



The cultural beliefs, values and utilization of East Africa Sandalwood *Osyris lanceolata* Hochst. & Steud. (1832) in and around Chyulu Hills Ecosystem, Kenya

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Research

Abstract

Background: In Kenya, the endangered East African Sandalwood, sourced mostly from limited natural stands, is widely used by local rural populations for multiple purposes including for nutraceutical and health benefits, but its potential for domestication and poverty alleviation are largely unknown. The purpose of this study was to identify current sources and uses of the plant, cultural values, taboos, and beliefs associated with its use and management, and how local knowledge of the plant is acquired and transmitted to younger generations, all with a view of contributing to its conservation and sustainable use.

Methods: The data on demographic and socioeconomic characteristics, local knowledge of plant utilization, cultural beliefs, values, and taboos associated with the plant, and transmission of inter-generational knowledge were collected from May 2018 to November 2018. Data were collected from seven traditional healers and 384 household heads with knowledge of the plant, residing in sixty Kamba villages and thirty Maasai villages on the Eastern and Western sides of Chyulu Hills Ecosystem, respectively, using structured questionnaires, semi-structured interviews, and Focus Group Discussions.

Results: Findings revealed that the plant was mainly sourced from the natural protected forests. The major uses were medicinal while knowledge on cultural values, taboos and beliefs related to East African Sandalwood were known by only 35% of participants. Plant knowledge was transmitted inter-generationally mainly by parents and grandparents (74%). Differences between ethnic group ($p=0.000$, $\chi^2=176.173$), occupation ($p=0.000$; $\chi^2=122.615$) and on-farm sources of income ($p=0.000$, $\chi^2=131.568$) as well as ethnic group ($p=0.000$, $\chi^2=138.433$), occupation ($p=0.000$, $\chi^2=113.999$) and on-farm sources of income ($p=0.008$, $\chi^2=64.668$) were statistically significant on current uses and the cultural values, taboos, and beliefs of the plant respectively

Conclusions: The results should contribute to the on-going domestication, propagation, and sustainable conservation of the plant. Although the species is used for multiple purposes, its main value was found in medical applications and hence has a commercial potential in the alternative pharmaceutical sector.

Keywords: East African Sandalwood, Chyulu Hills Ecosystem, Traditional knowledge, Cultural values, Cultural taboos, Cultural beliefs

Background

The endangered native species of East African Sandalwood (*Osyris lanceolata* Hochst. & Steud.) has many traditional livelihood, medicinal and cultural uses among several ethnic communities in rural Kenya, but interest in its commercialization for nutraceuticals and essential oils is increasing. This paper examines local knowledge on the use and management of East African Sandalwood with a view to assessing its potential for domestication for rural poverty alleviation and sustainable conservation.

As a member of the family *Santalaceae* the plant is an evergreen, highly branched shrub or small tree that is quite variable in height ranging from 1.5-9 m (Orwa *et al.* 2009, Polhill 2005, Wilson 2018). All parts are glabrous (Polhill, 2005). Flowers are small and unisexual with male flowers in axillary cymes and female solitary (Orwa *et al.* 2009). Leaves are alternate, elliptic or elliptic-oblong, rarely obovate, varying in size from 1.5-6.5 x 0.7-4.0 cm (Pothill, 2005). Great variation in leaf size and shape has elicited a considerable synonymy in this species (CITES 2013) and has led to 15 synonyms as listed on The Plant List (2016). Similar scientific synonyms for the species include *O. abyssinica* Hochst, *O. arborea*, *O. arborea* var. *rotundifolia*, *O. arborea* var. *stipitata*, *O. densifolia*, *O. laeta*, *O. oblanceolata*, *O. parvifolia*, *O. quadripartite*, *O. rigidissima*, *O. tenuifolia*, *O. urundiensis* De Wild., *O. wightiana* Wall. ex Wight (also known as Nepalese sandalwood), *O. wightiana* var. *rotundifolia* P.C. Tam, and *O. wightiana* var. *stipitata* (Lecomte) P.C. Tam (Global Plants 2016, The Plant List 2016). In Kenya, East African Sandalwood occurs frequently in semi-arid to arid ecosystems, primarily on stony and rocky soils along an altitudinal range of 900-2175 m. a.s.l (metres above sea level) (Kokwaro 2009). The plant has broad and narrow-leaved varieties that can be found in natural stands in protected areas such as Chyulu Hills, Oldonyo Sabuk National Park and East Pokot trustlands (Mukonyi *et al.* 2012). However, in agro-pastoral and other land uses there are signs of intense harvesting of the plant such as in Kajiado-Loitokitok area and Makueni- Chyulu areas (Mukonyi *et al.* 2012).

The plant is hemi parasitic (Texeira Da Silva *et al.* 2016) and requires a host. The major preferred initial or intermediate hosts are *Rhus natalensis*, *Dodonaea viscosa*, *Tecomaria capensis*, *Catha edulis*, *Apodytes dimidiata* Meyer, *Brachystegia spiciformis*, *Maytenus acuminatus* and *Aphloia theiformis* (Mwang'ingo *et al.* 2005). Seed or root suckers are the natural mode of propagation. *Osyris lanceolata* Hochst. & Steud. is used for multiple purposes. It is used in ethno medicinal applications as traditional medicine in different parts of the world such as South Africa, Zimbabwe, Kenya, Ethiopia, and parts of Asia e.g Nepal (Erasmus *et al.* 2015, Eshetu *et al.* 2015, Hilonga *et al.* 2019, Kefalew *et al.* 2015, Lourens *et al.* 2015, Muthee *et al.* 2011, Njoroge & Bussmann 2006, Nyahangare *et al.* 2015, Subba *et al.* 2016).

In Kenya, it is culturally used for medicinal purposes such as an antimalarial (Njoroge & Bussmann 2006), antibacterial and antifungal (Ooko 2009) to treat diarrhea, chest problems and joint pains (William 2010) as well as ringworm, impotence and fatigue (Muthee *et al.* 2011). Texeira Da Silva *et al.* (2016) after Girma *et al.* (2015) reported that methanol extracted from leaves inhibited the growth of pathogens such as *P. aeruginosa*, *P. mirabilis*, *S. typhi* and *S. paratyphi*. The tree is also a source of firewood and timber, especially for carvings, grain mortars, pestles, pegs, and for building poles and bedsteads. It is traditionally used to preserve milk in gourds for long periods and the bark produce dyes to brew herbal tea (William, 2010). The bark is also used for leather tanning and provides a strong dyestuff. Root fibers are used in basketry. The scented roots and wood provide essential oils which are used to make cosmetics and perfumes (Orwa *et al.* 2009). Many households utilize *O. lanceolata* Hochst. & Steud. for their subsistent livelihoods and as a medicinal source for human and ethno veterinary purposes (Moichwanetse 2020).

The heartwood of East African Sandalwood contains essential oil that is traded internationally in the perfumery industry (Bunei 2017, Ochanda 2011) as well as herbal medicine which is traded locally (Hilonga *et al.* 2018, Kariuki *et al.* 2018, Omara 2020). This may provide an opportunity for its domestication and commercialization in Kenya, particularly it was used as a substitute for essential oil as natural populations elsewhere such as *Santalum* and the *Pterocarpus* species had either been banned from export or had diminishing natural populations (Groves & Rutherford 2016, Hilonga *et al.* 2019). Its further development in Kenya should enhance livelihood benefits and help alleviate poverty among rural pastoral and agro-pastoral households (Mutisya *et al.* 2019). On the other hand, over-harvesting of this endangered plant among natural populations, as has occurred in Kajiado-Loitokitok and Makueni-Chyulu areas (Mukonyi *et al.* 2012) and exploitive practices such as uprooting an entire tree for its essential

oil, as well as illegal wood trade of a protected species are sustainability challenges to be overcome (Bunei 2017, Kariuki *et al.* 2018)

Though *O. lanceolata* Hochst. & Steud. is a threatened species, protected under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2013, Wilson 2018), of which Kenya is a signatory, research on its sustainable utilization and management is lacking in Kenya (Mukonyi *et al.* 2012). In particular indigenous knowledge systems on the use and management of East African Sandalwood have not been systematically studied among diverse cultural communities residing in ecological zones conducive to this species. A concern that indigenous knowledge about Sandalwood may be disappearing, just as its commercialization is intensifying, adds urgency to such research. The purpose of this study is to describe local knowledge about the use of East African Sandalwood with a view to enhancing its sustainable conservation. It aims to identify knowledge on current and traditional utilization, indigenous beliefs, values and taboos of the plant, and intergenerational transmission of this knowledge. It also assesses how the current and traditional use is influenced by demographic (gender, age) and socioeconomic (ethnicity, education, occupation, sources of income, religion) attributes, and time of stay in the area.

The field research adopted a case study approach focused on the Chyulu Hills Ecosystem, a UNESCO World Heritage Site (UNESCO & WHC 2010), that is straddled on the Western and Eastern sides by the Maasai and Kamba ethnic groups, respectively. The traditional knowledge, use and management of East African Sandalwood are ascertained for each group. Findings from this case should contribute to the on-going sustainable domestication, commercialization, and conservation of this species in Kenya.

Materials and Methods

Study Area

The Chyulu Hills Ecosystem is located in the expansive (2000 Km²) Amboseli-Tsavo Ecosystem 190 Km South-East of Nairobi (GoK 2013). The hills cover an estimated 775.8 Km² with a population density of 0.11 Km² (Kanui *et al.* 2016). They comprise mainly the Chyulu Hills National Park, Tsavo West National Park, Kibwezi Forest Reserve and also the West Chyulu Game conservation area. Administratively, the study area is in Kibwezi and Makindu Sub-counties of Makueni County and Loitokitok Sub-County of Kajiado County, located on the Eastern and Western sides of the Chyulu Hills Ecosystem, respectively (Figure 1).

The area is characterized by temperature ranges from 20 to 30°C and bimodal rainfall with average annual precipitation varying between 350-500 mm/yr in the lowland rangelands and slightly more than 1000 mm/yr in the Chyulu Hills, which supports a montane forest (Kiringe *et al.* 2015, Reid *et al.* 2004). The regional slope has a gradient of 30-60%. Altitude varies from less than 900m above sea level to a maximum of 2175 m above sea level. Climatically, the ecosystem is arid and semi-arid, and in agro-climatic zone IV with low potential for crop production (Muriuki *et al.* 2011, Sombroek *et al.* 1982).

In recognition of its distinct volcanic landforms, unique biodiversity and conservation importance, the Chyulu Hills Ecosystem was nominated in 2010 by the Kenya Wildlife Service as a UNESCO World Heritage Site (UNESCO & WHC 2010). Distinctive habitats include hilltop forests, woodlands, groundwater forests, wooded lava outcrops, grasslands, and caves (Kiringe *et al.* 2016). *O. lanceolata* Hochst. & Steud. is distributed in this ecosystem and, although protected under CITES, was heavily smuggled and exploited in the hills between the years 2000 and 2005 (CITES 2013).

The Maasai and Kamba ethnic groups dominate the study area. Kamba villages are found at the Eastern side of the Chyulu Hills at elevations below 1100 m, which are dominated by *Acacia-Commiphora* bushland. The Kamba's are primarily agro-pastoralists, growing a variety of drought resistant grains and pulses like pigeon peas, maize, sorghum, millet, and beans, as well as livestock for milk and meat (GoK 2010). They value woody plant resources for herbal medicine, charcoal, and wood-carving activities (GoK 2013a).

Maasai villages predominate the Western side of the Chyulu Hills at elevations generally below 1300 m where there is dry grassland, mixed with *Acacia drepanolobium* (KWS 2008). The Maasai are traditionally pastoralists who own and manage Mbirikani and Kuku group ranches for pastoralism and ecotourism activities. Farming is also done in wetland areas where there is more reliable rainfall (GoK 2013b). The Maasai value woody plant resources for livestock fodder and medicinal purposes (Kimondo *et al.* 2015).

Data Sampling and Collection

People bordering Protected Areas (PAs) are usually very knowledgeable regarding threatened plants for which PAs remain the main refuges (Balima *et al.* 2018). Households in the study area were surveyed to ascertain this knowledge for East African Sandalwood among several locals. Initially, chiefs and communities were consulted to clarify the objectives of the study and identify potential participants who had knowledge of East African Sandalwood.

Data collection tools included structured questionnaires, semi-structured interviews, and Focus Group Discussions (Creswell 2014). These tools have been used to collect ethno-botanical data by different authors (Arévalo-Marín *et al.* 2015, Rajbanshi & Thapa 2019, Teka *et al.* 2020). Alexiades (1996) has also recommended their suitability for conducting ethnobotanical research for wild plants. These tools were designed to answer six research questions: (1) What is the local name of East African Sandalwood and its meaning? (2) What beliefs, values, or taboos are associated with the use and management of Sandalwood in your community? (3) What is East African Sandalwood used for? (4) How is knowledge about this plant and its use and management conveyed to others? (5) Who transmits this knowledge to others? (6) What socio-economic factors influence cultural beliefs and utilization of sandalwood?

Multistage sampling was used to obtain a representative sample from each of the following locations selected for their proximity to the Chyulu Hills Ecosystem: Makindu, Kikumbulyu, Nthongoni, Utithi, Tsavo West National Park, Chyulu Game Reserve, Kenyewa, Merrueshi and Kiboko (Figure 1). Simple random sampling was used to select households in villages within and 0-5 Km from the Chyulu Hills Ecosystem.

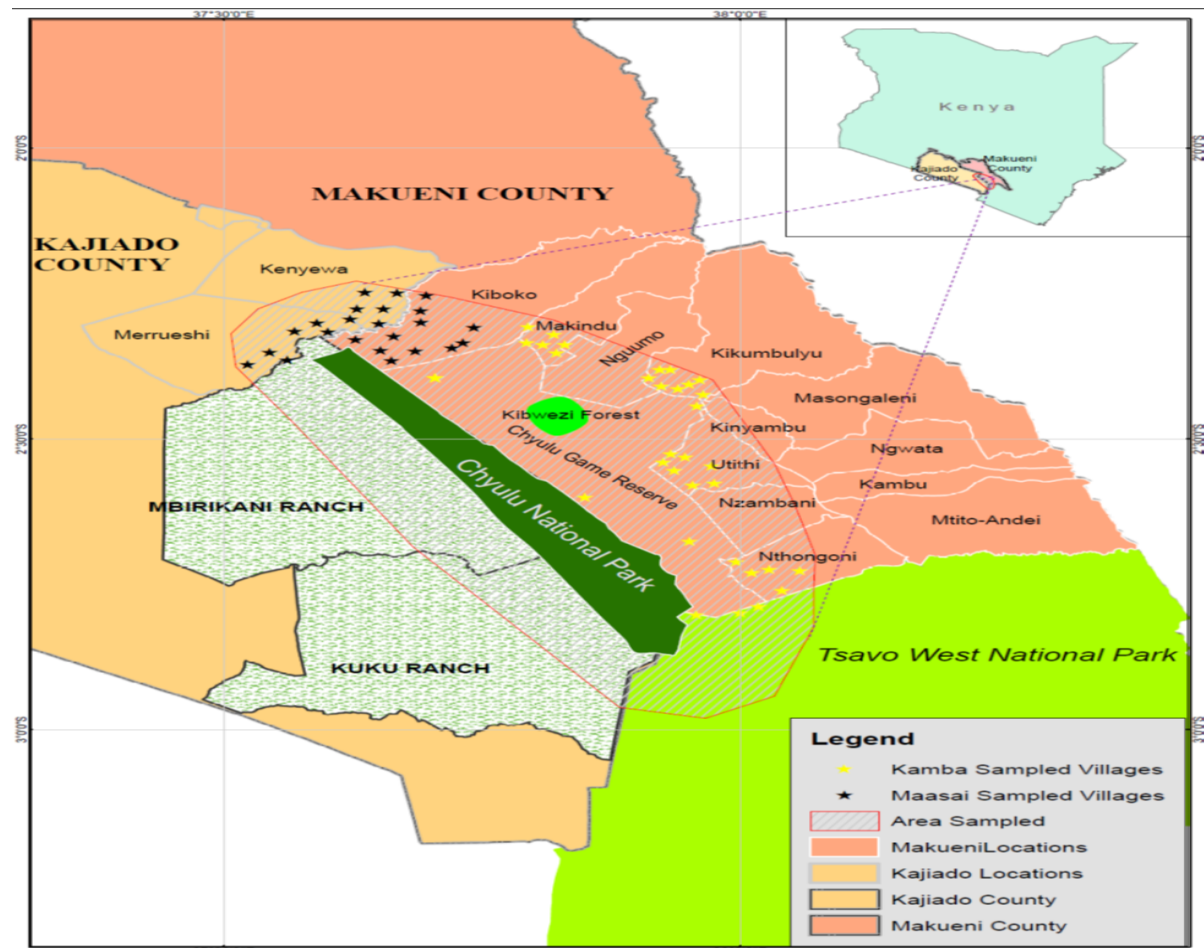


Figure 1. Map of the Chyulu Hills Ecosystem showing the locations sampled among the Kamba and Maasai communities in Kajiado and Makueni Counties.

The structured questionnaire was pretested among 45 randomly selected participants using the split-half technique and a reliability coefficient of at least 0.7 (Fraenkel & Wallen 2009). Since a reliability coefficient of 0.72 was obtained from the pretest, the instrument was considered suitable for the survey.

A total of 384 adult participants (232 men, 152 women) were surveyed, all 18 years and above. This sample size was calculated by the formula (Omona 2013):

$$n = \frac{Z^2pq}{d^2}$$

Where n was the desired sample size, Z is the standard normal deviate at the required confidence level, P is the proportion in the target population estimated to have used or knew the species (50%), q is 1-p and is the proportion of individuals not knowing the species = 1-p (50%) and d is the level of the statistical significance. Through the pre-test it was discovered that 50% of the interview participants in all the sub-locations, know and use *O. lanceolata*. A sample size of 384 persons was determined for a 5% level of statistical significance. More men accepted to sign the consent protocols and participate in the study, probably because they had more knowledge of the plant as they are typically the primary users and sellers of it, (89.6%) as compared to women who are more involved in domestic tasks (Ochanda 2010)

The 384 structured questionnaires focused on the informant's demographic (gender, age) and socioeconomic (ethnicity, education, occupation, sources of income, religion) characteristics, time of stay in the area, knowledge of utilization of the plant in their local areas, cultural beliefs, values and taboos associated with the plant, and transmission of inter-generational knowledge regarding utilization and management of Sandalwood.

Seventeen semi-structured interviews and two focus group discussions in the Kamba and Maasai communities further explored and verified how plant-based knowledge of the East African Sandalwood is transmitted and how it is associated with cultural beliefs, values, and taboos. Participants (9 Kamba, 8 Maasai) for the semi-structured interviews were selected using a snowball sampling strategy (Creswell 2014) in consultation with the chiefs from each location to identify individuals known for their knowledge of plants. Participants in the two focus group discussions were also selected in consultation with the respective chiefs from each ethnic community, and consisted of 13 Kamba (7 men, 3 women, 3 traditional healers) and 13 Maasai (5 men, 4 women, 4 traditional healers) (Alexiades 1996).

The structured questionnaires, semi-structured interviews and focus group discussions were administered in the Kamba and Maasai languages with the assistance of local translators, and responses transcribed into English.

Data analysis

Descriptive statistics such as frequencies, percentages, standard deviations, means and bar charts were used in the analysis and are summarized below. Chi-square was used to determine the association between the socio-economic factors (education level, age, gender and religion on-farm and off-farm sources of income), time of stay in the area and cultural beliefs, values, taboos and the knowledge systems on utilization and management of the plant. The analysis was performed in SPSS Version 22 (IBM 2013). The data from semi-structured interviews and focus group discussions was analyzed by thematic content analysis.

Results

Major sources of East African Sandalwood

The major source of Sandalwood reported by the research respondents was the natural protected forests (90%) (Figure 2). However, sources differed by subspecies and location. The narrow leaved is commonly used by Kamba (46%) and Maasai (21%) communities, whereas the broad leaved is used mostly by the Maasai Community (17%). Other sources include my farmland (5%), other people's farmlands (4%) and home gardens (1%), but only by the Kamba Community. Overall, the narrow leaved sourced from the forests is the main subspecies in use.

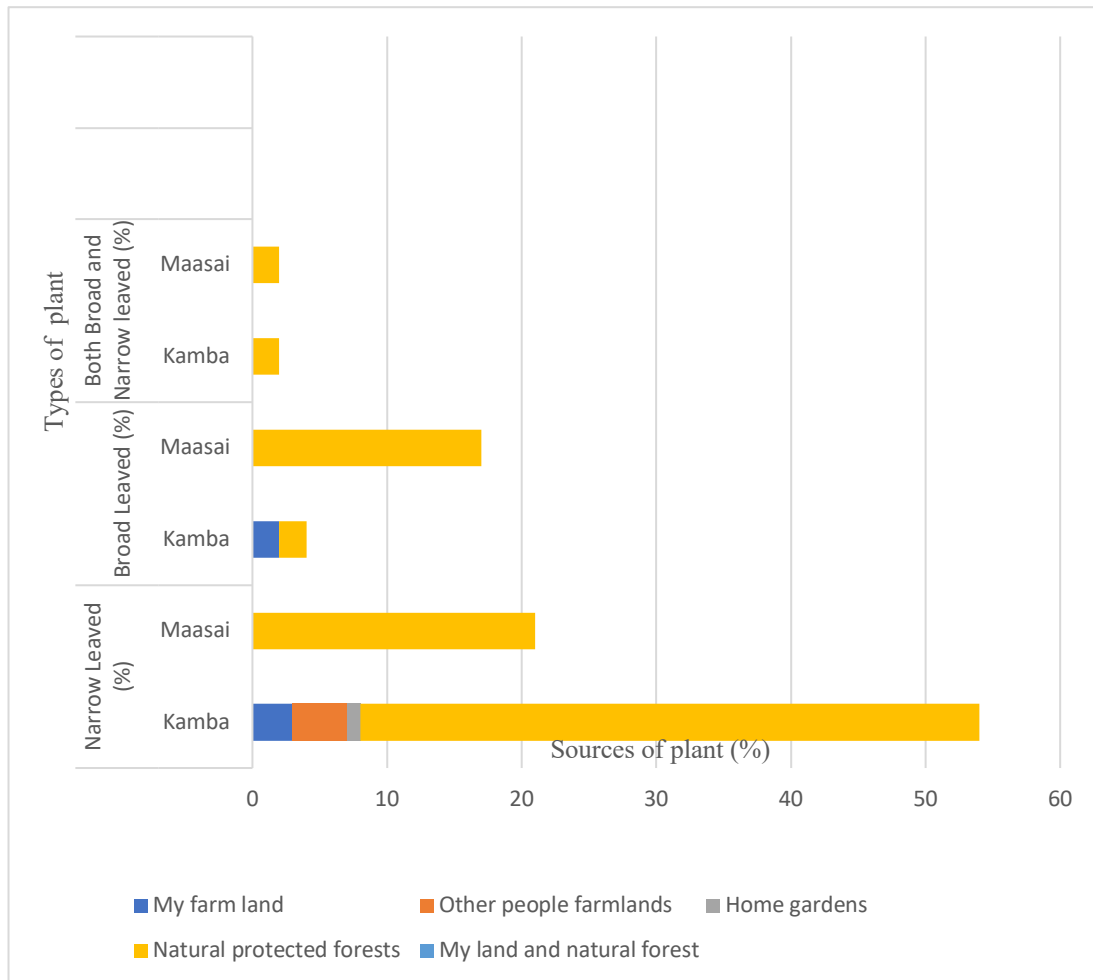


Figure 2. Major sources of East African Sandalwood (n=352)

Local names and meanings for East African Sandalwood

Local names were elicited from participants in each ethnic group. 'Ndonga' is the most common name among the Kamba and 'Ololesiai' among the Maasai (Table 1). However, the meanings of local names varied among and within both groups. For example, 42% of Kamba participants reported that 'Ndonga' meant a cure for all infections and diseases but only 3% of the Masaai described the same meaning for 'Ololesiai'. Some (8%) Kamba respondents reported that 'Ndonga' meant richness and had been derived from the name 'Kitonga', a rich person. Other reported meanings included poison, neutralizer of poison or coloring in basketry. In contrast, 11% of Kamba and 36% of Maasai respectively claimed that 'Ndonga' and 'Ololesiai' local names did not have any local meaning.

Table 1. Local names and their meanings for East African Sandalwood

Local Name (n=384)	Meanings of Local Name (%)			Total
	Cure/Medicinal	Richness	No local meaning	
Ndonga (Kamba)	42	8	11	61
Ololesiai (Maasai)	3	0	36	39
Total	45	8	47	100

Utilization of East African Sandalwood

East African Sandalwood was mainly used for medicinal purposes (64%) by both communities (Table 2). This constituted 48% for the Kamba tribe and 16% for Maasai tribe. Local examples included a powder made from plant parts was applied on snake bites and scorpion and centipede stings to neutralize poison. A paste made from plant parts mixed with water was used to heal ring worm and skin rashes, applied on open wounds to clot blood, and dry and heal them, as a pain killer for circumcision and toothache, and for ethnoveterinary purposes (goats, chicken,

and cows). A paste made from plant parts mixed with milk was used for nutraceutical purposes in children and generally as a curative and preventive drug against diarrhea in children.

Table 2. Knowledge on the utilization of East African Sandalwood amongst respondents.

Category of uses (n=376)	Frequency (%)		
	Maasai Community	Kamba Community	Total
Medicinal purposes	48	16	64
Tonic in soups	1	0	1
Medicinal purposes, tea from roots and tonic in soups	0	21	21
Medicinal purposes and firewood	11	0	11
Medicinal purposes and tonic in soups	0	0	1
Medicinal purposes and building	1	0	1
Medicinal purposes and sell it to other traders for export	1	0	1

A difference in use among the two groups is that Kamba respondents (21%) reported using the plant to brew tea from roots and make tonic in soups, in addition to medicinal purposes (Table 2). Only 1% of the Maasai Community uses the plant as a tonic in soup. On the other hand, only the Maasai Community (11%) claimed using the plant for both medicinal purposes and firewood. Use for building material (1%) and selling of plant parts to traders for export (1%) is minor.

Cultural beliefs, values and taboos associated with use and management of East African Sandalwood in Kenya

This study identified several beliefs, values and taboos associated with the use and management of *O. lanceolata* Hochst. & Steud. although 65% of the interview participants mentioned that they were not aware of them (Table 3). Of those that were, 13% (Kamba 5%, Maasai 8%) identified the main cultural value of the plant as medicine. For example, the sandalwood leaves are boiled and given to women during their monthly periods to control pain and is also believed to stop bleeding in women. However, a contrary belief claimed by a few Kamba (4%) and Maasai (1%) respondents is that the plant is believed to cause barrenness in women, and miscarriages and abortion if touched or used by pregnant women.

Table 3. Beliefs, values ,and taboos associated with use and management of East African Sandalwood in Kenya

Cultural beliefs (n=384)	Frequency (%)		
	Kamba Community	Maasai Community	Total
Believed and known to cause miscarriage to pregnant mothers and barrenness in women and ladies	4	1	5
Believed that owning sandalwood in your area/forest/land implies richness	1	0	1
Children not allowed to use it, go where it is planted or hold it as it is preserved for adults	1	0	1
Believed that once its branch is lit it helps to stop and chase away snakes	7	0	7
Believed and used as medicine for all human and animal diseases and especially children.	5	8	13
Associated with marriage and circumcision cultural events and rituals	6	0	6
Associated with witchcraft/wizards especially those who made medicine from it	1	0	1
Believed in making rain if plant material was smeared on a goat being slaughtered	1	0	1
Don't know	35	30	65

Several cultural beliefs, values and taboos were reported only among the Kamba respondents (Table 3). For instance, it was reported during their Focus Group Discussions that dried plant powder was believed to remove

("Kalinga") food that got stuck in the throat when eating. In addition, they believed that if the branch of the plant was lit, it could be used to chase away snakes (7%). They also associated the plant with marriage and circumcision events and rituals (6%). For example, it was a sign of pride to circumcised boys who had applied the plant powder, and it was traditionally used as a bind between husbands and wives who divorced frequently and re-married again. The plant also produced a pleasant aroma in shrines when offering sacrifices. It was also believed that owning Sandalwood in your area/forest/land implied richness (1%). In addition, it was believed that it would rain if plant powder was smeared on a goat being slaughtered (1%). Moreover, the children were not allowed to harvest it or touch it as the plant is only to be used by adults (1%).

Transfer method for knowledge on use and management of East African Sandalwood

The most common way of transferring knowledge on the use and management of East African Sandalwood is by word of mouth (Kamba 58%, Maasai 38%) (Table 4). The other ways of transmitting knowledge were training through seminars (1%), school (1%), farmer field school (1%), self-taught (1%) but only reported by Kamba respondents.

Table 4. Transfer method for knowledge on use and management by Kamba and Maasai community

Transfer Method (n=369)	Frequency (%)		
	Kamba Community	Maasai Community	Total
Oral knowledge passed down	58	38	96
Training Seminar	1	0	1
School	1	0	1
Farmer field school	1	0	1
Self-taught	1	0	1
Total	62	38	100

Medium used to obtain knowledge on use and management of East African Sandalwood

Knowledge on use and management of East African Sandalwood was mainly acquired from parents and grandparents (74%), followed by farmers (15%), friends and businesspeople (8%), as well as sellers and buyers (1%) (Table 5). For example, the children were taught by their mother when they were being given the plant for medication, so that they didn't misidentify it. Also, those who used the plant taught each other to distinguish it from other plants.

Table 5. Medium used to obtain knowledge on use and management of East African Sandalwood.

Person who transferred Tawseef Ahmad Mir*, Rakesh Kumar Khare and Muatasim Jan (n =369)	Frequency (%)		
	Kamba Community	Maasai Community	Total
Grand father	16	3	19
Grand mother	13	2	15
Father	3	10	13
Mother	3	7	10
Read from books	1	0	1
Farmers	15	0	15
School teachers	1	0	1
Father and Mother	0	4	4
Grandfather and grand mother	1	2	3
Grandfather/grand mother and father/mother	0	10	10
Friends and businesspeople	8	0	8
Sellers and buyers	1	0	1

Demographic and socioeconomic factors affecting knowledge of East African Sandalwood

The ethnic group ($p=0.000$, $\chi^2=176.173$), level of education ($p=0.011$, $\chi^2=42.712$), occupation ($p=0.000$, $\chi^2=122.615$) and on-farm sources of income ($p=0.000$, $\chi^2=131.568$) were significant and positively associated with

the ethno botanical knowledge of current utilization of the plant (Table 6). Other factors like gender, religion, off-farm sources of income, years of stay in community and age were insignificant in this study.

Table 6. Socio-economic factors influencing knowledge on use of East African Sandalwood

	Cultural values on use and management of East African Sandalwood		Uses of East African Sandalwood	
	χ^2 Value	Sign. (2-sided)	χ^2 Value	Sign. (2-sided)
Ethnic tribe	138.433	0.000*	176.173	0.000*
Sex	7.175	0.518	9.632	0.141
Education level	66.699	0.000*	42.712	0.011*
Occupation	113.999	0.001*	122.615	0.000*
Religion	2.351	0.968	1.723	0.466
Off-farm sources of income	40.452	0.772	29.907	0.470
On-farm sources of income	64.668	0.008*	131.568	0.000*
Years of stay in community	115.579	0.000*	51.101	0.353
Age	89.461	0.003*	41.517	0.492

Knowledge on cultural beliefs, values and taboos associated with use and management of the plant varied significantly and was positively associated with the ethnic group ($p=0.000$, $\chi^2=138.433$), age ($p=0.003$, $\chi^2=89.461$), years of stay in the village ($p=0.008$, $\chi^2=115.579$), level of education ($p=0.000$, $\chi^2=66.699$), occupation ($p=0.000$, $\chi^2=113.999$) and on-farm sources of income ($p=0.008$, $\chi^2=64.668$) (Table 6).

Discussion

Local names and meanings for East African Sandalwood

The local names 'Ndonga' as elicited by Kamba and 'Ololesiai' by Maasai participants agreed with the names documented for East African Sandalwood by different studies (Muthee *et al.* 2011, Orwa *et al.* 2009). However, the meanings of these names have not been reported in any other study. Further, similarities in the meanings between the two ethnic groups may be elucidated by the common medicinal usages associated with the plant. The slight similarities on meanings of local names (curative/medicinal) of East African Sandalwood between Kamba and Maasai community may be an indication of common indigenous knowledge of the curative properties of *O. lanceolata* Hochst. & Steud.

Categories of uses of East African Sandalwood

This study's findings of the local use of East African Sandalwood for various medicinal purposes (64%) are congruent with those of many other studies. In Kenya, it was used to cure diarrhea (Orwa *et al.* 2009) as well as treat human and livestock diseases among the Kamba in Chyulu Hills, Kibwezi Sub-county (Ochanda 2011). In Loitokitok Sub-County, it was used by the Maasai Community to treat ringworm, impotence, and fatigue (Muthee *et al.* 2011).

In Tanzania, it was used to cure anemia and Sexually Transmitted Diseases (STDs) and its plant extracts cures Hepatitis B (Orwa *et al.* 2009). In the Southern Highlands it treated STDs, anemia, backbone and stomach pains, fungus and typhoid (Mbunde *et al.* 2017).

In South Africa, it was used to manage candidiasis and related infections in the Venda region (Masevhe *et al.* 2015) and treat Erectile dysfunction in Capricorn District Lepelle-Nkupi Municipality in Limpopo Province (Erasmus *et al.* 2015). In different parts of Ethiopia, a similar plant *Osyris quadripartita* Salzm. ex. Decne was traditionally extracted in its leaves by the local people to treat malaria (Girma *et al.* 2015).

The medicinal use of this plant was scientifically validated for its pharmacological activities by various studies carried out in the world. For example, the bioactive secondary metabolites noted in the root, stem and stem bark of *O. lanceolata* Hochst. & Steud. in Kenya were active against *Staphylococcus aureus* (Ooko 2009). Those noted in the leaves of a similar plant, *Osyris wightiana* Wall in Nepal were highly active against *Escherichia coli*, *Klebsiella pneumonia*, *Pseudomonas aeruginosa*, *Proteus mirabilis*, *Salmonella typhi* and *Candida albicans*. They had both antibacterial and antifungal activities (Paudel & Gyawali 2014). Similarly, Bhandari *et al.* (2017) revealed that, the

antibacterial property of methanolic extract of leaves of *O. lanceolata* Hochst. & Steud. from the Western region (Rupandehi and Palpa districts) of Nepal may have been due to dihydro-bagarofuran polyesters chemicals that were also isolated by Yeboan and Majinda (2013) from the root bark and stem bark of the same plant harvested in Botswana. The polar organic compound also showed antibacterial activity against *S. aureus* and *E. coli*. It also displays multiple pharmacological activities due to their unique framework that can provide ligands to interact with multiple receptors. They have been described to have acetyl cholinesterase (AChE) inhibition activities, insecticidal, anti-HIV, anti-cancer and multidrug resistance (MDR) reversal in literature (Yeboan & Majinda 2013). However, their pharmacological activities have not been fully scientifically validated in Kenya.

Although both the Kamba and Maasai reported use of *O. lanceolata* Hochst. & Steud. for numerous medicinal purposes only the Maasai respondents (21%) use the plant to brew tea from roots and make tonic in soups, in addition to medicinal purposes. Similarly, the dried leaves of *Osyris wightiana* Wall are used in Central Nepal as a traditional wild herbal substitute for tea (Paudel & Gyawali 2014, Shyaula 2012).

Though the selling of the plant parts to traders was minor, it is surprising because 64% of the respondents previously reported being involved in selling the plant among the Kamba Community in Kibwezi Sub-County (Ochanda 2011) and Kitui County (Mutisya *et al.* 2019). This change in use may be attributed to a reduced appearance of the plant in its local distribution or its protected status (CITES 2013).

Nevertheless, extensive local knowledge of East African Sandalwood and its widespread use for medicinal purposes among the Kamba and Maasai people, as well as supporting scientific evidence of the plant's pharmacological and medicinal properties, point to its potential commercial value although further pharmacological studies are required to ascertain if *O. lanceolata* Hochst. & Steud. in Kenya has similar or other phytochemicals as reported elsewhere. If so, the Kamba and Maasai, and other indigenous groups in Arid and Semi-Arid lands, may be motivated to propagate and domesticate the species for improved livelihoods while concurrently conserving the remaining natural populations.

Cultural beliefs, values and taboos associated with use and management of East African Sandalwood in Kenya.

The lack of awareness (65%) of beliefs, values and taboos associated with the use and management of *O. lanceolata* Hochst. & Steud. may be attributable to a change in the inter-generational transmission of local knowledge and cultural values as an older generation gives way to the next, which may exhibit less interest in traditional knowledge and culture due to social changes associated with economic development, technology, and globalization (Geng *et al.* 2016). Another explanation may be that it is hard to codify the esoteric elements that are embedded in Africa's indigenous knowledge practices in traditional medicine as it is considered secret for a select few traditional healers who utilize it for their livelihood. This limits transmission of certain types of indigenous knowledge within the same generation and from one generation to another (Masango 2020). Although this study set out to identify traditional beliefs, values and taboos associated with the plant, and is among the first to do so, socio-cultural changes imposed from the outside and secretive indigenous knowledge may impinge on the potential development and commercialization of East African Sandalwood.

According to the Focus Group Discussions, the plant was considered a taboo as it was thought to protect the family against ("Kalinga") which was believed to be witchcraft among the Kamba community. This implied that the plant is useful for achieving magic-religious fulfillments in families by protecting them against wizards, enemies, and witchcraft. This taboo protected the unnecessary cutting of the plant, hence prohibited its misuse. The taboos preventing unnecessary cutting of trees have been observed in other studies where particular natural grooves or sites associated with spirituality or sacred spaces had a positive impact on conserving them (Adewoyin *et al.* 2020, Ssebunya & Okyere-Manu 2017).

Considered a fetish, the plant is believed to fulfill personal desire or aspirations such as richness - owning Sandalwood on one's land or in one's community symbolized riches (1%). In addition, the plant was believed to have supernatural powers for rainmaking - it would rain if its powder was smeared on a goat being slaughtered.

Segment taboos were also reported for this plant. Segment taboos occur if a cultural group bans the use of a species for specific time or age, sex, or social status. For example, the Kamba women were prohibited from harvesting *O. lanceolata* Hochst. & Steud. during menstruation and pregnancy as it could cause barrenness and cause miscarriages. In addition, the children were not allowed to harvest it or touch it as the plant is only to be

used by adults. Segment taboos for women, pregnant women, children, and menstruating females are common (Colding & Folke 2001, Sharma *et al.* 2021) and encountered for other plant species among African groups such as the Vhavenda and the Bapedi in South Africa (Constant & Tshisikhawe 2018, Ooko 2009, Rasethe *et al.* 2013).

Though the plant is an actively protected species in Kenya; there is lack of evidence to ascertain that the restrictions like the beliefs, values and taboos reported in this study will ultimately contribute to sustainable use of the plant, in part because these are unknown to 65% of the Kamba and Maasai respondents, and possibly because their traditional practices may be gradually eroding from one generation to the next or considered indigenous secrets. Nevertheless, traditional beliefs, values and taboos may contribute to *in-situ* conservation of East African Sandalwood among the Kamba and Maasai communities. This is because understanding local cultural values is essential for sustainable use and management of the species (Etongo *et al.* 2017). The continuation of ritual practices has critical potential for conservation of natural resources. Keeping traditional beliefs and practices alive may contribute to endangered species conservation, including through sustainable harvesting (Kosoe *et al.* 2020). In the absence of effective public conservation policies, local beliefs, and practices play an important role in both conserving endangered species and their domestication, propagation, and sustained use for poverty alleviation (Sharma *et al.* 2020).

Knowledge transmission on use of East African Sandalwood

Knowledge of Sandalwood was mainly transmitted vertically (from parent to offspring) through mouth and 'learning by doing' from everyday interactions with relatives such as helping parents to harvest the plant for medicinal purposes as well as preparing plant materials for use. A similar finding by Amsalu *et al.* (2018) indicated that indigenous knowledge on medicinal plants was orally passed to the family members. This is supported by Teka *et al.* (2020) that found that the participants obtained their indigenous knowledge of medicinal plants orally, and 82% of them obtained it from family members. A study by Wanjohi *et al.*, (2020) and Kewessa *et al.* (2015), likewise indicated that, knowledge of the use of indigenous plant species was obtained orally from parents, grandparents, relatives, and friends.

Knowledge was also acquired through oblique transmission from formal apprenticeships with farmers, friends, businesspeople, and traditional healers among the Kamba community, as well as clan gatherings during the life stage of moranism when they learn the tribal customs, cultural meetings in the bush, storytelling and herding in Maasai Community. This is consistent with some studies on knowledge acquisition of other plants, which reported that learning of plant knowledge took place through hands-on experience and observation that was, in turn, reinforced through apprenticeships with knowledgeable elders and relatives (Constant & Tshisikhawe 2018).

The inter-generational transmission of traditional knowledge is intrinsically linked with continuity in the means of interaction and engagement with plants and the land through the presence of well-informed elders and apprentices. This system of knowledge acquisition may be disrupted if the elders and next generation do not engage with the land and plants in daily life (Murphy *et al.* 2016). Local leaders and community members should encourage and facilitate the uptake of traditional beliefs, values and cultural taboos/practices and adherence to local regulations that are conducive to the sustainable use and management of East Africa Sandalwood (Constant & Tshisikhawe 2018).

Influences of socio-economic factors on knowledge of East African Sandalwood

The significant differences in use by ethnic group implied that these are group-specific and are probably due to preferences of each group and historical use. Each ethnic group has different ethnic affiliations (Salako *et al.* 2018). This study revealed that the Kamba ethnic groups had more knowledge and more uses of *O. lanceolata* Hochst. & Steud compared to the Maasai Community. Such variations could also be explained by differences in cultural beliefs and values, as highlighted by other ethno-botanical findings (Balima *et al.* 2018) as well as plant distribution range and abundance (Atakpama *et al.* 2015; Salako *et al.* 2018). The dissimilarities could also be due to variations in cultural livelihoods (e.g., farmers vs pastoralists) or different methods of transmission of knowledge from one generation to another. Further investigations are needed to gain additional insight into transmission of knowledge of uses of *O. lanceolata* Hochst. & Steud. between Maasai and Kamba ethnic groups, especially in an African context where traditional knowledge is orally transmitted from one generation to another (Goudégnon *et al.* 2017).

The significant association of knowledge on use of East African Sandalwood with educational level might have been attributed to more awareness of biodiversity (forests and other natural resources) and sustainability issues like deforestation, CITES etc. This concurred with other studies that indicated that the medicinal plant knowledge

among the respondents significantly differed with the education level (Dapar *et al.* 2020). However, this study disagreed with the study carried out by Kunwar *et al.* (2018) which reported that there was higher knowledge of medicinal use for plants among the non-literate participants.

Other sociocultural factors such as occupation and on-farm sources of income also had significant association with knowledge of use of East African Sandalwood. Different studies also reported the influence of occupation on knowledge of plant use (Atreya *et al.* 2018, Dapar *et al.* 2020, Paniagua-Zambrana *et al.* 2014). Participant age and length of stay were insignificant in this study, as was reported by Goudégnon *et al.* (2017), for *Lannea microcarpa* plant in the Benin's Sudanian Savannah. However, many studies for other plants have reported positive association of age with the ethno-medicinal knowledge of plant use (Kunwar *et al.* 2018, Salako *et al.* 2018).

The positive significant association of cultural beliefs values and taboos with the ethnic group revealed significant differences between the Kamba and Maasai groups. These variations in ethnicity with cultural uses, values and beliefs corroborate other findings for other plants that showed significant influences of ethnicity on cultural plant uses (Balima *et al.* 2018).

The significant and positive association between age and years of stay of the informants with the ethnobotanical knowledge of cultural uses, values and beliefs indicated that the elders had more knowledge of the plant than youngsters. The result from the interview schedules and Focus Group Discussions further showed that as the age of the interview participants increased, their level of knowledge on use as well as cultural values and beliefs associated with use of the plant increased (Atakpama 2015). This could have been due to the various uses and the cultural beliefs and values they experienced as their age increased. For instance, Kunwar *et al.* (2018) reported that longer length of stay in an area helps in accumulating greater amount of knowledge required for wise use of natural resources.

The age-based differences in knowledge of plants could also have been derived from experience and degree of cultural contact with indigenous plants. The lower local or regional abundance of the plant may also have slowed the process of knowledge acquisition, resulting in greater knowledge discrepancies among the age categories, especially between the younger and older informants (Dapar *et al.* 2020, Salako *et al.* 2018). However, further studies would be needed to clarify this proposition in *O. lanceolate* Hochst. & Steud. While the acquisition of knowledge depends on time (Albuquerque & Hanazaki 2009), the magnitude of the gap of knowledge among age categories depends on the local or regional abundance of the plant (Salako *et al.* 2018).

For education level, there was a significant difference between those who were literate and illiterate. Those who had higher levels of education had more knowledge on cultural values and beliefs associated with use and management of East African Sandalwood. This agreed with the study conducted by Zent (1999) which revealed that, the inhabitants of the Southern Amazon who had formal education placed greater value on traditional knowledge and struggled harder to acquire it. However, this study contrasted with that of Constant and Tshisikhawe (2018) which revealed that, modern education systems often eclipse the transmission of traditional forms of knowledge, where the youth perceive the former to be superior to the latter. The introduction of systems of western education led to less time spent on the land, lack of plant-based knowledge and not adhering to moral codes, rituals, and taboos (Constant & Tshisikhawe 2018). Similarly, Umair, Altaf and Abbasi (2017) reported, higher traditional knowledge of plant use among non-literate participants in the Pakistan Himalayas.

Conclusions and Recommendations

This study concludes that East African Sandalwood plays a traditional but significant medicinal role among the Kamba and Maasai communities of Makueni and Kajiado Counties, respectively. This important function should be a key component of a sustainable use, management and conservation plan for the species while taking into consideration the ethnic affiliations, education level, occupation, and on-farm sources of income of the targeted group. Enhancing this traditional medicinal role is a reason for its on-going domestication. The multipurpose use of the plant among the Maasai and Kamba communities implies that domestication is likely to be welcomed. Based on the plant's many and varied preventive and curative claims, some supported by scientific knowledge, *O. lanceolate* Hochst. & Steud. also has significant commercial potential although more research on medicinal and pharmacological properties is needed to support such development.

The commercial role of the plant in Kibwezi District (now part of Makueni County) was previously recognized by Ochanda (2011), before the plant became threatened (CITES 2013). It is now opportune to integrate the plant's

potential for commercialization and need for propagation, so that both people and the species may benefit. There is a need to raise more awareness for *in-situ* and *ex-situ* conservation among the local communities.

Knowledge on the use and management of East African Sandalwood was mainly acquired orally from parents and grandparents. Keeping this means of transmission intact is critical for the next generation of highly knowledgeable elders as the guardians of indigenous knowledge and sustainable use, management, and conservation of the species for future generations. This study was among the first to identify traditional beliefs, values and taboos associated with the East African Sandalwood among the Kamba and Maasai communities. Time is urgent because only a few respondents still retained this cultural knowledge of the plant for transmission to the next generation. However, this should be done while taking into consideration their level of education, ethnic affiliations, occupation, on-farm sources of income, length of stay and age.

From the study findings, it recommended that further research should address the following issues: -

1. Determine the interacting effects of multi-scale abundance, socio-demographic attributes, and the transmission of cultural knowledge on values, rituals and taboos of East African Sandalwood.
2. Determine the detailed role of traditional beliefs, values, and rituals in conserving the East African Sandalwood in all parts of Kenya where it grows.
3. Investigate the ethno-veterinary and human utilization of the plant and transmission of this knowledge in the other parts of Kenya where it grows.
4. Identify adequate activities, laws and policies that would help to stop the illegal smuggling and trafficking of the plant and promote sustainable cultivation of the plant as economic source of income.

Declarations

List of abbreviations: UNESCO & WHC: United Nations Educational, Scientific and Cultural Organization & World Heritage Centre; CITES: Convention on International Trade in Endangered Species; GoK: Government of Kenya

Ethics Approval and consent to participate: The research permit was obtained from National Commission for Science, Technology and Innovation (NACOSTI) in Kenya (Ref No. NACOSTI/P/18/59631/20783). Prior to data collection we reported to the County Commissioners and the County Directors of Education in Kajiado and Makueni Counties for final authorization in conducting the research.

The data collection in both Kajiado and Makueni Counties were done from May-November 2018 where the Chiefs in both counties were consulted of the initial meetings with communities, to clarify the aims and objectives of the study as well as determine the informants who had knowledge of plants. Each participant was presented with a consent form (approved by the Kenyatta National Hospital-University of Nairobi Ethics Research Committee (KNH-UoN ERC) which clarified the objectives of the study, and all informants were asked to sign consent forms to secure informed consent to participate in the study. A total of 393 people were contacted for interviews, and 384 (232 men and 152 women) agreed to sign a Free Consent form and be interviewed about their knowledge on use and management of East African Sandalwood.

Consent for publication: Not applicable

Availability of data and material: The collected data was not deposited in any public repositories.

Competing interests: The authors declared no conflicting interests.

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Author's contributions: JGM carried out fieldwork, data analysis and drafted the manuscript. HS and JTN configured the research project, supervised the work, and improved the manuscript. All the authors read, reviewed, and approved the final version of the manuscript.

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