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The role of candlenuts in sustaining rural livelihoods from forests to household welfare

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Abstract. *Abdullah, Makkarennu, Syahidah. 2026. The role of candlenuts in sustaining rural livelihoods from forests to household welfare. Asian J For 10: r100101. https://doi.org/10.13057/asianjfor/r100101.* The utilization of candlenuts (*Aleurites moluccanus*) represents a sustainable livelihood strategy for forest-adjacent communities, contributing to both household income and food security while promoting the diversification of Non-Timber Forest Products (NTFPs). However, despite the widespread use of candlenuts in rural economies, empirical evidence remains limited on how candlenut utilization simultaneously affects household welfare and the sustainability of forest resources, particularly within community-managed forest landscapes. Addressing this empirical gap, this study examines the sustainability potential and economic contribution of candlenut utilization to rural livelihoods, as well as its implications for household welfare. The study was conducted within the Limited Production Forest (LPF) managed by the Maros Protected Forest Management Unit (PFMU) in South Sulawesi Province, Indonesia. Primary data were collected from 17 farmer members, representing all active candlenut farmers within the local Forest Farmers Group (FFG), through field surveys, interviews, and document reviews. The data were analyzed using a physical balance approach, income contribution analysis, and the household welfare index based on rice equivalent. The findings indicate that most respondents possessed an initial reserve of fewer than 40 candlenut trees, with depletion rates exceeding tree additions resulting in declining and increasingly constrained resource conditions that indicate high harvesting pressure. Economically, candlenuts provide the highest income among local commodities such as corn and cocoa, with 58.82% of farmers classified as highly dependent on candlenut-based activities. The welfare assessment indicates that the majority of farmer households (64.71%) fall within the adequate category, while 23.53% are classified as nearly poor and 11.76% have attained a decent living standard. Overall, the findings contribute to knowledge on NTFPs and household welfare by integrating sustainability and income analyses, showing that candlenut supports rural livelihoods but faces increasing sustainability pressures.

Keywords: Candlenut, community welfare, economic contribution, forest farmers group, physical balance

INTRODUCTION

Non-Timber Forest Products (NTFPs) are a crucial component of sustainable forest resource management (Shrestha et al. 2020; Pasaribu et al. 2021; Talukdar et al. 2021; Zhang et al. 2021; Derebe and Alemu 2023; Ichsan 2024; Latifah et al. 2025). At the global level, NTFPs are increasingly recognized as an alternative to timber extraction because they generate economic benefits while reducing pressure on forest ecosystems. Previous studies emphasize that, unlike timber forest products, which. Often cause significant ecological degradation, NTFPs provide a more environmentally friendly livelihood option for communities living near forests (Nghonda et al. 2023; Panda et al. 2024; Asamoah et al. 2025). In this context, NTFPs are widely promoted as instruments for balancing conservation objectives with rural economic development. Beyond their ecological advantages, NTFPs play an important socio-economic role by supporting household income, reducing poverty, and strengthening livelihood resilience particularly under participatory and community-based forest governance arrangements (Mushi et al. 2020; Nguyen et al. 2020; Wimolsakcharoen et al. 2020; Rosenfeld et al. 2024). Empirical evidence from tropical regions demonstrates that sustainable NTFP utilization can simultaneously enhance household welfare while maintaining forest ecological functions welfare while maintaining forest ecological functions (Tieminie et al. 2021; Zhu and Lo 2021; Makkarennu et al. 2022; Hazari et al. 2023; Miranda et al. 2024; Shackleton et al. 2024). Together, these findings underline that NTFPs play a pivotal role not only in supporting household economies but also in reinforcing the long-term socio-ecological resilience of forest-dependent communities.

At the local level, however, the performance and sustainability of specific NTFP commodities vary widely depending on management practices, market access, and harvesting pressure. One type of NTFP that has considerable potential but remains underutilized is candlenut (*Aleurites moluccanus*) (Makkarennu et al. 2021; Variyana et al. 2023; Jumiyati et al. 2024). This plant grows naturally and is cultivated in forests and on community-owned land (Golar et al. 2021; Ningsih et al. 2021). Candlenut seeds have high economic value because

they can be processed into candlenut oil, food ingredients, cosmetics, charcoal briquettes, and traditional medicines (Zahara et al. 2024; Afadil et al. 2025). In addition, candlenut is relatively easy to cultivate and tolerant of diverse environmental conditions, making it attractive for smallholder farmers (Shaah et al. 2021; Fachrina and Broto 2023; Elisa et al. 2024; Jamu et al. 2024). These characteristics position candlenut as a promising NTFP for strengthening rural livelihoods and sustainable forest-based economies.

Candlenuts serve as an alternative source of income for forest farmer groups, particularly in social forestry schemes through community forestry patterns that encourage community-based forest management (Dalya and Mujetahid 2020; Jumiyati et al. 2021). In many cases, candlenut farming activities are carried out collectively by farmer groups and are able to help meet basic household needs (Rachman et al. 2021). This contribution makes candlenuts one of the key drivers of the local economy, especially in difficult times such as the dry season. Despite its economic significance, there remains a clear research gap, as few studies provide empirical evidence on how candlenut-based livelihoods contribute across multiple dimensions production, income, and household welfare. This lack of integrated analysis limits understanding of the actual role of candlenuts in supporting rural livelihoods and constrains the development of targeted interventions for farmer welfare improvement.

This study addresses that gap through an integrated assessment encompassing household welfare, livelihood strategis, and the sustainability potential of candlenut as an NTFP. By examining how candlenut farming contributes to household welfare and rural livelihood, the study provides relevant and useful information for policy development, empowerment programs, and the sustainable enhancement of the economic value of candlenut for communities living near forests.

MATERIALS AND METHODS

Study area

This study was conducted in Batu Putih Village, which lies within the Limited Production Forest (LPF) area managed by the Maros Protected Forest Management Unit (PFMU), South Sulawesi Province, Indonesia. Administratively, the village belongs to the Mallawa Sub-district of Maros District. Geographically, the Maros PFMU is located between 4°47'20" South Latitude and 119°55'59" East Longitude at an elevation of approximately 300 meters above sea level. The area is characterized by varied topography, ranging from flat and gently sloping to undulating and steep terrain, supporting diverse vegetation and land-use types. The study area has a tropical climate characterized by average humidity ranging from 60-82%, an average monthly rainfall of approximately 347 mm with around 16 rainy days, and an average temperature of about 29°C. These climatic conditions strongly influence agricultural practices and the productivity of candlenut-based livelihoods.

The community in Batu Putih Village is predominantly dependent on agriculture and forest-based activities, particularly candlenut, corn, cacao and seasonal crops, which form the main sources of household income. These socio-economic characteristics make forest products especially candlenuts an important component of household welfare and livelihood stability. Figure 1 illustrates the research location and its spatial position within the Maros PFMU, showing the village's proximity to forest areas that support candlenut-based livelihoods.

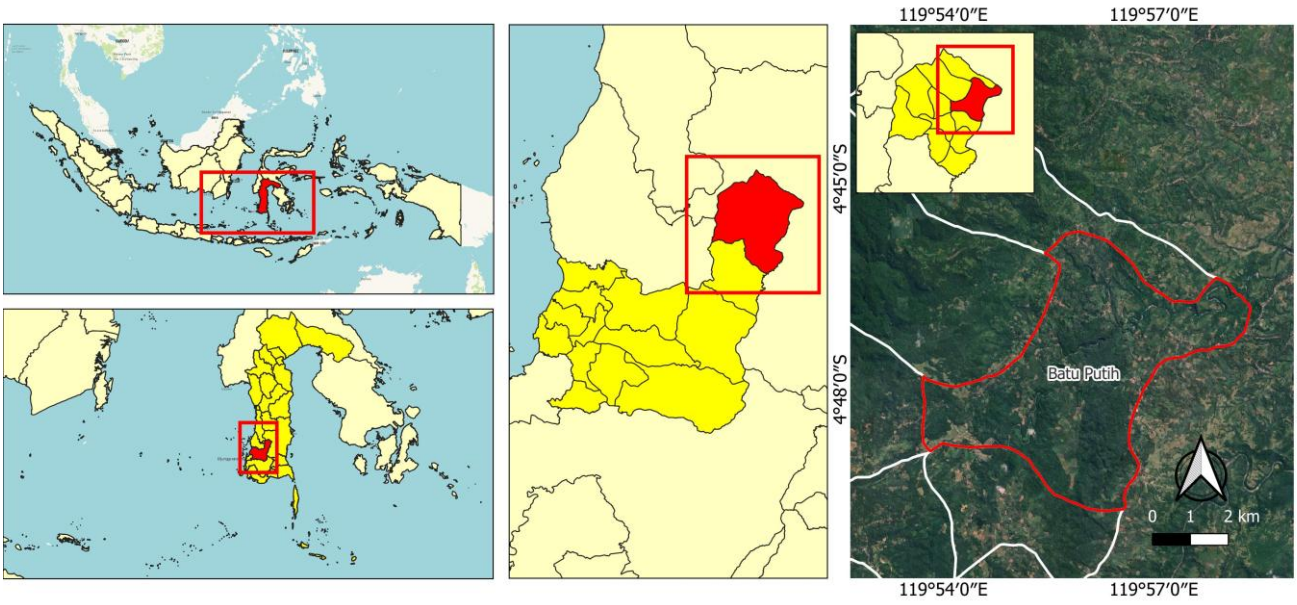

Figure 1. Map of the research location in Maros, South Sulawesi, Indonesia

Data collection

Data were collected through field surveys, interviews, questionnaires, and document studies conducted from May to August 2025. Field surveys were carried out to identify the actual conditions of candlenut management in the field, including direct observation of candlenut plots to assess existing potential. Interviews and questionnaires were administered directly to farmers to obtain information related to management practices, production potential, and business development of candlenut enterprises.

The population in this study consisted of members of the Forest Farmers Group (FFG) in the study area, totaling 38 individuals. However, only 17 members were identified as active candlenut farmers, defined as those currently managing candlenut trees and directly involved in production and marketing activities. The remaining members were excluded because they were inactive or no longer engaged in candlenut-related activities. As the number of active farmers was imited, a census approach was applied by including all 17 active farmers to provide an in-depth representation of candlenut-based livelihoods within the group, rather than aiming for statistical generalization. The questionnaire focused on key aspects of candlenut production and its contribution to household livelihoods and was validated through pilot field testing and direct verification at each respondent's plot. Validation involved cross-checking questionnaire responses with field observations and follow-up interviews to ensure consistency and data reliability.

Data analysis

Physical balance

We analyzed the physical balance of forest resources utilized by the community by estimating the initial reserves in terms of the number of trees. The initial reserve represents the number of candlenut trees owned by farmers at the beginning of the study period, addition indicates the number of new trees acquired or planted during the same period, and depletion indicates the reduction in these resources, specifically referring to the number of trees harvested. The physical balance was then calculated using the following equation.

$C_t = C_{t-1} + A_t - D_t$

Where:

C_{t-1} : Initial reserve (trees)

A_t : Addition (trees/year)

D: Depletion (trees/year)

t : Time period (year)

C_t : Final reserves (trees/year)

Contribution

The contribution aims to formulate the amount of contribution obtained from the management of candlenuts carried out by farmers. The contribution can be calculated based on the income obtained by farmers from candlenut and other commodities (Abate and Tebkew 2025).

Income

I = TR-TC

Where:

I : Income (IDR)

TR : Total Revenue (IDR)

TC : Total Cost (IDR)

Contribution

Contribution = $(I_{candlenut} / I_{candlenut} + I_{other})$ x 100%

Where:

$I_{candlenut}$ = Income from candlenut-related activities (IDR/year)

I_{other} = Income from other household activities (IDR/year)

This approach provides a simplified measure of economic reliance on candlenut production. Income components were annualized, with candlenut income derived from sales of unshelled and shelled nuts, while other income mainly came from corn and cocoa. Costs accounted for equipment and labor used in candlenut production.

The level of household dependency on candlenut-based income was analyzed by calculating the proportion of candlenut income to total household income, expressed as a percentage. To facilitate interpretation, dependency levels were categorized into four classes: non-dependent (0%), low dependency (0.01-33.33%), moderate dependency (33.34-66.66%), and high dependency (66.67-100%) (Akwilin et al. 2023). This classification was used to assess variations in household economic reliance on candlenut production and to compare the relative contribution of candlenut-related activities to overall household livelihoods.

Household of Welfare Index

The welfare level was determined using a Household Welfare Index based on Rice Equivalent (HWI-RE) representing the household's capacity to meet basic consumption needs through rice equivalence. The level of welfare is calculated based on the per capita expenditure of farming families in one year, which is then converted into the value of rice measured in kilograms. The measurement is carried out using the following equation.

$E_{pc} = E_{total} / N_{family}$

Where:

E_{pc} : Per capita household expenditure (IDR/person/year)

E_{total} : Total annual household expenditure (IDR/year)

N_{family} : Number of family dependents (persons)

Household expenditure data were collected through structured interviews using a one-year recall period. Respondents were asked to report their average monthly spending, which was then annualized. Expenditure categories included food consumption, clothing, housing maintenance and repairs, education, and farm or forestry-related operating costs. The latter covered input and maintenance expenses for agricultural activities (corn and cocoa cultivation) and candlenut-based forest management.

To evaluate household welfare in terms of purchasing power for staple foods, per capita household expenditure is converted into rice equivalents. The household welfare index was assessed using the rice equivalent approach, which has been widely applied in Indonesia and adapted in recent socio-economic studies (Puryantoro and Mayangsari 2020). This method facilitates comparisons between

households with different income levels and reflects their ability to meet basic consumption needs. The per capita expenditure in IDR was divided by the prevailing rice price to obtain the rice equivalent per person per year (kg/person/year). The rice price used in this study was based on the average local market price in the study area at the time of data collection (2025). The following formula was used to calculate rice equivalent expenditure:

$E_{rice} = E_{pc} / P_{rice}$

Where:

E_{rice} : Per capita expenditure in rice equivalent (kg/person/year)

E_{pc} : Per capita household expenditure (IDR/person/year) average rice price (IDR/kg)

P_{rice} : Average rice price (IDR/kg)

The welfare level is obtained based on the expenditure of farming families equivalent to the rice categorized in Table 1.

RESULTS AND DISCUSSION

Physical balance sheet

The physical balance sheet describes the initial and final stock conditions of a natural resource and the changes that occur, expressed in specific physical units (Zhu et al. 2021; Wang et al. 2024; Makkarennu et al. 2025a). Changes in this balance sheet include additions and depletion in stock, which cover the initial reserves, additions, depletion, and final reserves. Stock declines are generally caused by extraction activities for production purposes, although other factors such as exploration activities can also affect stock changes. In this study, the physical balance sheet was analyzed using trees as the unit of measurement. The physical balance sheet for candlenut businesses can be seen in Figure 2.

Figure 2 shows that the average initial reserve was 45.35±8.42 trees (range: 30-60 trees), with an average depletion of 39.53±6.07 trees (range: 30-50 trees) and an average addition of 5.82±6.62 trees (range: 0-20 trees), resulting in a final reserve of 11.65±13.24 trees (range: 0-40 trees) (n=17). This represents an average reduction of approximately 74% of the initial candlenut tree stock within one annual management cycle, indicating a substantial decline in the final reserve. Such a sharp reduction implies declining future yields and may increase household income vulnerability, given the strong dependence of respondents on candlenut-based livelihoods. Based on respondents' practices, this decline is mainly associated with intensive harvesting of mature trees and limited regeneration efforts, as replanting or natural regeneration remains minimal and irregular. A key limitation of this analysis is the small sample size, as only 17 farmers representing all those actively managing candlenut enterprises in the Forest Farmers Group. Despite this, the study provides a detailed, in-depth local case study that offers important insights into candlenut resource management and the challenges for long-term sustainability, which are relevant to similar community-managed forest contexts. The distribution of respondents based on candlenut resource balance characteristics can be seen in Table 2.

Table 2 shows the distribution of respondents based on the characteristics of candlenut resource balance. More than half of the respondents (52.94%) had an initial reserve of less than 40 trees, while only 17.65% maintained reserves exceeding 50 trees. Most respondents (70.59%) experienced depletion rates between 36 and 45 trees, reflecting a relatively high depletion rate. Conversely, only 5.88% reported depletion exceeding 45 trees. Most farmers (64.71%) added fewer than six trees annually, indicating limited regeneration efforts. As a result, 64.71% of respondents ended up with a final reserve of fewer than 13 trees. The high proportion of households with low initial reserves combined with limited annual regeneration suggests that current harvesting practices may exceed natural replenishment rates, potentially threatening the long-term sustainability of candlenut resources. This pattern highlights the need for targeted management interventions to balance extraction with regeneration and maintain household benefits over time. While this study provides useful insights into the current status of candlenut stocks at the household level, it does not include direct measurements of forest condition, canopy cover, regeneration, or productivity. Although the findings indicate that candlenut cultivation continues to support household welfare, further research integrating ecological indicators such as regeneration rates and canopy dynamics is needed to conclusively determine its sustainability and contribution to forest conservation. Consequently, future research should prioritize integrating such indicators to more comprehensively evaluate the long-term ecological sustainability of candlenut-based forest management.

Table 1. Welfare level criteria

Number	Rice Equivalent Expenditure (kg/year)	Criteria
1.	<180	Extremely Poor
2.	181-240	Very Poor
3.	241-320	Poor
4.	321-480	Near Poor
5.	481-960	Adequate
6.	>961	Decent Living

Table 2. Distribution of respondents based on candlenut resource balance characteristics

Initial reserve (trees)	Respondents by initial reserve (%)	Depletion (trees)	Respondent by depletion (%)	Addition (trees)	Respondent by addition (%)	Final reserve (trees)	Respondent by final reserves (%)
<40	52.94	< 35	23.53	<6	64.71	<13	64.71
41-50	29.41	36-45	70.59	7-13	11.76	14-27	11.76
>50	17.65	>45	5.88	>14	23.53	18-40	23.53

Contribution

The contribution of a commodity to farmers' income basically reflects the extent to which that commodity plays a role in supporting household livelihoods (Waarts et al. 2021). Commodities with a large contribution are usually the main source of income, while commodities with a small contribution tend to serve only as additional income. The contribution in this study focuses on three main commodities cultivated by farmers in forest areas, namely candlenut, corn, and cocoa. The contribution of candlenut cultivation can be seen in Figure 3.

Figure 3 presents the distribution of respondents based on candlenut and other income levels, as well as their dependency category. The results show that the majority of farmers (82.35%) earned between IDR 8,000,000 and 16,000,000 per year from candlenut-related activities, while 11.76% earned more than IDR 16,000,000 annually. This income pattern indicates that candlenut cultivation serves as the dominant and subsistence-oriented income source within the household economic structure, particularly in the absence of substantial alternative income activities. According to Ningrum et al. (2025), the average candlenut income of IDR 8,585,557.38 found in their study is consistent with the income range identified in Bima Regency, reinforcing the significance of candlenut as a key economic contributor. In contrast, more than half of the respondents (52.94%) earned less than IDR 5,000,000 per year from other income activities. Based on the contribution analysis, dependency categories were defined according to the proportion of candlenut income relative to total household income, where, 58.82% of farmers were classified as highly dependent on candlenut cultivation, while 35.29% showed moderate dependency, and only 5.88% were categorized as having low dependency. These findings indicate that candlenut cultivation serves as a primary source of household income for most respondents, highlighting its substantial economic importance in supporting rural livelihoods. However, this high level of dependency also implies limited livelihood resilience, as household income becomes highly vulnerable to production shocks, price fluctuations, and resource depletion affecting candlenut availability, particularly because high depletion combined with very low regeneration rates reduces the stock of productive trees, threatens future yields, and underscores the urgent need for active regeneration through replanting and improved management to sustain candlenut-based livelihoods.

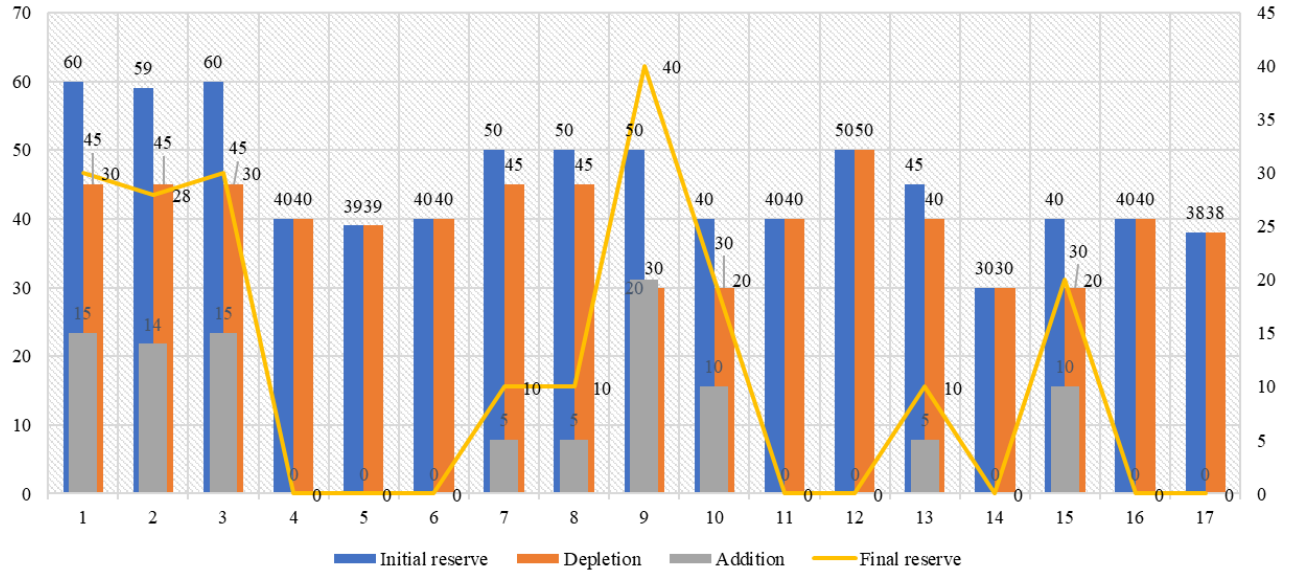

Figure 2. Physical balance sheet for candlenut business

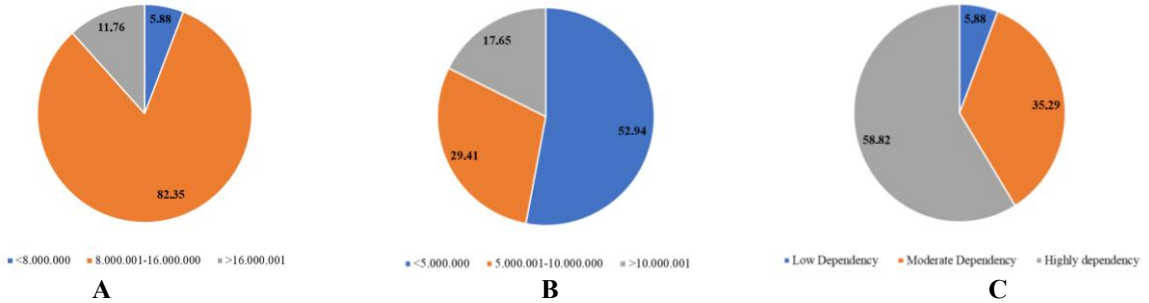

Figure 3. A. Candlenut income (IDR/year), B. Other income (IDR/year), C. Contribution of candlenut

The high contribution of candlenuts is closely related to their strong economic value, which is relatively more profitable compared to cocoa and corn. This is consistent with previous studies (Makkarennu et al. 2025b), which reported that NTFP farming contributed up to 88% of total household income, highlighting the significant role of high-value forest products in supporting rural livelihoods. The farm-gate price of candlenuts was recorded at approximately IDR 20,000/kg for unpeeled nuts and IDR 40,000/kg for peeled nuts. Farmers reported allocating most household labor to candlenut harvesting and post-harvest handling during peak seasons, while alternative income activities remained small-scale and irregular, largely due to capital constraints. Price variation was mainly determined by the quality and dryness level of the product, as all farmers reported selling only dried candlenuts to ensure higher value and market acceptance. In addition, candlenuts benefit from the availability of suitable land and a long-standing tradition of management passed down through generations, making them the main source of livelihood for farmers in the managed forest areas. This finding is in line with Makkarennu et al. (2021), who reported that candlenut processing and management rely on traditional tools and practices passed down through generations.

Level of welfare

The level of welfare of the community, especially farmers, basically reflects their ability to meet basic needs, improve their quality of life, and access adequate social services. The welfare level of candlenut farmers in this study was measured using the rice equivalent expenditure approach so that welfare conditions could be seen from the ability of households to meet their basic needs based on rice consumption. The expenditures of candlenut farmers can be seen in Table 3.

Table 3 illustrates the distribution of farmers' per capita expenditure per year and its rice-equivalent expenditure, using a rice price of IDR 12,000/kg (USD 0.80/kg, based on the exchange rate in 2025). The analysis shows that the majority of farmers (64.71%) have annual per capita expenditure ranging from IDR 6,000,001 to IDR 12,000,000, which is equivalent to rice consumption of 501-1,000 kg per capita per year. Meanwhile, 23.53% of farmers were recorded as being in the group with relatively low expenditure, namely less than IDR 6,000,000 per capita per year or less than 500 kg of rice equivalent. Only a small proportion of farmers (11.76%) had expenditures of more than IDR 12,000,000 per capita per year, equivalent to more than 1,000 kg of rice. This distribution shows that most farming households are at a medium level of expenditure. This condition indicates the limited economic capacity of the community, where expenditure is mainly allocated to basic needs. Household expenditure is primarily absorbed by essential consumption and production costs, leaving limited room for savings or long-term investment. Although candlenut farming contributes substantially to household income, this contribution reflects a subsistence-oriented livelihood pattern that is highly dependent on seasonal harvests rather than long-term economic security. This dependence implies that household welfare remains closely tied to the continuity and productivity of candlenut resources, making it sensitive to yield fluctuations and resource depletion.

The welfare level of farmers can be determined based on the amount of expenditure per year by farmers in rice equivalent. Most household spending is absorbed by essential consumption such as food, clothing, and housing maintenance, followed by education-related costs and production expenses for both agricultural (corn and cocoa) and forestry activities (candlenut). This spending pattern illustrates that while candlenut farming provides steady income, households still face limited capacity for savings or investment, reflecting a livelihood structure that remains highly dependent on seasonal harvest income. The welfare level of farmers can be seen in Table 4.

Table 4 shows the distribution of farmers' welfare levels based on expenditures equivalent to per capita rice consumption per year. The analysis shows that no farmer households fall into the poorest, extremely poor, or poor categories. Most farmers (64.71%) are in the adequate category, with equivalent expenditures of 481-960 kg of rice per capita per year. A total of 23.53% of farmers are classified as near-poor, with expenditures of 321-480 kg of rice per capita per year, while 11.76% of farmers have reached the decent living category, with expenditures of more than 961 kg of rice per capita per year. While the majority of households appear to have adequate criteria, the HWI-RE measure is a simplified proxy and may mask underlying economic fragility. In particular, the near-poor households remain vulnerable, and the heavy reliance of most households on candlenut as a primary income source despite observed depletion of tree stocks highlights potential livelihood vulnerabilities. If the decline in candlenut stock continues without adequate regeneration, households currently classified as adequate may face a downward shift in welfare status in the future.

Table 3. Farmer expenditures

Expenditure/ capita/ year (IDR)	Percentage (%)	Expenditure/ Per capita/ year equivalent to rice (kg)	Percentage (%)
<6,000,000	23.53	<500	23.53
6,000,001-12,000,000	64.71	501-1,000	64.71
>12,000,000	11.76	>1001	11.76

Note: 1 USD = 16.848,50 IDR

Table 4. Welfare level of farmers

Rice equivalent expenditure (kg/year)	Percentage (%)	Criteria
<180	0.00	Extremely Poor
181-240	0.00	Very Poor
241-320	0.00	Poor
321-480	23.53	Near Poor
481-960	64.71	Adequate
>961	11.76	Decent Living

This distribution shows that the majority of farmers have a relatively moderate level of welfare, with a small portion having reached a decent standard of living. This condition is inseparable from the contribution of candlenut farming as the main source of income, which provides economic stability for households compared to other commodities in the forest area. However, the existence of farmers in the near-poor category still indicates economic vulnerability, especially in the event of price fluctuations or decreased productivity. These findings suggest that while candlenut cultivation plays a vital role in sustaining household welfare, its economic benefits remain limited by small landholdings, fluctuating yields, and dependency on seasonal harvests. Therefore, sustaining household welfare in the long term requires not only income diversification but also improved management and regeneration of candlenut resources to secure future production. Improving post-harvest handling and developing small-scale processing units for candlenut oil or kernel products, along with better access to local markets and integration with other farm activities such as corn or cocoa cultivation, could strengthen farmers' income stability.

In conclusion, this case study highlights a fundamental tension between the current economic benefits of candlenut utilization and the long-term sustainability of the resource. As a non-timber forest product managed by local communities, candlenuts have substantial economic potential. Empirical findings demonstrate a significant decline in candlenut tree stocks, with an average net loss between initial and final reserves within one annual management cycle, indicating that current harvesting intensity exceeds natural regeneration capacity and signals a structural sustainability risk. Candlenuts contribute meaningfully to household welfare, with a considerable share of farmer households classified in the adequate welfare category based on the rice-equivalent index. However, this welfare status reflects a subsistence oriented income pattern that remains highly dependent on continuous extraction, creating a vulnerable livelihood system in which present economic well being is directly tied to a declining natural asset. To address this imbalance, management recommendations must be grounded in the observed depletion regeneration gap. Feasible actions include community-based nurseries to increase tree recruitment, mandatory annual replanting targets at the Forest Farmer Group (FFG) level, and regulated harvest cycles to reduce pressure on productive trees. Given the high dependence of many households on candlenuts, these measures should be complemented by livelihood diversification strategies, with support from Forest Farmer Groups, local governments, and the Maros Protected Forest Management Unit (PFMU). Overall, this integrated analysis of welfare, livelihoods, and resource sustainability demonstrates that while candlenuts currently support household welfare, declining tree stocks threaten future productivity, forest structure, and livelihood resilience. Although this study is limited to a case-study context and relies on tree-count-based stock assessments and simplified welfare indicators, it underscores the need for future research incorporating long-term regeneration monitoring, tree health assessment, and broader socio-economic sampling. This case study demonstrates that for non-timber forest products such as candlenuts to function as engines of sustainable rural development, explicit and targeted management policies are essential to simultaneously address ecological replenishment and the economic vulnerability of dependent communities, ensuring benefits can be sustained for future generations.

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