Socioeconomic Drivers of Household Tree-Cutting in Talakag, Bukidnon: Evidence from a Forest Frontier Municipality in the Philippines

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ABSTRACT

Deforestation remains a significant environmental concern in the Philippines, particularly in forest frontier municipalities where agricultural expansion and settlement growth interact with remaining forest landscapes. This study examines the socioeconomic determinants of household tree-cutting behavior in Talakag, Bukidnon. Primary data were collected from 103 rural households in Barangays Indulang and Dominorog through a structured survey conducted between December 2022 and February 2023. Descriptive statistics indicate that households reported an average of 539.78 or 540 trees cut, reflecting substantial variation in forest-use practices. To estimate the determinants of tree-cutting behavior, a Poisson regression model was applied, complemented by Generalized Linear Modeling (GLM) and Negative Binomial specifications to assess robustness. The results show that agricultural expansion is associated with approximately 31.6% higher expected tree-cutting counts, while migration is associated with a 22.1% increase and infrastructure development with a 10.5% increase, holding other factors constant. Years of land occupation also exhibit a positive and statistically significant association with tree-cutting behavior. In contrast, education, sex, and household timber extraction are not statistically significant predictors. Diagnostic tests confirm that the Poisson specification provides a good model fit (Pseudo $R^2 = 0.653$) with no evidence of overdispersion and consistent results across alternative count-data models. However, given the cross-sectional nature of the data and the potential endogeneity of key variables, the estimated relationships were interpreted as conditional associations rather than causal effects. The findings suggest that deforestation in Talakag is closely associated with agricultural land expansion and settlement dynamics in forest frontier areas, highlighting the importance of integrated forest governance, sustainable land-use planning, and agroforestry systems to reduce pressure on forest resources in upland communities.

Keywords: deforestation, Poisson regression, agricultural expansion, forest frontier, Philippines

INTRODUCTION

Deforestation remains a major environmental concern worldwide because forests provide critical ecological and socioeconomic services, including biodiversity conservation, watershed regulation, and support for rural livelihoods. However, forest cover in many tropical countries has declined significantly due to agricultural expansion, population growth, and increasing demand for natural resources. These processes often occur gradually as forest landscapes are converted into agricultural land and settlements.

Agricultural expansion has been widely recognized as one of the primary drivers of forest loss in tropical regions. Historically, a large share of newly cultivated land has been derived from previously forested areas (Gibbs et al., 2010). Advances in satellite imagery and geospatial monitoring have made it possible to observe these

transformations across large geographic scales, providing important insights into patterns of forest loss and land-use change (Hansen et al., 2013). Nevertheless, spatial data alone cannot fully explain the decision-making processes of rural households who interact directly with forest resources.

Studies on deforestation frequently distinguish between proximate causes and underlying drivers of forest loss. The framework proposed by Geist and Lambin (2002) identifies proximate causes as immediate activities that directly lead to forest clearing, such as agricultural expansion, infrastructure development, and timber extraction. In contrast, underlying drivers refer to broader socioeconomic forces including demographic pressures, economic incentives, institutional arrangements, and market conditions that shape land-use decisions.

From an economic perspective, deforestation can be interpreted as the outcome of household decision-making under resource constraints. Rural households located in forest frontier areas often clear land to expand agricultural production, secure land claims, or obtain timber and other forest resources that contribute to household income and subsistence needs (Angelsen & Kaimowitz, 1999). These decisions are frequently influenced by limited employment opportunities, uncertain land tenure, and increasing household demand for food and income. Consequently, forest clearing may emerge as part of livelihood strategies shaped by economic incentives and resource limitations (Barbier & Burgess, 2001).

The Philippines provides a notable case of long-term forest decline. Historical estimates indicate that forests once covered approximately 21 million hectares, or nearly 70 percent of the country's land area in the early twentieth century. Over time, extensive logging, agricultural expansion, and population growth have substantially reduced forest resources (Walpole, 2016). Recent monitoring data suggest that forest degradation continues, with approximately 37.7 thousand hectares of natural forest lost in 2021 alone. Moreover, humid primary forests declined by approximately 3.3 percent between 2002 and 2020 (Global Forest Watch, 2023). Current estimates indicate that forests account for only about 24.46 percent of the country’s land area in 2023, equivalent to roughly 7.2 million hectares.

At the regional level, Bukidnon province in Northern Mindanao remains an important forested landscape but has also experienced increasing pressure from agricultural expansion and settlement growth. Within the province, the municipality of Talakag has recorded one of the highest levels of tree cover loss. Between 2001 and 2021, approximately 4.50 thousand hectares of forest were lost in the municipality (Global Forest Watch, 2024). Although natural forest covered about 70.4 thousand hectares in 2010, representing approximately 73 percent of the municipal land area, continued land conversion and resource extraction have gradually transformed portions of this landscape.

Despite growing research on deforestation in tropical regions, detailed household-level analyses remain limited in many forest frontier areas of the Philippines. Existing studies often rely on satellite-based analyses or national-level data, which provide valuable information on spatial patterns of forest loss but offer limited insights into the socioeconomic factors influencing household land-use decisions.

Previous research has identified several key drivers of deforestation in tropical landscapes, including agricultural expansion, migration, infrastructure development, and timber extraction (Acderas & Pulhin, 2018; Ambio et al., 2020; De Dios & Fabella, 2012; Hosonuma et al., 2012). However, micro-level empirical evidence examining how these drivers operate within rural communities remains relatively scarce, particularly in forest frontier municipalities such as those found in Bukidnon.

Understanding household decision-making is therefore crucial in explaining deforestation dynamics. Rural households often operate within a complex system of constraints involving land availability, labor supply, market access, and institutional regulations governing forest use. Their livelihood strategies frequently involve a combination of agricultural production, forest resource extraction, and other income-generating activities. Examining how these factors interact provides valuable insights into the socioeconomic mechanisms underlying forest clearing.

This study examines the socioeconomic drivers of household tree-cutting behavior in Talakag, Bukidnon. Using household survey data collected from 103 respondents in two upland barangays, the study analyzes how

demographic characteristics, land-use practices, and livelihood activities influence forest resource utilization. A Poisson regression model is applied to estimate the relationship between these factors and the number of trees cut by rural households. By focusing on micro-level patterns of forest use, the study contributes to the literature on deforestation and rural livelihoods in developing countries and provides insights that may inform forest governance and sustainable land-use policies in forest frontier communities.

Objectives of the Study

The study examines the socioeconomic factors that contribute to deforestation in Talakag, Bukidnon by using household-level data and applying Poisson regression analysis. The intention is to look more closely at how household conditions and economic activities may be associated with tree-cutting practices in the area.

More specifically, the research seeks to:

1. describe the socio-economic and demographic characteristics of household heads such as age, education, land tenure, occupation, and years of residency;
2. present the proximate land-use activities (L_i) associated with forest resource extraction, including agricultural expansion, migration, infrastructure development, fuelwood extraction, timber extraction, and kaingin practices; and
3. estimate the associations among underlying socioeconomic factors (D_i), proximate land-use activities (L_i), and household tree-cutting behavior (TreeCut).

Hypotheses of the Study

Grounded in the conceptual framework of tropical deforestation proposed by Geist and Lambin (2002), this study examines how demographic characteristics and livelihood activities are associated with household tree-cutting behavior in a forest frontier municipality. Rural households in upland areas often make land-use decisions based on livelihood needs, access to land, and economic opportunities. These decisions may influence the extent to which forest resources are utilized or converted for agricultural and settlement purposes.

In this study, the number of trees cut by each household serves as the observable indicator of forest-clearing behavior. Based on existing theoretical and empirical literature on deforestation and land-use change, the following hypotheses are tested:

H1: Age of the household respondent is significantly associated with the number of trees cut by households in Talakag, Bukidnon.

H2: Educational attainment of the household respondent is significantly associated with household tree-cutting activities.

H3: Years of land occupation are positively associated with the number of trees cut by households.

H4: Agricultural expansion is positively associated with household tree-cutting behavior.

H5: Migration into the community is positively associated with household tree-cutting activities.

H6: Infrastructure development is positively associated with the number of trees cut by households.

H7: Fuelwood extraction is positively associated with household tree-cutting behavior.

H8: Household timber extraction is positively associated with the number of trees cut.

H9: Commercial timber extraction is positively associated with household tree-cutting activities.

H10: Households practicing kaingin (shifting cultivation) exhibit significantly different levels of tree-

cutting behavior compared with households that do not practice kaingin.

These hypotheses allow the study to empirically examine whether demographic characteristics, settlement history, and livelihood strategies are statistically associated with household-level deforestation activities in a forest frontier setting.

Scope and Limitations

This study examines the socioeconomic correlates of deforestation in Talakag, Bukidnon, Philippines, using household-level data collected from two upland barangays—Barangay Indulang and Barangay Dominorog. These communities were selected due to their documented exposure to forest clearing and ongoing land-use change within the municipality. The analysis focuses on household tree-cutting behavior in relation to agricultural expansion, timber extraction, and other livelihood-related activities. Primary data were obtained through a structured household survey conducted between December 2022 and February 2023, covering 103 respondents engaged in agricultural and forest-dependent livelihoods. While the sample size is modest, such scale is consistent with household-based studies in forest frontier settings, where dispersed settlements and logistical constraints limit large-sample data collection (Angelsen et al., 2018).

The empirical analysis combines descriptive statistics with Poisson regression to examine the statistical associations between selected socioeconomic characteristics and the number of trees cut by households. The model includes demographic and livelihood-related variables such as age, education, years of land occupation, migration, agricultural expansion, infrastructure development, and timber extraction activities. Given the cross-sectional design and the potential endogeneity of key regressors—particularly agricultural expansion and migration—the estimated coefficients should be interpreted as conditional associations rather than causal effects. The results therefore reflect correlational patterns at the household level and do not capture broader institutional, market, or policy-driven determinants of deforestation.

Several limitations warrant careful consideration. First, the geographic scope is confined to two barangays within Talakag, which may limit the external validity of the findings for other municipalities in Bukidnon or the Philippines. Second, the dependent variable—self-reported cumulative tree-cutting—is subject to recall bias and potential measurement error. Respondents may misreport long-term forest-clearing activities, which could attenuate or distort estimated relationships. Moreover, the cumulative nature of the variable does not distinguish between the timing or intensity of tree-cutting behavior. Third, the cross-sectional structure of the data constrains the ability to address unobserved heterogeneity and dynamic processes, thereby limiting causal inference. Finally, although diagnostic tests support the Poisson specification, alternative count-data models yield qualitatively similar results, suggesting that the findings are not driven by a single model choice but should nonetheless be interpreted with caution.

Despite these limitations, the study provides micro-level empirical evidence on the socioeconomic factors associated with household forest-clearing behavior in a forest frontier municipality. By focusing on household decision-making within a resource-constrained environment, the analysis contributes to the broader literature on deforestation and rural livelihoods, while highlighting the need for more rigorous identification strategies in future research.

CONCEPTUAL FRAMEWORK

This study is anchored in the deforestation framework of Helmut J. Geist and Eric F. Lambin (2002), which distinguishes between underlying (indirect) drivers and proximate (direct) causes of forest loss. To enhance analytical precision, the framework is further interpreted through a microeconomic lens, where deforestation is modeled as the outcome of household utility-maximizing behavior under resource and institutional constraints.

At the core of the framework is the assumption that rural households allocate land and labor in response to economic incentives, livelihood needs, and access to resources. Let household iii choose land-use strategies to maximize expected utility subject to constraints on land, labor, capital, and institutional conditions. In this context, forest clearing (tree-cutting) emerges as a derived demand for land and forest products, rather than an

exogenous activity.

Within this structure, underlying drivers—including demographic characteristics (age, education), human capital, and tenure-related factors (years of land occupation)—shape household preferences, capabilities, and opportunity sets. These variables influence both the expected returns to agricultural expansion and the relative costs of forest conservation versus land conversion. For example, longer land occupation may increase incentives for land consolidation, while limited education may restrict access to non-farm income, reinforcing dependence on land-intensive activities.

These underlying conditions operate through proximate land-use decisions, which constitute the immediate mechanisms of deforestation. In this study, proximate drivers include agricultural expansion, migration, infrastructure development, fuelwood extraction, and timber extraction. These activities represent observable behavioral choices through which households convert forest land into productive or subsistence uses. For instance, agricultural expansion reflects the conversion of forest into cropland, while infrastructure development reduces access costs and alters the shadow price of land and forest resources.

Formally, the conceptual relationship can be expressed as a reduced-form behavioral function:

$$TreeCut_i = f(D_i, L_i, \varepsilon_i)$$

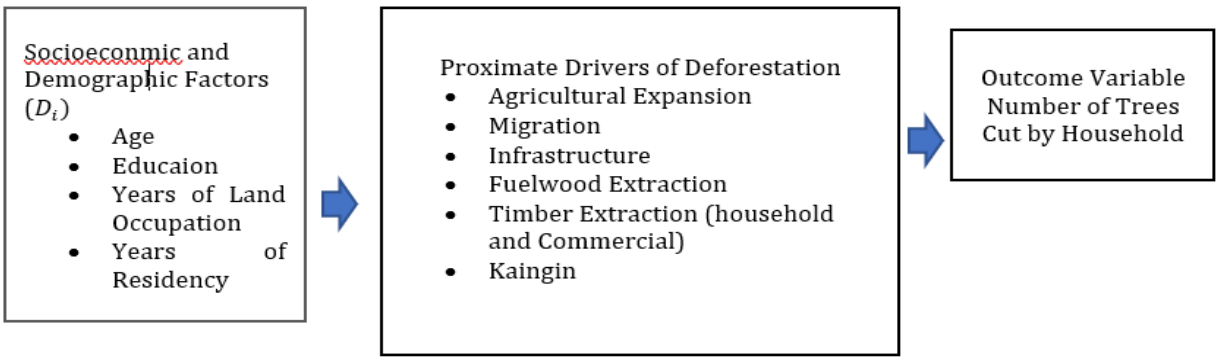
where $TreeCut_i$denotes the number of trees cut by household i, D_i represents underlying demographic and socioeconomic characteristics, $L_i$captures proximate land-use and livelihood activities, and ε_i reflects unobserved factors such as institutional quality, market access, and environmental conditions.

Importantly, the framework recognizes that proximate drivers may be endogenous to household decision-making. For example, agricultural expansion both requires and induces tree cutting, implying simultaneity between explanatory variables and the outcome of interest. As such, the empirical model is interpreted as capturing conditional associations rather than structural causal effects.

In the context of Talakag, Bukidnon, this framework conceptualizes household tree-cutting behavior as the observable outcome of interactions between socioeconomic conditions and land-use decisions in a forest frontier setting. The Poisson regression model operationalizes this relationship by estimating how variations in demographic characteristics and livelihood activities are statistically associated with the intensity of tree-cutting behavior.

Figure 1 presents the conceptual structure linking underlying drivers to proximate causes and, ultimately, to observed deforestation outcomes. This analytical formulation clarifies the mechanism through which household-level factors are associated with forest clearing, while explicitly acknowledging the limitations of causal interpretation.

Figure 1. Conceptual framework of household drivers of deforestation



Note. Adapted from *"Proximate causes and underlying driving forces of tropical deforestation,"* by H. J. Geist and E. F. Lambin, 2002, *BioScience, 52*(2), p. 146. https://doi.org/10.1641/0006-3568(2002)052[0143:PCAUDF]2.0.CO;2

The framework distinguishes between underlying socioeconomic conditions (D_i) and proximate land-use decisions (L_i) that jointly determine household tree-cutting behavior ($TreeCut_i$). Arrows represent behavioral pathways through which demographic and economic factors influence deforestation outcomes. The dashed feedback loop indicates potential endogeneity between land-use decisions and forest clearing. Unobserved factors (ε_i), including institutional and market conditions, may simultaneously affect both decision variables and outcomes.

METHODOLOGY

Study Area

The research took place in the municipality of Talakag, situated on the western side of Bukidnon in Northern Mindanao, Philippines. For anyone familiar with the geography of the province, Talakag sits roughly 35 kilometers west of Malaybalay City, the provincial capital. Reaching the area involves traveling through increasingly rugged terrain. Hills gradually rise into more pronounced uplands, and stretches of forest still remain visible along parts of the landscape. Much of the municipality is mountainous, with extensive forestlands interspersed with upland farms and several important watershed systems. Geographically, Talakag borders Lanao del Sur to the west, Impasug-ong and Malaybalay City to the east, Baungon to the south, and Misamis Oriental to the north. These boundaries place it squarely within what many would describe as a forest frontier zone. Agricultural expansion and settlement are steadily pushing outward, often meeting the edges of what remains of the province's natural forest.

Large portions of Talakag still contain natural forest dominated by dipterocarp species, the same towering hardwood trees that define much of the remaining lowland rainforest across the Philippines. These forests serve several roles at once. They support biodiversity, regulate water systems that feed downstream communities, and, perhaps less formally but just as significantly, sustain everyday rural livelihoods. Local households depend on forest resources in ways that are often practical and immediate. Timber is used for small construction, fuelwood for cooking, and various non-timber products supplement household needs. Yet the condition of these forests has gradually changed over the past two decades. Forest monitoring data from Global Forest Watch indicate that Talakag recorded the highest level of tree cover loss in Bukidnon. Between 2001 and 2021 alone, approximately 4.50 thousand hectares of forest disappeared. That figure becomes more striking when placed beside earlier estimates. Around 2010, natural forest still covered roughly 70.4 thousand hectares, accounting for about 73 percent of the municipality's land area. Even so, agricultural expansion, timber extraction, and the steady growth of settlements have continued to erode portions of this forest landscape.

The empirical component of the study focused on two upland barangays: Barangay Indulang and Barangay Dominorog. These communities sit in areas where forest clearing and land conversion have become increasingly visible. Farming here is largely smallholder-based. Most households cultivate modest plots using upland cropping systems, often combining corn, root crops, and other staple plants suited to sloping land. Mixed agroforestry practices are also present, although they vary widely from farm to farm. In some places fruit trees or timber species are integrated into crop fields. In others, shifting cultivation, locally known as kaingin, still appears as a practical strategy when soils begin to lose fertility. Infrastructure remains limited. Roads are uneven, market access is not always reliable, and basic services can be distant. Under these circumstances, dependence on natural resources becomes less a matter of preference and more a matter of necessity. Population movements toward upland areas have also intensified pressure on surrounding forests. New households clear small patches of land for farming or settlement, gradually extending the agricultural frontier.

Talakag was selected as the study site because it captures, perhaps quite clearly, the tensions present in many forest frontier municipalities in Bukidnon. On one hand, significant forest cover still exists. On the other, tree cover loss continues at a noticeable pace. Understanding why households engage in tree-cutting activities in such contexts requires looking closely at the socioeconomic conditions shaping daily decisions. Livelihood needs, land availability, migration patterns, and agricultural practices all interact in ways that are not always straightforward. Examining these dynamics in Talakag therefore offers a window into the broader processes driving deforestation in upland rural communities. The expectation is that insights from the study may help guide

more grounded policy responses, particularly those aimed at promoting sustainable land management while recognizing the livelihood realities faced by households living along the forest frontier in Bukidnon and similar regions of the Philippines.

Data Collection

Primary data for this study were collected through a structured household survey conducted in two selected barangays of Talakag: Barangay Indulang and Barangay Dominorog located in Bukidnon, Philippines. These barangays were purposively selected because they are among the areas experiencing significant forest clearing and land-use conversion within the municipality. Data collection was conducted between December 2022 and February 2023. Household surveys are widely used in studies of land-use change and forest resource utilization because they allow researchers to capture micro-level information on household decision-making, livelihood strategies, and land management practices that are often not available in secondary datasets (Angelsen et al., 2018; Sunderlin et al., 2005).

A structured questionnaire was developed to collect information on the socio-demographic characteristics of households, land tenure history, livelihood activities, and factors associated with tree-cutting practices. The questionnaire included sections on respondents' age, sex, educational attainment, years of land occupation, and years of residency in the community. Additional questions captured household participation in activities related to forest resource utilization, including agricultural expansion, migration, infrastructure development, fuelwood extraction, household timber extraction, commercial timber extraction, and shifting cultivation (kaingin). Similar household survey instruments have been widely applied in studies examining the socioeconomic drivers of deforestation and forest resource use in tropical regions (Angelsen et al., 2018; Hosonuma et al., 2012).

The dependent variable of the study is the number of trees cut by each household. Respondents were asked to report the estimated number of trees they had cut cumulatively over their period of land occupation rather than the number cut within a single year. This approach captures long-term household forest clearing activities associated with land preparation, agricultural expansion, and other livelihood-related uses of forest resources. The use of cumulative self-reported estimates is common in household-based studies of land-use change because it allows researchers to approximate long-term patterns of forest clearing when historical records or continuous monitoring data are unavailable (Angelsen et al., 2018; Barbier & Burgess, 2001). Consequently, the reported values reflect cumulative tree-cutting behavior across the duration of household settlement in the area.

A total of 103 households were selected using a simple random sampling technique from the two barangays. The sampling frame consisted of households engaged in agricultural and forest-related livelihood activities in the study area. Household heads or adult household members with sufficient knowledge of household land-use practices were interviewed to ensure the reliability of the responses. Prior to the main survey, the questionnaire was pre-tested in a nearby community with similar socioeconomic characteristics to assess the clarity and relevance of the survey questions. Necessary revisions were made based on the results of the pre-test. Pre-testing survey instruments is widely recommended in social science research to improve question design, minimize ambiguity, and enhance the reliability of collected data (Fowler, 2014).

Data were collected through face-to-face interviews conducted by the researchers and trained enumerators. This approach allowed for clarification of survey questions, ensured accurate recording of responses, and minimized potential non-response or misinterpretation of survey items. Face-to-face surveys are particularly effective in rural communities where literacy levels may vary and where direct interaction helps ensure the accuracy and completeness of responses (Groves et al., 2009). After the interviews, the completed questionnaires were reviewed, coded, and organized to ensure data accuracy and completeness prior to statistical analysis.

Ethical considerations were strictly observed throughout the data collection process. Respondents were informed about the objectives of the study, the voluntary nature of their participation, and their right to withdraw from the survey at any time without any consequences. Prior informed consent was obtained from all participants before conducting the interviews. Respondents were assured that the information they provided would be used solely for academic purposes and that their identities would remain confidential. Personal identifiers were excluded from the dataset to protect the privacy and anonymity of respondents, in accordance with standard ethical

practices in social science research (Israel & Hay, 2006).

Research Design

This study utilized a descriptive-correlation cross-sectional research design using household survey data to analyze the determinants of tree-cutting behavior in Talakag, Bukidnon. The empirical analysis combined descriptive statistics with econometric modeling to examine how socioeconomic and livelihood-related factors influenced household deforestation activities. Specifically, a Poisson regression model was employed to estimate the relationship between household characteristics, land-use practices, and the number of trees cut by each household.

AI-assisted tools were used only to refine language and organize the manuscript structure. All econometric modeling, statistical analysis, and interpretation of results were conducted independently.

Variables and Measurement

The dependent variable in this study is the number of trees cut by each household, measured as the cumulative number of trees cleared over the household's period of land occupation. Explanatory variables include demographic characteristics (age, sex, education), land-use variables (years of land occupation and residency), and livelihood activities related to forest resource use such as agricultural expansion, migration, infrastructure development, fuelwood extraction, and timber extraction.

Data Analysis

To analyze the data, the study employed both descriptive and inferential statistical techniques. Descriptive statistics, including frequencies, means, and standard deviations, were used to summarize the socio-demographic characteristics of the respondents, and frequencies and percentages to describe the distribution of variables related to household forest-use activities. These measures provide an initial overview of the characteristics and variability of households engaged in tree-cutting activities in the study area.

To examine the determinants of tree-cutting behavior, the study primarily applied a Poisson regression model. This approach is appropriate because the dependent variable—the number of trees cut by each household—is a count variable that takes non-negative integer values. Count outcomes do not satisfy the assumptions of ordinary least squares (OLS), particularly the assumptions of normally distributed and homoskedastic errors. Poisson regression, estimated via maximum likelihood, is therefore commonly used in empirical studies where the dependent variable represents the frequency of an event.

Under the Poisson framework, the expected count of events is modeled as a function of a set of explanatory variables. In this study, the expected number of trees cut by the *ith* household is assumed to depend on a vector of socioeconomic and livelihood-related variables. The model estimates how these factors are statistically associated with the expected frequency of tree-cutting activities while accounting for the discrete nature of the dependent variable. The specification can be expressed as follows:

$$Y_i \sim Poisson\ (\mu_i)$$

$$E(Y_i|X_i) = \mu_i = \exp\ (\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ \cdots + \beta_k X_{ki})$$

Log-linear form:

$$\ln(\mu_i) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ \cdots + \beta_k X_{ki}$$

where:

Y_i=number of trees cut by household i;

μ_i = expected number of trees cut;

β_0 = intercept;

$\beta_1 \ldots \beta_k$ = estimated parameters;

X_i = vector of explanatory variables included in the model.

The estimated coefficients are interpreted in terms of log changes in the expected count, while exponentiated coefficients represent incidence rate ratios (IRRs), indicating multiplicative effects on the expected number of trees cut.

To assess the robustness of the results, alternative count-data specifications were also estimated. A generalized linear model (GLM) with Poisson family and log link produced results identical to the standard Poisson model, confirming consistency in estimation. In addition, a Negative Binomial regression model was estimated to account for potential overdispersion. The estimated coefficients remained stable across specifications, and the likelihood ratio test for the dispersion parameter was not statistically significant, indicating that overdispersion is not present and that the Poisson model provides an appropriate and parsimonious specification.

Diagnostic tests were further conducted to evaluate model adequacy. Goodness-of-fit tests indicate that the model fits the observed data well, while specification tests (e.g., link test) show no evidence of functional form misspecification. These results support the reliability of the estimated associations.

It is important to note, however, that given the cross-sectional nature of the data and the potential endogeneity of key explanatory variables, the estimated relationships should be interpreted as conditional associations rather than causal effects.

Estimation Procedure

All econometric analyses were conducted using Stata 19.5, employing maximum likelihood estimation techniques for count-data models. Robust standard errors were used to improve inference reliability. Post-estimation diagnostics and alternative model specifications were systematically applied to ensure the validity, consistency, and robustness of the empirical results.

RESULTS AND DISCUSSION

Table 1 presents the socio-demographic characteristics of households engaged in tree-cutting activities in Talakag, Bukidnon. The survey covered 103 households from Barangays Indulang and Dominorog, conducted between December 2022 and February 2023.

Table 1 — Socio-demographic profile of households in Talakag, Bukidnon

Variable	Mean	SD	Min	Max
Tree Cutting (trees)	539.78	98.89	356	791
Age (years)	43.72	8.58	30	59
Years of Education	5.79	3.40	0	12
Years of Land Occupation	18.10	9.71	0	35
Years of Residency	19.30	10.58	0	39

Source: Authors' household survey (December 2022–February 2023).

The descriptive statistics offer a preliminary glimpse into the pattern of tree cutting reported by households in the study area. On average, respondents indicated that about 539.78 or 540 trees had been cut, with a standard deviation of 98.89. The figures are not tightly clustered. Some households reported cutting as few as 356 trees, while others reached as high as 791. Such variation hints at differences in how families make use of land and forest resources. For some households, forest clearing appears closely tied to farming needs. Others may depend on forest products in different ways, perhaps for timber, fuelwood, or additional sources of income. Similar patterns have been observed in many forest frontier regions, where clearing land becomes part of the process of establishing or expanding agricultural livelihoods (Geist & Lambin, 2002; Runyan & Stehm, 2020). Historical evidence also reminds us that much of the expansion of agriculture in tropical regions occurred through the conversion of forests, particularly during the latter half of the twentieth century when forests often served as the most accessible source of new farmland (Gibbs et al., 2010; Rudel et al., 2009). In that sense, what appears in Talakag is not entirely unusual, though the local dynamics still matter.

Looking at the demographic profile of respondents, the average age is 43.72 years, with a standard deviation of 8.58 and a range from 30 to 59 years. Most respondents therefore fall within what might reasonably be described as the economically productive stage of life. Individuals in this age group often combine practical farming experience with the physical ability required for demanding agricultural work. Clearing land in upland areas is rarely mechanized. It usually involves manual labor, sometimes with simple tools. Because of this, middle aged farmers frequently appear at the center of land clearing activities in many rural contexts (Teferi et al., 2015; Ashraf et al., 2017). Household labor availability often shapes land use decisions, especially in frontier areas where machinery is limited, and forest clearing remains physically intensive.

Education levels among respondents appear relatively modest. On average, individuals reported about 5.79 years of schooling, which suggests that many did not complete elementary education. Educational attainment varies considerably, ranging from no formal schooling to as much as 12 years. Limited schooling can influence livelihood opportunities in several ways. Without higher levels of education, access to non-agricultural employment tends to be restricted, particularly in rural regions where job markets are already thin. Under such circumstances, households often rely more heavily on natural resources to sustain their livelihoods. Research on forest communities in the Philippines and elsewhere has pointed to similar relationships between lower educational attainment and dependence on forest-based activities (Acderas & Pulhin, 2018; Van Khuc et al., 2018). From an economic standpoint, limited human capital may reduce opportunities for income diversification, which can reinforce dependence on land-intensive activities such as farming or timber extraction (Barbier & Burgess, 2001).

Land occupation patterns provide another interesting piece of the picture. On average, households have occupied their land for about 18.10 years, though the values range from newly settled households to those with up to 35 years of occupation. This suggests that many respondents are not recent arrivals but rather relatively established settlers. Over time, households often expand cultivated areas gradually. As families grow or as agricultural needs increase, additional land may be cleared to support crop production. Studies of land use transitions in forest frontier regions frequently describe this gradual expansion process, where longer tenure is associated with increasing agricultural activity and, in some cases, forest conversion (Angelsen & Kaimowitz, 1999; Kissinger et al., 2012). Evidence from several developing countries likewise points to agricultural expansion as a central driver of deforestation, particularly where population growth and demand for land continue to rise (Hosonuma et al., 2012).

A similar pattern appears when considering length of residence within the community. Respondents reported living in their respective areas for an average of 19.30 years, with residency ranging from newly arrived households to those who have lived there for nearly four decades. Long term residence often strengthens local social networks and deepens familiarity with surrounding natural resources. Households that have lived in a place for many years tend to know where certain timber species grow, which areas are suitable for farming, and how forest resources can be used to support daily needs. While such knowledge can support resource management, it can also increase reliance on nearby forests when alternative livelihood options remain limited. In many rural communities, forests continue to serve as both a safety net and a source of supplementary income (Jayathilake et al., 2021). Satellite based monitoring has also confirmed that forest loss persists in numerous

tropical regions where expanding agriculture and settlement growth intersect with forest landscapes (Hansen et al., 2013).

Taken together, these descriptive findings suggest that households involved in tree cutting in Talakag tend to share several characteristics. Many fall within the middle age group, have relatively modest levels of formal education, and have lived and farmed in their communities for extended periods. These conditions often correspond with livelihood systems that rely heavily on land and natural resources. In that respect, the situation in Talakag reflects broader patterns observed across tropical forest frontier areas. Rural livelihood needs, agricultural expansion, and demographic pressures frequently interact in ways that shape deforestation dynamics across developing regions (Barbier & Burgess, 2001; Hosonuma et al., 2012; Gibbs et al., 2010). At the same time, the specific local context still matters, and understanding those nuances remains essential for interpreting how and why forests continue to be transformed.

Drivers of Deforestation in Talakag, Bukidnon

Table 2 presents the distribution of household responses regarding potential drivers of deforestation in Talakag, Bukidnon.

Table 2 — Drivers of deforestation among households in Talakag, Bukidnon

Variable	Category	Sample	Percentage
Sex	Female (0)	50	48.54
	Male (1)	53	51.46
Agricultural Expansion	No	50	48.54
	Yes	53	51.46
Infrastructure Development	No	62	60.19
	Yes	41	39.81
Migration	No	63	61.17
	Yes	40	38.83
Fuelwood Extraction	None (0)	27	26.21
	Moderate (1)	48	46.60
	High (2)	28	27.18
Household Timber Extraction	No	52	50.49
	Yes	51	49.51
Commercial Timber Extraction	No	64	62.14
	Yes	39	37.86

Source: Authors' household survey (December 2022–February 2023).

About 51.46 percent of the respondents identified agricultural expansion as a major factor linked to deforestation

in the area. In practical terms, this usually means clearing land to grow crops or expand existing farms. Agricultural expansion commonly occurs through gradual farm enlargement as households extend cultivation areas to meet subsistence and income needs. A household that begins with a small corn plot may gradually extend its field a few meters each season, especially when family needs increase or when additional land promises better harvests. Situations like this are hardly unique to Talakag. Research across many parts of the tropics has repeatedly observed that forests are often converted into farmland, both for subsistence crops and for small-scale commercial production (Geist & Lambin, 2002; Kissinger et al., 2012; Ritchie, 2021). The pattern shows up in places as different as the Amazon basin and Southeast Asia, suggesting that the pressures shaping agricultural frontiers tend to follow somewhat similar economic logic. Evidence from several tropical regions reinforces this observation. Expanding agricultural boundaries frequently coincide with noticeable losses in forest cover (Doggart et al., 2020; Haddad et al., 2024). Historical analyses even suggest that during the late twentieth century, forests served as one of the most readily available sources of new agricultural land. When farmers needed space to cultivate crops, clearing forest often became the most immediate option (Gibbs et al., 2010). A broader cross-country analysis covering the period from 1970 to 2005 reached a similar conclusion. Much of the growth in cultivated land during those decades occurred through the conversion of forest landscapes, particularly in developing regions where agricultural expansion remained a key pathway for rural development (Rudel et al., 2009). More recent global assessments of deforestation drivers continue to echo this pattern, identifying agricultural expansion as one of the most frequently reported causes of both deforestation and forest degradation across tropical countries (Hosonuma et al., 2012). Satellite-based monitoring has also added another layer of evidence. With improved imagery and long term data, researchers have been able to track forest cover changes more precisely, often confirming that forest loss tends to cluster in areas where agricultural activity is spreading (Hansen et al., 2013). From an economic standpoint, these outcomes are not entirely surprising. Rural households frequently view land as a productive asset, something that can generate food, income, or both. Clearing forest to establish farmland may therefore appear less as environmental destruction and more as a rational livelihood strategy, especially in places where alternative income opportunities remain limited (Barbier & Burgess, 2001). The decision, however, is rarely simple. It reflects a balance between shorter-term survival and longer-term environmental consequences, a tension that many rural communities continue to navigate.

Migration also emerged as an important factor in the responses, with 38.83 percent of participants identifying population inflows as contributing to pressure on forest resources. Movement of people into frontier areas often brings new demands for land. Newly arrived households need space to build homes, cultivate crops, and establish livelihoods. In many cases, that process begins with clearing forested areas. Settlement expansion can then follow, sometimes accompanied by small roads, basic infrastructure, or additional farming plots. Over time, these changes accumulate and gradually reshape the surrounding landscape.

Similar patterns have been documented in forest frontier regions where migration is frequently associated with rapid land-use change and forest conversion as new settlers establish farms and residential areas (Van Khuc et al., 2018; Ashraf et al., 2017). In many developing-country contexts, migration to frontier areas occurs when households seek access to land and economic opportunities, circumstances that are often associated with the conversion of forest landscapes into agricultural fields.

A noticeable share of respondents, about 39.81 percent, associated infrastructure development with forest loss in the area. When people speak about infrastructure in places like Talakag, they usually mean roads, small transport routes, or improvements that make remote areas easier to reach. At first glance these developments seem entirely positive. A new road, for instance, shortens travel time to the nearest market and lowers the cost of transporting crops. Farmers who previously relied on rough trails can suddenly move sacks of corn or vegetables with far less effort. However, easier access also changes how forests are used. Areas that were once difficult to reach gradually become open for logging, farming, or settlement. Earlier research has pointed to a similar pattern. Road building and infrastructure expansion tend to coincide with rising deforestation in many forest frontier regions because improved access allows people and goods to move more freely into previously isolated landscapes (Geist & Lambin, 2002; Richards & Friess, 2016). As transportation networks improve, economic activity often follows. New opportunities appear, sometimes in the form of small trading points, farm expansion, or timber extraction. While such developments may support rural economies, they can also accelerate land conversion when forested land becomes easier to exploit.

Fuelwood use also appears to be a regular part of household life in the area. About 46.60 percent of respondents reported moderate levels of fuelwood collection, while another 27.18 percent indicated relatively high extraction. For many rural families, firewood remains the most reliable source of cooking energy. In communities where electricity is inconsistent or where liquefied petroleum gas is too costly, collecting wood from nearby forests often becomes the practical option. One can picture the routine quite clearly. Early in the morning someone walks toward the forest edge with a bolo or small axe, gathering branches or cutting smaller pieces of wood to carry back home. The environmental consequences of this activity, however, are not always straightforward. The impact depends largely on how the wood is obtained. Some households collect fallen branches or dead biomass, which may have limited ecological effects. Others cut live trees, particularly when larger pieces of wood are needed. The difference matters. Harvesting live trees places more pressure on forest ecosystems and can contribute to gradual degradation if practiced intensively (Runyan & Stehm, 2020). In most cases, though, fuelwood collection reflects household energy needs rather than commercial intent.

Timber extraction for household use is also common. Nearly half of the respondents, around 49.51 percent, reported harvesting timber for purposes such as constructing houses, building farm sheds, or putting up fences around crop fields. In rural communities, wood remains one of the most accessible building materials. A newly built house in an upland barangay, for example, often relies on timber posts, bamboo walls, and wooden roofing frames sourced from nearby forests. At the same time, a smaller yet notable proportion of respondents, about 37.86 percent, indicated involvement in commercial timber extraction. This suggests that market demand for wood products is present as well. When timber carries economic value, forests can quickly become attractive sources of income. Under such circumstances, the incentives for harvesting trees increase, particularly in areas where monitoring and enforcement of forest regulations are relatively weak (Haddad et al., 2024). Commercial demand can therefore shift forests from being viewed mainly as ecological resources to being treated as economic assets, sometimes with considerable consequences for forest conservation.

Taken together, these descriptive observations point toward several activities that appear closely connected with tree cutting in Talakag. Agricultural expansion, migration, infrastructure growth, and timber extraction all seem to play a role. None of these factors operate in isolation. Rather, they tend to interact with one another in ways that gradually reshape forest landscapes. Similar combinations of drivers have been identified in broader global assessments of tropical deforestation, where agricultural frontiers, population pressures, and expanding infrastructure often reinforce one another (Geist & Lambin, 2002; Jayathilake et al., 2021; Hosonuma et al., 2012). In many rural settings, forests remain deeply intertwined with everyday economic life. They provide land for crops, wood for energy and construction, and sometimes income through timber markets. Understanding this complex relationship is essential, especially when discussions about forest conservation intersect with the livelihood realities faced by households living along forest frontiers.

Factors of Deforestation

Table 3 presents the estimated relationships between socioeconomic characteristics, livelihood activities, and household tree-cutting behavior across three alternative specifications: Poisson regression with robust standard errors, generalized linear modeling (GLM), and Negative Binomial regression. The consistency of coefficient signs, magnitudes, and statistical significance across all models indicates that the results are robust to alternative count-data specifications.

It is important to emphasize that, given potential endogeneity and the cross-sectional nature of the data, the estimates should be interpreted as conditional associations rather than causal effects.

Table 3. Determinants of household tree-cutting behavior using Poisson, GLM, and Negative Binomial estimates

Variables	Poisson IRR (Robust SE)	GLM (Poisson-log) Coef.	NegBin Coef.	P-value
Age	1.002***	0.00237***	0.00237***	0.000

	(0.00047)			
Sex (Male=1)	0.999 (0.00866)	-0.00145	-0.00145	0.875
Years of Education	0.999 (0.00121)	-0.00086	-0.00086	0.526
Years of Land Occupation	1.011*** (0.00042)	0.01051***	0.01051***	0.000
Years of Residency	0.999 (0.00038)	-0.00023	-0.00023	0.578
Agricultural Expansion	1.316*** (0.01217)	0.27434***	0.27434***	0.000
Infrastructure	1.105*** (0.00868)	0.09971***	0.09971***	0.000
Migration	1.221*** (0.01109)	0.19996***	0.19996***	0.000
Fuelwood Extraction	0.988* (0.00579)	-0.01181*	-0.01181*	0.061
Timber (Household)	0.998 (0.00848)	-0.00219	-0.00219	0.801
Timber (Commercial)	1.022** (0.00863)	0.02148**	0.02148**	0.016
Kaingin	0.946*** (0.00992)	-0.05587***	-0.05587***	0.000
Model diagnostics: Poisson GOF p ≈ 0.34 → good fit Dispersion φ ≈ 1.05 → no overdispersion NB α ≈ 0, LR test p = 0.498 → Poisson preferred Link test p(_hatsq) = 0.787 → no misspecification				

Note: N = 103. IRR = incidence rate ratio. GLM and NB coefficients reported in log form.
*, **, *** denote significance at 10%, 5%, and 1%, respectively.
Results are robust across specifications.

The results indicate that age is positively and statistically significantly associated with tree-cutting activities ($\beta = 0.00237$, $p < .001$). The incidence rate ratio suggests that each additional year of age is associated with an approximately 0.2% higher expected number of trees cut, ceteris paribus. This pattern suggests that older farmers may have greater farming experience and familiarity with land-use practices commonly observed in forest frontier areas. Similar patterns have been reported in studies of rural agricultural communities where experienced farmers are frequently associated with agricultural expansion and forest resource utilization (Ashraf et al., 2017). Notably, this relationship remains consistent across Poisson, generalized linear model (GLM), and Negative Binomial specifications, indicating that the observed association is robust to alternative estimation approaches.

The variable sex (male = 1) does not exhibit a statistically significant association with household tree-cutting behavior ($\beta = -0.00145$, $p = 0.875$). As a dichotomous variable, the coefficient reflects the difference in expected tree-cutting counts between male-headed and female-headed households. The estimated incidence rate ratio is approximately unity (IRR ≈ 0.999), indicating no meaningful difference in tree-cutting intensity between male and female respondents, ceteris paribus.

This result suggests that gender, as measured in this study, does not appear to be a primary factor associated with variation in household tree-cutting behavior in the study area. One possible explanation is that land-use decisions and forest resource utilization in upland communities are often determined at the household level rather than by individual gender roles alone. In such contexts, both male and female members may contribute jointly to livelihood decisions, particularly in agricultural production and resource use. Similar findings have been reported in studies of rural land-use behavior, where gender differences are not consistently associated with deforestation outcomes once economic and livelihood factors are taken into account (Angelsen & Kaimowitz, 1999; Geist & Lambin, 2002).

The lack of statistical significance across Poisson, generalized linear model (GLM), and Negative Binomial specifications further indicates that this result is robust to alternative model assumptions. Overall, the findings suggest that socioeconomic and livelihood-related factors play a more substantial role than gender in explaining variation in household tree-cutting behavior in forest frontier settings.

Years of land occupation are positively and statistically associated with tree-cutting activities ($\beta = 0.01051$, $p < .001$), indicating that each additional year of land occupation is associated with approximately 1.1% more trees cut, ceteris paribus. Longer land occupation periods are often associated with gradual expansion of cultivated land, as households adjust land use to support agricultural production. Economic models of deforestation frequently describe forest conversion as being associated with land tenure conditions and agricultural profitability, which shape household land-use decisions (Angelsen & Kaimowitz, 1999; Barbier & Burgess, 2001). The stability of this coefficient across GLM and Negative Binomial models further supports the robustness of this association.

Among the explanatory variables, agricultural expansion shows the strongest positive association with tree-cutting behavior ($\beta = 0.27434$, $p < .001$). As a dichotomous variable, the coefficient captures the difference between households engaged in agricultural expansion and those that are not. The incidence rate ratio indicates that households engaged in agricultural expansion are associated with approximately 31.6% higher expected tree-cutting counts compared to households not engaged in expansion, ceteris paribus. This relationship remains unchanged across alternative specifications, indicating that the result is robust to model choice. Agricultural expansion is widely documented in the literature as being closely associated with deforestation across tropical regions where forest lands are converted into cropland or pasture to support rural livelihoods (Geist & Lambin, 2002; Kissinger et al., 2012; Doggart et al., 2020). Historical evidence further indicates that tropical forests served as the primary source of newly cultivated agricultural land during the late twentieth century (Gibbs et al., 2010), while cross-country analyses show that increases in cultivated land have frequently occurred through the expansion of agriculture into forested landscapes (Rudel et al., 2009). Global syntheses of deforestation drivers similarly identify agricultural expansion as a dominant correlate of forest loss and degradation in many developing countries (Hosonuma et al., 2012).

Infrastructure development exhibits a positive and statistically significant relationship with household tree-

cutting activities (β = 0.09971, p < .001). As a binary indicator, the results imply that households with access to or involvement in infrastructure development are associated with approximately 10.5% higher expected tree-cutting counts relative to those without such exposure, ceteris paribus. Improved access through roads and transport networks may reduce transaction costs and increase the feasibility of land conversion and forest resource extraction. Similar relationships between infrastructure development and forest clearing have been reported in several tropical regions where improved accessibility is associated with land-use change (Richards & Friess, 2016; Jayathilake et al., 2021). This result is likewise consistent across Poisson, GLM, and Negative Binomial models.

Migration exhibits a positive and statistically significant association with household tree-cutting activities (β = 0.19996, p < .001). Interpreted as a dichotomous variable, the estimated incidence rate ratio indicates that households affected by migration are associated with approximately 22.1% higher expected tree-cutting levels compared to non-migrant households, holding other factors constant. Population inflows into forest frontier areas often lead to the expansion of settlements and the conversion of forest land into agricultural areas. These dynamics have been widely documented in studies of land-use change in developing regions, where migration contributes to increased pressure on forest resources through agricultural expansion and settlement development (Van Khuc et al., 2018; Ashraf et al., 2017). The consistency of this result across all model specifications reinforces its empirical reliability.

Fuelwood extraction exhibits a negative and marginally statistically significant association with household tree-cutting activities (β = −0.01181, p = 0.061). The estimated incidence rate ratio suggests that an increase in the level of fuelwood extraction—from none to moderate or from moderate to high—is associated with approximately 1.2% lower expected tree-cutting counts, ceteris paribus. Given that the variable is measured categorically (none, moderate, high), the coefficient reflects the incremental change in expected tree-cutting behavior across these ordered levels of fuelwood use. This negative association may indicate that households engaged in higher levels of fuelwood extraction rely more on the collection of small branches, fallen wood, or already available biomass rather than clearing additional trees for agricultural or commercial purposes. In this sense, fuelwood collection may represent a subsistence-oriented activity that does not necessarily require large-scale forest clearing. Similar observations have been noted in studies of rural forest use, where the environmental impact of fuelwood extraction depends on the intensity and method of collection, particularly whether households harvest deadwood or live trees (Runyan & Stehm, 2020). However, the statistical significance of the variable is relatively weak (significant at the 10% level), suggesting that the relationship should be interpreted with caution. The consistency of the coefficient across Poisson, generalized linear model (GLM), and Negative Binomial specifications nonetheless indicates that the observed pattern is not driven by model choice. Overall, the results suggest that fuelwood extraction is not a primary driver of tree-cutting behavior in the study area and may instead reflect routine household energy needs rather than land-use expansion or market-oriented forest exploitation.

Household timber extraction does not exhibit a statistically significant association with tree-cutting behavior (β = −0.00219, p = 0.801). As a dichotomous variable, the coefficient reflects the difference between households engaged in timber extraction for household use and those that are not. The estimated incidence rate ratio is close to unity (IRR ≈ 0.998), indicating that there is no meaningful difference in expected tree-cutting counts between these two groups, ceteris paribus.

This result suggests that timber extraction for household consumption—such as for housing materials or basic domestic use—may be relatively small in scale and does not substantially contribute to overall tree-cutting intensity. Unlike commercial timber extraction, which is driven by market demand and income-generating incentives, household-level timber use is typically subsistence-oriented and limited in scope. As a result, its contribution to aggregate forest clearing appears negligible in the study area. Similar findings have been reported in studies of forest-dependent communities, where subsistence use of forest resources is often less associated with large-scale deforestation compared to market-oriented extraction and agricultural expansion (Angelsen & Kaimowitz, 1999; Geist & Lambin, 2002; Hosonuma et al., 2012).

The lack of statistical significance across Poisson, generalized linear model (GLM), and Negative Binomial

specifications further indicates that this finding is robust to alternative model assumptions. Overall, the results imply that subsistence-oriented timber use is not a primary factor associated with variation in tree-cutting behavior, particularly when compared to land-use activities such as agricultural expansion and migration, which are more consistently identified as key correlates of deforestation in tropical frontier settings (Rudel et al., 2009; Gibbs et al., 2010).

Commercial timber extraction shows a positive and statistically significant association with household tree-cutting activities ($\beta = 0.02148$, $p = .016$). As a binary variable, this result indicates that households engaged in commercial timber extraction are associated with approximately 2.2% higher expected tree-cutting counts compared to those not engaged in such activities, ceteris paribus. This reflects the role of market demand and income-generating opportunities in shaping forest resource use. Market-oriented timber extraction has been widely associated with increased forest utilization in regions where economic incentives for forest products are present (Haddad et al., 2024; Hansen et al., 2013). This finding remains consistent across GLM and Negative Binomial models, although the magnitude of the effect is relatively modest compared to agricultural expansion.

The variable kaingin exhibits a negative and statistically significant coefficient ($\beta = -0.05587$, $p < .001$). As a dichotomous indicator, the results imply that households practicing shifting cultivation are associated with approximately 5.4% lower expected tree-cutting counts relative to households that do not practice kaingin, ceteris paribus. Traditional swidden systems are often associated with smaller-scale forest clearing activities compared with permanent agricultural expansion. Some studies suggest that shifting cultivation systems may be associated with lower long-term forest disturbance when fallow cycles allow vegetation regeneration (Runyan & Stehm, 2020). This negative association is also robust across alternative model specifications.

In contrast, sex, years of education, years of residency, and household timber extraction are not statistically significantly associated with tree-cutting activities across all model specifications. These findings suggest that demographic characteristics alone may have limited explanatory power relative to livelihood strategies and land-use decisions. Similar patterns have been reported in empirical studies examining the socioeconomic correlates of deforestation across tropical regions (Jayathilake et al., 2021).

Therefore, the econometric estimates indicate that several factors appear to be statistically associated with household tree-cutting activities in Talakag, Bukidnon. In particular, agricultural expansion, migration, infrastructure development, years of land occupation, and commercial timber extraction show consistent relationships with the number of trees cut by households across Poisson, GLM, and Negative Binomial models. The consistency of these results suggests that the findings are not driven by model specification and that the Poisson model provides an adequate representation of the data, as further supported by diagnostic tests indicating no overdispersion.

However, it is important to note that these relationships should be interpreted as associational rather than causal, given the potential endogeneity of key regressors and the cross-sectional nature of the data. Nonetheless, the observed patterns are consistent with the broader literature on tropical deforestation, where forest loss is commonly linked to agricultural expansion, population pressure, and market incentives (Gibbs et al., 2010; Hosonuma et al., 2012; Hansen et al., 2013). The results also align with the analytical framework of Geist and Lambin (2002), which emphasizes the interaction between proximate land-use activities and underlying socioeconomic conditions. Similar dynamics have been documented in Southeast Asia and the Philippines, where forest frontier areas experience increasing pressure from agricultural expansion, migration, and infrastructure development (Nolos et al., 2023; Araza et al., 2021; Jardeleza et al., 2019).

Diagnostic Test for Model Validation

Diagnostic tests were conducted before and after estimating the Poisson regression model to assess the underlying econometric assumptions and to evaluate the adequacy of the model specification, respectively. The results presented in Table 4 indicate that the Poisson regression model provides an appropriate specification.

Table 4 — Diagnostic tests for model specification and goodness of fit

Diagnostic Test	**Result**	**Interpretation**
VIF	Mean = 1.11	No multicollinearity
Poisson goodness-of-fit	$p \approx 0.34$	Good model fit
Dispersion	$\varphi \approx 1.05$	No overdispersion
Negative binomial LR test	$p = 0.498$	Poisson preferred
Link test	p(_hatsq) = 0.787	Correct specification

Note. VIF= variance inflation factor; GOF = goodness-of-fit; LR = likelihood ratio; φ = dispersion parameter.

Multicollinearity among the explanatory variables was examined using the Variance Inflation Factor (VIF). The estimated mean VIF of 1.11 is well below the commonly used threshold value of 10, indicating that the explanatory variables are not highly correlated with one another. This suggests that multicollinearity is not a concern in the model and that the estimated regression coefficients can be interpreted with reasonable stability.

After estimating the Poisson model, a goodness-of-fit (GOF) test was conducted to evaluate whether the predicted counts adequately represent the observed data. The test produced a p-value of approximately 0.34, indicating that the model provides an acceptable fit to the observed distribution of the dependent variable.

The dispersion parameter was also examined to verify the equidispersion assumption of the Poisson model, which requires the conditional mean and variance of the dependent variable to be equal. The estimated dispersion statistic ($\varphi \approx 1.05$), calculated as the ratio of the Pearson chi-square statistic to its degrees of freedom, is close to unity. This suggests that the equidispersion assumption holds and that overdispersion is not present in the data.

To further assess model suitability, a likelihood ratio test comparing the Poisson and negative binomial models was performed. The resulting p-value of 0.498 indicates that the dispersion parameter in the negative binomial specification is not statistically different from zero. Consequently, the negative binomial model does not provide a better fit than the Poisson model, supporting the selection of the Poisson specification.

Finally, a link test was conducted to detect potential specification errors in the Poisson regression model. The squared predicted value term (_hatsq) was statistically insignificant ($p = 0.787$), indicating no evidence of omitted variable bias or functional form misspecification.

Collectively, the diagnostic results confirm that the Poisson regression model provides an appropriate and reliable framework for analyzing household tree-cutting activities in Talakag, Bukidnon. The absence of multicollinearity, heteroskedasticity, and overdispersion, together with satisfactory model fit and correct specification, supports the robustness of the estimated regression results.

CONCLUSIONS

This study analyzed the socioeconomic drivers of deforestation in Talakag, Bukidnon using household-level data and count-data modeling approaches, including Poisson regression, generalized linear modeling (GLM), and Negative Binomial estimation. The results indicate that household tree-cutting behavior is statistically associated with land-use activities, demographic conditions, and livelihood-related resource utilization. In particular, agricultural expansion, migration, infrastructure development, years of land occupation, and commercial timber extraction exhibit consistent positive associations with the number of trees cut by households across all model specifications. The stability of these estimates suggests that the findings are robust to alternative count-data

models and are not driven by a specific estimation technique.

The empirical results further indicate that longer periods of land occupation and accumulated farming experience are associated with higher levels of forest clearing, reflecting gradual land-use expansion patterns commonly observed in forest frontier areas. In contrast, variables such as education, sex, residency, and household-level timber extraction show weak or statistically insignificant associations across all models, suggesting that broader land-use and livelihood dynamics may play a more prominent role than individual demographic characteristics in shaping deforestation behavior.

Taken together, the findings suggest that forest clearing in Talakag is closely associated with the expansion of agricultural production and settlement dynamics in upland communities. However, these relationships should be interpreted as associational rather than causal, given the cross-sectional nature of the data and the potential endogeneity of key explanatory variables. As such, the results reflect observable patterns in household behavior rather than definitive causal mechanisms.

From a policy perspective, the results highlight the importance of addressing the economic and institutional conditions that shape land-use decisions in forest frontier areas. Interventions that promote sustainable agricultural practices, improve land-use planning, and strengthen forest governance may help mitigate pressure on forest resources. In particular, agroforestry systems and sustainable upland farming practices offer potential pathways for balancing livelihood needs with environmental conservation. At the same time, the feasibility and effectiveness of such interventions depend on local institutional capacity, market conditions, and community participation, suggesting that policy design should be context-specific and grounded in local realities.

Therefore, the study contributes micro-level empirical evidence on the socioeconomic conditions associated with deforestation in a forest frontier municipality. Future research may build on these findings by incorporating longitudinal data, spatial analysis, or quasi-experimental methods to better address endogeneity and strengthen causal inference in the study of deforestation dynamics.

RECOMMENDATIONS

The findings suggest that addressing deforestation in Talakag, Bukidnon requires policy approaches that balance forest conservation with the livelihood needs of upland communities. Given that agricultural expansion and settlement dynamics are consistently associated with higher levels of tree-cutting across model specifications, policy responses should focus on managing land-use pressures while maintaining viable income opportunities for rural households. Strengthening national rehabilitation programs such as the Enhanced National Greening Program under the Department of Environment and Natural Resources may contribute to the restoration of degraded forest areas. Expanding reforestation and restoration initiatives in municipalities experiencing significant forest loss can also support livelihood generation through agroforestry and community-based tree-growing activities. However, the effectiveness of these programs depends on sustained financial support, technical capacity, and local implementation conditions.

Community participation remains a critical component of sustainable forest management. Strengthening mechanisms under the Community-Based Forest Management Program may encourage greater involvement of local communities and people's organizations in forest protection, monitoring, and responsible resource use. Participatory approaches can improve compliance with forest regulations, reduce illegal extraction, and promote collective stewardship of forest resources. At the same time, their effectiveness depends on clearly defined property rights, institutional support, and incentives aligned with community welfare.

Given the strong association between agricultural expansion and tree-cutting behavior, promoting agroforestry and sustainable upland farming systems should be prioritized. Programs supported by the Department of Agriculture and the Department of Environment and Natural Resources can facilitate the integration of tree crops into farming systems. Agroforestry practices have the potential to improve soil conservation, enhance farm productivity, and diversify income sources, thereby reducing pressure to expand agricultural land into forested areas. Nevertheless, adoption depends on access to markets, extension services, and initial investment support

for farmers.

Effective forest protection also requires stronger coordination between local government units and national environmental programs. Aligning local development initiatives with national environmental policies and funding priorities may improve the implementation of reforestation, watershed protection, and biodiversity conservation programs in Bukidnon. In addition, environmental education and livelihood diversification initiatives can help shift household dependence away from forest-intensive activities. The feasibility of such interventions, however, is contingent on local governance capacity and the availability of alternative economic opportunities.

Finally, continued research is necessary to strengthen the evidence base for forest management policies. Future studies may extend the analysis beyond Talakag to other municipalities in Bukidnon and Northern Mindanao to improve external validity. Incorporating spatial analysis, satellite-based monitoring, and longitudinal data would allow for a more comprehensive understanding of deforestation dynamics and help address current limitations related to endogeneity and causal inference. Such approaches can support the design of more targeted and evidence-informed environmental policies in forest frontier areas of the Philippines.

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