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Value chain and sustainability of mangrove wood harvesting in Lamu, Kenya

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ABSTRACT

Mangrove forests provide harvestable wood and non-wood resources to human society globally. The current study evaluated value chain of mangrove wood products from Lamu, Kenya, and how these impacts on resources' sustainability. Results show that, exploitation of mangrove wood products in Kenya involves several actors, including national regulator, licensees, cutters, transporters, stockists and the consumers. Based on the differences between allowable and harvest data, Lamu mangroves can be said to be under-exploited. For the 1992–2018 period, an average of 223.5 scores $ha^{-1}yr^{-1}$ of mangrove poles were target for harvesting from Lamu. During the same period, the harvest data indicate an average of 6.2 scores $ha^{-1}yr^{-1}$ of mangrove poles were removed. However, based on stand level data generated as part of this study, mangroves in Lamu are over-exploited and stocked with non-merchantable poles. There are differentiated net income among various actors in mangrove trade in Kenya. Mangrove cutters are among the 'losers' in mangrove trade value chain earning a monthly net income of USD118.6 ± 17.9. Winners in mangrove trade is the Kenya Forest Service, Licensees, transporters, and mangrove dealers (or stockists) in urban centers. The findings of this study are critical in development of the harvesting plan for Lamu mangroves. The results will provide insights toward streamlining mangrove trade for community development, revenue generation and environmental sustainability.

1. Introduction

Mangroves are trees and shrubs uniquely adapted to thrive in the intertidal areas of tropical and subtropical coasts around the world (FAO, 2010; Tomlinson, 2016). These 'blue carbon' ecosystems (Nellemann and Corcoran, 2009) are important for the livelihood of coastal communities as they provide a wide range of goods and services and support national development (Spalding et al., 2010; UNEP, 2014; MEA, 2015). Mangroves provide harvestable wood products to adjacent human society that utilizes them for building and fuelwood (Kirui, 2013; Duke et al., 2014; Constanza et al., 2014; Hamza et al., 2020). Equally, mangroves provide fishery resources, dyes, and traditional medicine that are widely used by coastal communities (Salem and Mercer, 2012a; Vegh et al., 2014). In Kenya, it is estimated that communities adjacent mangrove derives about 80% of their wood requirements from the forest (Huxham et al., 2018).

Despite the environmental, ecological, and economic values of mangroves, they are being lost and degraded at an alarming rate of 1-2% per year, which is significantly higher than any other natural ecosystem (Giri et al., 2011; Van Bochove et al., 2014; Thomas et al., 2017; Goldberg et al., 2020). Causes of mangrove loss and degradation have been associated with over-harvesting of wood products, conversion of mangrove areas for other land uses such as pond aquaculture, plantation agriculture, and infrastructure development; pollution effects, and climate change (Spalding et al., 2010; Giri et al., 2011; Van Bochove et al., 2014). Over the 1985–2010 period, for instance, Kenya experienced a 20% reduction in mangrove cover; with disproportionately higher losses reported in urban centres than in rural areas (Kirui, 2013; Bosire et al., 2012).

Demand on forest wood products is directly proportional to human population increases globally. Kenya human population is heavily dependent on wood fuel energy and as a result the country is wood deficient with an annual supply potential of 31.4 million m^3 against a demand of 41.7 million m^3 (Githiomi and Oduor, 2012). A gradually increasing deficit is signified by forecasts for a 20-year period which indicate a 20% increase in supply and 21.6% increase in demand by the year 2032 (Githiomi and Oduor, 2012). This shows uncertainty in wood supply chain and hence need for integrated approaches to ensure

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sustainability by the stakeholders including local communities and government agencies (Ototo and Vlosky., 2018). Mangrove forests management in Kenya is vested with the Kenya Forest Service (KFS) or in partnerships with the Kenya Wildlife Service (KWS) where these forests occur within marine protected areas (GoK, 2017). Since the commercial exploitation of the mangrove forests for wood products is regulated through the annual licenses issued by KFS, there is need to understand the dynamism of forest exploitation, supply chain and the role of each actor in mangrove wood market. This study aimed to evaluate sustainability of mangrove harvesting in Lamu based on the quantity of wood extracted from the forest, harvesting regime and the market demand. Results of this work are vital in the understanding of *winners* and *losers* in the mangrove wood trade.

2. Materials and method

2.1. Description of the study area

This study was carried out in the northern part of Kenya coast in Lamu (County 1.6537°S, 41.5598°E and 2.4776°S, 40.7060°E). The County is characterized by an extensive hinterland bordering the seascape with 65 islands that constitutes the Lamu archipelago. Out of the total only Lamu, Manda, Pate, Kiwayu, and Ndau islands are inhabited. The rest have challenges of insecurity, inaccessibility, and lack of fresh water (Lamu County Integrated Development Plan, 2018). The climate in Lamu is characterized by hot and humid conditions, with a mean annual temperature above 25 °C and rainfall of 900 mm per year. Most of the soils in the county are sandy, which leads to low agricultural productivity (MoALF, 2018).

2.2. Mangroves of Lamu

The cover of mangrove forests in Lamu is estimated at 37,350 ha, representing 62% of the mangrove coverage in Kenya (GoK, 2017). All the nine mangroves' species described in Kenya occur in Lamu county. The dominant species are *Rhizophora mucronata* (or 'Mkoko' in Swahili language) and *Ceriops tagal* (Mkandaa) that constitutes more than 73% of the forest formation (Kairo et al., 2002b). Other species are *Sonneratia alba* (Mlilana), *Brugueria gymnorrhiza* (Muia), *Avicennia marina* (Mchu), *Xylocarpus granatum* (Mkomafi), *Xylocarpus moluccensis* (Mkomafi dume), *Lumnitzera racemosa* (Kikandaa), and *Heritiera littoralis* (Msikundazi). The species occur in single or mixed formation (Table 1).

Historically, mangroves in Lamu have provided harvestable wood and non-wood products to the people (Hamza et al., 2020; Kairo et al., 2009). This is in addition to the value of mangroves to shoreline protection and biodiversity conservation (Kairo et al., 2008, 2009; Kirui, 2013). According to the national mangrove management plan (GoK, 2017), mangroves in Lamu have been classified into five management blocks where channels, islands, and creeks form natural boundaries (GoK, 2017). The northern swamps extend from Mlango wa Chano to Kiunga; and is dominated by pure stands of *Rhizophora mucronata*. The north central swamps extend from Mlango wa Chano to the mouth of Dodori creek. They include mangroves of Uvondo and Ndau islands. The northern central forests are highly stocked with *Ceriops tagal* and *Rhizophora mucronata* stands. Mongoni and Dodori creek swamps comprises the mangroves found in Mongoni, Dodori creek and Manda Bay; and are stocked with pure stands of *Ceriops tagal*. Pate island swamps includes the mangroves surrounding Pate Island, Shindabwe, Kizingitini and Chongoni. Southern swamps are the largest of the five management blocks; and include mangroves of Mkunumbi and Kimbo creeks (Fig. 1). Mangroves in northern swamps and in some parts of the northern central swamps are within the Kiunga Marine National Reserve (KMNR). This study adopted the same management boundaries for ease of reference and comparisons. KFS controls harvesting of mangroves through issuance of harvesting license (GoK., 2017). However, the permit issued are often based on the wood demand rather than the available stocks of the product (Kairo et al., 2002). This procedure has contributed to near depletion of the market sized poles in northern central swamps where commercial harvesting is extensive (Kairo et al., 2009; Okello et al., 2022).

Table 1
Mangrove forest formation in Lamu (source: GoK, 2017).

Classification	Area (ha)	% Cover
Avicennia marina	6966	18.7
Avicennia mixed with *Ceriops*	1961	5.3
Ceriops tagal	5155	13.8
Ceriops mixed with *Brugueria, Rhizophora and Avicennia*	1901	5.1
Ceriops-Rhizophora	5138	13.6
Rhizophora mucronata	5558	14.9
Rhizophora mixed with *Ceriops, Brugueria, Avicennia*	8649	23.2
Sonneratia alba	1165	3.1
Sonneratia-Rhizophora	856	2.3
Total Mangrove cover	37,350	100

2.3. Socio-economic status

Lamu being one of the earliest seaports in East Africa, attracted traders from various parts of the world including Portugal, India, China, Turkey and from the Middle East which led to intermarriages and hence Lamu has a rich cultural diversity that led to designation as UNESCO world heritage site. This long culture and its diversity is conserved through art in form of woodcarving, furniture making, boat building, jewellery, calligraphy, and poetry (Lamu County Integrated Development Plan, 2018).

Majority of the people in Lamu, derive their livelihood from the income earned through fishing, mangrove harvesting, pastoralism, subsistence farming, eco-tourism, traditional wood curving and carpentry. These sectors employ over 80% of Lamu's labor force (Lamu County Integrated Development Plan, 2018). Commercial harvesting and marketing of mangrove wood products support more than 30,000 families in Lamu (Lamu county spatial plan, 2017).

2.4. History of mangrove exploitation in Lamu

For centuries, mangrove poles were an important commercial commodity between East Africa and the treeless Arab countries (Rawlins, 1957; Curtin, 1983; Idha, 1998; Mohamed et al., 2009). By the beginning of 20th Century, Kenya was exporting an average of 24,150 scores (1 score = 20 poles) of mangrove poles from Lamu alone, translating to 483,000 poles per year (Grant, 1938). Between 1941 and 1956 this export averaged 709,026 poles then dropping to 275,488 poles in the

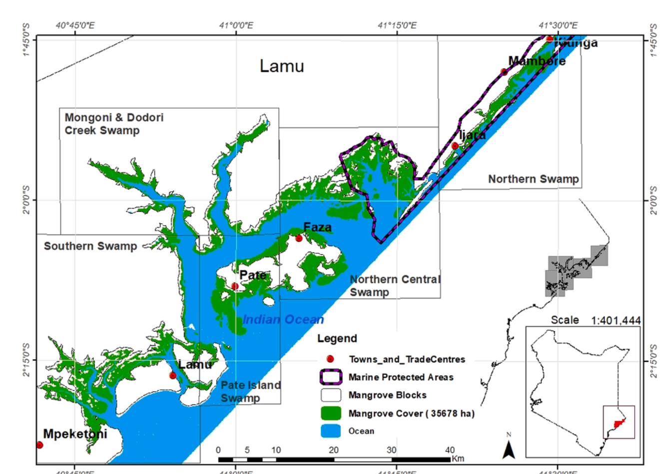

Fig. 1. Map of mangrove forests cover on the Lamu Archipelago, Lamu County.

period 1991/96.

Due to the escalating deforestation trend, a presidential ban was imposed on foreign export of mangrove poles in 1982 followed by a national ban in 1997 (Mohamed et al., 2009; GoK, 2017). Despite the ban, the annual harvest from Lamu for subsistence use remained 634, 680 poles up to 1983. In 1992, removal of 1,442,000 mangrove poles was licensed in Lamu for domestic use (Mohamed et al., 2009; GoK, 2017).

The major challenges facing sustainable management of mangroves in Kenya include overexploitation of wood products (GoK., 2017), low community participation in mangrove management efforts, the poverty status of many indigenous coastal communities (Kairo, et al., 2002), limited budget allocation directed to mangrove resources management, and poor governance (Kairu et al., 2018). These challenges persist even with the development of a national mangrove management plan (GoK, 2017). Unpredictable trends in harvesting of mangroves, unclear market trends as well as limited information on multiple actors hinder sustainable utilization of mangrove resources hence leading to numerous economic losses and degradation of the forest.

2.5. Theoretical framework

Value chain is the range of activities required to bring a product or service from production to final consumption (Tuan, 2013; Lowitt et al., 2015). It shows how the values attached to each part of the chain are distributed (Zafar and Ahsan, 2006; Sathirathai, 1998; Thyresson et al., 2013) hence helps in understanding the relationships and interactions amongst actors in a chain as well as considering the potential implications for development (Graef, 2014). Resource value chains are driven by the market forces of demand and supply which directly determines the benefits acquired by the stakeholders involved (Liquete et al., 2013; Ototo and Vlosky., 2018; Sarmin et al., 2018; Owuor et al., 2019). Value chain analysis (VCA) includes a range of activities from production of the material, and the role of the actors or companies in the negotiation, processing, stocking, transportation, and commercialization until the produce reach the consumer (Brander and Gomez, 2010; Tuan, 2013; Rosales et al., 2017). This form of analysis systematically maps the economic agents involved in the production, distribution, and sales of a particular product, assessing the characteristics of economic agents, profits and costs, goods flow throughout the chain, the destination, and sales volumes (Njie, 2011; Rosales et al., 2017). Sustainable resource exploitation calls for the understanding of the various stages of the chain as well as the interactions between the actors. For mangroves VCA, only extractable products are considered (poles, fuel wood and fisheries) (Tuan, 2013; Vegh et al., 2014) and involves multiple actors who play different roles along the value chain. In this study, only mangrove wood value chain was considered since poles are the only wood products that could easily be mapped from Lamu to other urban centres (Kairo et al., 2009; Hamza et al., 2020).

The actors in mangrove wood value chain include: KFS, licensee, cutters, transporters, stockist, and final consumers (Njie, 2011; Rosales et al., 2017). Licensees are the primary actors since they buy from the cutters and then sell to the secondary buyers (pole stockists) in various urban centers who in turn sell to the final consumers. Transporters ferry the poles from the cutters to the licensee (mostly by dhows) and also supply the poles from the licensee (mostly by lorries) to the stockists in various urban centres.

The licensees register with the KFS by paying a royalty fee of \$ 93.17 year^{-1}. The issued license designates harvesting areas, utilization classes and quantity of mangrove poles to be extracted from the forest (Mbuvi et al., 2003; Kairo et al., 2008). Licensees then hire cutters who do the logging. The cutters use dhows to enter the forest where they do selective harvesting using a handsaw and an axe (Atheull et al., 2009). Through traditional knowledge of the monsoon wind patterns; *Kussi* (Southeast monsoon winds) or *Kaskazi* (Northeast monsoon winds) they can decide the specific areas for harvesting.

Harvested mangrove poles are categorized into different utilization classes based on butt diameter, height, and straightness of the poles as well as the number of nodes in a pole (Kairo et al., 2002). The most preferred classes are the *boriti* sized poles (11.5–13.9 cm) that are used to construct the house framework. This is followed by *mazio* (8.9–11.4 cm) and *pau* (4.0–7.9 cm) poles (Kairo et al., 2002; Table 2).

As part of processing, the bark is removed in *boriti* and *vigingi* sized poles before sale. Cutters ferry the poles to the landing site using wooden dug out vessels *(Jahazis or Mashua)*. An average *Mashua* (or Dhow) can transport 150 scores of *boriti*. Licensees pay cutters for mangrove poles delivered at Ndau, Amu or Mokowe landing sites. At the landing sites, poles are graded into different size classes and quality awaiting transportation to urban centers (Arton et al., 2017).

KFS officials at the landing site counts, mark and stamps each pole with a unique code designed for a forest zone. Permit levy for pole movement varies depending on tonnage. A load less than 3 tonnes is charged \$ 9.32; whereas a load of 3.1–6.9 tonnes and $\geq$ 7 tonnes are charged \$13.98, and \$18.6, respectively. The poles are sold to stockists in different urban centers at the coastal region before they are sold to consumers. Price margin of poles changes across the value chain.

2.6. Data collection

The study used mixed method approaches to obtain data on forest stock and mangrove wood trade from Lamu. Stratified random sampling design was used for vegetation surveys. Stock level data was collected within 400 m^2 square plots established along belt transects perpendicular to the waterline. A total of 152 quadrats were sampled in 56 transects. The following vegetation attributes were collected: species, tree height (m), stem diameter taken at 130 cm breast height (DBH, cm), and crown cover (%); from which local stand tables (m^2 ha^{-1}) and standing density (stems ha^{-1}) were derived following the procedure in Kairo et al. (2021). To assess the quality of forest stand, all trees with stem diameter > 5.0 cm within sampling plots were assigned into quality classes (Form) depending on their suitability for construction. Quality Class (QC) 1 trees had straight poles suitable for construction, QC 2 trees have intermediate quality poles which can be modified and used for construction, while QC 3 are trees with generally crooked poles, unsuitable for building (Kairo, 2001; Kairo et al., 2021). In order to establish harvesting patterns of mangroves in Lamu, harvest data was retrieved from KFS and compared with allowable cut for the period 1992–2018.

2.6.1. Mangrove value chain

Purposive sampling was adopted for the collection of the primary sale data. The value chain actors were identified by snowball sampling procedure (Maraseni et al., 2018). Actors were recruited by referral from one stage of the value chain to the next, based on respondent information about the other actors (Maraseni et al., 2018). This was helpful in triangulating and validating information provided by different actors. Semi-structured interviews were used to document key actors in

Table 2
Utilization classes of mangrove poles in Kenya and their uses.

Utilization classes	Butt diameter range (cm)	Uses
Fito	2.5–3.9	Used to fill walls of the traditional houses
Pau	4.0–7.9	They are used for roofing
Mazio	8.0–11.4	Used as roof frames
Boriti	11.5–13.9	main frame of the house walls is made of *Boriti*
Nguzo 1/ vigingi	14.0–16.9	used mostly for fencing and covering pit latrines
Nguzo 2	17.0–20.4	Used for fencing, supporting main roof of larger tourist hotels and covering pit latrines
Nguzo 3	20.5–30.4	Used to support main roof of larger tourist hotels and covering pit latrines
Banaa	≥30.5	Not harvested

mangrove trade (ter Mors et al., 2013; Schaafsma et al., 2017). Northern central swamps at Ndau was chosen as the base village for interviews as the livelihood of about 85% (of 3000 resident population) was derived from mangrove activities (Table 3). Data collected during field interviews included: (i) mangrove utilization classes (ii) price per pole (iii) transporting costs, and (iv) taxations. Interviews with KFS officials sought to understand procedures to acquire harvesting permits, amounts and utilization classes harvested, operation sites, and general regulations.

2.6.2. Market survey

Informants were identified purposively following visits to the various urban centers (Malindi, Watamu, Kilifi and Mombasa) where mangrove poles were sold. Only stockists who were in mangrove business for at least 10 years were selected as their information was considered more reliable. The sample size of 30 stockists was determined by their availability and willingness to participate in the survey (Table 3). The questions included prices for the different pole sizes, transport and any other associated costs. The market price method (Spaninks and Beukering, 1997; Brander and Gomez, 2010; Adeyemi et al., 2012) was used to assess the value of mangrove poles which was established through the exchange of goods and services in the market (Splash, 2007; Carson, 2012), and the interaction between the production (supply) and the consuming (demand) values (Spaninks and van Beukering, 1997; Adeyemi et al., 2012). The existing market prices were used to estimate the costs, revenue, and profits for each actor in the value chain from a typical sale of mangrove poles (Macamo et al., 2016b). Similar approaches have been used in mangrove valuation studies in other areas in Thailand (Sathirathai, 1998), Germany (Brander and Gomez, 2010), Kenya (Adeyemi et al., 2012) and Mozambique (Macamo et al., 2016b; Machava-António et al., 2020). During the interviews, all the costs and returns for the different actors were recorded with the consent of the participant (Maraseni et al. 2018).

2.6.3. Data analysis

All statistical analysis were done using R- Statistics (version 3.6.1). Differences between utilization classes were compared using ANOVA. Stem densities across the five management blocks were compared using t-test. The net profit for each actor was calculated by subtracting the total costs incurred from the total revenue received. The differences in profits accrued by each of the actors was compared to identify the 'winners' and 'losers' in the value chain. Thus:

$$\text{Profit from wood} = \sum (Pw\ Qw - Cw),$$

where Pw = price of wood (KSh), Qw = quantity of wood (in scores), Cw = total costs incurred (KSh)

The cost benefit ratio was computed by dividing total cost and production value for each of the actors. The mean differences in profits amongst value chain actors were compared using ANOVA.

3. Results

3.1. Stocking rates

The stocking rates of principal mangrove species in Lamu County ranged from 1048–2142 stems ha^{-1} (mean: 1425 ± 191 stems ha^{-1}) for Rhizophora mucronata and 104–967 stems ha^{-1} (mean: 605 ± 178 stems ha^{-1}) for Ceriops tagal. In all the management blocks where harvesting was allowed, the merchantable densities of the principal species were about 1361 stems ha^{-1}; constituting mostly pau (554 stems ha^{-1}), fito (480 stems ha^{-1}) and mazio (117 stems ha^{-1}) (Table 5). Banaa (≥ 30.5 cm) are not harvested since they are not viable for the market. They are of a huge butt diameter hence not suitable for construction. Dodori-Mongoni creek swamps had a higher density of merchantable poles (1271 stems ha^{-1}; which constituted 68%) of the total, followed by northern central swamps with 1469 stems ha^{-1} accounting for 64 %. The Southern swamps recorded the least proportion of total merchantable stems (1743 stem ha^{-1} out of 3035 stems ha^{-1}; constituting 57%) (Table 4).

Table 3
Value chain actors interviewed.

Actor	Male	Female	Total number interviewed
KFS officials	4	2	6
Licensees	5	3	8
Cutters	50	0	50
Jahazi transporters	7	0	7
Lorry transporters	5	0	5
Stockists	24	6	30

Densities of merchantable and non-merchantable poles was not statistically significant ($p \geq 0.05$) across the management blocks.

With an average stocking density of 43 merchantable stems ha^{-1}, nguzo 2 (17.0–20.4 cm) sized poles were the least followed by nguzo 1 (14.0–16.9 cm) 46 stems ha^{-1} and then boriti (11.5–13.9 cm) 47 stems ha^{-1} in all the management blocks (Table 5).

3.2. Patterns of mangrove wood utilization in Lamu County

Patterns of harvest data and allowable cut from Lamu mangroves is given in Fig. 3. Looking at the 26 years' harvest data alone, one may conclude that mangroves in Lamu are being underexploited (Fig. 3). The highest number of poles removed from the forest was about 20,000 scores in 2014 against allowable cut of 240,000 scores. This is contrary to stand level data that has depicted a forest devoid of merchantable poles (Table 5). Most of the management blocks are stocked with non-merchantable mangrove poles an indicator of human pressure (Table 4).

3.3. Pricing of mangrove poles and various charges

Prices of mangroves poles in Kenya vary with size classes, pole quality and the demand. *Nguzo* sized poles fetches the highest prices followed by *vigingi, boriti, mazio* and *pau* (Table 6). Overall, products sold in Malindi fetch better prices than other coastal towns. The variation in prices at the different urban centers is due to demand and the additional costs incurred during transport and storage. *Fito* are allowed to be harvested but are consumed locally in filling the walls of traditional houses. Forest levy charges vary depending on utilization classes while movement permit is based on load tonnage (Table 6). At least 14% of the mangrove forest levy is government tax.

3.4. Costs, revenue and profit margin along mangrove wood value chain

Cutters who are hired by the licensees carry out selective harvesting of the poles. There are currently 415 mangrove cutters registered under the 22 licensees in Lamu. Only 13 licensees were active during the study period. Commercial mangrove harvesting is male dominated. At least 85% of the respondents reported that pole logging is a tedious activity hence only men do it while females engage in firewood collection for subsistence use (Table 3). A group of 4–6 cutters work together and can stay in the forest for 4-5 days harvesting poles. Harvesting is carried out twice per month to coincide with spring tides for easy accessibility and removal of harvested poles from the forests. Within this duration, the team manage to harvest about 113 scores.

Net profit varies along the value chain for the different actors. The national regulator; KFS, receives the highest monthly income of USD 2587.8, followed by licensee in Mombasa (USD 1809.5), Malindi (USD 1705.4) and Kilifi USD (1698.1). A *Jahazi* transporter receives USD 1291.9/month, whereas a stockist in Malindi, Mombasa and Kilifi take home a monthly income of USD 359.1, 323.8 and 307.0, respectively. On average a lorry transporter receives a monthly income of USD 170.04 while a cutter receives only USD 118.6 for the same period (Table 6).

Table 4
Size class distribution (Stems ha^{-1}) of principal mangrove species in Lamu County.

		Fito	Pau	Mazio	Boriti	Nguzo 1	Nguzo 2	Nguzo 3	Banaa	Total
Block		2.5–3.9	4.0–7.9	8.0–11.4	11.5–13.9	14.0–16.9	17.0–20.4	20.5–30.4	≥30.5	
NS	Merchantable	109	320	222	42	41	70	115	19	**939 (66)**
	Non-merchantable	83	199	16	56	67	16	25	21	483 **(34)**
	Total Stems/ha	192	519	238	99	108	86	140	40	1422
NCS	Merchantable	516	680	110	47	25	19	52	19	**1469 (64)**
	Non-merchantable	285	312	112	12	26	26	49	10	831 **(36)**
	Total Stems/ha	801	992	221	59	51	46	101	29	2300
SS	Merchantable	624	716	178	50	70	30	60	15	**1743 (57)**
	Non-merchantable	340	617	145	40	30	65	44	12	1293 **(43)**
	Total Stems/ha	965	1333	323	90	99	95	104	27	3035
PIS	Merchantable	256	342	85	44	56	87	77	13	**960 (63)**
	Non-merchantable	123	244	87	29	15	17	52	6	573 **(37)**
	Total Stems/ha	379	587	171	73	71	104	129	19	1533
DMS	Merchantable	523	479	96	45	32	36	41	20	**1271 (68)**
	Non-merchantable	116	295	95	36	16	16	14	0	588 **(32)**
	Total Stems/ha	639	773	191	80	48	52	55	20	1859

Merchantable poles consist of Quality Class 1 &2, non-merchantable stems consist quality class 3. NS- Northern swamps, NCS- Northern central swamps, SS- Southern swamps, PIS- Pate Island swamps, DMS- Dodori Mongoni creek swamps. *Values in Parentheses indicate percentage merchantable /non-merchantable stems per management block. Second Row values represent the stem diameter (cm)

Table 5
Densities of merchantable and non- merchantable stems across the utilization classes in Lamu.

Utilization classes	*Fito*	*Pau*	*Mazio*	*Boriti*	*Nguzo 1*	*Nguzo 2*	*Nguzo 3*	*Banaa*	Total (Stems ha^{-1})
Merchantable	480	554	117	47	46	43	58	17	1361
Non-merchantable	216	367	110	29	22	31	40	7	822
***P* value**	0.02*	0.08^{ns}	0.38^{ns}	0.03*	0.04*	0.28^{ns}	0.08^{ns}	0.01*	0.03*

* Means statistically significant while ^{ns} means non-statistically significant at $p \leq 0.05$.

Table 6
Mangrove trade across urban centres in Kenya. All prices are in USD (1USD = KSh 107.33 as of August, 2020).

Utilization class	Forest levy (USD/ Score)	Prices/score Kilifi	Malindi	Mombasa	Cost/ Benefit (%)
Boriti	4.66	46.17 ± 1.75	52.29 ± 3.82	49.61 ± 2.75	
Mazio	3.73	30.2 ± 2.12	35.64 ± 2.24	28.88 ± 3.28	
Pau	1.86	27.74 ± 1.40	21.55 ±1.19	25.16 ± 0.93	
Nguzo	5.59	64.60 ± 1.76	68.01 ± 1.93	63.59 ± 0.74	
Vigingi	5.59	49.90 ± 1.58	56.14 ± 3.00	55.90 ± 4.65	
Net income for various actors					
Stockist	-	307.0 ± 91	359.1 ± 166.5	323.8 ± 80.2	73.55
Licensee	-	1698.1 ± 292	1705.4 ± 293	1809.5 ± 311	40.43
KFS	-	2587.8	-	-	36.27
Lorry Transporter	-	170.0 ± 37.6	-	-	67.89
Jahazi transporter	-	1291.9 ± 119.6	-	-	7.16
Cutter	-	118.6 ± 17.9	-	-	9.24

Costs associated with mangrove trade include annual harvesting permit, forestry levy, national tax, movement and business permits, county cess and municipality tax. The profit margin across the value chain is statistically significant ($p < 0.05$). A cost benefit analysis amongst the actors in the value chain show cutter and Jahazi transporter have the least cost benefit ratio hence make higher profits (Table 6).

4. Discussion

Mangroves in Lamu are dominated by *Rhizophora mucronata* and *Ceriops tagal;* the two valuable species that are harvested for their wood products (Kirui, 2013; GoK, 2017). Based on the findings of this study mangroves in Lamu are stocked with non-merchantable poles; an indicator of present and past human pressure. There are low quantities of *nguzo, boriti* and *mazio* sized poles (Table 4). This observation is contrary to data on harvest and allowable cut that indicate the forest to be underutilized (Fig. 3). Northern central swamps where harvesting is intense, recorded the lowest stocking densities of *boriti, vigingi,* and *mazio* (Table 4). Due to the long period of harvesting, selective removal of quality poles has degraded the forest leading to inferior stands stocked with non-merchantable pole classes (Kairo et al., 2002). Clear felling of mangroves for fuelwood was noted in Pate Island swamps hence compromising sustainability of future forest (GoK, 2017; Kairo et al., 2002; Okello et al., 2022).

Nguzo sized poles fetches highest prices in the market but have low demand (Table 6). In a similar study in Mozambique (Machava-António et al., 2020) the price of mangrove poles varied greatly along the value chain. In this study, the chain followed by mangrove trade is from cutters, licensee, retailers (stockists), and finally the consumers (Fig. 2). Licensees serve as the link between mangrove cutters with the market. Looking at the profit margins alone, the *winners* in mangrove trade are KFS and licensees, whereas the cutters are net *losers* in the market chain (Table 6). Due to the low literacy level of the cutters, they are not well informed on the dynamics of the market and their rights hence end up being exploited. Cutters do the most laborious task of harvesting mangrove poles yet receive least net income (Table 6). Similar observations were made in a mangrove wood value chain study in Mozambique (Machava-António et al., 2020) where mangrove harvesters received least payment. Most of the KFS expenses in mangrove trade are absorbed by the government through salaries and patrols; and hence are not captured in the mangrove wood value chain. Studying the chain shows why pressure on natural resources can lead to degradation

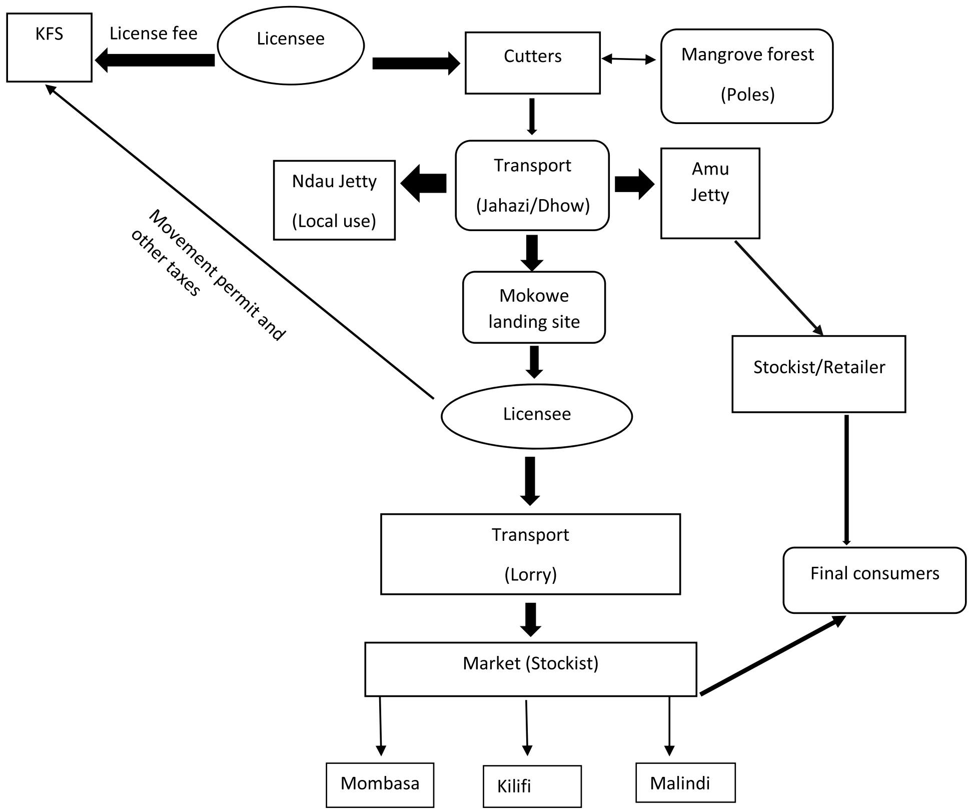

Fig. 2. Mangrove wood value chain in Lamu, Kenya. Malindi, Kilifi and Mombasa are the main urban centres where mangrove poles are traded.

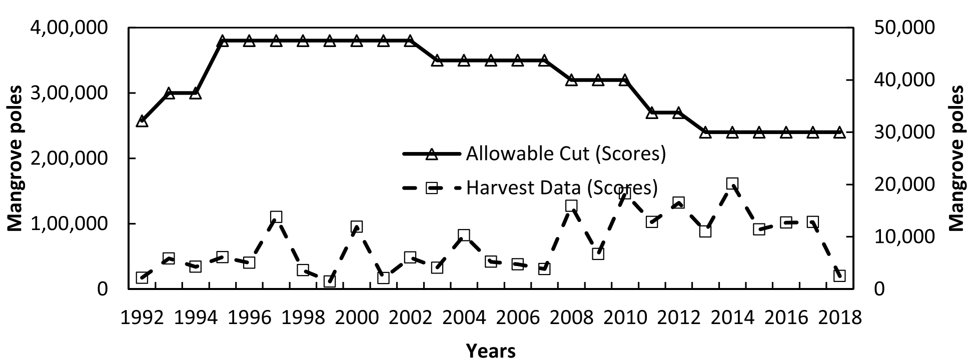

Fig. 3. Mangrove poles harvesting (scores/year) from 1992–2018 in Lamu, Kenya; showing allowable and actual harvests. (1 score = 20 poles).

(Macamo et al., 2016a, 2018) and unsustainable exploitation (Masalu, 2003) hence its significance in streamlining the trade for sustainable use of the resource. Ecosystem valuation plays an important role in making informed decisions in ecosystem conservation (Daily et al., 2009; TEEB, 2010; Mukherjee et al., 2014; Guerrya et al., 2015).

5. Conclusion and recommendations

Harvest data on mangroves from Lamu depicts an underexploited forest. This contradicts with the actual stock data which indicate a forest at risk of degradation. Most of the management blocks are stocked with non-merchantable poles and imbalanced distribution of size classes. Lamu mangrove forest is overexploited. The contradiction between the forest condition as reported by KFS records and stock level data points to a governance failure. Most preferred pole size classes (*boriti* and *vigingi (nguzo 1 & 2)*) are the least abundant across the blocks. In the mangrove wood value chain, there is great variations in the profit margins across actors. KFS and the licensees are the overall winners of the mangrove trade; whereas cutters are net losers. Mangrove trade need to be monitored to ensure supply meets the demand. Developing and implementing mangrove harvest plans would ensure the forest restock itself after disturbance. Monitoring by KFS and other stakeholders would ensure adherence to harvest guidelines and restoration plan. The results of this study provide insights towards streamlining mangrove trade to ensure improved livelihood and resource sustainability.

Declaration of Competing Interest

I write to declare that the authors of the above articles which I am submitting to the journal Trees, Forests and People, declare no conflict of interest.

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