

Impact of Arecanut Plantation on Farming System and Livelihood: A Case Study of Chhuzanggang Gewog, Sarpang

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Abstract

Farming systems are dynamic and context-specific, shaped by interactions between crops, livestock, labour and natural resources. In Bhutan, a growing shift from subsistence mixed farming to market-oriented cash crop cultivation has become prominent in the subtropical regions. This study assessed the impact of increasing arecanut plantations on the performance of the farming system and the livelihoods of the farmers of Chhuzanggang Gewog, Sarpang Dzongkhag. A cross-sectional multi-stage sampling method was employed, combining a household survey (n = 117) with field observations and secondary data. Farms were categorized into three groups based on arecanut land coverage: Low Arecanut Coverage (LAC) (<25%), Medium Arecanut Coverage (LAC) (25-75%), and High Arecanut Coverage (LAC) (>75%). Four farm indicators, i.e., area allocation for crop cultivation, food self-sufficiency, income per capita, and crop diversity, were compared among three farm categories. The results showed higher farms under MAC (n=62, 53%), followed by LAC (n=44, 38%), and HAC (n=11, 9%). The HAC farms showed the lowest percent household calorific fulfilment of 0.00% compared to MAC (14.7%) and LAC (92.20%). However, HC farms were found to have the highest per capita income of 5.52\$PPP per day per person. Crop diversity was also observed to decrease with increasing arecanut plantations; an SDI score of 0.16 was recorded in HAC, indicating low diversity. These findings highlight a trade-off between household food self-sufficiency and income generation, suggesting that rapid arecanut expansion may undermine the rich agro-biodiversity and household food self-sufficiency in the long term. Therefore, there is a need for balanced land use policies promoting sustainable arecanut production integrated with food crops to enhance the livelihood of farming communities.

Keywords: *Arecanut; farming system; impact; livelihood*

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1 Introduction

Farming systems represent the complex interactions between crops, livestock, labour, and natural resources within specific agro-ecological and socio-economic settings. They form the backbone of rural economies, with almost half of the world's households connected to agri-food systems and employing around 1.23 billion people globally (FAO, 2023). These systems have continuously evolved as a result of demand for food and fibre, adapting to local ecological conditions and cultural contexts (Reijntjes *et al.*, 1992). A prominent trend has been the gradual shift from diverse, subsistence-based farming to specialised, market-oriented cash crop production, driven by population growth, market demand, climate variability, and technological change (Thompson & Scoones, 2009; Reardon *et al.*, 2018; Kuchimanchi *et al.*, 2022).

Understanding the changing characteristics of farming systems is critical for enhancing technology adoption, guiding policy decisions, and reducing risks for rural communities (Valbuena *et al.*, 2015). Farming households are sensitive to external shocks, such as market variations and input price volatility, which can destabilise livelihoods. For example, the removal of fertilizer subsidies in Mali during the COVID-19 outbreak drastically reduced cotton production, forcing farmers to shift toward lower-input crops and indicating the importance of affordable inputs in sustaining cash crop production (Dissa *et al.*, 2024).

In South Asia, farming is typically integrated, combining agriculture, livestock, forestry, and fisheries, with 65% of the population residing in rural areas. (FAO & IFAD, 2019). Despite this reliance, 14.9% of the population remains undernourished, and 216 million live below the international poverty line of \$ 1.90 per day (Shrestha *et al.*, 2021). Land use changes, including the expansion of commercial crops, have increasingly displaced native crops, reducing dietary diversity and threatening long-term food and nutrition security (ICIMOD, 2018).

Bhutan reflects many of these regional dynamics, but with unique challenges due to its geography. Only 2.93% of land is arable, much of it situated on steep slopes, and the average household landholding is just 2.16 acres (Ministry of Agriculture and Forests [MoAF], 2011; National Statistics Bureau [NSB], 2018). Farming systems are primarily subsistence-oriented, integrated, and self-sufficient, with households cultivating diverse crops and rearing livestock to meet food needs (Katwal, 2013). However, Bhutan remains dependent on imports for

essential food items, with cereal self-sufficiency estimated at 77.3% and rice at only 47.1% (Dukpa et al., 2021).

Cash crop cultivation has emerged as a major livelihood source, reducing poverty and improving rural infrastructure (Shangdiar, 2021). Additionally, exports create employment opportunities and promote economic growth. Conversely, the shift towards cash crop farming disrupts ecosystem services and promotes monoculture (Zhang et al., 2012). In Bhutan, the gradual replacement of indigenous crop varieties by cash crops poses a significant risk of permanent displacement and on-farm extinction (Wangda et al., 2019).

Areca nut cultivation has become a major cash crop in Bhutan's subtropical region, with cultivation now extending to ten districts. The production has risen by 69.3% in recent years, (NSB, 2021), driven by the rapid expansion of cultivated area. Consequently, it adds income advantages. Yet, this shift towards cash crop cultivation raises concerns about reduced food self-sufficiency at the farm level, poor dietary diversity, and the displacement of indigenous crop varieties (Behera et al., 2016). Despite its growing importance, the implications of expanding areca nut cultivation for farming systems and community livelihoods have not been studied. Understanding this transition is essential for evidence-based agricultural planning and policy decision-making. Therefore, this study assessed the impact of the increasing areca nut plantations on the farming system and livelihoods. This study was conducted in Chhuzanggang Gewog, where areca nut cultivation predominates in dryland areas. A cross-sectional mixed-method research design was employed, incorporating both quantitative and qualitative data collection approaches.

2 Materials and method

2.1 Study area

This study was conducted in five Chiwogs of Chhuzanggang Gewog under Sarpang Dzongkhag (Figure 1) in December 2022. Geographically, it is located on the eastern side of Sarpang (26°52'04.76'' N and 90°31'32.25'' E) and 56 km away from the Dzongkhag headquarters. It has a land area of 53.20 square kilometres and an altitude ranging from 195-300 masl. The cropping system is centred on paddy as the primary cereal crop, with areca nut, ginger, and winter vegetables produced as major cash crops. Cattle, poultry, and goats are the most commonly raised livestock. Chhuzanggang was selected as the study site since it is one of the highest areca nut-producing gewogs in the district, with farmers increasingly allocating more dryland to areca nut plantations each year.

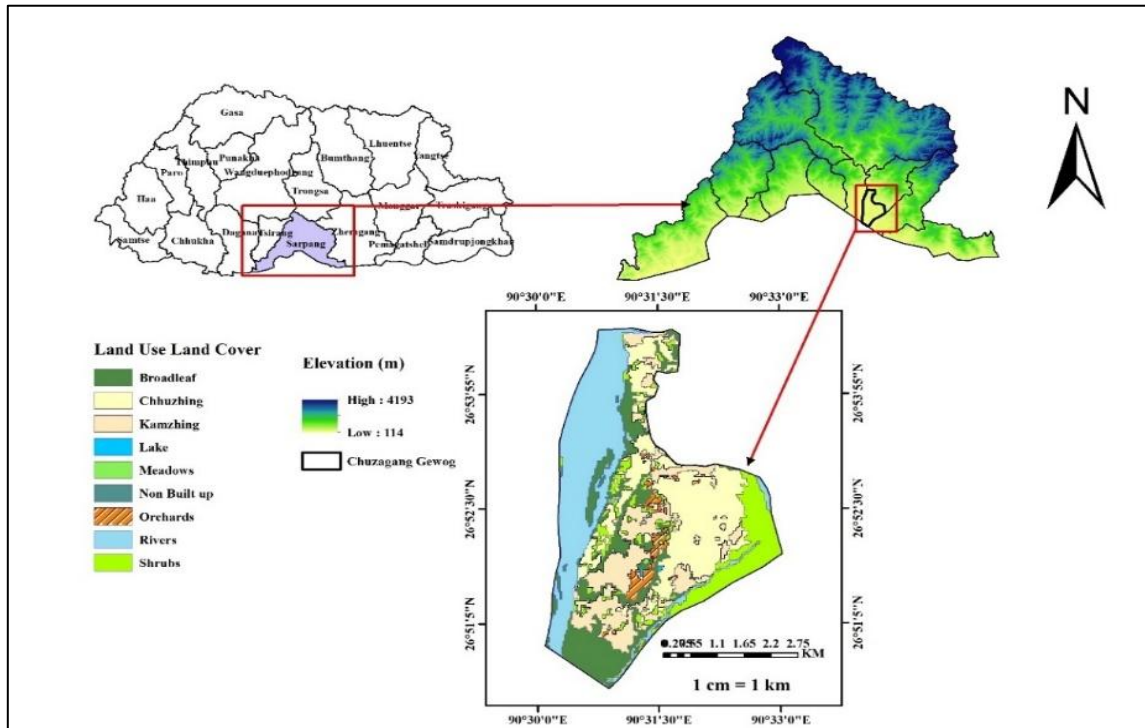


Figure 1: Map of Bhutan showing the location of the study area, Chhuzanggang Gewog in Sarpang Dzongkhag

2.2 Sampling method and data collection

A cross-sectional, mixed-methods research design was employed, integrating both quantitative and qualitative data collection approaches. Primary data were obtained from selected farmers using a semi-structured questionnaire. Chhuzanggang comprises 389 households, of which 30% ($n = 117$) were included in the study (Table 1). Given the similarity of farming systems across the five Chiwogs in Chhuzanggang, a 30% sampling intensity was considered sufficient to represent the population. Moreover, Hair et al., (2009) suggest that a minimum sample size of 100 observations is generally adequate for inferential analyses. After determining the sample size, a three-stage sampling procedure was employed; purposive sampling in the first stage, followed by proportionate sampling, and finally, simple random sampling.

Purposive sampling was employed to select Gewogs aligned with the study objectives, followed by proportionate sampling to ensure that Chiwogs with larger household numbers and more extensive arecanut cultivation contributed proportionally to the sample. Simple random sampling was then conducted within each Chiwog, providing all households an equal probability of selection.

Table 1: Proportionate sample from each Chiwog with geo-coordinates

Chiwog	Total household (N)	Sample size (30% of N)	Geo-coordinates
Barthang	102	31	26.85°N, 90.52°E
Yueling	103	31	26.87°N, 90.52°E
Shawapang	61	18	26.90°N, 90.52°E
Pangzor	69	21	26.91°N, 90.52°E
Chaskhar	54	16	26.88°N, 90.52°E
Total	389	117	

The questionnaire was developed in “My Survey Solution” web-based application, and the data collection was carried out using the mobile application “Interviewer” through face-to-face interviews. The survey questionnaires captured information on multiple variables, such as household information, land holding and utilization, crop and livestock production, household income from the crop, and area allocation for crop production. In addition, field observations, literature reviews, and secondary data maintained by the Renewable Natural Resources Extension Centre of Chhuzanggang and the NSB were also used.

2.3 Farm categorization

Most of the farmers in Bhutan are small-holders, and their ways of producing crops vary based on the availability of resources. Thus, this study included three farm categories to examine the impact of increased arecanut plantations on the farming system and livelihood. The farm categorization was carried out similarly to the study conducted by (Anderman et al., 2014), where it was based on a percentage of land allocated to cash crops; Farm Category 1: Low Arecanut Coverage (LAC); defined as land having <25% of arecanut plantations, Farm Category 2: Medium Arecanut Coverage (MAC); defined as land having 25% to 75% of arecanut plantations, and Farm Category 3: High Arecanut Coverage (HAC); defined as land having >75% of arecanut plantations.

2.4 Parameter used for assessing the impact

To determine the impact of increased arecanut plantation, the study considered four indicators: 1) area allocation for the crop cultivation, 2) food self-sufficiency, 3) Income per capita, and 4) diversity of crops.

2.4.1 Area allocation (ac)

The cultivated area refers to the land utilized by individual farms for growing crops. It was determined by adding the areas dedicated to cereal, vegetables, spices, fruit, and arecanut cultivation. The survey inquired about farming practices, including recording the household's total cultivated land and crop-wise area allocation. These measurements were based on estimates provided by the farmers for one year.

2.4.2 Food self-sufficiency (FSS%)

Food self-sufficiency was calculated based on the fulfilment of the household calorific need by on-farm production of calories. The total calories produced on a farm were estimated from the household's annual crop production, and the calorie requirements were derived based on the gender and age composition of household members. Food self-sufficiency was then expressed as the percentage of total caloric needs met through on-farm production, as shown in the equation (Eq.1).

$$FSS(\%) = \frac{\text{Calorie produced on farm}}{\text{HH calorie requirement}} * 100 \dots\dots\dots (1)$$

In this study, only cereal crops, *i.e.*, paddy, maize and millet, were considered as food crops supplying calories, as they are the most commonly cultivated and consumed in Bhutan. Since food self-sufficiency focuses on self-produced food, food purchased outside the farm was not included in the calculation. The caloric content of each cereal was determined according to standards set by the FAO (2001), and the total on-farm calorie production was calculated using the equation (Eq. 2):

$$\text{Calorie produced on farm} = \sum_c(\text{calorie content}_c * \text{prod}_c) \dots\dots\dots (2)$$

Where:

Calorie content_c: the crop-specific calorie content (kcal kg⁻¹)

prod_c: production of the crop (kg)

The total household calorific requirement was estimated using Equation (Eq.3), accounting for differences in gender (male and female) and generations (children and adults). As the study was conducted within a farming community, an active lifestyle was assumed. Caloric requirements for each gender and generation were derived following Britten et al. (2006).

$$\text{HH calorie requirement} = 365 * \sum(a + b + c + d) \dots\dots\dots (3)$$

a = Reqcal * TMC

b = Reqcal * TMA

$$c = \text{Reqcal} * \text{TFC}$$

$$d = \text{Reqcal} * \text{TFA}$$

Where:

Reqcal: Calorie requirement as per the gender and generation day (kcal day⁻¹)

TMC= Total number of male children

TMA= Total number of male adults

TFC= Total number of female children

TFA= Total number of female adults

a: calorie requirement for the total number of male children per day (kcal day⁻¹)

b: calorie requirement for the total number of male adults per day (kcal day⁻¹)

c: calorie requirement for the total number of female children per day (kcal day⁻¹)

d: calorie requirement for the total number of female adults per day (kcal day⁻¹)

HH calorie requirement: Total household calorie requirement per year (kcal year⁻¹)

2.4.3 Income per capita

Per capita income was calculated using the equation (Eq. 4), taking into account the revenue generated from crop sales and the number of household members present in a year. Per capita income was expressed in US dollars purchasing power parity (\$PPP) to compare with the international poverty line of 2.15 \$PPP day⁻¹ person (World Bank, 2022). Local currency income (Bhutanese Ngultrum, BTN) was converted to USD PPP using the PPP conversion factor of 19.37 BTN per USD PPP for 2022, as reported by CEIC (2023).

$$\text{Income per capita (\$ppp/day)} = \frac{\text{Net crop income}}{\text{HH members} * 365} \dots\dots\dots (4)$$

2.4.4 Diversity of crops

Crop diversity was calculated using Simpson’s diversity index (SDI) because it considers relative crop abundance; additionally, it is the most commonly used indicator in many studies (Lourme-Ruiz et al., 2021). The proportional abundance of each crop type was determined by dividing the area of each crop type by the total area of all crops. The crop diversity was calculated using the equation (Eq. 5), and the resulting Simpson Diversity Index (SDI) scores were interpreted according to the classification proposed by Guajardo (2015).

$$\text{Simpson Diversity Index (SDI)} = 1 - \sum(pi)^2 \dots\dots\dots (5)$$

Where:

p_i = Proportional abundance of each crop type

2.5 Data Analysis

The statistical analysis was performed using R (version 4.5.1) and Microsoft Excel (version 2021) to assess the impact of arecanut plantations. The normality of the data was initially checked using Q-Q plots and histograms, but the assumptions required for parametric tests were not met. Therefore, the Kruskal-Wallis H test was used to examine the effects of the three farm types on area allocation for crop cultivation, food self-sufficiency, per capita income and crop diversity. When significant differences were observed among groups with more than two levels, post-hoc pairwise comparisons were conducted using Dunn's test with Bonferroni correction at a significance level of $p < 0.05$. Additionally, descriptive statistics, including mean, standard deviation, minimum, maximum, and quartiles, were computed for each farm category.

3 Results and Discussion

3.1 Demographic characteristics of the respondents

Table 2 presents the profiles of the study respondents, showing that the majority were female (55.60%). Male respondents accounted for a smaller proportion (44.40%), resulting in a male-female ratio of 1.24. The mean age of the respondents was recorded as 52.78 ± 14.66 years, ranging from 23 to 80 years of age, and the majority (39.32%) of them were illiterate. Among the literate participants, those who had received non-formal education constituted the highest proportion (29.06%), while participants with tertiary education represented the lowest proportion (1.7%).

Table 2: Demographic profile of the respondents (n=117)

Characteristics	Categories	Percentage (%)
Gender	Male	44.40
	Female	55.60
Age	60 years and below	67.50
	61 years and above	32.50
Literacy level	Illiterate	39.32
	NFE	29.06
	Primary school	18.80
	High school	11.11
	Tertiary education	1.71

3.2 Impact of arecanut plantation

The majority of households in Chhuzanggang fall under the medium arecanut coverage farm category, followed by low and high (shown in Figure 2). The statistical analysis revealed a significant difference in food self-sufficiency, income per capita, crop diversity, and area allocation for cereal among the three categories ($p < .05$). However, the results did not show a significant difference in the area allocation of vegetables, spices, and fruit ($p > .05$).

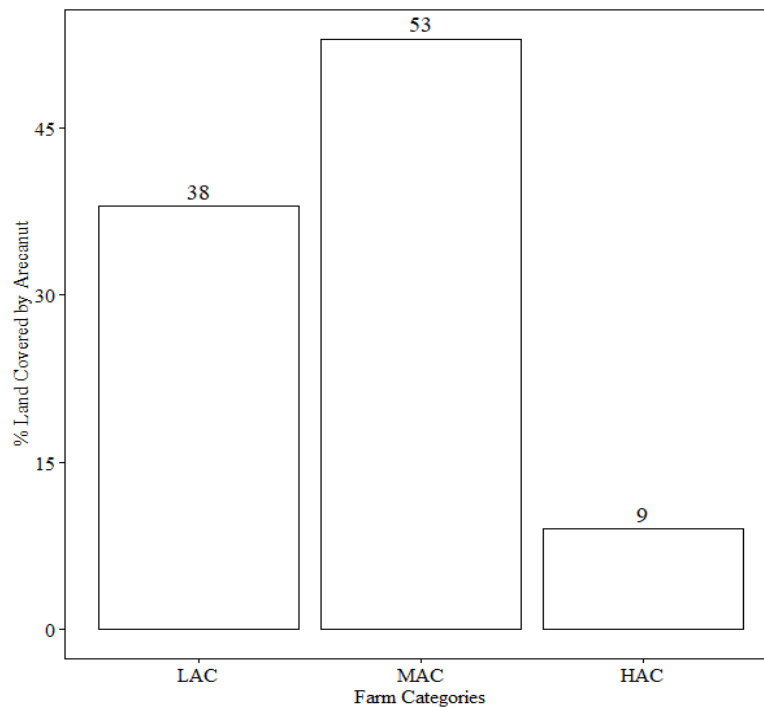


Figure 2: Number of households under each farm category

3.2.1 Area allocation for the cultivation of crops:

The study results revealed a significant difference in land allocation for cereal cultivation among farm categories, $H(2) = 20.41$, $p < 0.001$ (Table 3). Post-hoc pairwise comparisons using Dunn's test with Bonferroni adjustment indicated that households with Low Arecanut Coverage allocated significantly more land than those with Medium Arecanut Coverage ($Z = 3.17$, $p = 0.005$) and High Arecanut Coverage ($Z = 4.11$, $p < 0.001$). No statistically significant difference was observed between Medium and High Arecanut Coverage groups ($Z = 2.33$, $p = 0.060$).

Table 3: Descriptive statistics of the area (ac) allocated for crop (Mean \pm SD)

Farm categories	$n=117$	Cereal (ac)	Vegetable (ac)	Spices (ac)	Fruit (ac)
LAC	44	2.09 ± 1.65^a	0.08 ± 0.17^a	0.03 ± 0.09^a	0.08 ± 0.05^a
MAC	62	1.13 ± 1.35^b	0.06 ± 0.09^a	0.04 ± 0.11^a	0.09 ± 0.05^a

HAC	11	0.17 ± 0.42 ^b	0.04 ± 0.02 ^a	0.05 ± 0.08 ^a	0.10 ± 0.04 ^a
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* Values with different superscripts within rows are significantly different [$p < .05$] at a 95% confidence interval. Significance values have been adjusted by the Bonferroni correction for multiple tests.

No significant differences were found in the allocation of land for fruit, vegetable, and spices cultivation among the three farm categories ($p > 0.05$). This lack of difference may be attributed to the widespread practice of intercropping among farmers, with 93.20% cultivating arecanut alongside vegetables, fruits, and spices, which results in similar land allocation patterns across farm types. The feasibility of intercropping other crops with arecanut was supported by previous studies. For example, Sujatha et al. (2006) recommended utilizing the space available between arecanut trees for crop cultivation, as arecanut occupies only 35% of the available area for growth and survival, leaving the remaining 65% underutilized. In contrast, cereal crops were not intercropped with arecanut due to their higher sunlight requirements (Dufour et al., 2013), which resulted in observable differences in area allocation for cereals among the three farm categories.

3.2.2 Food self-sufficiency

According to the FAO (1999), “The concept of food self-sufficiency is generally taken to mean the extent to which a country can satisfy its food needs from its domestic production.” This study considers the concept of food self-sufficiency at the household level. The study found a significant relationship between household food self-sufficiency and the allocation of land to arecanut plantations. The test results (Figure 3) showed a significant difference in food self-sufficiency among households with different levels of arecanut coverage ($H(2) = 14.64, p < 0.001$). Post-hoc pairwise comparisons indicated that households with Low Arecanut Coverage were significantly more self-sufficient than those with Medium ($Z = 2.56, p = 0.032$) and High Coverage ($Z = 3.55, p = 0.001$). However, no significant difference was observed between Medium and High coverage groups ($Z = 2.12, p = 0.102$).

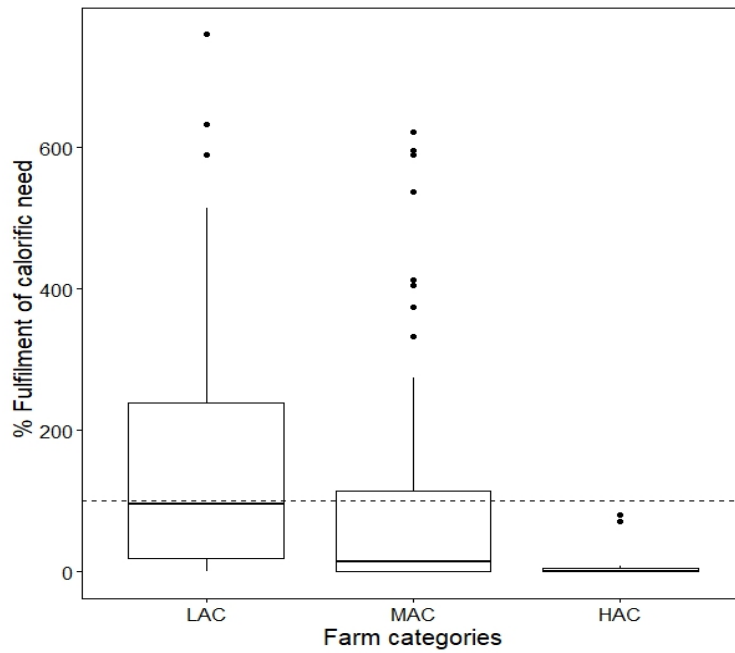


Figure 3: Percentage of calorific fulfilment of the three farm categories. The horizontal black dashed line shows the 100% benchmark for calorie self-sufficiency

The median percentage of caloric fulfilment was highest in Low Arecanut Coverage households (96.2 [19.0-239.0]), followed by Medium (14.7 [0-115.0]), and lowest in High Coverage households (0 [0-4.32]). These results suggest that increasing land allocation to arecanut may reduce household food self-sufficiency. Similar observations have been reported by (Anderman et al., 2014), who found that farmers dedicating more land to cash crops faced greater challenges in meeting their own food needs. Furthermore, households with greater emphasis on cash crop production were also found to have poorer dietary habits.

3.2.3 Income per capita

The income per capita varied significantly across the three farm categories (Figure 4), $H(2) = 17.60$, $p < 0.001$. The household with Low Arecanut Coverage had significantly lower income than those with Medium Arecanut Coverage ($Z = -2.69$, $p = 0.022$) and High Arecanut Coverage ($Z = -3.95$, $p < 0.001$). Additionally, the household with Medium Arecanut Coverage had significantly lower income than those with High Arecanut Coverage ($Z = -2.45$, $p = 0.043$). Median income per capita (\$PPP day⁻¹ person⁻¹) was lowest among households with Low Arecanut Coverage (1.36 [0.71-3.01]), followed by Medium Arecanut Coverage (2.50 [1.20-5.63]), and was highest among households with High Arecanut Coverage (5.52 [4.12-12.50]).

The observed income differences across arecanut coverage categories suggest a positive association between arecanut cultivation intensity and household income, consistent with previous findings that cash crop expansion can enhance farm income ((Meng et al., 2020; Masanjala., 2006). These results are based on univariate group comparisons and observed differences in income across farm categories; variation in farm size, household size, education, and labour availability may influence the results, which were not considered in the analysis.

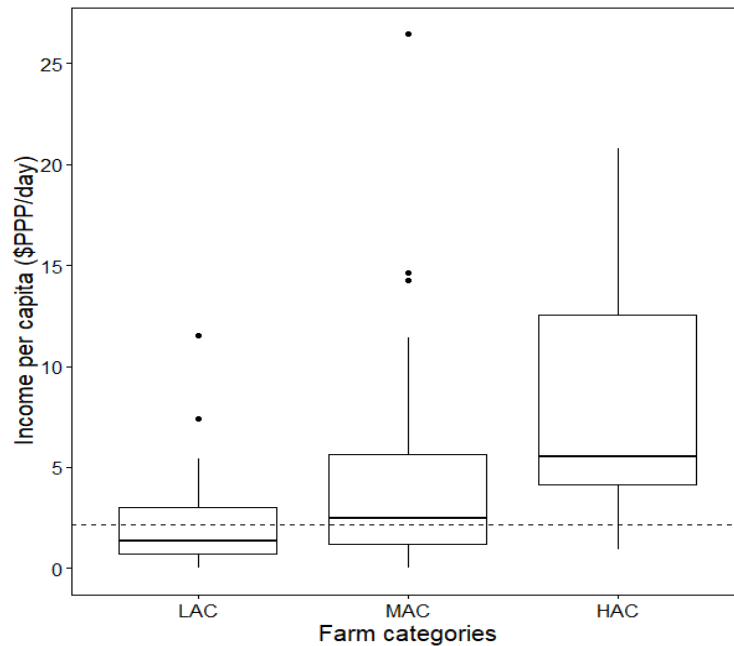


Figure 4: Income per capita of a household of three farm categories. The horizontal black dashed line represents the benchmark for the international poverty line of 2.15 \$PPP day⁻¹ person

3.2.4 Crop diversity

The study documented 37 crop types, with individual households cultivating between 3 and 29 types. Arecanut was cultivated by all households, and its cultivation significantly affected household-level crop diversity. A statistically significant difference in crop diversity was observed among households with different Arecanut Coverage, $H(2) = 17.68, p < 0.001$. Post hoc pairwise tests showed that households with Low Arecanut Coverage did not differ significantly from those with Medium Arecanut Coverage ($Z = -0.08, p = 1.000$). However, households with Low Arecanut Coverage had significantly higher diversification than those with High Arecanut Coverage ($Z = 3.92, p < 0.001$), and households with Medium Arecanut Coverage also had significantly higher diversification than those with High Arecanut Coverage ($Z = 4.09, p < 0.001$).

Households with low and medium arecanut coverage exhibited moderate levels of crop diversity, whereas households with high arecanut coverage showed comparatively low crop diversity (Table 4). This pattern is consistent with the findings of Abebe (2013), who reported that increased allocation of farm resources to cash crops is associated with reduced agrobiodiversity, a decline in staple crop cultivation, and a shift toward monoculture practices. At the national level, poverty alleviation and food self-sufficiency remain key development priorities, with crop diversification identified as a central approach to achieve these objectives (MoF, 2004; MoAF, 2020). However, the expansion of arecanut plantations in Chhuzanggang appears to constrain crop diversification within the study area.

Table 4: Descriptive statistics of crop diversity index of farm categories (Mean \pm SD)

Farm categories	Household (%)	Simpson score	Degree of diversity
LAC	38	0.44 \pm 0.14 ^a	Moderate diversity
MAC	53	0.42 \pm 0.18 ^a	Moderate diversity
HAC	9	0.16 \pm 0.13 ^b	Low diversity

* Values with different superscripts within rows are significantly different [$p > .05$] at a 95% confidence interval. Significance values have been adjusted by the Bonferroni correction for multiple tests.

4 Conclusions

The findings of this study demonstrate that the expansion of arecanut plantations has a significant influence on food self-sufficiency, income generation, and crop diversity of the farm. Farms with higher proportions of land under arecanut cultivation achieved higher income per capita, indicating the economic benefits of arecanut as a cash crop. However, this economic gain was accompanied by a marked decline in household food self-sufficiency. The reduction in cereal cultivation area among farms with high arecanut coverage underscores the trade-off between commercial crop production and household food self-sufficiency. These findings suggest that increased dependence on arecanut may enhance short-term income but poses long-term risks to household nutritional security and agricultural resilience. Furthermore, as more land was allocated to arecanut plantations, crop diversity on the farm decreased significantly. Therefore, there is a need for a balanced agricultural development approach that integrates both cash crop production and food crop cultivation to sustain rural livelihoods. Policymakers and extension agencies should promote diversified farming

systems and intercropping models that enable farmers to maintain food production while benefiting economically from arecanut.

5 Acknowledgments

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6 Author's contribution statement

Ugyen Gyeltshen contributed as the corresponding author, conceptualization, writing-original draft, review and editing, developing the survey questionnaire, coordinating the survey, data curation, and formal analysis. Tenzin Wangchuk contributed to supervision, conceptualisation, writing, review, and editing, and formal analysis.

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