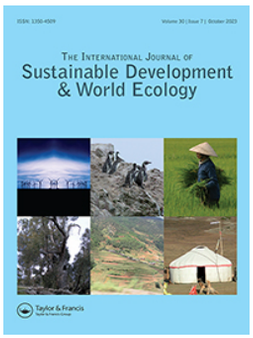

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Sustainable natural resource management must recognise community diversity

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ABSTRACT

Deforestation and overexploitation of mangrove forests are affecting the livelihoods of millions of families that rely on their ecosystem services. Understanding local perceptions about the status and threats to mangroves is therefore crucial in addressing this issue. This research aims to enhance understanding of how sociodemographic factors influence resource use and perceptions of environmental changes through a questionnaire survey ($n = 592$ households) in five locations in Lamu County, home to 62% of Kenya's mangroves. The results highlight the variability of mangrove use, ecosystem service recognition, and perceptions and drivers of change across locations, which are influenced by sociodemographic factors such as gender, education, and occupation. Although 89% of respondents reported using mangrove products, only 56% were able to identify mangrove ecosystem services, with those without formal education being less likely to recognize them. Interestingly, 50% of respondents perceived an increase in mangrove cover, contrary to research showing mangrove loss in the area over the last decade. Results show that communities are diverse and perceptions vary between groups, suggesting that implementing uniform management measures may be incomplete or ineffective. Awareness campaigns and capacity-building efforts must be tailored to reduce misperceptions about the state of local resources and to address the specific needs and challenges faced by different groups. Recommendations made here are widely applicable to promote more inclusive and sustainable community engagement in the management of natural resources in developing countries worldwide.

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Community perception; mangroves; natural resource use; sustainable management; Kenya

Introduction

Natural capital (such as water, forests and wildlife) provide opportunities for economic growth and sustainable development (Barbier 2005; Wang et al. 2011; Erdoğan et al. 2021) and are key elements of people's livelihoods worldwide. Natural resource management has often faced local resistance due to the impact it has on local livelihoods (Ghai 1994; Cobbinah 2015; Ihemezie et al. 2021). Divergent viewpoints of local stakeholders, state agencies and private investors pose a challenge to the sustainable management of these resources due to competing ecological, social and economic trade-offs (Roe et al. 2009; Arumugam et al. 2020). It is increasingly recognised that the success of conservation efforts depends largely on local context (Thomas and Koontz 2011; Maxwell et al. 2020). As a result, there has been a growing interest in understanding local perspectives and socioeconomic, environmental and political pressures that shape these perceptions and management practices (Roe et al. 2009; Aymoz et al. 2013; Hai et al. 2020; Soman and Anitha 2020).

Mangrove forests are one of the most important natural resources in tropical and subtropical areas, and have societal relevance at the local and global scale (Schwenke and Helfer 2021). They provide sources of income and a range of ecosystem services benefiting local communities, such as the provision of food, raw materials and coastal protection (Walters et al. 2008; Barbier et al. 2011; Karanja and Saito 2018; Hai et al. 2020). Per unit area, mangroves capture and store up to ten times more carbon than their terrestrial counterparts (Donato et al. 2011; Alongi 2020). Due to their relatively small total surface area, mangroves have a limited role in mitigating anthropogenic carbon emissions at the global scale (Taillardat et al. 2018; Alongi 2020). However, they can be important carbon sinks compensating carbon emissions at the national level in countries with relatively large mangrove cover; or conversely contributing to emissions in countries with high deforestation rates (Taillardat et al. 2018; Alongi 2020).

Human activities have been a major driver of loss and degradation of mangrove ecosystems; mostly due

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to overexploitation, habitat conversion, and pollution (Alongi 2002; Spalding et al. 2010; Warner et al. 2016; Goldberg et al. 2020; Spalding and Leal 2021). Mangrove loss and degradation can lead to reduction in fisheries (Rönnbäck 1999; Manson et al. 2005), shortage of harvestable products (Mbatha et al. 2022), and increased vulnerability to climate change (Lovelock and Ellison 2007; Kamil et al. 2021). These impacts overwhelmingly affect the poorest people whose livelihoods heavily depend on mangrove goods and services, particularly in rural coastal communities in developing countries (Scales and Friess 2019; Hamza et al. 2020). Global loss of mangrove coverage has decreased from an estimated 1.9% per year in the 1980s (FAO 2007) to 0.26% from 1996 to 2010 (Spalding and Leal 2021) and 0.13% between 2000 and 2016 (Goldberg et al. 2020). This reduction in mangrove loss is an effect of intensified conservation and reforestation efforts (Spalding and Leal 2021). Despite large geographical variation in the rate of change and the dominant driver, 62% of mangrove loss worldwide between 2000 and 2016 has been attributed to direct human impact; with the remaining 38% driven by extreme weather events, flooding and erosion (Goldberg et al. 2020).

Engaging the local community in decision-making is increasingly recognised as a key aspect contributing to the long-term sustainability of local natural resources management (Kellert et al. 2000; Berkes and Turner 2006; Datta et al. 2012; Owuor et al. 2019). Community engagement is greatly influenced by local experiences and individual perceptions about resource availability and the effects of management (Coulibaly-Lingani et al. 2011; Arumugam et al. 2020). Research capturing community perceptions of changes in mangrove forests, uses and management is still limited in number and scope. Analysing over 10,000 mangrove-related publications, Schwenke and Helfer (2021) concluded that, to support local adaptation and mangrove conservation, more research is needed to better understand the socio-environmental linkages between threats to mangroves and livelihoods.

Previous studies (Dahdouh-Guebas et al. 2000; Okello et al. 2019; Owuor et al. 2019; Arumugam et al. 2020) indicate that local perceptions are shaped by a complex interplay between demographic characteristics of the local population, their location and how much they use or rely on mangroves. However, they offer little insight on the diversity across groups of people within and between neighbouring coastal communities and how the understanding of this diversity may be used to promote sustainable practices and management. The current study expands the scope and geographic coverage of previous research by investigating the socio-ecology of mangroves in Lamu County, in northern Kenya, aiming to advance the understanding of how resource use and the perceptions about environmental changes are influenced by different sociodemographic factors. It is estimated that 80% of community residing adjacent to mangroves in Kenya derives about 70% of their wood requirements from the forest (Huxham et al. 2015). According to the Kenya's National Mangrove Ecosystem Management plan (2017–2027), at least 40% of the mangrove forests in the country are in degraded conditions.

Methods

Study area

Lamu County has a surface area of 6,475 km^2 including the mainland and 57 islands forming the Lamu archipelago. The largest habitable islands are Lamu, Pate, Manda, Ndau and Kiwayu (Lamu 2017). According to the national census, there are~37,900 households in Lamu with an estimated population of~143,900 people and an average density of 23 persons/km^2 (Kenya National Bureau of Statistics 2019b). The dominant ethnic group is the Bajuni people whose traditional livelihoods depend on artisanal fishing, mangrove harvesting, subsistence farming, and animal husbandry (Lamu 2017).

The National Mangrove Ecosystem Management Plan (GoK 2017) indicated that Lamu County constitutes 62% of all mangrove coverage in Kenya. A recent mapping using satellite images of 2018/2019 measured 35,678 ha of mangroves in Lamu County and estimated that the average net loss accelerated from 60 ha/year between 1990 and 2019 to 114 ha/year between 2010 and 2019 (Kairo et al. 2021). Six out of the nine mangrove species found in Kenya were observed in Lamu County, where the dominant species are *Rhizophora mucronata* (Mkoko in Swahili language), *Avicennia marina* (Mchu) and *Ceriops tagal* (Mkandaa) (Kairo et al. 2021).

Commercial harvesting of mangrove wood has been a lifeline for local livelihoods (Idha 1998; Bosire et al. 2016), with trade occurring within and outside the County. Hotspots of mangrove loss and degradation were observed in parts of Ndau, Pate and Manda Island where mangrove poles are harvested commercially or trees are felled for use in traditional lime kilns (Kairo et al. 2021). Large-scale infrastructure development (ports and roads) has also contributed to loss of mangroves (Kairo and Bosire 2016). To reduce mangrove loss and degradation, the Kenyan government imposed a ban on the export of mangrove poles from Lamu in 1982 (Idha 1998; Taylor et al. 2003), followed by a national ban in 1997 (GoK 2017) and 2018, considerably impacting the economy of Lamu. After community outcry and petitions to Government, the mangrove harvesting ban in Lamu was lifted in February 2019.

Data collection

A questionnaire survey (S1) comprised of open and close-ended questions and Likert-scale questions was conducted in July 2019 across coastal communities in Lamu county. To reflect the diversity of communities regarding the range of uses and dependency on mangrove harvesting, the survey covered households in five areas (Figure 1): Lamu Mainland (Mbeya, Ndambwe and Mkunumbi), Lamu Island (Matondoni and Lamu), Manda Island (Maweni and Maganga), Pate Island (Pate, Shanga, Siyu, Kizingitini and Faza) and Ndau Island (Ndau village). For brevity, herein they will be referred to as Mainland with 580 households, Lamu Island (2,281), Manda (371), Pate (2,018), and Ndau (190). The main goal of the questionnaire was to identify: (1) the socio-economic characteristics of respondents (Nchimbi et al. 2020; Nyangoko et al. 2021); (2) the extent and the types of mangrove use in the study area (Dahdouh-Guebas et al. 2000; Hamza et al. 2020); and (3) the perceived environmental changes in mangrove areas and drivers of change (Arumugam et al. 2020; Nyangoko et al. 2022).

The survey used a systematic sampling method (Cochran 1946), which targeted every other house starting from the southeasternmost outcast of the settlement, until at least 10% of the households in the village were visited. A total of 592 responses were obtained, representing a sampling intensity 12% in Pate, 11% in Lamu Island, 10.3% in Mainland, 8.9% in Ndau and 6.2% in Manda. Seeking consistency of information, only the household heads (if unavailable, the eldest person) were interviewed. The interviewer asked the questions in Swahili and systematically filled the questionnaire, taking 30 to 40 minutes per household on average. The data collection was conducted with the informed consent of all respondents following the Economic and Social Research Council's framework for research ethics. Ethical approval (ID 27,207) was granted by Bournemouth University.

Data analysis

Answers to open-ended questions were coded into categories based on themes emerging from the responses. Chi-square test of independence (χ^2) or Fisher's Exact test (when contingency tables were 2×2) were used to determine whether there was any statistically significant association between demographic groups for nominal variables, such as whether perceptions of changes in mangrove areas differ between male and female respondents or respondents from different locations. The effect size was measured using Cramer's V (Cramer 1946) calculated using the formula:$V = \sqrt{\frac{X^2}{n(c-1)}}$where X^2 is the Chi-square test statistic, n is the sample size and c is the smaller of the number of rows or columns. The interpretation of Cramer's V value depends on the degrees of freedom of the variables (defined as c-1), as indicated in Table 1.

Parametric one-way ANOVA or T-Test were employed to identify whether the mean values of variables between independent were significantly different, such as the length of time respondents from different locations lived in the local area. A Turkey

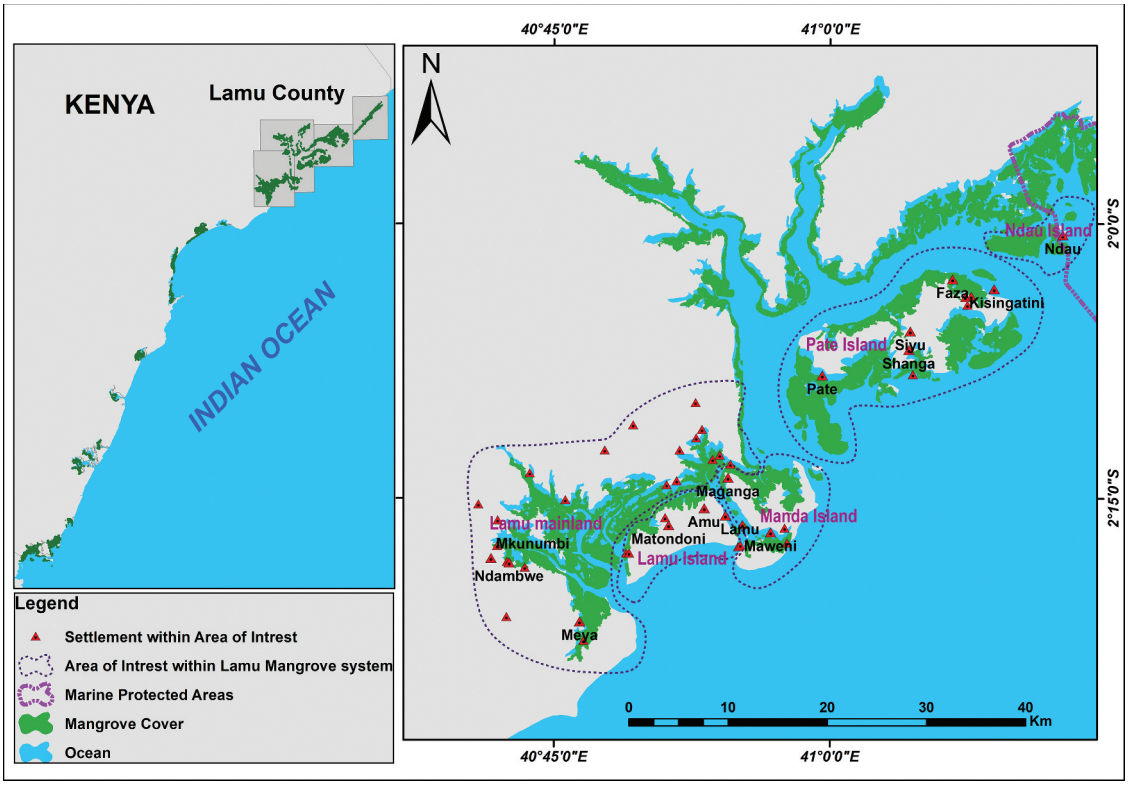

Figure 1. Occurrence of mangroves along the Kenyan Coast (left) and the study area (right).

Table 1. The strength of association according to Cramer's V and the degrees of freedom (based on Cohen 1988).

Degrees of freedom	Negligible	Small	Medium	Strong
1	<0.10	0.10 to <0.30	0.30 to <0.50	>0.50
2	<0.07	0.07 to <0.21	0.21 to <0.35	>0.35
3	<0.06	0.06 to <0.17	0.17 to <0.29	>0.29
4	<0.05	0.05 to <0.15	0.15 to <0.25	>0.25
5	<0.04	0.04 to <0.13	0.13 to <0.22	>0.22

HSD was then applied to identify which groups differ. All statistical tests were undertaken using the Statistical Package for Social Scientists (SPSS V.28.0).

Results

Demographics of respondents

Most respondents were of age group 35–59 years old (57%) and of male gender (66%), these two groups were dominant in all locations (Table 2). Overall, 37% of the respondents in Pate, Lamu Island and Mainland lacked formal education (Table 2). The prevalence of respondents with no formal education was higher than that recorded in Lamu County (20.1%) and in the country (16.3%) (Kenya National Bureau of Statistics 2019a). However, spatial variations exist, as only 4–6% of respondents had no formal education in Ndau and Manda (Table 2). In these locations, most respondents attended primary school, but none obtained higher education, while 3% to 7% did in the other locations. Household size ranged between 1 and 20 people with median and mean equal to 6 (standard deviation, SD = 2.9), higher than the reported for Lamu County.

The four most common primary occupations in the study area were fishing (17%), small business (16%), skilled workers (14%) and commercial mangrove harvesting (11%), with noticeable variations across locations (Table 2) and gender (Figure 2). Mangrove harvesting was the dominant primary occupation of respondents from Ndau (100%) and Mainland (30%); skilled workers dominated in Manda (65%) and Lamu Island (18%), and fishing dominated in Pate (24%). Fishing was the most common occupation of male respondents (24%), while small businesses (29%) and domestic work (28%) were the most common occupations among female respondents (Figure 2). Small business, crafting and domestic work were occupations dominated by women (respectively, 67%, 87% and 98% of respondents in these occupations were female). Other occupations were dominated by men, including the ones that more directly depend on the natural environment, such as fishing (95% male) and mangrove harvesting (94% male).

Over 66% of respondents have lived in their area for 30 years or more (mode = 40; median = 35.5; mean = 35.9; SD = 17.12) with no significant difference across gender (t (445.702) =-0.241, $p = 0.810$, two-tailed). Respondents had lived in Manda for a significantly (F (4) = 12.026, $p < 0.001$) shorter period (mean = 13.22

Table 2. Demographic of respondents across locations.

	N (%)					
Demographics	Lamu Island	Pate	Mainland	Manda	Ndau	Total
Respondents	250 (42%)	242 (41%)	60 (10%)	23 (4%)	17 (3%)	592 (100%)
Gender						
Male	168 (6 7%)	152 (63%)	36 (60%)	18 (78%)	16 (94%)	390 (66%)
Female	82 (33%)	90 (37%)	24 (40%)	5 (22%)	1 (6%)	202 (34%)
Age group						
18–34	60 (24%)	73 (30%)	14 (23%)	6 (26%)	3 (18%)	156 (26%)
35–59	146 (58%)	132 (55%)	30 (50%)	17(74%)	18 (82%)	339 (57%)
Over 60	44 (18%)	37 (15%)	16 (27%)	0 (0%)	0 (0%)	97 (16%)
Education level						
No formal education	98(39%)	99 (41%)	22 (37%)	1 (4%)	1 (6%)	221 (37%)
Incomplete primary	51 (20%)	69 (29%)	16 (27%)	3 (13%)	11 (65%)	150 (25%)
Complete primary	53 (21%)	43 (18%)	18 (30%)	12 (52%)	4 (24%)	130 (22%)
Incomplete secondary	6 (2%)	8 (3%)	0 (0%)	3 (13%)	1 (6%)	18 (3%)
Complete secondary	25 (10%)	15 (6%)	2 (3%)	4 (17%)	0 (0%)	46 (8%)
Higher education	17 (7%)	8 (3%)	2 (3%)	0 (0%)	0 (0%)	27 (4%)
Occupation						
Fishing	33 (13%)	57 (24%)	5 (8%)	0 (0%)	0 (0%)	95 (16%)
Small businesses	43 (17%)	36 (15%)	7 (12%)	0 (0%)	0 (0%)	86 (15%)
Skilled workers	46 (18%)	18 (7%)	5 (8%)	15 (65%)	0 (0%)	84 (14%)
Mangrove harvesting	17 (7%)	8 (3%)	18 (30%)	2 (9%)	17 (100%)	62 (11%)
Casual worker	30 (12%)	22 (9%)	6 (10%)	2 (9%)	0 (0%)	60 (10%)
Domestic worker	20 (8%)	26 (11%)	12 (20%)	0 (0%)	0 (0%)	58 (10%)
Farming	13 (5%)	20 (8%)	2 (3%)	4 (17%)	0 (0%)	39 (7%)
Employed	20 (8%)	16 (7%)	2 (3%)	0 (0%)	0 (0%)	38 (6%)
No specific occupation	19 (8%)	15 (6%)	2 (3%)	0 (0%)	0 (0%)	36 (6%)
Crafting	10 (4%)	24 (10%)	1 (2%)	0 (0%)	0 (0%)	35 (6%)

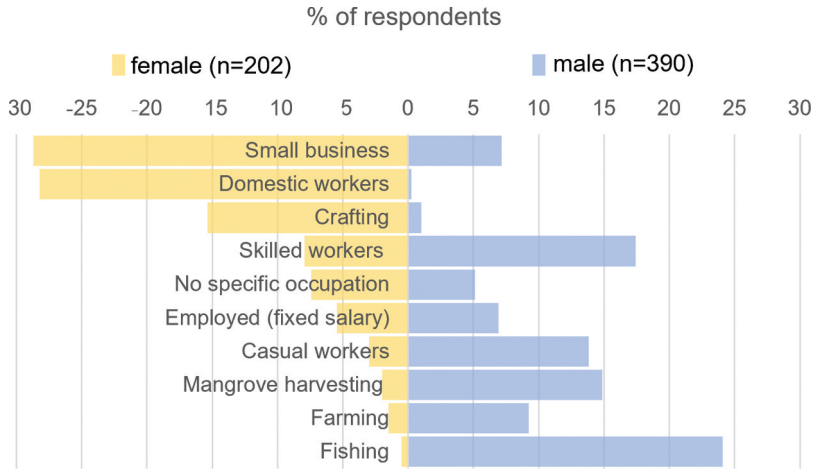

Figure 2. Primary occupation of respondents according to gender.

years) than in other locations (mean>35.47 years). Manda has a relatively larger proportion of skilled workers (Table 2), most involved in coral mining, and others such as plumbers, painters, carpenters, masons) and they tend to come from outside the local area. A significant association was found between occupation and the length of time living in the area ($F(9) = 3.048$, $p = 0.001$). The Tukey HSD post-hoc test indicated that skilled workers have lived in the area significantly less time than fishers (mean difference of 8 years) or respondents with no specific occupation (14 years). This difference was not attributed to age, as no significant difference was found between the distribution of fishers and skilled workers per age group ($\chi^2 = 5.8778, p = 0.0529$).

Mangrove use

Results show that 89% of the 592 respondents use mangroves products (Table 3). At least 56% of the respondents purchase the product from licensed cutters; whereas 22% harvest the products from the forest, 10% do both and<1% do not use mangrove products but their livelihoods depend on mangroves (e.g. they transport or sell mangrove products for a living). More than 81% of respondents across all occupations are mangrove users (Table 3) and a statistically significant association ($p < 0.05$) was found between mangrove use and primary occupation of respondents (Table 3). Unsurprisingly, all respondents who harvest mangroves for sale are also users of mangrove products.

Table 3. The relationship between use of mangroves and demographic traits of respondents ($n = 592$).

		Mangrove use (% no. of response)				
Demographic characteristics	*n*	Yes	No	χ^2	*df*	*P*
All respondents	**592**	**88.9**	**11.1**			
Gender of respondents				**0.021**	**1**	**0.886**
Male	390	88.7	11.3			
Female	202	89.1	10.9			
Age				**12.043**	**2**	0.002
18–34	156	85.7	14.3			
35–59	403	72.6	27.4			
Over 60	33	89.9	10.1			
Area				**35.653**	**4**	< .001
Lamu Island	250	86.8	13.2			
Manda	23	56.5	43.5			
Pate	242	90.5	9.5			
Mainland	60	100.0	0.0			
Ndau	17	100.0	0.0			
Education level of respondents				**7.755**	**5**	**0.170**
No formal education	221	91.9	8.9			
Incomplete primary	150	88.7	11.3			
Complete primary	130	83.1	16.9			
Incomplete secondary	18	88.9	11.1			
Complete secondary	46	93.5	6.5			
Higher education	27	85.2	14.8			
Primary occupation of respondents				**19.573**	**9**	0.021
Fishing	95	91.6	8.4			
Business	86	90.7	9.3			
Skilled workers	84	83.3	16.7			
Mangrove harvesting	62	100.0	0.0			
Casual workers	60	81.7	18.3			
Domestic workers	58	82.8	17.2			
Farming	39	87.2	12.8			
Employed (fixed salary)	38	89.5	10.5			
No specific occupation	36	83.3	16.7			
Crafting	35	97.1	2.9			

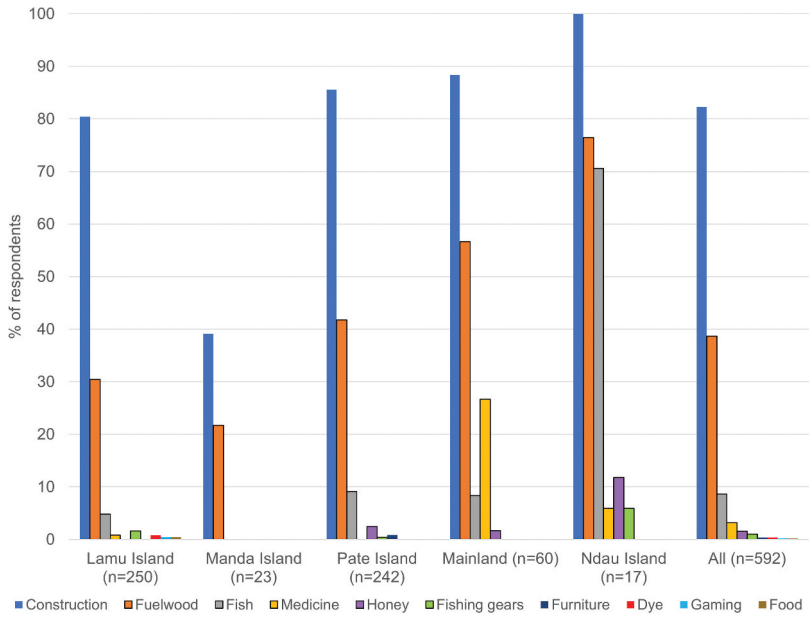

Figure 3. Types of mangrove use mentioned by respondents across locations.

Mangroves are used for multiple purposes (Figure 3). In all locations, wood is the most used product, and the two most common uses are in construction (82%) and as fuelwood (39%) for cooking and lime production. Respondents mentioned the use of five mangrove species and the tree parts they use for different purposes (Table 4). *Rhizophora mucronata* and *Ceriops tagal* are the most preferred species for construction (46% and 30% respectively) and fuelwood (44% and 38% respectively). Respondents prefer to use mangrove wood as fuelwood because it burns for longer and provides more heat than other types of wood. All species and the whole tree are used in lime production. Mangrove poles are widely used for the construction of walls and roofs of traditional buildings and respondents replace the poles every 20 to 30 years. Mangrove forests are also used to obtain fish and shellfish (9%), traditional medicine (3%) and honey (2%).

Mangrove use and location of respondents

The types of uses of mangrove products and the proportion of users vary across locations (Figure 3). While all respondents from Ndau and Mainland use mangrove products, only 57% are mangrove users in Manda (Table 3), where only the two most common uses were mentioned (Figure 3). Most respondents from Ndau (76%) and Mainland (57%) use mangroves as fuelwood for cooking; this use is less common in other locations, where most respondents cook using either gas or charcoal made from other types of wood. Most of the respondents using gas have used mangrove wood in the past but switched when cooking with gas became affordable to them.

Other uses were particular of some locations. Mangroves used as medicine were mentioned by 27% of the respondents from Mainland and by none from Manda or Pate (Figure 3). Wood is used to make fishing gears in Ndau and Lamu Island and furniture in Pate. Fishing in mangrove areas is prevalent in Ndau (71% of respondents) and practised by less than 10% of respondents from other areas (Figure 3). Differences in mangrove use across locations might be partly attributed to the occupation of respondents, as a strong statistically significant association ($\chi^2 = 292.555, df = 36, p < .001$) was found between the respondents' area and their primary occupation. All respondents from Ndau are mangrove harvesters and use mangrove products. On the other hand, most respondents from Manda are skilled workers, of which only 25% are mangrove users.

Table 4. Mangrove species preferred by respondents for different uses.

Species	Uses (plant part)
Rhizophora mucronata	Construction (wood), fuelwood (twigs/whole tree in lime production), medicine (roots)
Ceriops tagal	Construction (wood), fuelwood (twigs/whole tree in lime production)
Avicennia marina	Fuelwood (twigs/whole tree in lime production), mosquito repellents (twigs), gaming (seeds)
Sonneratia alba	Construction (wood), fishing gears (wood)
Bruguiera gymnorhiza	Fuelwood (twigs/whole tree in lime production)

Recognising other mangrove ecosystem services

Of the four types of ecosystem services listed in the questionnaire, fisheries support (bait, crabs, fish nursery) was the one most recognised (31% of 592 respondents), followed by: climate regulation (17%), such as carbon capture, brings rain, provides nice breeze; coastal protection (15%); and habitat for animals, including insects and fish (8%). Other services spontaneously identified by respondents were livelihood support (8%, a source of employment, education, clothing, health); recreation and tourism (3%, a place to relax, ecotourism, natural beauty); forest regeneration (1.5%); while obtaining honey, safety and shelter during boat accidents and area for making boats were also mentioned (<1%). Only 56% of all respondents recognised mangrove ecosystem services other than goods (Figure 4), 38% identified only goods, and 6% did not identify any services.

The proportion of respondents who could identify additional mangrove ecosystem services varied from 45% in Lamu Island to 83% in Mainland (Figure 4). There was a moderate (*Cramer'sV* = 0.236) statistically significant association between respondents' recognition of mangrove services and household location ($\chi^2 = 66.182, df = 8, p < .001$). Surprisingly, in Manda and Pate, a larger proportion of non-mangrove users (80–86%) than mangrove users (56–62%) were able to identify other ecosystem services provided by mangroves. In contrast, only 33% of non-users and 47% of users from Lamu Island could identify additional mangrove ecosystem services.

Moderate (*Cramer'sV* = 0.40–0.46) statistically significant associations were found between location and the ability to identify the service of fisheries support ($\chi^2 = 60.808, df = 4, p < .001$) and livelihood ($\chi^2 = 59.869, df = 4, p < .001$). Respondents from Pate and Lamu Island identified a larger range of services, while fewer services were identified in Manda. Fisheries support and provision of habitat for other organisms were more widely recognised in Mainland (by 73% and 20% of respondents, respectively) than in other locations, where these services were recognised by 12–31% and 0–10% of respondents, respectively. Livelihood support was more readily recognised in Ndau (41%) than elsewhere (0–12%); climate regulation was more cited in Pate (24%) than in other areas (0–20%); and recreation and tourism in Manda (9% contrasting with 0–2.5%). Less differences were found in the ability to recognise the service of coastal protection, ranging from 11% (Pate) to 17% (Manda) of respondents.

Male respondents were more likely to recognise mangrove services than women (63% of males and 43% of females identified additional ecosystem services). This association was found to be statistically significant ($\chi^2 = 25.224, df = 2, p < .001$) but weak (*Cramer'sV* = 0.206). Female respondents were significantly less likely to identify the service of fisheries support (Fisher's exact, $p = 0.028$) and climate regulation (Fisher's exact, $p = 0.039$) than male respondents.

Respondents who did not attend formal education were less likely to identify ecosystem services and more likely to answer '*I don't know*' than any other respondent. Only 44% of respondents without formal education were able to identify ecosystem services contrasting with 59%-83% of respondents

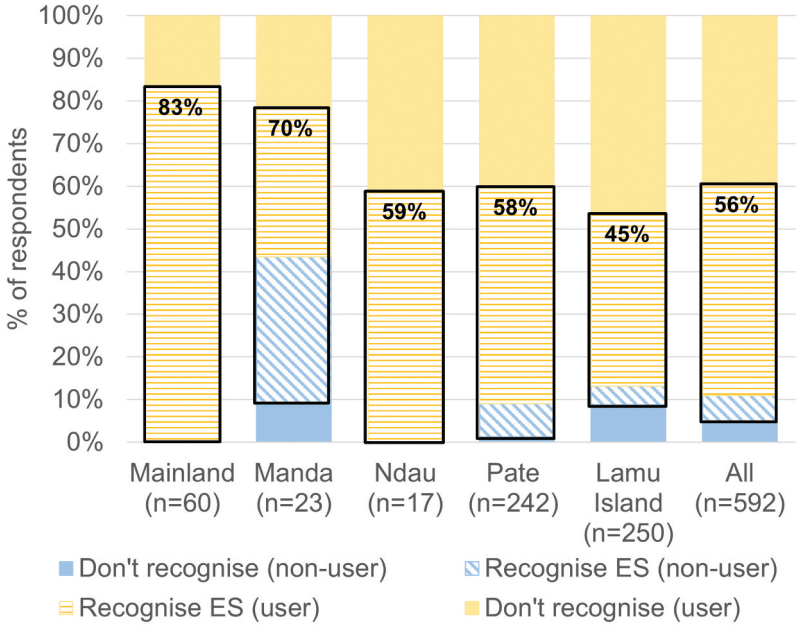

Figure 4. Proportion of respondents (mangrove users and non-users) per location who did and did not recognised mangrove ecosystem services other than the provision of wood. The black box indicates the total proportion of respondents who identified other services.

with higher education levels. A weak (*Cramer'sV* = 0.155) statistically significant association($\chi^2 = 28.525, df = 10, p = 0.001$) was found between education level and the ability to identify mangrove services. Only 14–16% of respondents who had incomplete primary education or no formal education were able to identify the service of coastal protection, a significantly lower proportion than (30–41%) other respondents ($\chi^2 = 19.435, df = 5, p = 0.002$). Respondents who attended higher education were three times more likely to recognise that mangroves provide habitat for other organisms than other respondents (36% contrasting with 10–13%, respectively).

Perceived changes in mangrove forests in the last 10 years

Over 79% of respondents identified changes in mangrove forests, 14% 'didn't know' whether changes had occurred or not and 7% either perceived no changes or 'didn't know' depending on the variable. Most respondents identified changes in mangrove cover (75%), density (62%) and height (62%), dominantly indicating an increase (Figure 5), while only a minority perceived changes in mangrove species (5%) and biodiversity (7%). Over 71% of respondents indicated no changes in mangrove species and 81% said they 'don't know' whether changes in biodiversity occurred, contrasting with only 17–25% who 'don't know' about changes in the other variables (Figure 5). Respondents who identified changes in more than one variable tended to perceive that they were in the same direction, i.e. 48% identified an increase in mangrove cover, density, height, number of mangrove species or biodiversity; 21% a decrease; and only 11% identified increase in some variables and decrease in others.

Overall, women were more likely to say they 'don't know' whether changes had happened in mangrove forests than men and less likely to report an increase than men (Figure 5). Statistically significant associations were found between gender and perception of changes that were moderate (Cramer's V = 0.301) for mangrove cover($\chi^2 = 53.570, df = 3, p < .001$) and weak (Cramer's V = 0.237–0.291) for density($\chi^2 = 33.112, df = 3, p < .001$); height($\chi^2 = 40.130, df = 3, p < .001$); and species($\chi^2 = 50.053, df = 3, p < .001$).

Perceptions varied across locations. Respondents from Ndau never said 'I don't know', and 'no change' was their most common perception in all aspects, always in greater proportion than in other locations

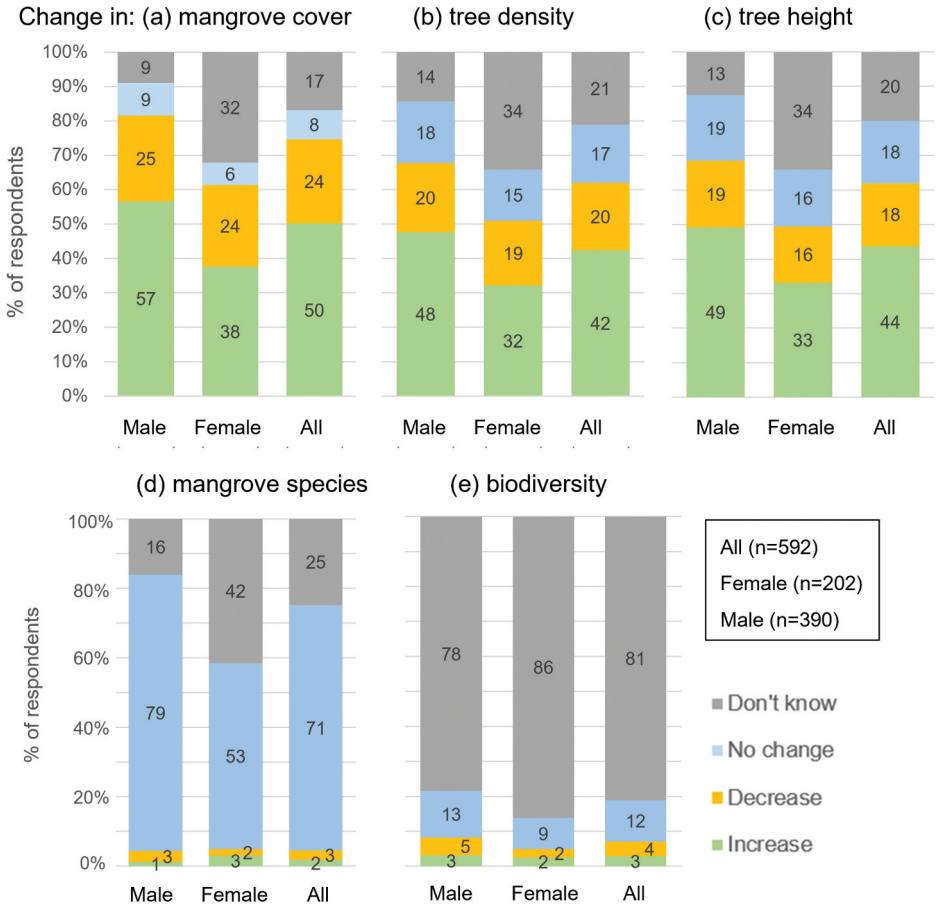

Figure 5. Respondents perceived changes in mangrove forests in the last 10 years by gender.

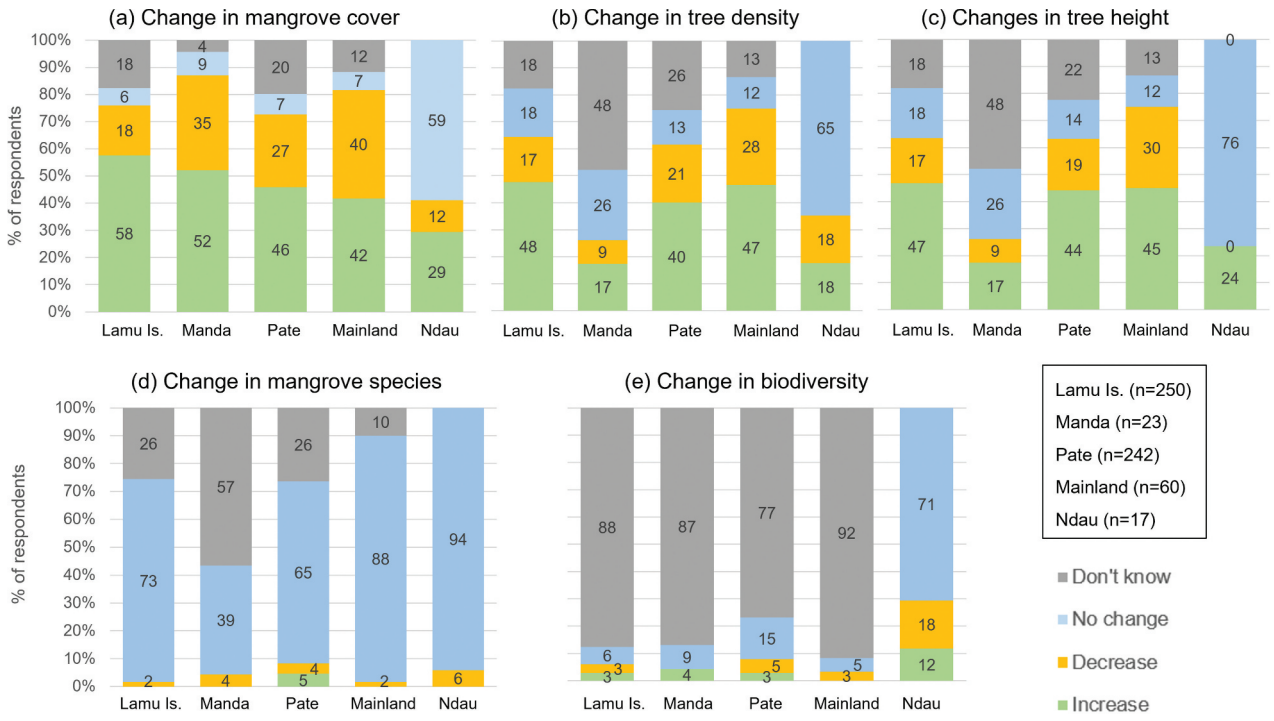

Figure 6. Respondents perceived changes in mangrove forests in the last 10 years by location.

(Figure 6). An increase in forest cover was the dominant perception in other locations (varying from 42% to 58% of respondents), contrasting with Ndau, where only 29% reported an increase in cover (Figure 6). An increase in tree density and height was the most common perception (40–47% of respondents) in Lamu Island, Mainland and Pate (Figure 6), while 'I don't know' (48%) was the dominant answer in Manda, followed by 'no change' (26%). Most respondents (>65%) from all locations indicated no changes in mangrove species, except in Manda where 'I don't know' was the most common answer (Figure 6). Most respondents (>77%) in all locations felt unable to assess changes in biodiversity, except in Ndau, where 71% indicate 'no change', 18% report a decrease and 12% an increase (Figure 6).

Younger respondents (18–34 years old) were more likely to say 'I don't know' than older respondents when asked about changes in mangrove forests. A weak statistically significant association was found between age and perception of changes in mangrove density($\chi^2 = 16.882, df = 6, p = .01$); height($\chi^2 = 21.995, df = 6, p = .001$); and mangrove species($\chi^2 = 21.410, df = 8, p < .01$).

Drivers of change in mangrove areas

Logging was the only driver of mangrove change identified by most respondents (65% of 592), of which 59% indicated a positive impact and 41% denoted a negative impact. Across sites, the proportion of respondents identifying logging as a driver of change varied from 50% (in Mainland) to 96% (in Manda). A moderately strong ($Cramer'sV = .231$) significant association ($\chi^2 = 63.416, df = 8, p < .001$) was found between the respondent's location and the type of change that logging was perceived to cause. In Manda, 57% of respondents perceived logging to be affecting mangrove forests negatively, and 39% indicated positive effects. This contrasts with responses from Lamu Island and Ndau, where positive effects are perceived by 51% and 59%, respectively, and negative effects are perceived by only 26% and 12%, respectively. In Mainland and Pate, opinions were almost equally divided between positive and negative effects.

Other causes of changes identified by respondents include enforcement of the mangrove ban (46%), siltation associated with heavy rain (13%), increased awareness on the value of mangroves (10%), the use of chainsaw (8%), reforestation (7%), agriculture/aquaculture (3%), fishing (2%), land reclamation (1%), residential and commercial development (1%) and erosion (1%). The proportion of respondents identifying these drivers varied across locations and significant associations were found to be moderately strong for enforcement of mangrove ban ($\chi^2 = 76.237, df = 4, p < .001, Cramer'sV = 0.359$), raising awareness ($\chi^2 = 90.019, df = 4, p < .001, Cramer'sV = 0.390$) and chainsaw use ($\chi^2 = 78.602, df = 4, p < .001, Cramer'sV = 0.364$), and weak ($Cramer's\ V = .275$) for logging ($\chi^2 = 44.614, df = 4, p < .001$).

Large variations were found in the proportion of respondents who indicated that raising awareness (from none in Ndau to 61% in Manda) and the use of chainsaw (from none in Manda to 47% in Ndau) were drivers of changes in mangrove areas. All respondents perceived the former to cause positive changes and all, but one respondent (from Pate), perceived the use of chainsaw to be negative. A significantly higher proportion of mangrove harvesters (27%) than other occupations (3% to 10%) identified the use of chainsaw as a cause of change in mangrove forests ($\chi^2 = 38.199, df = 9, p < .001$).

The ban on mangrove harvesting was identified as a cause of change in mangrove areas by most respondents from Manda (74%) and Lamu Island (63%), contrasting with 48% from Mainland, 29% from Pate and 24% from Ndau. A larger proportion of respondents perceived the ban to have a positive than negative effect in Manda (44%/30%), Mainland (42%/7%) and Lamu Island (37%/26%), while respondents were divided in Ndau (12%/12%) and Pate (14%/13%). This association is statistically significant($\chi^2 = 87.615, df = 8, p < .001$) and moderately strong ($Cramer'sV = 0.272$).

When asked on the level of agreement to statements offered, opinions were divided about climate change, droughts, human activity, and policy and conservation; and were more aligned about floods and poor management (Figure 7). About 49% of respondents agreed/strongly agreed and 39% disagreed/strongly disagreed, that 'current policy/management is helping the conservation of mangrove resources'. Most respondents (68%) agreed/strongly agreed with the statement 'poor management of mangrove areas is a main cause of concern'. A statistically significant($\chi^2 = 81.896, df = 16, p < .01$) and moderately strong association ($Cramer'sV = .195$) was found between the level of agreement with this statement and location. While most respondents from Lamu Island (75%) and Mainland (92%) strongly agree/agree that poor management is a cause of concern, in Ndau 41% agree/strongly agree and 59% respondents disagree with the statement. Most respondents (67%) strongly disagreed/disagreed that floods are contributing to changes in mangrove areas, and a significant($\chi^2 = 78.397, df = 16, p < .01$) and moderately strong ($Cramer'sV = .191$) association was also found between the level of agreement and location. A much higher proportion of respondents from Ndau (88%) strongly disagree that floods are a cause of change to mangroves compared to only 9% from Manda.

Discussion

It is increasingly accepted that, to be sustainable, natural resource management must be culturally aware and sensitive, focusing equally on livelihoods and nature conservation needs (Warner et al. 2016; Queiroz et al. 20172017). Therefore, aligning management objectives with the needs of local livelihoods is needed to gain communities' support and sustain their commitment through time (Suich 2013; Baddianaah and Baaweh 2021). In line with previous studies in developing countries in Africa and elsewhere (e.g. Rönnbäck et al. 2007; Delgado-Serrano and Escalante Semerena 2018; Okello et al. 2019; Owuor et al. 2019; Nyangoko et al. 2021; Gnansounou et al. 2022), results presented here show that occupation, level of education and gender influence the use of natural resources (mangroves in this case) and opinions concerning

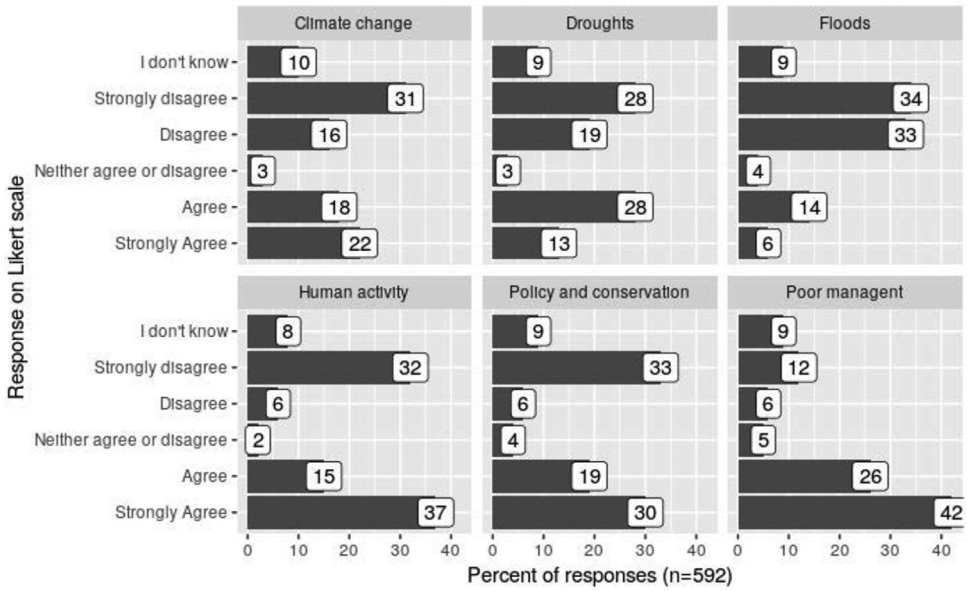

Figure 7. Responses to Likert scale questions on the effects of selected factors on mangrove areas.

environmental changes. This is the largest household survey focusing on mangrove use in Kenya to date and the first in Lamu County, expanding the geographical coverage of previous studies and scope by identifying the diversity found across neighbouring communities.

These results make a strong case to argue that natural resource management must recognise local diversity and address the needs of different groups to be successful. Strategies based on one-size-fits-all measures are flawed, as they are likely to benefit some groups and negatively impact others without making provisions to address these disparities. Three initial steps are required to align resource management with local needs: (1) to recognise that local needs vary across groups and cannot be generalised; (2) to understand how local needs and perceptions vary with gender, education and occupation; and (3) to tailor management approaches and community engagement to address the needs of local groups, particularly resource users.

The next subsection discusses existing evidence concerning the demographics of communities near mangrove areas to justify the importance of an inclusive management that considers the range of local needs. This knowledge is then used to elaborate recommendations of management measures that account for local diversity.

The diversity of communities in mangrove areas

According to the Kenya Forest Service (2019), 30000 families (corresponding to 79% of the total households) directly depend on mangrove trade in Lamu County, which is considerably higher than evidenced in the data presented here. Estimates of mangrove dependency based on extrapolations of data obtained from limited number of locations are unlikely to produce a fair generalisation over a wider area. Variations were observed across communities, with greater dependency on direct income and mangrove use in Ndau and Mainland, where 100% and 30% of respondents are harvest mangroves, respectively. Dependency on mangroves is prevalent in smaller rural communities closer to mangrove forests (Scales and Friess 2019; Nchimbi et al. 2020) where other sources of income are limited (e.g. Ndau). Mangrove dependency reduces where a wider range of income opportunities exist, such as in the larger villages of Pate and Lamu Island, or where there is demand from specific industry (e.g. mining in Manda). Policy interventions that prevent extraction of forest resources, such as the harvest bans implemented in Kenya, have shown deeper social consequences in areas of greater dependency (Geng et al. 2020).

Primary occupation of respondents in this survey was found to be a predictor of mangrove use. Respondents engaged in activities that extract natural resources (e.g. mangrove harvesting, fishing and makuti weaving) were significantly more likely to use mangrove products than other occupations. Livelihoods near mangrove areas are mainly supported by fishing and other associated activities, with mangrove harvesting providing secondary or supplementary income, but many rely on mangroves for subsistence needs (Walters et al. 2008). Mangroves are undoubtedly important to coastal communities in Lamu, where 89% of survey respondents use mangroves and 25% harvest mangroves as the main or secondary source of income. The trade of mangrove wood also contributes to the income of workers involved in the supply chain (Machava-António et al. 2020; Riungu et al. 2022), who are unaccounted in the 25% of respondents indicated above. As mangroves have a key role in supporting fisheries, it can be argued that they contribute to the income of the 16% of respondents who listed fishing as their main occupation.

The dominant age group and gender of respondents in this research are similar to household surveys focusing on other communities near mangrove areas in Kenya (Crona and Ronnback 2007; Okello et al. 2019; Owuor et al. 2019), Tanzania (Nchimbi et al. 2020; Nyangoko et al. 2022), Nigeria (James et al. 2013) and Malaysia (Sarmin et al. 2018). This is unsurprising as, in many countries in the Global South, households are culturally headed by men, and they are normally the main source of information. However, the main source of income and level of education vary geographically, even between villages that are relatively close together, as the ones in Lamu County surveyed in this study and around Mtwapa Creek in southern Kenya (Okello et al. 2019).

Despite local variations, communities close to mangrove areas tend to have lower levels of education. In the villages of Lamu County surveyed in this study, 37% of all respondents lacked formal education, a higher proportion than the County (20%) and national (16%) averages (Kenya National Bureau of Statistics 2019a). Similarly, respondents with no formal education varied from 19% in Mida Creek in Kilifi County, (Owuor et al. 2019) to 44% in the communities around Mtwapa Creek at the border of Mombasa and Kilifi Counties (Okello et al. 2019). Around Mtwapa Creek, the main income was farming, while in Mida Creek and Lamu communities the primary occupations were small business and fishing. These communities are also poorer and with larger household sizes (>6 on average) than the national average of 3.9 (Kenya National Bureau of Statistics 2019a), reflecting more dependents. While 37% of Kenya's population had an average daily income lower than US$1.90 in 2015 (World Bank 2022), around Mtwapa Creek, 57% of

respondents lived with less than US$1.70 per day (Okello et al. 2019). In Sub-Saharan Africa, most people living below poverty line are uneducated, practice subsistence farming (Masron and Subramaniam 2019) and heavily depend on natural resources (Orchard et al. 2014), which creates a nexus between poverty and environmental degradation (Barbier 2010; Masron and Subramaniam 2019). Africa ranks second (after Asia) in deforestation rate in general, mostly due to increased demand for resources associated with population growth (Amoah and Korle 2020), as also observed in Asia (Qasim et al. 2011).

Recommendation to policy and management

There is great pressure on the long-term sustainability of natural resources adjacent to communities highly dependent on them for their basic needs (Scales and Friess 2019; Nyangoko et al. 2022). Basic needs can lead to overexploitation of resources even when it contradicts people's knowledge and beliefs (Walters et al. 2008). This section offers recommendations that can stimulate the social transformations needed to reduce reliance of local communities on natural resources. Although based on results from Lamu, the discussion and recommendations presented here are applicable to the management of mangroves and other natural resources in the Global South.

Community-based management

Community-based natural resource management aims to promote both poverty alleviation and nature conservation (Suich 2013). Engaging the community creates a sense of ownership and can more effectively identify solutions that align management objectives with the needs of local groups, as achieved in the management of mangroves in the Mekong Delta, in Vietnam (Warner et al. 2016), forest and wildlife in Ghana (Baddianaah and Baaweh 2021) and reef fisheries in Honduras (Rivera et al. 2021). Community engagement can dwindle through time if financial returns benefit only a few or are insufficient to support the livelihoods of the ones involved, as seen in forest management in Mozambique and Namibia (Suich 2013). The Zukpiri community resource management area in Ghana succeeded by building local capacity to obtain income from non-wood products, tourism and fines imposed on illegal activities, generating both community benefits (solar power, school buildings, latrines) and income for households (Baddianaah and Baaweh 2021).

Financial sustainability is particularly important in areas where many depend on natural resources and there are limited opportunities for alternative income earning activities. Financial benefits were shown to be the main driver of engagement in co-management of mangrove areas in the Volta estuary (Ghana), where mangroves planted were harvested for sale (Aheto et al. 2016). Considering community diversity, it is important to ensure that the most vulnerable and marginalised groups (e.g. women) are not left behind. The success of co-management of natural resources has been linked to: (a) the involvement of organisations able to aggregate support, promote collaboration and improve accountability; and (b) the sustained community participation in decision-making, open to trust and contribute to the collective (Arumugam et al. 2020; Rivera et al. 2021), which is unlikely to be realised without direct financial benefit to participants (Aheto et al. 2016).

Payment for Ecosystem Service schemes that offer financial incentives to the community for the conservation of the forest may be an alternative, although existing examples on mangroves are limited (Locatelli et al. 20142014). In Kenya, Mikoko Pamoja was the first community-based carbon offset project on a mangrove area, generating an annual revenue of US$ 12500 for the capture and storage of 3,000 tons of carbon dioxide (Bosire et al. 2016; Kairo et al. 2018). The sale of carbon credits requires financial, technical and expert support to quantify gains and losses of carbon; and ensure net additionality of conservation interventions (Warner et al. 2016).

Reduce gender inequalities

In the study area, women were significantly less educated (45% without formal education) than men (33% without formal education), similar to observations across Africa, where social norms place a lower priority on girls' education and they are more likely to interrupt studies to help with family chores or due to early pregnancy or marriage (Wodon et al. 2018). Attending some years of secondary education was shown to be more effective in reducing gender inequality than income (Carlsen 2020). Enabling girls' to attend secondary education enhances opportunities in terms of income and wellbeing with positive effects on their children and community, and to development more widely, reflected on lower population growth, better health and contributions to national wealth (Wodon et al. 2018).

Women have less opportunity to express their views than men (e.g. Baddianaah and Baaweh 2021). The management of natural resources must reduce gender inequalities or at least not contribute to exacerbating them. Women groups across coastal Kenya and elsewhere in the region have been instrumental in mangrove conservation and restoration. These groups have created sources of income for local women, stimulate community participation and interact with government agencies. Women groups in Mida Creek and Gazi have created nurseries of mangrove seedlings

that are sold to support local conservation projects, and engage in associated activities, such as beekeeping and ecotourism. These women are examples in their community and, supported by government agencies and NGOs, they can become role models and vectors of knowledge of sustainable practices in awareness campaigns to stimulate other women across the country and beyond.

Raise awareness about the state of local resources

Perceptions of changes on mangrove forests and the main drivers are influenced by gender, occupation and location, indicating that some views are not reflecting the actual state of local resources. Diverging discourses regarding mangrove management in Senegal illustrate that perceptions are shaped by personal experiences and interests (Arumugam et al. 2020). People are more likely to accept restrictive management measures and engage with nature conservation when they understand why they are needed and the consequences to their livelihoods if they are not implemented. Therefore, awareness campaigns that address misconceptions and inform the community about the state of local natural resources and expected impacts of management options should be integral part of management strategies.

Analysis of satellite data showed a net decrease in mangrove cover in Lamu County between 2010 and 2019, with larger losses in concession sites in Ndau and Pate and an increase in mangrove area in Manda (Kairo et al. 2021; Hamza et al. 2022). A reduction in mangrove cover in the last 10 years was perceived by only 24% of all respondents. In Ndau 59% of respondents indicated no change in mangrove cover and only 12% indicated a reduction. In Manda, 52% of respondents perceived an increase in mangrove cover, which is a closer reflection of the changes reported in that area. This is slightly unexpected as Manda has the largest proportion of respondents who are not from the local area and the lowest proportion of mangrove users. All respondents from Ndau harvest mangroves as primary occupation and they might intentionally refrain from indicating negative impacts due to vested interest. The ban on mangrove harvesting was seen as harmful, mostly by the people whose livelihoods depend on the forest, a resentment also reported during a previous ban (Idha 1998).

Men were more likely to perceive an increase in mangrove cover, tree density and tree height than women. Women were significantly less likely to identify mangrove services and offer views concerning changes in mangrove forests than men, similar to previous studies (e.g. Okello et al. 2019; Nyangoko et al. 2021). Women might feel less confident about their knowledge, as they visit mangrove forests less often than men, and when they do, they only access nearby areas to undertake specific tasks, such as the collection of fuelwood, crabs and molluscs. Men are generally more involved in mangrove harvesting, accessing wider areas making decisions influenced by forest conditions. Most men and women indicated no change in mangrove species and were unable to assess changes in biodiversity. Tailoring messages to specific groups (e.g. women) and covering specific topics (e.g. biodiversity) can help levelling the knowledge where there is poor awareness or greater divergence of opinions.

Awareness campaigns targeting mangrove users should disseminate and encourage practices that are proven to be sustainable and beneficial to both mangrove forests and users. Illegal harvesting using chainsaw was the most cited cause of negative impact on mangrove forests, as also reported elsewhere in Kenya (Dahdouh-Guebas et al. 2000; Mohamed et al. 2009; Bosire et al. 2016; Mungai et al. 2019). The use of a chainsaw in harvesting mangroves is illegal in Kenya, but was reported in Mainland, Ndau and Pate, as also observed in Kilifi County after earlier bans (Okello et al. 2019). A higher proportion of mangrove harvesters than other occupations perceive traditional logging as a form of sustainable management that encourages forest regrowth, as also noted by Kabii and Spencer (1996). Small-scale selective cutting can alter forest structure and composition (e.g. Walters et al. 2008; Scales and Friess 2019; Rasquinha and Mishra 2021). In India, small-scale harvesting for fuelwood targets small trees, which increases the relative proportion of larger trees when compared to non-harvested areas, but carbon stocks and the density of saplings and seedlings were reduced (Rasquinha and Mishra 2021). On the contrary, small-scale harvesting on Bay of Assassins (southwest Madagascar) targets larger trees and the preference for *Rhizophora* resulted in harvested areas having smaller trees and a shift in the dominant species (Scales and Friess 2019).

Embed ecosystem services in local school curriculum

Education plays crucial roles in stimulating engagement with environmental protection (Qasim et al. 2011; Dong et al. 2011; Masron and Subramaniam 2019). The ecosystem services framework facilitates the understanding of cultural perspectives concerning the wider importance of natural resources (e.g. Walters et al. 2008, 2018; James et al. 2013; Thiagarajah et al. 2015). Benefits of mangrove forests other than direct provision of goods were recognised by only 57% of respondents in Lamu County; the two most cited were fisheries support and climate regulation, also identified by other communities in Kenya (Rönnbäck et al. 2007) and elsewhere (Aye et al. 2019; Teka et al. 2019; Nyangoko et al. 2021). Surprisingly, only a minority identified mangroves as a source of livelihood (7%) and offering opportunities for recreation and tourism (2%). Mangroves are known to provide important cultural services and while these are less readily perceived

(Thiagarajah et al. 2015), local communities are likely to identify them if prompted, as observed in Nigeria (James et al. 2013).

Increased awareness of the wider benefits provided by mangroves can help attract people's interest in sustainable uses and resource conservation (Bosire et al. 2016; Kumagai et al. 2022). Embedding ecosystem services and the principles of sustainable natural resources management in schools is a win-win solution that can be implemented relatively quickly and at a low cost. Improved levels of education often lead to wider options for employment and higher income (Wodon et al. 2018), which have been associated with increased awareness about the consequences of environmental degradation (Dong et al. 2011) and can facilitate the shift to activities that are less damaging to the environment (Masron and Subramaniam 2019). Through time, investment in education enables the younger generations to engage in occupations less dependent on the extraction of mangrove wood.

Opportunities to reduce the use of mangrove wood

Wood for construction and fuel are the most common uses of mangroves in coastal communities (Walters et al. 2008), as observed in Lamu and elsewhere in Kenya (Dahdouh-Guebas et al. 2000; Owuor et al. 2017) and East Africa (Scales and Friess 2019; Nyangoko et al. 2021). Less reliance on mangrove wood was observed in Manda and Lamu Island, where larger proportion of respondents have education beyond primary school and a lower proportion has fishing or mangrove harvesting as main occupation. Raising awareness about sustainable ways of harvesting and using mangrove wood can reduce pressure on mangrove forests. However, to make a positive impact, alternative options must be affordable to a large proportion of people and for the long term. Otherwise, the change is not sustained, as seen in Eastern Europe, where communities shifted back to the use of fuelwood sourced from local forests when gas prices increased (Cvitanović et al. 2016).

Local communities should seek ways to use resources more efficiently, as inefficiency prevails in the use of natural resources in East Africa (Kimengsi et al. 2022). Incentivising the use of energy-saving stoves showed benefits in southern Kenya (Bosire et al. 2016; Kairo et al. 2018), as less wood is needed for cooking, saving money for people who purchase fuelwood or time for the ones who collect it from local forests.

The use of alternative source of wood for some uses may face local resistance as mangrove wood is easily available, low-cost and there is traditional knowledge of their qualities and uses. *Rhizophora* trees are often preferred for producing wood that is resistant to termites and has high heat capacity (Dahdouh-Guebas et al. 2006; Walters et al. 2008). Exceptions exist, as in southwest Madagascar, fuelwood obtained from dry forests is preferred for being drier and more easily combustible than local mangrove wood (Scales and Friess 2019), the difference might be on the species of trees that are locally available. Awareness campaigns about the benefits of using alternative wood sources might help change local preferences, particularly if wood quality and cost is demonstrated to be similar. Areas for plantations of fast-growing trees (e.g. *Casuarina*) could be an alternative source of wood and employment, although careful planning is needed to minimise potential impacts on local ecosystems and water resources.

Offer capacity building and financial incentives

Creating capacity for local groups to engage in alternative sources of income that are culturally accepted can reduce pressures on natural resources (Bosire et al. 2016; Baddianaah and Baaweh 2021; Nyangoko et al. 2021). Management strategies must offer opportunities for livelihoods to be supported that are long-term (Aheto et al. 2016; Arumugam et al. 2020; Nyangoko et al. 2022). Past mangrove harvest bans have led to community resentment and an increase in illegal harvesting (Okello et al. 2019), outcomes that bring no benefits. During the ban, mangrove harvesters temporarily switched to other alternative sources of income but returned to harvesting when the ban was lifted. Lack of skills to adequately make a living from other trade prevents longer-term changes (Arumugam et al. 2020). Better results could be achieved by supporting the development of site-specific mangrove harvest plans and alternative livelihood options as seen in Rufiji Delta, Tanzania (Nyangoko et al. 2022). Offering capacity building opportunities can help mangrove harvesters to gain new skills, but this would only work if the demand for such skills is sufficient to support local livelihoods. Seaweed farming, ecotourism, integrated aquaculture, beekeeping, and forest management focusing on carbon trading are some possible options but their suitability to the local environment and community needs must be assessed.

Mangrove harvesting is an activity intrinsic to local identity (Idha 1998). Burton and Paragahawewa (2011) state that policies that are not culturally sustainable will fail if they are not accepted within the local culture. Such social changes require time and investment, and an interim solution is needed until they take effect. Facilitating licensing for local consumption based on sustainable harvesting must also be considered to preserve both the local heritage and livelihoods. The number of licences and volume of trade can be defined based on the conditions of the forest, local needs and co-managed with community forest associations, already existing in Kenya.

Conclusions

This paper presents results from a social survey of 592 households from five locations in Lamu County aiming to understand local perceptions of the status and uses of mangrove resources. Some 89% of respondents use mangrove products, mostly wood in construction and as fuelwood, while 25% harvest mangroves as a primary or secondary source of income. As a major finding of the study, perceptions about changes in mangrove forests and drivers of change can vary considerably between villages that are relatively close to each other. The villages have different social compositions in terms of sources of income and levels of education. These characteristics, together with gender and age influence individual experiences related to mangrove use, dependency on natural resources, and their understanding of ecosystem services, changes in mangrove forests and the main drivers of change. For instance, only 56% of respondents recognise mangrove ecosystem services other than the provision of wood. Women and respondents with no formal education are less likely to identify services than men and respondents with some formal education, respectively. It is increasingly recognised that to be sustainable, the management of natural resources must focus equally on community needs and environmental sustainability. Therefore, management approaches need to recognise that local needs vary between groups and locations, and ensure that decision-making is inclusive and that it reduces, rather than exacerbates, inequalities. To align resource management with local needs, it is necessary to recognise that they vary across groups and, therefore, management approaches cannot be generalised. Recommendations are offered to promote the social transformations needed for the sustainable management of mangrove resources, which are also applicable to other natural resources within and beyond Kenya.

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All authors contributed to the study's conception and design. Fieldwork and analysis were performed by AJH. The first draft of the manuscript was written by AJH and all the other authors made major contributions to revising the manuscript. All authors read and approved the final manuscript.

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