terms, thereby augmenting the practical significance of the findings.

Table 5. Regression Results of Livelihood Diversity Indices on Household Income

Variable	Expected Sign	B (Unstandardized Coeff.)	Std. Error	Beta (Standardized Coeff.)	T-value	Sig.
Constant		6.720	0.186	–	36.225	0.000
Simpson Diversity Index *(Livdiv)*	+	0.741	0.237	0.367	3.125	**0.003**
Land Size *(l_size)*	-	0.000046	0.000	0.262	2.351	**0.022**
Gender	+/-	0.053	0.124	0.049	0.432	0.667
Age of Household Head *(age)*	+	–0.009	0.005	–0.213	–1.825	**0.073**
Education Level *(edu)*	+	–0.035	0.068	–0.060	–0.521	0.604
Remittance *(remit)*	+	0.076	0.117	0.076	0.649	0.519
R^2	**0.255**					
Adj. R^2	**0.187**					
F	**3.713 (Sig. 0.003)**					

This study uses multiple linear regression analysis to identify the effect of livelihood diversity on farmer household income (Table 5). In addition, the analysis also includes several variables such as land size, gender, education level, remittance, and age of the household head. The results revealed that livelihood diversity variable, represented by the Simpson's Diversity Index (SID) value, showed a positive and significant effect on household income. This finding indicated that a household with a wider diversity of livelihood sources had a higher potential for increased overall income [17]. Diversity in economic activities opens access to various non-agricultural sectors such as livestock, trade, services, and migrants. The combination of income from these various sectors has been proven to strengthen the economic capacity of farming households. Field observations also support this finding, where households that combine agricultural and non-agricultural activities tend to have higher income levels than households that rely solely on agriculture.

In addition to SID, the variables of land area and age of the household head also have a significant effect on income. Land area had a positive and significant relationship. This positive relationship shows that the more land farmers own, the higher the potential income of households. Thus, land area was an important indicator in determining agricultural income [17,18]. In contrast to these two variables, the age of the household head had a significant

negative effect on income. This condition can be explained by the decline in physical ability and productivity with age, especially in agricultural activities that require intensive labor. Older age of the household's head tends to limit the ability to diversify economic activities, especially in the non-agricultural sector, which requires adaptation to new opportunities. However, a certain productive age can still have a positive effect through the accumulation of experience and knowledge in farm management, before finally declining after passing the optimal point of productivity. Therefore, the transition from unproductive to productive age warrants further examination to understand its implications.

Based on these results, it can be concluded that livelihood diversity (SID) was the variable with the most dominant influence on increasing farm household income, followed by land area and the age of the household head. Meanwhile, other variables such as gender, education level, and dependence remittance did not show a statistically significant influence [17]. The absence of a significant effect of gender on household income may be attributed to the fact that income in these households is not solely derived from the individual labor contribution of male or female members. Instead, household income tends to be the result of collective efforts and shared economic activities among family members. In addition, this study only considers the gender of the household head, without involving for the roles and economic contributions of other household members who may also influence total household income.

The level of education also had no effect because the distribution of education levels in the study location tended to be homogeneous and dominated by primary education, so the variation was not strong enough to explain the difference in income. Meanwhile, the remittance variable also did not have a significant effect on farmer household income. This is likely due to the nature of remittances, which are mostly allocated for consumptive needs, such as education costs and household consumption, rather than for productive investment. Moreover, some sectors also contribute high income to particular household. As a result, the contribution of remittance is more short-term in improving welfare but does not directly imply an increase in long-term income. Overall, the results of this study indicate that livelihood diversity is a key strategy in increasing the income of farming households, especially in areas with limited resources such as karst ecosystems. Improving access to non-agricultural opportunities and more productive land resource management can be key to strengthening the economic welfare of farmers in a sustainable manner.

4 Conclusion and recommendations

The results revealed that most farming households in Gunungkidul engaged in three to four different income-generating activities. Based on the Simpson Diversity Index (SID) analysis, the overall level of livelihood diversity among these households was categorized as moderate. The dominant livelihood activities included agriculture, migration-related work, and livestock. Livelihood diversification is generally associated with improved household welfare, as households with a broader range of income sources tend to achieve higher total incomes. Moreover, other factors influencing household income were land size and the age of the household head. Larger landownership was found to positively contribute to income levels, whereas older household heads who are typically less productive tended to have lower household earnings. Meanwhile, factors such as gender, education level, and remittance receipt showed no statistically significant effect. Overall, the findings highlight that promoting livelihood diversification and optimizing land resource utilization are essential strategies for enhancing household economic resilience in resource-constrained karst environments.

Acknowledgment. The author wishes to express gratitude to the farming households in Gunungkidul and the research collaborators from Universitas Muhammadiyah Yogyakarta for their invaluable

assistance and cooperation, which greatly contributed to the successful completion of this research. This study has played a significant role in the fulfillment of the author's master's thesis.

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