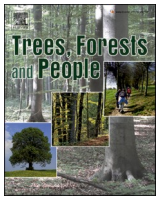
Trees, Forests and People 27 (2026) 101441



Contents lists available at ScienceDirect

Trees, Forests and People

journal homepage: www.sciencedirect.com/journal/trees-forests-and-people



Socioeconomic importance, utilisation patterns and climate resilience potential of *Mikoche* (*Hyphaene* spp.) in Pangani District, Tanga, Tanzania

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ARTICLE INFO

Keywords:
Natural capital
Climate
Resilience
Mikoche trees
Sustainable livelihoods
Pangani District

ABSTRACT

This study examines the potential of the *Mikoche* tree (*Hyphaene* spp.), an indigenous palm species found in Pangani District, Tanzania, as a critical natural resource that can contribute to both ecological and socio-economic resilience amid changing environmental conditions. The study employed a mixed-methods approach involving household surveys, key informant interviews, focus group discussions, and participatory rural appraisal techniques to assess the distribution, utilisation patterns, value addition opportunities, and challenges associated with *Mikoche*. Data were collected from Kimang'a and Madanga wards, where the species is commonly found. The findings indicate that local communities primarily use *Mikoche* for traditional construction materials, handicrafts, fencing and occasional consumption of its fruit. However, its potential for producing flour, cooking oil, and other value added products remains largely unexplored. The study further reveals significant differences in the utilisation and economic benefits derived from *Mikoche* between Kimang'a and Madanga wards, despite their similar ecological settings. Key barriers to wider utilisation include limited awareness of value-addition opportunities, inadequate processing technologies, poor market access, and a lack of supportive policies and institutional frameworks. The findings demonstrate that *Mikoche* has considerable potential to contribute to food security, income generation, and climate-change adaptation in coastal Tanzania. To realise this potential, targeted interventions are needed, including community capacity building, investment in processing infrastructure, market development, and policy support for sustainable resource management.

1. Introduction

Given the increasing impacts of climate change on conventional crops, particularly coconut palms along the Tanzanian coast, there is an urgent need to identify alternative indigenous species that can support sustainable livelihoods and food systems. *Mikoche* is among the trees, naturally drought tolerant, adapted to harsh coastal environments (Stauffer et al., 2018), and possesses considerable potential for food, nutrition, and income generation (Aminu et al., 2022; Martins and Shackleton, 2022; Omire et al., 2020a).

Mikoche trees (*Hyphaene* spp.), commonly known in Swahili as "*Mikoche*," are ecologically, economically, and culturally important resources in the Pangani District of Tanzania. The genus *Hyphaene* comprises approximately 8–10 species distributed across Africa, occurring in diverse habitats including savannas, woodlands, riverine ecosystems, and coastal regions (Idohou et al., 2015; Martins and Shackleton, 2021). Ethnobotanical studies have shown that local communities distinguish different *Hyphaene* morphotypes based on observable characteristics, particularly fruit size, shape, and quality (Assogbadjo et al., 2011; Seltmann et al., 2007; Moussa et al., 1998). Fruit traits are often the most important features used by local people to identify and differentiate species and varieties. Several *Hyphaene* species are widely distributed throughout Africa. For instance, *Hyphaene coriacea* occurs along coastal dunes and creek systems from Somalia to Mozambique, South Africa, Madagascar (Martins and Shackleton, 2021), and parts of Kenya (Lokuruka, 2008). *Hyphaene thebaica* is common in Djibouti and other parts of northeastern Africa, while *Hyphaene compressa* is widely found in the coastal regions of Tanzania and Kenya. *Hyphaene petersiana* has also been reported around the shores of Lake Eyasi in Tanzania (Omire et al., 2022; Stauffer et al., 2018).

Hyphaene species play a vital role in supporting both ecosystem functions and rural livelihoods (Martins and Shackleton, 2022). They

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https://doi.org/10.1016/j.tfp.2026.101441

Available online 3 August 2026
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contribute significantly to household economies and cultural traditions through the provision of multiple products and services (Omire et al., 2020a;; Stauffer et al., 2018). Various parts of the tree are utilised for different purposes. The stems are commonly used as construction materials, while the leaves are woven into baskets, mats, hats, and other handicrafts because of their durability and long fibres (Idohou et al., 2017; McKean, 2003). *H. thebaica* fruits are rich in dietary fibre, antioxidants, minerals, vitamins, essential oils, and flavonoids, making them valuable for nutrition and health (Khider et al., 2022). Similarly, *H. coriacea* produces edible nuts and sap that can be processed into palm wine in parts of southern Africa (Martins and Shackleton, 2021; McKean, 2003).

Although *Hyphaene* spp. (*Mikoche*) is widely distributed along the coastal regions of Tanzania and contributes to local livelihoods through the provision of construction materials, weaving materials, food, and traditional medicine, its socioeconomic and commercial potential remains largely underutilised. Previous studies have primarily focused on the taxonomy, ecology, distribution, genetic diversity, and ethnobotanical uses of *Hyphaene* species in different parts of Africa, with limited attention given to their value addition, food product development, processing technologies, and contribution to climate-resilient livelihoods in Tanzania. Consequently, there is little scientific evidence on community utilisation patterns, aspirations for sustainable use, processing constraints, climate adaptation potential, and opportunities for developing value-added products such as juice, flour, cookies, and edible oil. This knowledge gap limits informed policy formulation, investment, and commercialisation of one of Tanzania's most valuable indigenous multipurpose palms. Therefore, the objective of this study was to document the adaptation, uses, and challenges associated with *Mikoche* trees in Pangani District, Tanga Region, Tanzania.

The importance of addressing this gap has increased as climate change continues to threaten conventional livelihood resources in coastal Tanzania. Rising temperatures, prolonged droughts, increasing soil salinity, and erratic rainfall have reduced the productivity of climate-sensitive crops, particularly coconut. At the same time, indigenous species such as *Mikoche* continue to thrive under similar environmental conditions. This study is among the first in Tanzania to integrate ethnobotanical knowledge, socioeconomic assessment, climate resilience, and value-addition opportunities within a single framework. Specifically, it documents household utilisation patterns, community perceptions, processing constraints, and the livelihood contributions of *Mikoche*, while identifying opportunities to develop novel food products and strengthen local value chains. By generating evidence on the utilisation, resilience, and commercial potential of *Mikoche*, this study provides a scientific basis for promoting its sustainable conservation, domestication, and commercialisation as a climate-resilient indigenous resource capable of enhancing food security, income diversification, and sustainable rural development in coastal Tanzania.

2. Materials and methods

2.1. Description of the study area

The field survey was conducted in Pangani District, Tanga Region, Tanzania (Fig. 1), where *Mikoche* (*Hyphaene* spp.) are commonly distributed along the coastal belt of the country (Omire et al., 2022; Stauffer et al., 2018). Tanga Region is located in northeastern Tanzania, and Pangani District lies approximately 45 km south of Tanga City, between latitudes 5°–6° S and longitudes 38°–39° E (Robertson et al., 2018). The district covers an area of approximately 1763 km² and has a population of 75,642, with a population density of about 42.9 persons per km² (URT, 2022). Pangani District experiences a tropical climate characterised by bimodal rainfall patterns, with the long rainy season occurring from March to May and the short rainy season from October to December. Mean annual temperatures range from 26 °C to 26.6 °C, while annual rainfall varies between 1015 and 1214 mm (Kijazia and Reason, 2009; Mwanga et al., 2019). The local economy is largely dependent on fishing and agriculture, with major crops including cassava, maize, paddy rice, cowpeas, and green gram (CANTZ, 2022).

Like many coastal districts in Tanzania, Pangani is increasingly vulnerable to the impacts of climate change (Ahmed et al., 2023a). The high dependence of local communities on rain-fed agriculture exposes

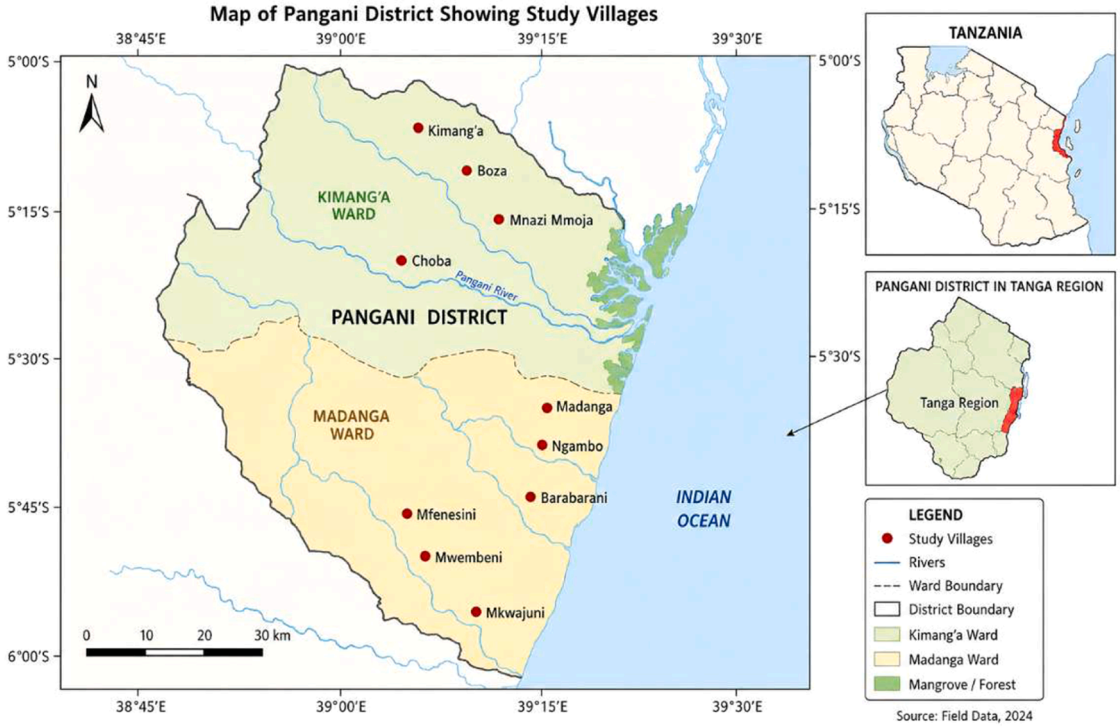


Fig. 1. Map of Pangani District showing the surveyed villages.

households to risks associated with drought, erratic rainfall, and declining agricultural productivity. Consequently, many households have limited adaptive capacity and livelihood options (Ahmed et al., 2023a; CANTZ, 2022). These challenges highlight the need to identify and promote alternative natural resources that can contribute to food security, livelihood diversification, and environmental sustainability. Given its abundance, ecological adaptability, and multiple uses, *Mikoche* represents a promising resource for enhancing community resilience in the district.

The survey was specifically conducted in Kimang'a and Madanga wards, where *Mikoche* trees are abundant. Within the district, Kimang'a and Madanga wards were purposively selected due to the abundance of Mikoche and their contrasting levels of market access, value addition, and utilisation practices, enabling comparison of household use patterns, community perceptions, and the factors influencing Mikoche's contribution to sustainable livelihoods and climate adaptation. Data were collected from ten villages: Kimang'a, Boza, Mnazi Mmoja, Choba, Madanga, Ngambo, Barabarani, Mfenesini, Mwembeni, and Mkwajuni. These villages were selected because of their proximity to *Mikoche* habitats and their dependence on natural resources for household livelihoods.

2.2. Study design

A mixed-methods approach combining quantitative and qualitative techniques was used in this study. Secondary data from governmental and non-governmental organisations, published literature, and institutional reports were reviewed to assess the ecological, economic, and social importance of *Mikoche* (Hyphaene spp.) in Tanzania and beyond. Information on edible oil extraction from *Mikoche* kernels and its storage quality was also examined. Primary data were collected through household surveys in two selected wards of Pangani District to assess the utilisation and challenges associated with *Mikoche*. Qualitative data were obtained through direct field observations, focus group discussions (FGDs), and key informant interviews involving farmers, traders, processors, and community leaders. These methods provided insights into local knowledge, utilisation practices, and livelihood benefits. The study was conducted in four phases: baseline assessment, field data collection, data analysis, and report writing, enabling a comprehensive evaluation of *Mikoche* resources and their potential contribution to sustainable livelihoods.

2.3. Sampling technique and sample size calculation for the household respondents

The household sample size was determined using the formula developed by Lwanga and Lameshow (1991), as presented in Eqs. (1a) and (1b). This method was selected because it provides a statistically reliable and representative sample, ensuring that the study findings are robust and generalisable. The approach is particularly suitable for assessing the socioeconomic importance of *Mikoche*, as it allows for accurate estimation of population characteristics while minimising sampling errors and survey costs. Based on this formula, a sample size of 195 respondents was required to achieve a 95% confidence level with a margin of error of ±5%. To account for potential non-response, an additional 5% (10 respondents) was included, resulting in a final sample size of 205 households from the two study wards.

$$\textit{Unlimited population}: n = z^2 * \hat{p}(1-\hat{p})/\varepsilon^2 \quad (1a)$$

$$\textit{Limited population}: n' = n/[1+((n-1)/N)] \quad (1b)$$

Where:

z is the z score = 1.96;
ε is the margin of error = 7% at a 95% confidence interval
N is population size = 75642; and
p̂ is the population proportion = 50%
Thus, n = ((1.96*1.96) *0.5*(1–0.5)) / (0.07*0.07) =196
n' = 196 / (1+((196–1)/75642)) = 19

2.4. Data collection

A cross-sectional survey design was employed to collect information on the uses and utilisation constraints of *Mikoche* trees in Pangani District, Tanzania. Villages and households were randomly selected to ensure representative participation. Data were collected using structured questionnaires that were initially designed, pre-tested, and subsequently refined to improve clarity and reliability. A random sample of respondents was then interviewed to assess individual knowledge, perceptions, and household practices related to *Mikoche*. Details of the sample size determination are provided in Section 2.3. In addition, two focus group discussions (FGDs) and direct field observations were conducted to obtain deeper insights into community perceptions, utilisation practices, and challenges associated with *Mikoche*. Key informant interviews involving agricultural and forestry officers were also undertaken to complement and validate information obtained from households and FGDs.

2.5. Data management and analysis

The collected data were coded and analysed using IBM SPSS® version 25. Descriptive statistics were generated and presented as frequencies and percentages. Differences in socioeconomic characteristics, knowledge, attitudes, and practices among respondent groups were assessed using the Chi-square (χ^2) test at a significance level of $p \leq 0.05$. Furthermore, a generalised linear model (GLM) was applied to identify factors influencing the adoption, utilisation, and limitations of *Mikoche* in Pangani District.

2.6. Ethical considerations

Before the commencement of the study, research clearance with reference numbers Kumb. Na. RA/E.10/51/167 and Kumb. Na. HWP/E.40/19/VOL.IV/147 were obtained from the District Executive Director of Pangani District. This was done in compliance with established ethical guidelines and to ensure that informed consent was obtained from all participants prior to their involvement in the study. Participation was voluntary, and respondents were informed of the purpose of the research and their right to withdraw at any stage. Furthermore, anonymity and confidentiality were strictly maintained throughout data collection, analysis, and reporting to protect participants' privacy and ensure the ethical handling of information.

3. Results

3.1. Demographic and socioeconomic differences between Kimang'a and Madanga wards

The demographic characteristics of respondents involved in the utilisation of *Mikoche* in Pangani District are presented in Table 1. The results show a broadly similar age distribution across the two wards, with the majority of respondents falling within the economically productive age groups (25–64 years). In both wards, the largest proportion of respondents was aged between 35 and 54 years. The gender composition followed a comparable pattern, although women constituted a slightly higher proportion of respondents in both communities. Educational attainment was generally low across the study area. Most respondents had completed primary education, while approximately one-fifth had no formal education. Only a small proportion had attained secondary education (13.2%), and very few had completed advanced secondary education (0.5%). These findings indicate relatively low levels of formal education among respondents.

Table 1
Demographic characteristics of the respondents for the use of *Mikoche* in Pangani District.

Variable	Kimang'a Ward (%)	Madanga Ward (%)	Total (%)	χ^2, df	*p*-value
Age	***n* = 103**	***n* = 94**	***n* = 197**		
15–24	4.9	6.4	5.6		
25–34	17.5	13.8	15.7		
35–44	16.5	19.1	17.8		
45–54	20.4	18.1	19.3		
55–64	18.4	14.9	16.8		
65–74	12.6	19.1	15.7		
Above 75	9.7	8.5	9.1	2.728,6	0.842
Gender	***n* = 103**	***n* = 94**	***n* = 197**		
Female	60.2	67.0	63.5%		
Male	39.8	33.0	36.5%	0.988,1	0.320
Level of education	***n* = 103**	***n* = 94**	***n* = 197**		
Advanced secondary education	0.0	1.1	0.5%		
Secondary education	10.7	16.0	13.2		
Primary education	68.9	62.8	66.0		
No formal education	20.4	20.2	20.3	2.417, 3	0.490
Duration of residence (years)	***n* = 103**	***n* = 94**	***n* = 197**		
Less than 1 year	3.9	1.1	2.5		
1–5	6.8	4.3	5.6		
5–10	17.5	0.0	9.1		
More than 10 years	71.8	94.7	82.7	21.633, 3	0.000*
Occupation	***n* = 103**	***n* = 94**	***n* = 197**		
Farmer	57.3	78.7	67.5		
Fisherman	4.9	0.0	2.5		
Teacher	0.0	1.1	0.5		
Public servant	1.0	1.1	1.0		
Farmer and Fisherman	10.7	1.1	6.1		
Farmer and Livestock	1.0	1.1	1.0		
Farmer and Other	6.8	2.1	4.6		
Other	18.4	14.9	16.8	19.189, 7	0.008*
Source of household income	***n* = 103**	***n* = 94**	***n* = 197**		
Agriculture	64.1	55.3	59.9		
Wage employment	1.0	1.1	1.0		
Small business	16.5	31.9	23.9		
Agriculture and livestock	1.0	3.2	2.0		
Agriculture and small business	11.7	7.4	9.6		
Agriculture and other	1.0	0.0	0.5		
Other	4.9	1.1	3.0	10.851, 6	0.093
Total annual household income (Tsh)	***n* = 103**	***n* = 94**	***n* = 197**		
Below 100,000	1.9	11.7	6.6		
100,000–400,000	22.3	28.7	25.4		
400,000–700,000	53.4	46.8	50.3		
Above 1000,000	22.3	12.8	17.8	10.842,3	0.013*

A *p*-value below 0.05 indicates a statistically significant difference (reject null), whereas $p \geq 0.05$ indicates no significant difference.

The duration of residence indicates long-term settlement in both wards, particularly in Madanga. In Madanga, 94.7% of respondents had lived there for more than 10 years, compared to 71.8% in Kimang'a. Kimang'a had more medium-term residents, with 17.5% living there for 5–10 years compared to none in Madanga.

Farming was the main occupation in both wards, but a higher proportion of respondents in Madanga were full-time farmers. Kimang'a showed greater livelihood diversification, including fishing and mixed activities. Income sources also varied. In Kimang'a, 57.3% were solely farmers and 10.7% combined farming and fishing, while in Madanga, 78.7% were solely farmers and few reported combined occupations. The "Farmer and Fisherman" category was notably higher in Kimang'a (10.7%) than in Madanga (1.1%). Kimang'a also had a higher proportion of households in the upper income category (above TZS 1,000,000), whereas Madanga had more households in lower income categories. Categorical variables were compared using chi-square (χ^2) tests of independence. A *p*-value below 0.05 indicates a significant difference, while $p \geq 0.05$ indicates no significant difference.

As shown in Table 1, age distributions were similar between wards. Approximately 20% of respondents in each ward were aged 45–54 years, while the youngest (15–24 years) and oldest (>75 years) age groups were the least represented. No significant difference was found in age distribution between Kimang'a and Madanga ($\chi^2 = 2.728$, df = 6, $p = 0.842$). Females predominated in both wards (Kimang'a: ~60%; Madanga: ~67%), but the difference was not significant ($\chi^2 = 0.988$, df = 1, $p = 0.320$). Educational attainment was also similar, with most respondents having primary education (66%) or no formal education (20.3%), and very few having secondary or higher education. Duration of residence differed significantly between wards ($\chi^2 = 21.633$, df = 3, $p < 0.001$), indicating that Madanga had a more stable population, while Kimang'a had a larger proportion of newer residents. This may reflect differences in settlement patterns, resource dependence, or mobility.

Occupation also differed significantly ($\chi^2 = 19.189$, df = 7, $p = 0.008$). Madanga was more dependent on farming, whereas Kimang'a had a more diversified livelihood structure. In contrast, the main source of household income did not differ significantly ($\chi^2 = 10.851$, df = 6, $p = 0.093$). Agriculture remained the primary income source in both Kimang'a (64.1%) and Madanga (55.3%), although small businesses were more common in Madanga (31.9%vs. 16.5%). This suggests that household income sources in both wards are similarly based on agriculture and related activities. Annual household income differed significantly between wards ($\chi^2 = 10.842$, df = 3, $p = 0.013$). Kimang'a had more high-income households (22.3% earning > TZS 1000,000) than Madanga (12.8%), and fewer very low-income households (< TZS 100,000) (1.9%vs. 11.7%).

Conclusively, the statistical analysis indicates that while demographic characteristics such as age, gender, and education were similar across the two wards, significant differences existed in occupation structure, residential stability, and income levels. These socioeconomic variations are important for understanding differences in resource use patterns, including the utilisation, management, and economic engagement with *Mikoche*. In particular, the higher dependence on farming and longer-term settlement in Madanga may influence resource availability and conservation practices, while relatively higher income and livelihood diversification in Kimang'a may enhance opportunities for value addition and commercialisation of *Mikoche* products.

3.2. Adaptation and diversity of Mikoche trees in Pangani District

The adaptation and diversity of *Mikoche* trees as reported by the respondents in Pangani District are presented in Table 2. None of the respondents indicated that they had planted the *Mikoche* tree; rather, all the available trees had grown naturally. Most of the households uproot the *Mikoche* trees in their infancy once they grow on their farms. Thus, most of the respondents (55.8%) don't have a single *Hyphaene* tree in either their household or farms. Nonetheless, the remaining proportion (44.2%) of the respondents indicated that they spare some trees in their farms to harvest the leaves for weaving, and at home for shade and fruits. Moreover, a GLM indicated that age, gender, level of education, occupation, duration of residence, source of household income, annual

Table 2
Adaptation and diversity of *Mikoche* trees as reported by the respondents in Pangani District.

Variable	Kimang'a Ward (%)	Madanga Ward (%)	Total (%)	χ^2, df	*p*-value
How many *Mikoche* trees do you currently have on your land?	***n* = 103**	***n* = 94**	***n* = 197**		
More than 100	1.0	0.0	0.5		
85 - 100	3.9	0.0	2.0		
70 - 85	1.9	0.0	1.0		
40 - 55	1.9	0.0	1.0		
25 - 40	1.0	0.0	0.5		
10 - 25	5.8	3.2	4.6		
Less than 10	34.0	35.1	34.5		
None	50.5	61.7	55.8	10.998, 7	0.139
Have you noticed different types of *Mikoche* in your area	***n* = 103**	***n* = 94**	***n* = 197**		
Yes	60.2	67.0	63.5		
No	39.8	33.0	36.5	0.988, 1	0.320
Types and description of *Mikoche*	***n* = 61**	***n* = 63**	***n* = 124**		
Shape of the tree	15.3	15.	30.6		
Fruit colour	6.5	4.8	11.3		
Fruit size	24.2	18.5	42.7		
Others	3.2	12.1	15.3	7.548, 3	0.056

A *p*-value below 0.05 indicates a statistically significant difference (reject null), whereas $p \geq 0.05$ indicates no significant difference.

household income, and ward were predictors of the number of *Mikoche* trees currently available in household land (Table 3). Occupation was a significant predictor of tree ownership, with farmers and fishermen owning more trees than other groups, such as civil servants ($\chi^2 = 79.467$, df = 49, $p = 0.004$). Regarding diversity, 60.2 –67.0% of respondents in both areas have observed multiple *Mikoche* varieties which are locally available, suggesting similar awareness of the plant. We observed branched trees and unbranched trees (Fig. 2). There was no significant difference in identifying the tree in the two wards. Both communities differentiate *Mikoche* using the shape of the tree, the sex of the tree, the fruit colour, and the size.

3.3. Products and uses of Mikoche trees in Pangani District

The products and uses of *Mikoche* trees reported by respondents in Pangani District are summarised in Fig. 2 and Table 4. About 98% of respondents reported using *Mikoche* products in their households. The main uses (Table 4) include woven products (mats, hats, ropes, and baskets), fruits, and construction timber. There was no significant difference in the main uses of *Mikoche* between the two wards (Table 4). However, product utilisation and sources differed significantly. Most respondents in Kimang'a Ward reported using *Mikoche* for timber, whereas those in Madanga Ward mainly used it for making baskets, mats, and hats. While 59.3% of households produced *Mikoche* products for their own use, 78.9% of respondents in Madanga Ward reported purchasing them, mainly from Kimang'a Ward. Overall, 58.5% of households bought *Mikoche* products, while 41.5% made them themselves. About 2% of respondents in Madanga Ward reported not using *Mikoche* products because they associated them with poverty or conservatism. Field surveys in both wards showed that communities primarily value *Mikoche* for construction and handicrafts. Around 40% of households in each ward cited its use in construction, while 10–12% reported using it for weaving baskets, mats, and hats.

3.3.1. Household-level usage

At the household level, Kimang'a and Madanga differ markedly in how *Mikoche* is used and obtained (Table 4). In Kimang'a, more families produce and use *Mikoche* products themselves. For example, 59.3% of Kimang'a households reported that a family member makes *Mikoche* crafts (baskets, mats, etc.), compared to only 20.2% in Madanga. Likewise, 59.3% of Kimang'a households make their own *Mikoche* products, whereas 78.9% of Madanga households purchase them. In other words, Kimang'a is largely self-reliant, with about six in ten families producing their own *Mikoche* items, while Madanga depends more on external sources and markets. This is reflected in the products used: Kimang'a households use *Mikoche* timber (22.8%vs. 12.7%) and fruits (8.6%vs. 4.6%) more than those in Madanga, whereas Madanga households more frequently use woven leaf products (baskets, mats, and hats) (28.4%vs. 20.8%). These differences were statistically significant ($p < 0.01$).

These patterns suggest that Kimang'a households are more involved in harvesting and processing *Mikoche* locally, whereas Madanga households rely more on purchasing ready-made products, likely from nearby producers or markets. Notably, none of the Kimang'a households reported not using *Mikoche* products, while 2.0% of Madanga households did, highlighting Kimang'a's greater dependence on the palm.

These patterns imply that Kimang'a families are more engaged in harvesting and processing *Mikoche* locally, whereas Madanga

Table 3
Generalised Linear Model (GLM) results showing the effects of socio-demographic and economic factors on the number of *Mikoche* trees present on household land, variety recognition, importance, and limits for consumption in Pangani District.

Predictor	Number of *Mikoche* trees currently on your land			Noticed different types of *Mikoche* in your area			Advantages of *Mikoche* trees in your community			Reasons for the limited use and consumption of *Mikoche* products		
	χ^2	df	*p*-value	χ^2	df	*p*-value	χ^2	df	*p*-value	χ^2	df	*p*-value
(Intercept)	40.147	1	0.000	1.141	1	0.285	3.479	1	0.062	0.055	1	0.815
Age	115.660	6	0.000	5.518	6	0.479	45.450	6	0.000	284.237	6	0.000
Gender	13.070	1	0.000	0.001	1	0.969	11.173	1	0.001	31.876	1	0.000
Level of education	9.771	2	0.008	1.573	2	0.455	2.039	2	0.361	43.215	2	0.000
Occupation	59.658	4	0.000	5.781	4	0.216	25.945	4	0.000	151.134	4	0.000
Duration of residence	223.340	3	0.000	0.397	3	0.941	1.509	3	0.680	57.071	3	0.000
Source of household income	162.264	3	0.000	2.331	3	0.507	3.721	3	0.293	272.469	3	0.000
Total annual household income	186.931	3	0.000	1.659	3	0.646	89.090	3	0.000	255.281	3	0.000
Household size	20.602	2	0.000	0.010	2	0.995	0.285	2	0.867	21.236	2	0.000
How much do you/the other person produce yearly	8698.945	30	0.000	NA	NA	NA	568.946	30	0.000	1093.253	30	0.000
Changes in livelihood	4.284	1	0.038	NA	NA	NA	1.517	1	0.218	15.264	1	0.000
Impact of wider adoption of *Mikoche* on the community	102.407	2	0.000	NA	NA	NA	2.446	2	0.294	NA	NA	NA
Ward	42.296	1	0.000	0.000	1	0.996	0.761	1	0.383	6.635	1	0.010

NA: Not Applicable.



Fig. 2. Pictures of (a) *Mikoche* trees, (b) their use in shelter construction, (c) leaves of young *Mikoche* trees used for crafting, (d) and (e) women weaving mats and baskets, (f) a bench made from Mkoche wood, (g) *kawa* (used to cover food) and *kipepeo* (hand fan) made from *Mikoche* leaves, (h) *dema* made from *Mikoche* bark and used for fishing, (i) fruits, and (j) a nut.

households depend on purchasing ready-made *Mikoche* items (likely from nearby producers or markets). Notably, none of the Kimang'a households reported using no *Mikoche* products, while 2.0% of Madanga households did, underscoring Kimang'a's higher overall reliance on the palm.

3.3.2. Community-level patterns

Both wards agree that construction material is the top *Mikoche* use (~40% of respondents) and weaving crafts second (~10–12%), with other uses (fruit, medicine, wine) being minor (Table 3). Furthermore, plant parts used, uses and challenges as reported by respondents in Pangani District during FGDs are presented in Table 5.

Among 56.3% of Kimang'a respondents reported positive changes in livelihood (mostly higher income) associated with *Mikoche*, while only 19.1% of Madanga respondents did. Among those who saw change, 64.9% in Kimang'a cited increased income (versus 14.3% in Madanga). This aligns with Kimang'a's stronger value addition engagement. In Madanga, where most *Mikoche* goods are bought, fewer families reported income gains from the palm.

3.4. Advantages, aspirations, and ambitions of the community towards Mikoche trees in Pangani District

The survey results on the advantages, aspirations, and ambitions of communities toward *Mikoche* trees are presented in Table 6. Respondents overwhelmingly cited income generation as *Mikoche*'s main advantage (Table 6). In Kimang'a, 50.5% of households identified income as the primary benefit, compared to 44.9% in Madanga. Other uses, such as shelter, food, and medicine, were mentioned by very few respondents, underscoring *Mikoche*'s perceived economic value. Importantly, about 77% of respondents (71.8% in Kimang'a and 83.0% in Madanga) believed that wider *Mikoche* adoption would benefit the community. This optimism differed significantly between wards, with Madanga residents being more positive than their counterparts. Overall, *Mikoche* is viewed mainly as a source of income and a positive contributor to community well-being.

In terms of adoption and use, 50.5% of respondents in Kimang'a and 43.8% in Madanga identified increased income as their main aspiration. Very few respondents (<3%) mentioned improved livelihoods, sustainability, or community development. Aspirations did not differ significantly between wards.

3.5. Limitations to uses and consumption of Mikoche trees in Pangani District

Table 7 presents the limitations to the use and consumption of *Mikoche* trees reported by respondents. Only 3.9% of respondents had attempted to extract oil from *Mikoche* nuts, but these efforts were unsuccessful due to challenges such as the hardness of the nut and difficulty cracking the kernel (Table 5). The main household-level constraint was lack of awareness. About 42% of respondents in both wards reported not extracting *Mikoche* oil because they were unaware of its

Table 4
Products and uses of *Mikoche* trees as reported by the respondents in Pangani District.

Variable	Kimang'a Ward (%)	Madanga Ward (%)	Total (%)	χ^2, df	*p*-value
Do you use any part of *Mikoche* trees?	***n* = 103**	***n* = 94**	***n* = 197**		
Yes	52.3	45.7			
No	0.0	2.0			0.050
Primary Uses of *Mikoche* in your community	***n* = 103**	***n* = 94**	***n* = 197**		
Construction material	42.1	36.0	78.2		
Weaving baskets/ mats/ Hats	10.2	11.7	21.	0.735, 1	0.391
Other Uses of *Mikoche* in your community					
Fruit	16.2	13.7	30.0		
Medicine	0.4	0.4	0.7		
Palm wine	0.0	0.2	0.2		
Others	0.0	0.2	0.2		
Products utilised by any family member in the household	***n* = 103**	***n* = 94**	***n* = 197**		
Timber	22.8	12.7	35.5		
Baskets/ mats/ Hats	20.8	28.4	49.2		
Fruit	8.6	4.6	13.2		
None	0.0	2.0	2.0	14.114,3	0.003*
Other Products utilised by any family member in the household					
wine	0.4	0.2	0.6		
Nuts	0.4	0.2	0.6		
Traditional medicine	0.6	0.0	0.6		
Others	1.3	2.4	3.7		
Source of the products in the household	***n* = 103**	***n* = 90**	***n* = 193**		
Make them	59.3	21.1	41.5		
Buy them	40.8	78.9	58.5	28.747, 1	0.000*
Are any of your family members producing *Mikoche* products	***n* = 103**	***n* = 94**	***n* = 197**		
Yes	59.2	20.2	40.6		
No	40.8	79.8	59.4	31.011, 1	0.000*
Main Products Produced by Family	***n* = 61**	***n* = 19**	***n* = 80**		
Timber	11.3	3.8	15.00		
Baskets/ mats/ Hats	58.8	17.5	76.3		
Fruit	6.3	0.0	6.3		
Nuts	0.0	1.3	1.3	8.010,4	0.091
Other Products Produced by Your Family					
wine	0.9	0.0	0.9		
Others	1.8	0.9	2.7		
Have you observed Changes in livelihood	***n* = 103**	***n* = 94**	***n* = 197**		
Yes	56.3	19.1	38.6		
No	43.7	80.9	61.4	28.643, 1	0.000*
Changes in livelihood	***n* = 58**	***n* = 19**	***n* = 77**		
Increased income	64.9	14.3	79.2		
Improved food security	9.1	5.2	14.3		
Environmental benefits	0.0	1.3	1.3		
Others	1.3	3.9	5.2	10..760, 3	0.013*

A *p*-value below 0.05 indicates a statistically significant difference (reject null), whereas $p \geq 0.05$ indicates no significant difference.

Table 5
Uses and challenges of the *Mikoche* parts as reported by respondents in Pangani District during FGDs.

Plant part	Uses	Challenges
Whole tree	Shade, to avoid landslides and degradation	Decreased due to human activities; no policy
Fruit	Eaten fresh; dried fruits are used as firewood; and feed for animals, including cows and monkeys.	• Many fibres get stuck between teeth. • Can damage pans with holes, and difficult to extinguish the fire due to high energy
Roots and barks	Traditional medicine for *Kifaduro;* Skin remedies; and Anaemia	Little knowledge
Nuts	Immature is eaten as a snack	• No oil production technology • Difficulty in cracking the kernel and the hardness of the nut
Wood and stalks	Construction materials for houses and latrines, chairs, fish traps (madema); beehives; and firewood	Hard to cut; damages the chainsaws.
Leaves	Used to make traditional hats, handbags, ropes, kibwebwe, kawa, vipepeo	Have pines, leafy selection (tender), no reliable market, tenants for *viunga*

potential. Likewise, 87.8% cited lack of awareness as the main reason for the limited use of *Mikoche* products.

Other factors were far less important: only 5.1% of respondents cited a lack of harvesting or processing technology, while limited time, market access, high costs, and low prices were each mentioned by fewer than 5%. Overall, knowledge gaps were the main barrier. This pattern was consistent across both wards, with no significant differences observed.

3.6. Climate change and variability

Table 8 summarises the perceived impacts of climate change and variability in Pangani District. Most respondents reported environmental changes, with temperature variability being the most common indicator, cited by 44.2% of households in Kimang'a and 42.6% in Madanga (86.8% overall). Changes in rainfall seasonality were less frequently reported (13.2% overall), with no significant difference between wards ($\chi^2 = 1.028$, $p = 0.311$). In addition, 30.9% of respondents reported changes in rainfall amount, with similar proportions across both wards.

Most respondents reported a decline in *Mikoche* distribution and productivity over the past decade, with 68.9% in Kimang'a and 66.0% in Madanga indicating noticeable reductions (67.5% overall). The difference between wards was not significant ($\chi^2 = 0.261$, $p = 0.877$). Only

Table 6
Advantages, aspirations, and ambitions of the community towards *Mikoche* trees as reported by respondents in Pangani District.

Variable	Kimang'a Ward (%)	Madanga Ward (%)	Total (%)	χ^2, df	*p*-value
Main Advantages of *Mikoche* trees in your community	***n* = 102**	***n* = 94**	***n* = 196**		
Income generation	50.5	44.9	36.2		
Shelter	1.0	2.6	32.3		
Food source	0.0	0.5	28.4		
Cure diseases	0.5	0.0	2.7		
Others	0.0	0.4	0.4	3.612,3	0.306
Could wider adoption of *Mikoche* impact your community?	***n* = 103**	***n* = 94**	***n* = 197**		
Yes	71.8	83.0	77.2		
No	1.9	9.6	5.6		
Not sure	26.2	7.4	17.3	15.947, 2	0.000*
Aspirations for the future regarding *Mikoche* tree adoption and utilisation?	***n* = 102**	***n* = 92**	***n* = 194**		
Increased income	50.5	43.8	94.3		
Improved livelihoods	1.0	2.1	3.1		
Environmental sustainability	0.5	0.0	0.5		
Community development	0.0	0.5	0.5		
Others	0.0	0.5	0.5		
None	0.5	1.0	1	4.086,5	0.537

A *p*-value below 0.05 indicates a statistically significant difference (reject null), whereas $p \geq 0.05$ indicates no significant difference.

Table 7
Limitations to uses and consumption of *Mikoche* trees as reported by respondents in Pangani District.

Variable	Kimang'a Ward (%)	Madanga Ward (%)	Total (%)	χ^2, df	*p*-value
Reasons for not extracting oil	***n* = 103**	***n* = 94**	***n* = 197**		
Lack of awareness	41.6	41.6	42.9		
Lack of harvesting technology	7.6	5.1	29.3		
Limited time	1.0	0.5	13.4		
Inadequate or lack of market	1.0	0.5	11.1		
High processing cost	1.0	0.0	2.3		
Others	0.0	0.2	0.2	3.262, 4	0.515
Low price	0.9	0.0	0.9		
Reasons for limited use and consumption	***n* = 103**	***n* = 94**	***n* = 107**		
Lack of awareness	43.7	44.2	87.8		
Lack of harvesting technology	2.5	2.5	5.1		
Limited time	2.0	0.0	2.0		
Inadequate or lack of market	4.1	0.5	4.6		
Others	0.1	0.5	0.5	10.060, 4	0.309*
High processing cost	0.4	0.2	0.6		
Low price	1.8	0.2	2.0		
Others	0.8	0.8	1.6		

A *p*-value below 0.05 indicates a statistically significant difference (reject null), whereas $p \geq 0.05$ indicates no significant difference.

14.7% reported no decline, while 17.8% were unsure.

Among respondents who observed declines ($n = 142$), perceptions of climate-related causes differed significantly between wards ($\chi^2 = 26.725$, $p < 0.001$). Most respondents rated climate factors as strong contributors, although a larger proportion in Madanga viewed their influence as low compared with Kimang'a. Conversely, more respondents in Kimang'a felt climate factors did not contribute at all. Perceptions of human activities as drivers of decline were similar across wards ($\chi^2 = 2.210$, $p = 0.530$), with 72.5% identifying activities such as tree cutting and land clearing as major contributors. Views on government policy were also comparable ($\chi^2 = 0.521$, $p = 0.914$); 53.5% considered policy a strong contributor, while smaller proportions rated its influence as moderate (14.1%), low (19.7%), or absent (12.7%).

However, during the focus group discussions, participants consistently reported that Mikoche was more tolerant of prolonged drought and increasing soil salinity than coconut. Several participants estimated that coconut populations had declined by more than 70% in some areas over recent decades, whereas *Mikoche* continued to survive and produce fruits under similar environmental conditions.

4. Discussion

4.1. Adaptation and diversity of Mikoche trees in Pangani District

This study examined the adoption, utilisation patterns, and constraints associated with *Mikoche* (*Hyphaene* spp.) in Pangani District, while also exploring community perceptions regarding its socioeconomic benefits and the impacts of climate variability on the species. Overall, the findings suggest that *Mikoche* remains a locally recognised but underutilised natural resource. Although households widely acknowledge its economic potential, particularly for weaving materials, construction, and income generation, its broader applications, such as oil extraction, food processing, and product diversification, remain largely unexplored. Significant differences were observed between Kimang'a and Madanga wards in terms of household engagement in *Mikoche*-related production, value addition, and livelihood outcomes. In addition, respondents perceived a decline in *Mikoche* distribution and productivity, which they attributed to both climate variability and human activities. While demographic characteristics such as age, gender, and education were broadly similar across the wards, significant differences in occupation, duration of residence, and household income suggest variations in livelihood structures that may influence resource utilisation. These findings highlight the need to understand not only how *Mikoche* is currently used, but also why its utilisation remains limited despite strong community recognition of its economic potential. The following discussion therefore interprets these findings in relation to the study objectives. The GLM indicated that age, gender, level of education, occupation, duration of residence, source of household income, annual household income, and ward were predictors of the number of *Mikoche* trees currently available in household land (Table 3). For example, the age of the household head may have had an influence on the tree ownership of the household because older farmers may have planted or inherited more trees. Further, the GLM showed that occupation is a significant predictor of tree ownership. The cross tab revealed that Farmers and fishermen had more trees compared to other occupations, such as civil servants (χ2, df, *p*-value = 79.467, 49, 0.004). Nevertheless, the findings reveal that none of the respondents had ever planted *Mikoche*, and the majority actively uproot the trees when they emerge naturally on their farms. Consequently, more than half of all households (55.8%) reported not having a single *Mikoche* tree on their farms or homesteads.

Table 8
Impact of climate change and variability as reported by respondents in Pangani District.

Variable	Kimang'a Ward (%)	Madanga Ward (%)	Total (%)	χ^2, df	*p*-value
Observed any of the Climate change	***n* = 103**	***n* = 94**	***n* = 197**		
Increase/decrease in Temp	44.2	42.6	86.8		
Shift in the rainfall season	8.1	5.1	13.2	1.028,1	0.311
Other					
Decrease/ increase in rainfall	15.8	15.2	30.9		
In the past 10 years, have you noticed a significant decrease in *Mikoche* tree distribution and productivity?	***n* = 103**	***n* = 94**	***n* = 197**		
Yes	68.9	66.0	67.5		
No	13.6	16.0	14.7		
Not sure	17.5	18.1	17.8	0.261, 2	0.877
If yes, indicate the extent to which climate change factors contributed to the above	***n* = 79**	***n* = 63**	***n* = 142**		
Strong	58.2	31.7	46.5		
Moderate	6.3	19.0	12.0		
Low	1.3	23.8	11.3		
Not at all	34.2	25.4	30.3	26.725, 3	0.000*
If yes, the level of human activity factors contributed to the above	***n* = 79**	***n* = 63**	***n* = 142**		
Strong	72.2	73.0	72.5		
Moderate	16.5	20.6	18.3		
Low	5.1	4.8	4.9		
Not at all	6.3	1.6	4.2	2.210, 3	0.530
If yes, the level of government policy contributed to the above	***n* = 79**	***n* = 63**	***n* = 142**		
Strong	55.7	50.8	53.5		
Moderate	13.9	14.3	14.1		
Low	17.7	22.2	19.7		
Not at all	12.7	12.7	12.7	0.521, 3	0.914

A *p*-value below 0.05 indicates a statistically significant difference (reject null), whereas $p \geq 0.05$ indicates no significant difference.

This behaviour reflects a broader trend observed in non-timber forest product (NTFP) systems, where communities rely heavily on wild tree populations rather than investing in domestication or cultivation. Similar patterns have been documented for Hyphaene species across Africa, where lack of awareness, long maturation periods, and competing land uses discourage tree retention or planting (Martins and Shackleton, 2017; Omire et al., 2022; Tobler et al., 2003).

Despite this, a minority of respondents indicated that they spare a few *Mikoche* trees, particularly for harvesting leaves for weaving and for providing shade and fruit at home. This selective retention suggests that while *Mikoche* is valued for its fibre and fruit, the benefits do not yet outweigh the perceived costs of keeping the trees for most households. This mirrors findings from other studies (Haule, 2022), where NTFPs are retained only when their economic or cultural value is immediately visible, or when households have traditional knowledge on processing their products. Nonetheless, demographic factors may have contributed to *Mikoche* tree conservation. For example, male-headed households may control more land; female-headed households may focus on small-scale agroforestry. Educated farmers may understand the long-term benefits of tree cultivation. Larger households may maintain more trees for labour or income. Farmers vs. fishermen vs. traders may differ in tree ownership. Longer settlement period, more time to plant or conserve existing trees. Also, households experiencing drought may keep more *Mikoche* as a resilience strategy. Moreover, *Mikoche* thrives in riverine areas, and flooding increases natural regeneration.

With respect to diversity and species recognition, 60% and 67% of respondents in both Kimang'a and Madanga wards, respectively, reported observing multiple *Mikoche* types in their local environment (Table 2). This indicates a relatively strong ecological awareness even in communities that do not practice active cultivation. The absence of significant differences between the wards in terms of identifying or classifying *Mikoche* suggests shared cultural or ecological knowledge systems. Communities in both wards distinguish *Mikoche* types based on morphological features such as tree shape, fruit colour, and fruit size, criteria commonly used in ethnobotanical classification across African farming systems (Assogbadjo et al., 2011; Moussa et al., 1998; Seltmann et al., 2007). Similarly, during the FGDs, it was mentioned that the trees were differentiated using geographical location, whereby the trees found along the sea are small and have a yellow colour, while those in the inland are big and red.

Scientifically, we observed species of *Hyphaene thebaica*, or doum palm, which is a branching palm tree with a distinctive Y-shaped trunk, reaching 10–17 m in height, with fruit that is typically brown when ripe, described as shiny brown and resembling a gingerbread or tawny colour. Immature fruits can range from green to maroon, with the final colour being a shade of brown as they mature.

Also, *Hyphaene compressa,* which is similar to the features reported by several authors, was observed. *H. compressa* is solitary, armed, pleonanthic, and dioecious, with stems about 20 m long; it grows in coastal lowland regions and extends to inland areas along water courses. It is grey in colour and fissured vertically; it produces 2–4 stems at the base, which in the adult plants divide dicotomously 4 or 5 times. Unripe fruit can be green or maroon, and mature fruit is typically described as glossy brown, with a range of colours from dark orange to pale brown when ripe (Borlay et al., 2024; Omire et al., 2020b; Stave et al., 2006).

The *Hyphaene coriacea* tree, commonly called the lala palm or ilala palm, is a species of palm tree native to eastern Africa. It is known for its distinctive forked or branched crown, fan-shaped greyish-green leaves with spines, and edible, pear-shaped fruits that are similar in taste to ginger. It typically grows 5 to 7 m tall but can reach up to 15 m The stem may be single or multi-stemmed, with a slight swelling in the middle. It is often covered by the persistent bases of old leaves. The leaves are large, fan-shaped, and greyish-green, with spines on the leaf stalks (petioles). Male and female flowers grow on different individual trees (dioecious). Fruits are pear-shaped, about 60- 80 mm in diameter, and change from green to orange to dark brown as they ripen. They have a sweet, ginger-flavoured, fibrous pulp surrounding a hard seed. Found in low-altitude bushland, coastal areas, dunes, and savannas in seasonally dry tropical climates. Native to the eastern Afrotropics, its range extends from Somalia to KwaZulu-Natal in South Africa, and it is also found in Madagascar. It is highly drought-tolerant and can grow in sandy and saline soils (Stauffer et al., 2018).

Hyphaene compressa is common in the Pangani district, where it grows sympatrically with *Hyphaene coriacea*. Previous researchers (citation) reported that the potential hybridisation between two Hyphaene species, including compressa and coriacea, may hybridise and make identification difficult (Stauffer et al., 2018).

However, despite strong ecological knowledge, none of the respondents reported planting *Mikoche*, and many actively uprooted natural seedlings. This reflects a disconnect between knowledge of a species

and investment in its domestication. Long maturation periods, land scarcity, and limited recognition of potential economic value could explain this behaviour.

The overall pattern of low cultivation, frequent uprooting, and dependence on wild vegetation highlights a critical management challenge. While communities recognise and use *Mikoche* diversity, their practices contribute little to sustaining or increasing its availability. This implies that wild populations of useful palms may decline without community-led conservation or domestication strategies. The fact that households in Pangani District only retain *Mikoche* for specific uses indicates opportunities for promoting their broader economic value, such as oil extraction, crafts, and food products, which could encourage preservation rather than removal.

4.2. Products and uses of Mikoche trees in Pangani District

This study revealed that *Mikoche* (*Hyphaene compressa*) serves multiple complementary functions for local communities, consistent with documented uses of Hyphaene palms elsewhere. In both Kimang'a and Madanga wards, households reported harvesting fruit and fibrous plant parts. Notably, our data suggest some differences in emphasis between the two wards. In Kimang'a ward, respondents tended to emphasise fibre and craft uses of *Mikoche* (e.g., weaving baskets and roofing thatch), whereas in Madanga ward, a greater proportion of households highlighted edible uses of the fruit (for nutrition and trade). These variations may reflect local factors such as market access, cultural practices, or resource availability. In FGDs, it was reported that roots of *Mikoche* are used as traditional medicine for whooping cough, synonymous with pertussis (*Kifaduro* in the Swahili language**),** and the immature nut is eaten as a snack. Also, the dried fruit was reported to be used as firewood, but the frequent use causes corrosion to the pans due to its high energy value. Moreover, wood and leaves are used as construction materials.

Nevertheless, in Pangani District, the fruit is rarely eaten fresh for hunger relief, nor is it processed in any form. Our review (Ahmed et al., 2023b) revealed vast uses of the fruit in Senegal, Kenya, Egypt, Sudan, Mozambique, and Zimbabwe. The fruit is eaten fresh or processed into juice, nectar, or wine; dried fruit powder is used as a flavouring agent for food or to make a mildly alcoholic drink by adding water and leaving it to stand; dried fruit powder is mixed with wheat flour to produce composite flour with improved dough rheological propertie; and as a natural source of dye extract (Abdel-rahman et al., 2014; Abdel-Rahman et al., 2015; Aboshora et al., 2019; El-Beltagi et al., 2018; Eldahshan et al., 2009; Mohammed et al., 2015). Considering that Hyphaene fruit is rich in fibre, vitamins, and essential nutrients (Aboshora et al., 2019; Chinnamma et al., 2019; Khalil et al., 2020), there is a need to integrate the use of the fruit in daily cuisine to promote food and nutrition security.

The fibrous leaves and petioles were reported to be woven into handicrafts and thatch, mostly in Kimang'a ward. These findings align closely with the ethnobotanical literature review by Ahmed et al. (2023b). Hyphaene stems and leaves are widely used as building material and for weaving baskets, mats, and hats (Foote et al., 2003; Martins and Shackleton, 2021). For example, Borlay et al. (2024) describe that communities in semi-arid Kenya rely on doum palm leaves to make mats, brooms, ropes, consumption of the fruits and medicinal uses. Similarly, the respondents reported similar uses in Pangani District. Focused group discussion corroborates this pattern; for instance, baskets and brushes made from doum palm leaves are commonly sold in nearby wards and local markets, including Muheza and Tanga Districts.

4.2.1. Household-level use and differentiated engagement

The present study examined the use of *Mikoche* trees between Kimang'a and Madanga wards in Pangani District. The results indicate that Kimang'a households are significantly more engaged in the direct processing and utilisation of *Mikoche* than those in Madanga. More than half of Kimang'a households produce their own *Mikoche* crafts, while the vast majority of Madanga households rely on buying such items. This demonstrates higher self-sufficiency and stronger artisanal traditions in Kimang'a. Research on NTFPs across sub-Saharan Africa consistently shows that communities with established skills in weaving or carpentry tend to integrate palm-based crafts into their household economies more deeply (Martins and Shackleton, 2022).

The differences in product types further reflect these dynamics. Kimang'a's higher use of *Mikoche* timber and fruit suggests familiarity with a broader range of palm parts, whereas Madanga's preference for woven leaf products implies narrower engagement with the resource. Importantly, the fact that none of the Kimang'a respondents reported non-use of *Mikoche* underscores the cultural embeddedness of the palm in daily activities. By contrast, a small fraction of non-users in Madanga suggests a more limited reliance on the resource.

These findings reveal that local knowledge systems and household skill levels influence both the intensity of use and the diversity of *Mikoche* products. They also explain the differences in perceived livelihood benefits between the two wards.

4.2.2. Community-level value chains and livelihood impacts

Although both communities identify construction and weaving as the main uses of *Mikoche*, it is the engagement in value-added production that differentiates their socioeconomic outcomes. In Kimang'a, a majority of households produce such products, whereas in Madanga, most households buy them. Specifically, only 21.1% of Madanga households make their own *Mikoche* crafts, compared to 59.3% in Kimang'a (Table 4). This suggests that Kimang'a has active local artisans and perhaps more standing palms, enabling home production. By contrast, Madanga residents appear to rely on outside sources, either trading with Kimang'a or buying at nearby markets, for woven *Mikoche* goods.

The data suggest that *Mikoche* has strong income potential in Kimang'a but is underutilised in Madanga. In Kimang'a, the prevalence of household production and reported income gains implies successful local economies (e.g., women's weaving co-ops). However, demographic factors influenced income potential and livelihood. For example, this study shows that doum palm crafts can raise living standards when markets are accessible. Cross tab also revealed that the respondents who lived in the areas for more than ten years (35.5%) observed more change in livelihood due to engagement in production and selling of the *Mikoche* products compared to those who lived less than 10 years (3%) ($\chi 2$, df, *p*-value = 8.108, 3, 0.044). Similarly, 64.5% of those who stayed over 10 years suggested that wider adoption of *Mikoche* would positively impact their community. Again, 80% of the households with more than 25 *Mikoche* trees observed more change in livelihood compared to 39.4% of those with fewer than 25 or without. Also, 88.8% of the households that produce *Mikoche* products observed a change in livelihood ($\chi 2$, df, *p-value* = 143.092, 1, 0.000).

Development initiatives could build on Kimang'a's momentum by improving craft skills and linking artisans to markets. In Madanga, low engagement represents a missed opportunity for local income generation. This aligns with studies showing that NTFP-derived livelihoods are strongly dependent on the extent of value addition, not merely resource availability (Belcher and Schreckenberg, 2007**).** Where communities have the capacity to process raw materials into retailable goods, income benefits tend to be higher and more widely distributed. Therefore, the findings imply that Kimang'a's stronger market orientation and artisanal networks play a key role in enabling households to benefit economically. Conversely, the limited exposure to training, markets, or production tools may explain the restricted economic gains in Madanga.

4.3. Community advantages, aspirations, and ambitions toward Mikoche in Pangani District

The findings reveal a strong economic orientation in community perceptions of *Mikoche* across Pangani District. Income generation

emerged as the most frequently cited advantage of the palm, with half of the respondents in Kimang'a (50.5%) and nearly as many in Madanga (44.9%) identifying economic benefits as the primary value of *Mikoche*. Other potential uses, such as shelter material, fruit consumption, or medicinal applications, were mentioned by almost none of the respondents, suggesting limited recognition of the species' multifunctionality. This pattern aligns with studies on non-timber forest products (NTFPs), where communities often prioritise species based on their direct economic returns rather than ecological or cultural attributes (Haule, 2022; Kaoma and Shackleton, 2015).

Importantly, community-level attitudes toward broader *Mikoche* adoption were highly positive. Approximately 77% of all respondents believed that scaling up *Mikoche* utilisation would benefit the village, with significantly higher optimism in Madanga (83.0%) compared to Kimang'a (71.8%). This difference may reflect Madanga's lower current engagement in *Mikoche* production, resulting in greater perceived potential for economic improvement if adoption expands. Such optimism suggests receptive conditions for interventions focused on value addition, microenterprise development, and market strengthening of the key components for unlocking NTFP-based livelihood gains.

However, while communities strongly acknowledge *Mikoche*'s economic potential, their aspirations and ambitions remain narrow in scope. About half of the respondents in both wards (50.5% in Kimang'a and 43.8% in Madanga) expressed aspirations centred solely on "increased income" from *Mikoche*. Other ambitions, such as improved livelihoods, environmental sustainability, community development, or enhanced food security, were cited by fewer than 3% of respondents. No significant difference in aspirations between wards indicates a shared conceptualisation of *Mikoche* primarily as a source of cash income rather than a broader development or ecological resource.

This singular focus on income aligns with patterns observed in marginalised rural economies, where households prioritise immediate financial gains over long-term ecological or social benefits (Haule, 2022; Kaoma and Shackleton, 2015). It also reflects gaps in awareness regarding the broader potential of *Mikoche*, such as its drought tolerance, utility as a construction material, nutritional uses, and value in climate resilience strategies. Without targeted extension, communities may fail to perceive the full spectrum of benefits that palm species can offer.

Taken together, these results highlight both opportunities and limitations for promoting *Mikoche*-based development in Pangani District. The strong economic motivation presents a strategic entry point for livelihood-focused interventions, while the positive community attitude toward wider adoption creates favourable conditions for scaling up. Yet, the narrow vision of *Mikoche*'s role suggests that any development strategy must incorporate awareness-building, training, and demonstration activities to expand community understanding beyond income alone. Also, encouraging diversification of *Mikoche* uses and integrating sustainability messaging will be essential to ensure long-term adoption and conservation of this valuable but underutilised species.

4.4. Limitations to the use and consumption of Mikoche trees in Pangani District

The study reveals that the primary barriers limiting the utilisation and consumption of *Mikoche* in Pangani District are overwhelmingly related to lack of awareness and knowledge rather than technical, economic, or environmental constraints. Only 3.9% of respondents reported any attempt to extract oil from *Mikoche* nuts, and even these efforts were unsuccessful due to challenges such as the difficulty of cracking the hard kernel and the overall hardness of the nut. This indicates that despite the potential value of *Mikoche* oil, households currently lack the practical knowledge and technological means required for effective extraction. Gender of the head of the household may be a hindrance factor. For example, female-headed families face a lack of awareness (88.0%), a lack of harvesting technology (5.6%), and limited time (2.4%) compared to men (87.5%, 4.2%, and 1.4, respectively).

Across both wards, 41–43% of households stated that they do not extract *Mikoche* oil simply because they do not know how to do so. Similarly, when asked why *Mikoche* products are used sparingly, 43–44% cited lack of awareness as the main reason. The consistency of these responses across Kimang'a and Madanga, along with the absence of statistically significant ward-level differences, suggests that the knowledge gap is district-wide rather than context-specific.

Technical challenges such as a lack of processing tools, absence of appropriate harvesting equipment, or difficulties with cracking the nuts were mentioned by only 5–7% of respondents, indicating that these are secondary issues. Even less importance was placed on economic or structural barriers such as lack of markets, high costs of processing, the low market price of *Mikoche* products, or limited time for processing, each typically cited by fewer than 5% of households. This further reinforces the conclusion that the constraints are rooted primarily in household capacity and information rather than in broader economic or infrastructural limitations.

The dominance of awareness-related constraints aligns with literature on non-timber forest products (NTFPs), which frequently highlights low knowledge of processing methods, value-addition techniques, and market opportunities as major factors limiting utilisation (Haule, 2022; Kaoma and Shackleton, 2015; Martins and Shackleton, 2022). When communities are unfamiliar with the broader potential of a species, whether for food, fibre, oil, or commercial use, it tends to remain underutilised despite ecological availability. In the case of *Mikoche*, even though the palm is abundant and well-recognised by households, its value beyond weaving and construction remains largely unrealised.

The findings also underscore a missed opportunity in rural livelihood diversification. *Mikoche* nuts are known in other regions of Africa for their edible oils, fibre applications, and craft potentials (Lokuruka, 2008; Ossoko et al., 2019). Yet in Pangani, the lack of processing knowledge prevents households from capturing this additional value. Given the community's strong aspirations for income generation from *Mikoche*, the knowledge gap represents a key leverage point for intervention. Therefore, the limitations identified in this study point to the need for training, extension services, and demonstration-based learning to unlock *Mikoche*'s potential.

Considering that the hardness of the *Mikoche* nut is similar to that of the palm nut, the same technology for extracting palm nut oil can be tested to extract oil from the *Mikoche* nut. Moreover, awareness creation, coupled with appropriate tools and small-scale processing technologies, could significantly enhance the utilisation of *Mikoche* products, including oil extraction, thereby supporting livelihood improvement, resource diversification, and climate-resilient food systems in Pangani District

4.5. Implications for climate resilience and sustainable resource management

The findings indicate that climate change is widely perceived in Pangani District, with temperature variability and changes in rainfall patterns emerging as the most commonly observed indicators. These perceptions reflect broader climate trends documented in coastal Tanzania, where communities increasingly report unpredictable seasons, rising temperatures, and altered rainfall regimes. The high percentage of respondents noticing climate changes (86.8%) highlights strong local awareness of environmental shifts that may influence plant productivity, including *Mikoche*.

The majority of households reported a decline in *Mikoche* tree distribution and productivity over the past decade, aligning with concerns about the vulnerability of natural palm populations under increasing climatic stress. While both Wards reported similar levels of decline, the interpretation of climate-change impacts differed significantly. Respondents in Kimang'a were more likely to perceive climate factors as strongly responsible for *Mikoche* reductions, whereas Madanga

households were more divided, with a notable portion rating climate impact as low. This difference may reflect contrasting exposure to environmental stresses, variation in ecosystem types, or differing levels of dependence on *Mikoche* as a livelihood resource.

Despite variation in climate-related perceptions, both wards strongly acknowledged the role of human activities in driving *Mikoche* decline. Over 72% attributed decreases to anthropogenic pressures such as land clearing, expansion of agriculture, and cutting of wild palms. This aligns with broader evidence that human disturbance often exacerbates climate-related declines in NTFP species, especially those not actively cultivated (Haule, 2022). The consistency across both wards suggests shared resource-use patterns and similar pressures on local vegetation.

Moreover, about 56.3% of residents who stayed over 10 years observed a significant decrease in *Mikoche* tree distribution in the past 10 years, compared to those who lived less than 10 years (11.2%). They further (33.8% out of 46.5%) strongly agreed that climate change could be the main contributor to the decrease of *Mikoche* ($\chi 2$, df, *p-value* = 20.021, 9, 0.018). Farmers and fishermen observed a greater decrease in the *Mikoche* trees due to climate change ($\chi 2$, df, *p*-value = 57.538, 21, 0.000).

Also, perceptions of government policy as a contributor to the decline of *Mikoche's* population were widespread. More than half of the respondents believed that weak policy enforcement or a lack of management guidelines contributes to the reduction of *Mikoche* trees. This reflects the absence of specific regulatory frameworks for *Mikoche* species in Tanzania and parallels findings from other regions where unregulated harvesting leads to the gradual depletion of wild palm resources.

Nonetheless, the present study indicates that climate variability, particularly increasing temperatures, prolonged droughts, erratic rainfall, and increasing soil salinity, together with anthropogenic pressures, is perceived by local communities as a major driver of changes in *Mikoche* productivity and distribution. During household surveys and focus group discussions, respondents consistently reported that *Mikoche* remained considerably more resilient than coconut under prolonged drought conditions, with several participants estimating that coconut populations had declined by more than 70% in some areas due to drought and salinity, whereas *Mikoche* continued to survive and produce fruits. These community observations are consistent with Patel & Kuttippurath (2023), who demonstrated that increasing tropospheric water vapour amplifies global warming, resulting in higher temperatures, increased atmospheric evaporative demand, and reduced soil moisture availability despite increasing atmospheric humidity. Such conditions intensify moisture stress in tropical ecosystems and contribute to the decline of climate-sensitive crops. The observed resilience of *Mikoche* is therefore plausible, given that the species is naturally adapted to arid and semi-arid environments and possesses characteristics that enable it to tolerate prolonged drought and harsh environmental conditions (Ahmed et al., 2023b). Similarly, during the field survey, we observed that *Mikoche* stands were observed to remain vigorous in Pangani District, whereas coconut trees declined due to drought conditions, reflecting their resilience.

The resilience observed during this study is further supported by molecular evidence showing that *Hyphaene compressa* possesses numerous drought-responsive genes associated with adaptation to water-limited environments (Borlay et al., 2024). Respondents also reported that *Mikoche* products provide an important source of food, construction materials, and income during prolonged dry periods, highlighting their role as a livelihood safety net under increasing climate variability. This finding agrees with Haule (2022), who reported that rural households in Tanzania increasingly depend on non-timber forest products to cope with climate-related shocks. Nevertheless, respondents recognised that climate change alone does not explain the observed changes in *Mikoche* populations; land-use change, overharvesting, and inadequate conservation were also identified as important threats. These findings underscore the need for integrated conservation, domestication, sustainable harvesting, and value-addition strategies to ensure that *Mikoche* continues to contribute to climate adaptation, livelihood diversification, and sustainable rural development in coastal Tanzania.

Despite its benefits, *Mikoche*'s slow growth and current harvesting patterns raise concerns about sustainability. The trees are long-lived and branch slowly. For example, after germination, only a single strip-shaped leaf is produced, with fan-shaped leaves emerging at ground level 2–3 years later. Thereafter, the Hyphaene tree can take up to 8 years to mature and produce fruit, which is about 50 kg per year (Orwa et al., 2009). Therefore, overexploitation (for example, cutting too many leaves and stems for handicrafts and fencing) could reduce future yield. Unfortunately, no policy or law currently regulates the cultivation, utilisation, and conservation of Hyphaene trees as a natural resource (Martins and Shackleton, 2017; Omire et al., 2022). This can make it difficult for farmers and other stakeholders to realise their potential benefits. For example, in Tanzania, *Hyphaene compressa* is considered a weed species in large-scale cattle ranching and is intensively treated with herbicides, followed by manual clearing (Tobler et al., 2003).

However, our data do not show obvious depletion yet, but the intensity of use highlights the need for careful management, as unrestricted harvest and habitat loss are major threats to wild resources globally. Ensuring that *Mikoche* remains available will require sustainable-use measures. For instance, selective harvesting (leaving some trunks intact), seasonal restrictions (to allow seed-set), and replanting could help maintain healthy populations. Local awareness of sustainable harvest was not systematically assessed, but given the economic importance of *Mikoche*, education and stewardship will be crucial.

4.6. Limitations and future research

This study was conducted in only two wards of Pangani District, therefore, the findings may not fully represent the utilisation and diversity of *Mikoche* across other coastal regions of Tanzania. In addition, the study focused primarily on socioeconomic aspects and household utilisation, while detailed investigations of genetic diversity, propagation techniques, agronomic performance, and large-scale commercial processing were beyond its scope.

Future research should evaluate the nutritional and functional properties of *Mikoche*-derived food products, optimise processing technologies for flour and edible oil production, and assess consumer acceptance and market potential. Studies on domestication, propagation, genetic diversity, and conservation strategies are also needed to support sustainable cultivation. Furthermore, economic feasibility and value chain analyses will be essential for guiding policy and investment aimed at transforming *Mikoche* into a commercially viable, climate-resilient crop that contributes to food security, income diversification, and sustainable development in Tanzania.

5. Conclusion

This study reveals that *Mikoche* (*Hyphaene* spp.) is an important but underutilised indigenous resource with significant potential to enhance rural livelihoods, income generation, and climate resilience in Pangani District, Tanzania. Although communities widely recognise its socioeconomic value, utilisation remains largely dependent on wild populations, with no evidence of active cultivation. Differences observed between Kimang'a and Madanga wards highlight the influence of local knowledge, value addition, and market access on the benefits derived from *Mikoche*. Given its drought tolerance and resilience to climate variability, *Mikoche* offers a promising alternative livelihood resource, particularly in the face of declining productivity of climate-sensitive species such as coconut. To realise its full potential, interventions should focus on promoting cultivation, sustainable harvesting, value addition, market development, and supportive policies. Strengthening

extension services and community awareness will further enhance its contribution to sustainable livelihoods and climate adaptation.

CRediT authorship contribution statement

Amina Ahmed: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Leonard Fweja:** Conceptualization, Methodology, Project administration, Supervision, Validation, Visualization, Writing – review & editing. **Happy Magoha:** Conceptualization, Methodology, Project administration, Supervision, Validation, Visualization, Writing – review & editing. **Fredrick Ojija:** Funding acquisition, Methodology, Project administration, Resources, Validation, Visualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors gratefully acknowledge the Mbeya University of Science and Technology (MUST) for providing financial support through the MUST Internal Research Fund (CoAST/DoFST/2024-2025/02), which made this study possible. We are grateful to the Pangani District Council, ward executive officers, village leaders, and the communities of Kimang'a and Madanga wards for their cooperation, hospitality, and willingness to participate in the household surveys, focus group discussions, and key informant interviews. Their valuable knowledge and experiences greatly enriched this study. We thank all colleagues and research assistants who contributed to data collection, field coordination, and data management. Their dedication and commitment were instrumental to the successful completion of this work. The authors further acknowledge all individuals who provided constructive comments, language editing, proofreading, and manuscript improvement during the preparation of this article. Their valuable suggestions significantly enhanced the clarity and scientific quality of the manuscript.

Data availability

Data will be made available on request.

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