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Conservation and trade dynamics of non-timber forest products in local markets in south western Cameroon

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ABSTRACT

Non-Timber Forest Products (NTFPs) are vital for rural livelihoods and biodiversity conservation in tropical forest regions. The unsustainable harvesting of NTFPs in Cameroon's tropical forests threatens biodiversity and rural livelihoods, necessitating an urgent evaluation of trade dynamics and conservation practices to ensure long-term ecological and economic sustainability. This study examines NTFP trade dynamics, usage, and conservation practices across four local markets (Muea, Mapanja, Batoke, and Etome) in a biodiversity-rich tropical forest region of Cameroon. Employing a triangulation approach, the study integrated quantitative data from structured questionnaires (n=62) with qualitative insights from six focus group discussions to characterize NTFP types, quantities, frequencies, and associated conservation practices across age groups. Findings reveal that white pepper (27.7%) and njangsang (25.5%) dominate trade, with balanced supply and demand (p=0.288). Conservation practices, including selective harvesting and latex tapping, vary significantly by age ($p=2.2\times10^{-16}$), with older adults (60–79 years) showing a near-universal adherence to sustainable methods, while the middle-aged (30–59 years) and younger (0–29 years) groups exhibit a moderate adoption. NTFPs contribute substantially to household income, with 38.5% of respondents earning 11,000–20,000 FCFA daily. However, the heavy reliance on wild collection (p=0.001) over farming highlights sustainability challenges. These findings underscore the need for targeted environmental education and NTFP cultivation initiatives to balance economic benefits with biodiversity conservation. It offers critical insights for policymakers and conservationists to promote sustainable NTFP management in tropical forest ecosystems.

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INTRODUCTION

Non-timber forest products (NTFPs), encompassing a diverse array of biological resources such as spices, fruits, medicinal plants, and resins, are pivotal to supporting rural livelihoods and promoting biodiversity conservation in tropical forest regions (Epanda *et al*., 2020; Tieminie *et al*, 2021, Atinga and Bannor, 2024). Unlike timber, NTFPs provide sustainable economic opportunities without necessitating deforestation, making them a cornerstone of forest-based economies (Njie *et al*., 2022; Derebe *et al*, 2023). Globally, NTFPs contribute significantly to food security, cultural practices, and income generation, particularly in rural communities where alternative economic opportunities are limited (Derebe *et al*, 2023; Mondo *et al*., 2024). In sub-Saharan Africa, products such as bush mango *Irvingia gabonensis* Baill, njangsang (*Ricinodendron heudelotii* Heckel), and bitter cola (*Garcinia kola* Heckel) are integral to local diets and traditional medicine, while also serving as marketable commodities (Yogom *et al.,* 2020; Yao *et al*., 2024). NTFPs contribute millions to global economies, with a substantial impact on household incomes in developing countries, where they can account for up to 30% of household income in forest-adjacent communities (Kimengsi *et al*., 2022; Qiao *et al*., 2024).

The economic significance of NTFPs is undeniable, yet their increasing commercialization raises concerns about overexploitation and its potential to threaten biodiversity and ecosystem services (Njie *et al*., 2022). Unsustainable harvesting practices, such as destructive bark collection or excessive fruit harvesting, can deplete seed banks and hinder forest regeneration, posing risks to long-term ecological sustainability (Zhang *et al*., 2021).

Overharvesting of high-value NTFPs like njangsang (*Ricinodendron heudelotii* Heckel) and white pepper (*Piper nigrum* L.) in Central Africa has been linked to reduced species abundance in some regions (Mbega *et al*., 2024). The reliance on wild collection over cultivation further exacerbates the risk of forest degradation, underscoring the urgent need for sustainable management practices (Atinga and Bannor, 2024). These challenges highlight the necessity of balancing economic benefits with ecological sustainability to ensure that NTFP extraction does not compromise forest ecosystems.

Conservation strategies are critical to mitigating the environmental impacts of NTFP harvesting. Practices such as selective harvesting of leaves, collecting only fallen fruits, or tapping latex without damaging trees have been proposed to minimize ecological harm (Gaoue *et al*., 2017; Chukwuone *et al*., 2020). However, the adoption of these practices varies widely across demographic groups, influenced by factors such as age, education, and market access. Younger and more educated individuals may be more likely to adopt sustainable practices due to greater exposure to environmental education, while older generations often rely on traditional, sometimes less sustainable, harvesting methods (Gaoue *et al*., 2017; Chukwuone *et al*., 2020; Chishaleshale *et al*., 2024). This variability suggests that targeted interventions are needed to promote sustainable practices across diverse community groups.

Despite the growing body of research on NTFPs, significant gaps remain in understanding their trade dynamics at the local market level, particularly in terms of the types, quantities, and economic contributions of NTFPs in specific markets. Previous studies have largely focused on regional or global trends, with limited attention to localized market dynamics and their implications for biodiversity conservation (Konsala *et al*., 2020; Zeh *et al*., 2022). The influence of education levels on the adoption of sustainable harvesting practices is underexplored, especially in regions where formal education varies widely (Ndo *et al*. 2024).

The increasing commercialization of NTFPs in local markets raises concerns about overexploitation and its impact on forest biodiversity, yet limited data exist on the trade dynamics, including the types, quantities, and economic contributions of NTFPs in specific markets. Additionally, the extent to which conservation practices are adopted, and how these vary across age groups and education levels, remains poorly understood.

This study addresses these gaps by investigating NTFP trade, usage, and conservation practices in four local markets within a tropical forest region. By integrating quantitative data from questionnaires and qualitative insights from focus group discussions, the study aims to provide a comprehensive analysis of NTFP dynamics and their implications for sustainable forest management. The objectives of this study were to characterize the types, quantities, and frequencies of NTFPs sold and bought in local markets, and to evaluate conservation practices associated with NTFP across different age groups. This study hypothesizes that the types, quantities, and frequencies of NTFPs sold and bought in local markets vary significantly depending on the product category, reflecting differences in demand and availability. Moreover, the conservation practices related to NTFP harvesting differ across age groups, with middle-aged and older-aged groups showing higher adoption rates.

By testing these hypotheses, this study seeks to fill critical knowledge gaps regarding NTFP trade dynamics and conservation practices at the local level. The findings will offer valuable insights for policymakers, conservationists, and community stakeholders seeking to promote sustainable NTFP management while supporting rural livelihoods. Through a detailed examination of market dynamics, demographic influences, and conservation behaviours, this research aims to contribute to the broader discourse on balancing economic development with biodiversity conservation in tropical forest regions.

MATERIALS AND METHODS

Study area

The study was conducted in four locations; Muea, Mapanja, Batoke and Etome, located in a tropical forest region known for its rich biodiversity and active NTFP markets. These areas were selected due to their proximity to forests, which serve as primary sources of NTFPs, and their established market systems for NTFP trade.

Muea is located 4.15 °N, and 9.25 °E, and Mapanja is located 4.11 °N and 9.11 °E in Buea area of Cameroon. The mean annual rainfall stands at about 3300 mm while the mean annual temperature is between 20 and 28° C, showing only limited variations of approximately 4°C throughout the year (Suh *et al.*, 2008; Manga *et al.*, 2013; Asongwe and Bame, 2025). The relative humidity varies between 70 and 80% while the annual sunshine lies between 900 to1200 hours (Asongwe and Bame, 2025). The rocks are dominantly basaltic and the soils are basically volcanic (Yerima and Van Ranst, 2005). Due to the generally hilly nature of the area, these soils are well drained and have also been weathered and partly covered by more recent deposits (Manga *et al.*, 2013).

Batoke is located 4.02 °N, 9.10 °E, and Etome is located 4.04 °N, 9.17 °E, in the Limbe area of Cameroon. Limbe is located at the Ambas Bay, the spot where Mount Cameroon meets with the Atlantic Ocean. The average temperature is equatorial, dominated with temperatures of more than 40° C at the peak of the dry season, while the annual relative humidity is above 82.5% with an average annual rainfall of about 600mm. The topography of Limbe is characterized by a low lying coastal plain, rising to a chain of horseshoe shaped hills with slopes of varying intensities with the highest points reaching 500m above sea level with its major elevation in Bonadikombo (Limbe City Counci, 2025).

Study design and data collection

This study employed a triangulation approach to characterize the types, quantities, and frequencies of non-timber forest products (NTFPs) sold and bought in local markets and evaluating conservation practices associated with NTFP harvesting across different age groups. Data collection was conducted through semi-structured questionnaires and focus group discussions (FGDs), enabling a robust integration of quantitative and qualitative data.

Six focus group discussions (FGD) were conducted across four market locations (Muea, Batoke, Mapanja, and Etome), with one FGD per location and two additional cross-location sessions to provide comparative context. Each FGD included 8 to 12 participants, purposively selected to represent diverse stakeholders, including traders, buyers, community leaders, and members of local

conservation groups. The FGDs were designed to familiarize participants with the study's objectives, introduce key concepts related to NTFP trade and conservation practices, and foster open dialogue to enhance subsequent questionnaire responses. Each session lasted 60 to 90 minutes and was guided by a semi-structured protocol focusing on general awareness of NTFP types and market activities, perceptions of conservation practices, and age-related perspectives on harvesting.

A structured questionnaire was developed to collect quantitative data on NTFP trade and conservation practices. The questionnaire was pre-tested with a pilot group of 15 traders and buyers across two markets to ensure clarity, reliability, and cultural appropriateness. It comprised sections on demographic characteristics (age, gender, role in market), types, quantities, and frequencies of NTFPs sold and bought, and conservation practices, including harvesting techniques and awareness of sustainability measures.

The questionnaire was administered to 62 respondents (30 traders, 32 buyers) across the four market locations, selected through stratified random sampling to ensure representation of diverse roles and demographics. The population was stratified by market location and respondent role (trader or buyer), with proportional random sampling applied to each stratum to achieve balanced participation. The sample size was determined using power calculations to detect significant differences in NTFP trade and conservation practices with 80% power and a significance level of $p<0.05$. Data collection was conducted in-person by trained research assistants to ensure consistency and minimize response bias.

Data analysis

Quantitative data from the questionnaires were analyzed using descriptive and inferential statistical methods in R Studio 4.5.1 and Microsoft Excel 2024. Descriptive statistics, including percentages, means, and standard deviations, were used to characterize the types, quantities, and frequencies of NTFPs sold and bought, as well as the prevalence of conservation practices across age groups. Pie charts and bar charts were generated to illustrate patterns in NTFP trade and conservation practices across the four market locations.

To evaluate differences in NTFP quantities sold versus bought, a paired sample t-test was applied for each NTFP type, comparing paired observations (quantities sold and bought) within each market. This test was chosen to assess whether the mean difference between the quantities sold and bought was statistically significant. Normality of the data was verified using the Shapiro-Wilk test; where normality was violated. The Wilcoxon signed-rank test was used as a non-parametric alternative.

To assess differences in conservation practices across age groups and market locations, conservation practices were grouped by three age categories: 0–29, 30–59, and 60–79 years.

For each age group, frequencies were first tallied, then converted into percentages to enable comparative analysis across groups. These percentages were interpreted to evaluate patterns in conservation behavior and to assess generational differences in sustainable NTFP harvesting practices. To statistically model the likelihood of conservation practice adoption, a probit regression analysis was employed as the response variable was binary, since respondents were asked to indicate either "Yes" or "No" to whether they practiced conservation at $p<0.05$. We assumed a normal cumulative distribution function to link the predictors to the binary outcome, allowing for robust estimation of how the likelihood of adopting conservation practices varies across age groups.

To assess differences in NTFP collection and farming practices across the four market locations (Muea, Batoke, Mapanja, and Etome), Wilcoxon Signed-Rank test was used, due to the non-normal distribution of responses and the presence of multiple independent groups. This test evaluated whether the number of respondents collecting NTFPs from forests and those farming NTFPs varied significantly across locations at $p<0.05$.

RESULTS

The results presented below provide a comprehensive analysis of non-timber forest product (NTFP) trade dynamics and conservation practices in four local markets (Muea, Batoke, Mapanja, and Etome) within a tropical forest region. Drawing from a sample of 62 respondents, the study characterizes the types, quantities, and frequencies of NTFPs sold and bought, alongside evaluating conservation practices across different age groups. The demographic profile reveals a predominantly female, married, and middle-aged population, with varying education levels influencing NTFP activities. Key findings highlight the dominance of white pepper and njangsang in trade, a balanced supply-demand dynamic ($p = 0.288$), and significant age-based differences in sustainable harvesting practices ($p = 2.2 \times 10^{-16}$). The heavy reliance on wild collection ($p = 0.001$) underscores sustainability challenges, offering critical insights for sustainable NTFP management and biodiversity conservation.

Demographic information

Locations

The sample size of 62 respondents is unevenly distributed across the four towns, with Muea having the highest representation (25 respondents, 40.3%), followed by Mapanja and Etome (15 each, 24.2% each), and Batoke with the fewest (7 respondents, 11.3%). This suggests that Muea may be a larger or more active market for NTFP trade, while Batoke's smaller sample could reflect a less active market (Table 1).

Table 1. Location of respondents

Surveyed towns	Frequency
Muea	25
Batoke	7
Mapanja	15
Etome	15
Total	62

Gender

The study observed a higher proportion of female respondents (36, 58.1%) compared to males (26, 41.9%). This trend is consistent across most locations, particularly in Muea (15 females vs. 10 males), Mapanja (9 females vs. 6 males), and Etome (11 females vs. 4 males). Batoke is an exception, with a strong male predominance (6 males vs. 1 female). The higher female participation suggests that women play a significant role in NTFP trade, possibly due to cultural or economic factors, such as women being primary harvesters or sellers in these markets (Table 2).

Table 2. Gender of respondents

Location	Male	Female	Total
Muea	10	15	25
Batoke	6	1	7
Mapanja	6	9	15
Etome	4	11	15
Totals	26	36	62

Marital status

The majority of respondents were married (38, 61.3%), followed by not married (20, 32.3%), and a small proportion are widowed (4, 6.5%). Muea and Mapanja have a high proportion of married respondents (14 and 13, respectively), while Etome has a notable number of unmarried respondents (9). The prevalence of married individuals may indicate that NTFP trade is a family-based economic activity, supporting household livelihoods, particularly in rural settings where alternative income sources are limited (Table 3).

Table 3. Marital status of respondents

Location	Married	Not married	Widowed	Total
Muea	14	9	2	25
Batoke	5	1	1	7
Mapanja	13	1	1	15
Etome	6	9	0	15
Totals	38	20	4	62

Age groups

The respondents were predominantly middle-aged (30–59 years, 35 respondents, 56.5%), followed by younger adults (0–29 years, 26 respondents, 41.9%), with only one respondent in the older age group (60–79 years, 1.6%) from Muea. The low representation of older adults may reflect physical limitations in participating in market activities or a generational shift toward younger and middle-aged individuals engaging in NTFP trade. The dominance of the 30–59 age group suggests that this demographic is the primary workforce in NTFP

harvesting and trading, likely balancing economic needs with physical capability (Table 4).

Table 4. Age groups of respondents

Location	Age			
	0-29	30-59	60-79	Total
Muea	13	11	1	25
Batoke	2	5	0	7
Mapanja	6	9	0	15
Etome	5	10	0	15
Totals	26	35	1	62

Education

The education profile shows that most respondents have basic education, with 27 (43.5%) of them having First School education, 18 (29.0%) with GCE O/L, 7 (11.3%) with GCE A/AL, and 10 (16.1%) with a Degree. Muea stands out with a higher proportion of educated respondents, including 10 with Degrees and 6 each with GCE O/L and A/AL, suggesting better access to education in this town. In contrast, Batoke, Mapanja, and Etome have lower education levels, with no Degree holders and a predominance of First School education (e.g., 10 in Etome, 9 in Mapanja). This variation indicates that education access differs across locations, which may influence awareness and adoption of sustainable NTFP practices, as higher education levels are often linked to greater environmental knowledge (Table 5).

Table 5. Educational levels of respondents

Location	Education				
	First school	GCE O/L	GCE A/AL	Degree	Total
Muea	3	6	6	10	25
Batoke	5	2	0	0	7
Mapanja	9	6	0	0	15
Etome	10	4	1	0	15
Totals	27	18	7	10	62

Quantity of NTFPs traded

To characterize the types, quantities, and frequencies of NTFPs sold and bought, data was analyzed from 62 questionnaire respondents across four localities. White pepper (27.7%) and njangsang (25.5%) were the most frequently sold NTFPs, while white pepper (16.7%) and bush pepper (15.4%) dominated purchases. From table p-value of 0.288 indicates that there was no significant difference between the overall quantities sold and bought ($p > 0.05$). This suggests that the volume of supply (sales) was relatively balanced with demand (purchases) for the listed NTFPs across the four localities (Table 6, 7&8).

Table 6. Quantity of NTFPs sold in the markets (RF = Relative Frequency)

Common name	Scientific name	Family	Frequency	RF(%)
White pepper	*Piper nigrum* L	Piperaceae	13	27.7
Bush mango	*Irvingia gabonensis* Baill	Irvingiaceae	4	8.5
Njangsang	*Ricinodendron heudelotii* Heckel	Euphorbiaceae	12	25.5
Country onion	*Afrostyrax lepidophyllus* Perkins	Huaceae	6	12.8
Bush pepper	*Piper guineense* Schum. & Thonn	Piperaceae	2	4.3
Bitter kola	*Garcinia kola* Heckel	Clusiaceae	6	12.8
Kola nut	*Cola nitida* Schott & Endl	Malvaceae	1	2.1
Total			47	100

Table 7. Proportions of NTFPs bought from the markets (RF = Relative Frequency)

Common Name	Scientific name	Family	Frequency	RF(%)
White pepper	*Piper nigrum* L	Piperaceae	13	16.7
Bush pepper	*Piper guineense* Schum. & Thonn	Piperaceae	12	15.4
Njangsang	*Ricinodendron heudelotii* Heckel	Euphorbiaceae	10	12.8
Bitter kola	*Garcinia kola* Heckel	Clusiaceae	7	9.0
Eru	*Gnetum africanum* Welw	Gnetaceae	7	9.0
Honey (from bees)	*Apis mellifera* L	Apidae	6	7.7
Kola nut	*Cola nitida* Schott & Endl	Malvaceae	6	7.7
Country onion	*Afrostyrax lepidophyllus* Perkins	Huaceae	5	6.4
Cloves	*Syzygium aromaticum* Merr. & L.M.Perry	Myrtaceae	4	5.1
Bush mango	*Irvingia gabonensis* Baill	Irvingiaceae	3	3.8
Total			78	100

Table 8. NTFPs sold versus NTFPs bought from the market

Common name	Scientific name	Family	Quantity sold	Quantity bought
White pepper	*Piper nigrum* L	Piperaceae	13	13
Bush mango	*Irvingia gabonensis* Baill	Irvingiaceae	4	3
Njangsang	*Ricinodendron heudelotii* Heckel	Euphorbiaceae	12	10
Country onion	*Afrostyrax lepidophyllus* Perkins	Huaceae	6	5
Bush pepper	*Piper guineense* Schum. & Thonn	Piperaceae	2	12
Bitter kola	*Garcinia kola* Heckel	Clusiaceae	6	7
Kola nut	*Cola nitida* Schott & Endl	Malvaceae	1	6
p-value			0.288	

Quantities of NTFPs sold

The quantities of NTFPs sold were predominantly in the 500g to 1kg range (66.7%), with 33.3% of respondents selling less than 500g. Larger quantities (>1kg) were rare, with no respondents reporting sales in the 1kg–75kg ranges, likely due to limited market demand or resource availability (Table 9).

Table 9. Quantities of NTFPs sold

Quantity	No of respondents	Relative frequency (%)
<500g	3	33.3
500g-1kg	16	66.7
1kg-10kg	5	0.0
10kg-50kg	7	0.0
50kg-75kg	2	0.0
75kg+	2	0.0

NTFP trading activities across different times of the day

Findings revealed that the mornings were the most active period for NTFP trade, with 13 instances recorded, followed by 9 in the afternoon and only 2 in the evening (Fig. 1). This clear trend highlights the morning as the peak trading period, reflecting higher market activity (customer presence,) and a preference among traders to conduct business earlier in the day for better sales and product turnover.

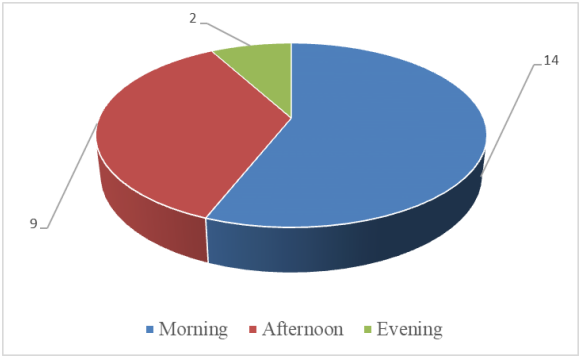

Fig. 1. NTFP trading activities across different times of the day

Economic contributions

Daily sales ranged from 5,000 to 30,000 FCFA, with 38.5% of respondents earning 11,000–20,000 FCFA (Fig. 2). These findings highlight the economic significance of NTFPs for low-income households.

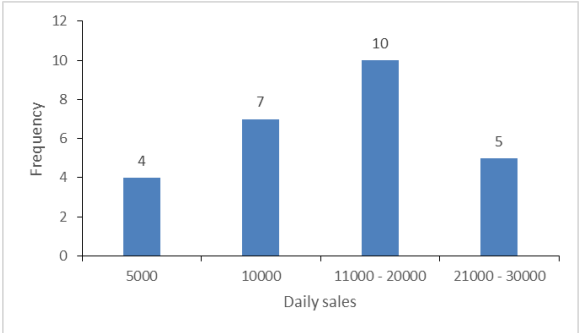

Fig. 2. Daily market sales

Use of NTFPs bought

NTFPs were primarily used for medicine (47.6%), followed by spices (33.3%) and food (19.0%) (Fig. 3), reflecting their cultural and practical importance in the study area.

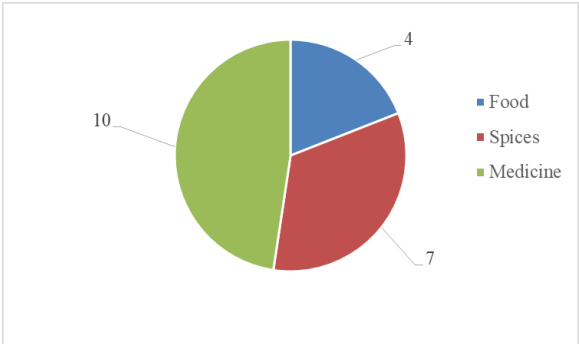

Fig. 3. Use of NTFPs bought

Conservation practices

To evaluate conservation practices associated with NTFP harvesting across different age groups,

sustainable practices were widely adopted (Table 10). The results indicated significant age differences in the adoption of conservation practices during NTFP harvesting. Among older adults (60–79 years), there was 100% adherence to almost all sustainable methods, including collecting only fallen wood and fruits, tapping latex without damaging trees, relying on NTFPs instead of timber, and selectively harvesting bark, leaves, and branches—except for leaf litter collection, where adherence was 0%. Middle-aged adults (30–59) showed high compliance in tapping latex (94.3%), selective branch and leaf harvesting (82.9%), and bark collection (80.0%), but only 5.7% collected fallen wood and fruits, 0% collected from leaf litter, and none relied solely on NTFPs. Younger adults (0–29) demonstrated 88.5% latex tapping, 69.2% selective harvesting, 61.5% bark collection, but only 34.6% collected fallen materials and 7.7% collected from litter.

Table 10. Conservation practices per age group

Conservation measure	Years					
	0-29		30-59		60-79	
	Yes	No	Yes	No	Yes	No
Collect wood only from fallen trees and branches, and fruits only from fallen fruits not harvest from tree to conserve seed trees	34.6	65.4	5.7	94.3	100	0
Collect leaves only from litter to protect forest biodiversity	7.7	92.3	0	100	0	100
Rely only on NTFPs instead of timber for conservation	0	100	0	100	0	100
Collect leaves and branches not the whole tree	69.2	30.8	82.9	17.1	100	0
Tap latex only not to damage wood or tree	88.5	11.5	94.3	5.7	100	0
Collect barks only to avoid damaging the tree	61.5	38.5	80	20	100	0
p-value	0.00000000000000022					

These variations suggest increased conservation awareness with age and highlight the importance of targeted environmental education and intergenerational knowledge sharing to foster sustainable harvesting practices among younger harvesters. The extremely low p-value (2.2×10^{-16}) at $p<0.05$ indicates a highly significant relationship between age and conservation practices, suggesting that age strongly influences sustainable NTFP harvesting behaviors across market locations.

Collection and farming of NTFPs

NTFP collection from forests was significantly higher than farming across all locations ($p < 0.05$), with Muea recording the highest collection frequency (25 respondents) and minimal farming (1 respondent in Mapanja) (Table 11). This reliance on wild collection highlights sustainability challenges. The resulting p-value of 0.001 indicates a highly significant difference ($p < 0.05$) in NTFP collection practices among the locations. Specifically, the data show that collection from the forest was significantly more common in Muea and Mapanja and Etome than in Batoke, while farming of NTFPs was nearly absent in all locations.

Table 11. Collection and farming of NTFPs

Location	Collect NTFPs from forest	Farm NTFPs
Muea	25**	0**
Batoke	7**	0**
Mapanja	15**	1**
Etome	15**	0**
p-value	0.001	

DISCUSSION

The findings of this study provide critical insights into the trade dynamics, usage, and conservation practices of non-timber forest products (NTFPs) in four local markets within a tropical forest region, addressing key gaps identified in the literature (Konsala *et al.*, 2020; Zeh *et al.*, 2022). The results confirm the economic and cultural significance of NTFPs, with white pepper (*Piper nigrum* L.) and njangsang (Ricinodendron heudelotii Heckel) emerging as the most frequently traded products, aligning with previous research highlighting their market prominence in Central Africa (Yogom *et al.*, 2020; Mbega *et al.*, 2024). The balance between supply and demand ($p = 0.288$) suggests a stable market for these NTFPs, with quantities sold predominantly in the 500g–1kg range, reflecting small-scale trade

suited to local demand and resource availability. However, the heavy reliance on wild collection over farming (p = 0.001) underscores sustainability concerns, as excessive wild harvesting can deplete seed banks and hinder forest regeneration, corroborating findings by Atinga and Bannor (2024) and Zhang *et al.* (2021).

The economic contributions of NTFPs, with daily sales ranging from 5,000 to 30,000 FCFA and 38.5% of respondents earning 11,000–20,000 FCFA, highlight their role in supporting low-income households, consistent with global estimates that NTFPs can contribute up to 30% of household income in forest-adjacent communities (Kimengsi *et al.*, 2022; Qiao *et al.*, 2024). The predominance of morning trading activities reflects strategic market behavior, likely driven by higher customer presence and better sales opportunities early in the day. The primary uses of NTFPs for medicine (47.6%), spices (33.3%), and food (19.0%) underscore their multifaceted role in local diets, health, and cultural practices, reinforcing findings by Derebe *et al.* (2023) and Mondo *et al.* (2024).

Conservation practices varied significantly across age groups ($p = 2.2 \times 10^{-16}$), partially supporting the hypothesis that younger and middle-aged groups (30–59 years) would show higher adoption rates of sustainable practices. Contrary to expectations, older adults (60–79 years) exhibited near-universal adherence to most sustainable methods, such as collecting fallen wood and fruits, tapping latex without damaging trees, and selective harvesting of bark and leaves. This high compliance may reflect traditional ecological knowledge accumulated over time, as suggested by Chukwuone *et al.* (2020). Middle-aged adults (30–59 years) showed a strong adoption of selective harvesting and latex tapping but a lower adherence to collecting fallen materials, possibly due to economic pressures prioritizing faster harvesting methods. Younger adults (0–29 years) demonstrated moderate adoption of sustainable practices, with lower rates of collecting fallen materials and leaf litter, potentially due to limited exposure to environmental education, as noted by Gaoue *et al.* (2017).

The near absence of NTFP farming, particularly in Muea, Batoke, and Etome, and minimal farming in Mapanja, highlights a critical challenge for sustainable NTFP management. Heavy reliance on wild collection increases the risk of overexploitation, as evidenced by reduced species abundance of high-value NTFPs like njangsang in Central Africa (Mbega *et al.*, 2024). This finding calls for interventions to promote NTFP cultivation, such as agroforestry systems, to reduce pressure on wild populations (Njie *et al.*, 2022). The significant variation in collection practices across locations (p = 0.001) suggests that local ecological and socio-economic factors influence NTFP harvesting, necessitating tailored conservation strategies.

Demographic factors, including education and age, played a nuanced role in conservation behaviors. While higher education levels (e.g., Degree holders in Muea) were associated with greater awareness of sustainable practices, the limited number of highly educated respondents (10 out of 62) suggests that education alone may not drive conservation adoption in these communities, aligning with Ndo *et al.* (2024). Gender and marital status showed no clear correlation with conservation practices, indicating that age and education are stronger predictors of sustainable behavior.

These findings have significant implications for policymakers and conservationists. The high adoption of sustainable practices among older adults suggests that intergenerational knowledge transfer could enhance conservation efforts among younger harvesters. Targeted environmental education programs, particularly for younger and middle-aged groups, could bridge the gap in sustainable harvesting practices. Additionally, promoting NTFP farming through incentives and training could mitigate overexploitation risks, ensuring long-term ecological sustainability while supporting rural livelihoods.

This study's integration of quantitative and qualitative data provides a robust framework for understanding local NTFP market dynamics and conservation practices. However, limitations include the small sample size (n = 62) and focus on only four

markets, which may not fully represent regional trends. Future research should expand to additional markets and incorporate longitudinal data to assess the long-term impacts of NTFP harvesting on forest ecosystems. By addressing these gaps, this study contributes to the broader discourse on balancing economic development with biodiversity conservation in tropical forest regions, offering actionable insights for sustainable NTFP management.

CONCLUSION

This study successfully characterized the types, quantities, and frequencies of non-timber forest products (NTFPs) sold and bought in four local markets within a tropical forest region, while also evaluating conservation practices across different age groups. The results confirm that white pepper (*Piper nigrum* L.) and njangsang (*Ricinodendron heudelotii* Heckel) were the most frequently traded NTFPs, with quantities sold predominantly in the 500g to 1kg range and no significant difference between quantities sold and bought (p = 0.288). These findings partially support the hypothesis that NTFP types, quantities, and frequencies vary significantly by product category, as trade was heavily skewed toward high-demand products like white pepper and njangsang, reflecting market preferences and resource availability. However, the lack of significant variation in overall quantities suggests a balanced supply-demand dynamic for these products.

Regarding conservation practices, the study found significant age-based differences ($p = 2.2 \times 10^{-16}$), with older adults (60–79 years) demonstrating near-universal adherence to sustainable methods, such as collecting fallen wood and fruits and selective harvesting, compared to moderate adoption among younger (0–29 years) and middle-aged (30–59 years) groups. This partially supports the hypothesis that middle-aged and older groups show higher adoption rates, though older adults outperformed expectations, likely due to traditional ecological knowledge. The reliance on wild collection over farming (p = 0.001) underscores sustainability challenges, emphasizing the need for interventions to promote NTFP cultivation and targeted environmental education, particularly for younger harvesters. These findings provide actionable insights for policymakers and conservationists to enhance sustainable NTFP management while supporting rural livelihoods and biodiversity conservation in tropical forest regions.

To promote sustainable non-timber forest product (NTFP) management, we recommend implementing agroforestry programs to encourage cultivation of high-value species like white pepper and njangsang, reducing pressure on wild populations. Targeted environmental education for younger harvesters (0–29 years) should emphasize sustainable practices, such as selective harvesting and latex tapping, to enhance adoption. Facilitating intergenerational knowledge transfer through community mentorship can leverage older adults' expertise. Local policies should establish harvesting quotas for high-demand NTFPs, improve morning market infrastructure to support peak trading, and promote value-added processing to boost incomes for low-income households. Further research is needed to monitor ecological impacts over time, ensuring the long-term sustainability of forest ecosystems and rural livelihoods in tropical forest regions.

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