



Hyphaene compressa, an important palm in the arid and semi-arid regions of Kenya

Agnes Omire, Johnstone Neondo, Nancy L.M. Budambula, Robert Gituru, and Cecilia Mweu

Research

Abstract

Background: Peasant agroecosystems in Kenya are considered to be a continuum of integrated traditional farming systems and natural ecosystem conservancy programs. *Hyphaene compressa* (dour palm) exists in arid and semi-arid lands (ASAL) of Kenya. While research in these areas is focusing on new plants to be brought to the areas, there is no focus on dour palm, which is already adapted to these areas. Scanty ethnobotanical knowledge exists in the form of unpublished material. The study aimed to determine domestication status, management practices, important use categories, plant part value, biotic and abiotic stresses of *H. compressa*.

Methods: Four sampling sites in the ASAL of Kenya were selected. Tharaka Nithi, Kwale, Tana River and Turkana. Responses of 79 informants were analyzed to establish dour palm domestication profile, uses, biotic and abiotic stresses affecting its growth.

Results: The domestication status varied across the sampled areas, with most regions showing no willingness to domesticate the plant. The study revealed that dour palm has fourteen uses with food (fruit) use, and prevention of soil erosion (roots) recording the highest and the least fidelity level scores, respectively, in the sampled areas. The most observed biotic stress was human interference and pest infestation, while the observed abiotic stress was drought and salinity.

Conclusion: The most important dour palm use is food. Due to the high usage and poor domestication, dour palm could be losing its gene pool and hence genetic diversity studies are important for its conservation.

Key words: Dour palm, *Hyphaene compressa*, domestication, ethnobotany, ASAL, conservation, biotic stress, abiotic stress, uses, plant part value

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Background

Traditional agroecosystems constitute major *in situ* repositories of both crop and wild plant germplasm. Sustainable utilization of these plant resources directly depends on cultural farming practices (Dulloo *et al.* 2010). *Hyphaene compressa* H.Wendl., is a common palm growing in wadis and at oasis found in arid and semi-arid lands (ASAL) of Eastern African countries (Vandenbeldt 1992, Orwa *et al.* 2009). This palm grows well between 0-1400m altitude, a mean annual temperature of above 28°C and a mean annual rainfall of 100-600mm (Orwa *et al.* 2009). It is one of the few perennial plants vastly growing in ASAL. There are no known mechanisms for dour palm propagation and conservation in Kenya.

Previous studies indicate that date (*Phoenix dactylifera* L.), coconut (*Cocos nucifera* L.), areca (*Areca catechu* L.) and African oil palm (*Elaeis guineensis* Jacq.) have been domesticated, but there is no documented evidence on doum palm domestication, despite its importance in predynastic Egypt (Clement 1992, Janick 2014). Doum palm was regarded as a sacred fruit in Egypt and fruits were discovered in ancient tombs of Pharaohs by archeologists (Hamdy & Fahmy 2018).

The *Arecaceae* family is considered one of the three most economically important families, only surpassed by the *Poaceae* family (Balslev *et al.* 2016, Lee and Balick 2008). Palms support basic needs in rural populations, where they are used as construction materials, medicines, food and to generate income for the local families (Macía *et al.* 2011, Paniagua-Zambrana *et al.* 2007). However, the importance of palms goes beyond the local rural needs to international importance (Balslev *et al.* 2016). In West Africa, palms are much appreciated as non-timber products (Stauffer *et al.* 2017). *Hyphaene compressa* plays an important role in ASAL, where the populace use it as construction material, food, medicine and as an ornamental plant (Amwatta 2004). The nomadic pastoralists and agro-pastoralists in the ASAL of Kenya heavily depend on its leaves for economic empowerment and sustenance, through the sale of woven doum palm products (Amwatta 2004). The Turkana prepare a mixture of the fruit powder and cow blood which they call 'Lokot'. They prepare this food when getting ready for long journeys or migrating to new areas for greener pastures (Maundu & Tengnass 2005). The fruits are also eaten by animals like donkeys, camels and goats. The young shoots and leaves are used as vegetables and fodder during drought (Maundu & Tengnass 2005).

The cumulative information on uses of plants and their products is passed on from generation to generation (Gadgil *et al.* 1993). This knowledge, however, is threatened by the aging population and lack of interest among the youth in acquiring it, due to the influence of western culture and trends (Nolan & Turner 2011). It is therefore important to protect traditional knowledge by thoroughly documenting it. *In situ* preservation of crops and wild plant genetic resources depends on proper documentation of their ethnobotany. Various methods are used to study the importance of plants in ethnobotany, including; descriptive studies, cultural consensus analysis, participatory methods and hypothesis testing (Stepp 2005). Various indices have been developed for quantifying and hypothesis testing of ethnobotanical data (Hoffman & Gallaher 2007).

Despite the wide land coverage of *H. compressa*, there exists scanty formal documentation on its ethnobotany in Kenya. In addition, doum palm is already adapted to ASAL and can sustain the ever-growing population in these areas yet there is very little focus on it. This study aimed to determine the management practices and perceptions on domestication, biotic and abiotic stress, the important use categories and plant part value of *H. compressa*. This study employed Relative Cultural Importance (RCI) indices that have been developed for quantifying ethnobotanical data (Hoffman & Gallaher 2007). Data collected on these indices were analyzed and used to test the study's hypothesis that doum palm uses are random with respect to regions sampled.

Materials and Methods

Study area

This study was done between January and September 2018 in Kenya. The four sampling sites (Fig.1), namely Turkana (34°30' and 36°40' East and 1°30' and 5°30' North), Tharaka Nithi (37°19' and 37°46' East and 00°07' and 00°26' South), Kwale (38°31 and 39°31' East and 30°3' and 40°45' South) and Tana River (38°25' and 40°15' East and 0°0' and 2°0' South) were selected based on previous studies (Amwatta 2004, Maundu & Tengnass 2005). These areas fall between agro-ecological zones v to vii, which are characterized by residual rainfall, high temperatures and low vegetation cover (Jaetzold & Schmidt 2009).

Turkana County, located in the northwestern part of Kenya, covering an area of 77,000 km², is an ASAL with Lake Turkana and River Turkwell as the perennial sources of water. It has elevated temperatures between 20°C and 41°C, irregular rainfall (mean annual rainfall of 200 mm) and a population of 855,399 people (Turkana County government 2013). The ethnic groups in Turkana are the Turkana, Rendile, Elmolo, Pokot and Samburu (Turkana County Government 2013). The Turkana are a minority community in Kenya who are nomadic, a state which makes them vulnerable to persistent poverty (Ng'asike & Swadener 2015). The county is considered a food stressed county with the main sources of food being wild fruits, livestock and relief food (Kenya interAgency rapid Assessment 2014). They keep zebu cattle, goats, donkeys and camels for milk, meat, wealth and dowry payment. Communities along Lake Turkana practice fishing (Turkana County government 2013). In this area, *H. compressa* is the predominant vegetation thus considered as forests of Turkana (Turkana County government 2013). Other plants growing include *Acacia* spp., *Aloe* spp., and *Osyris lanceolata*.

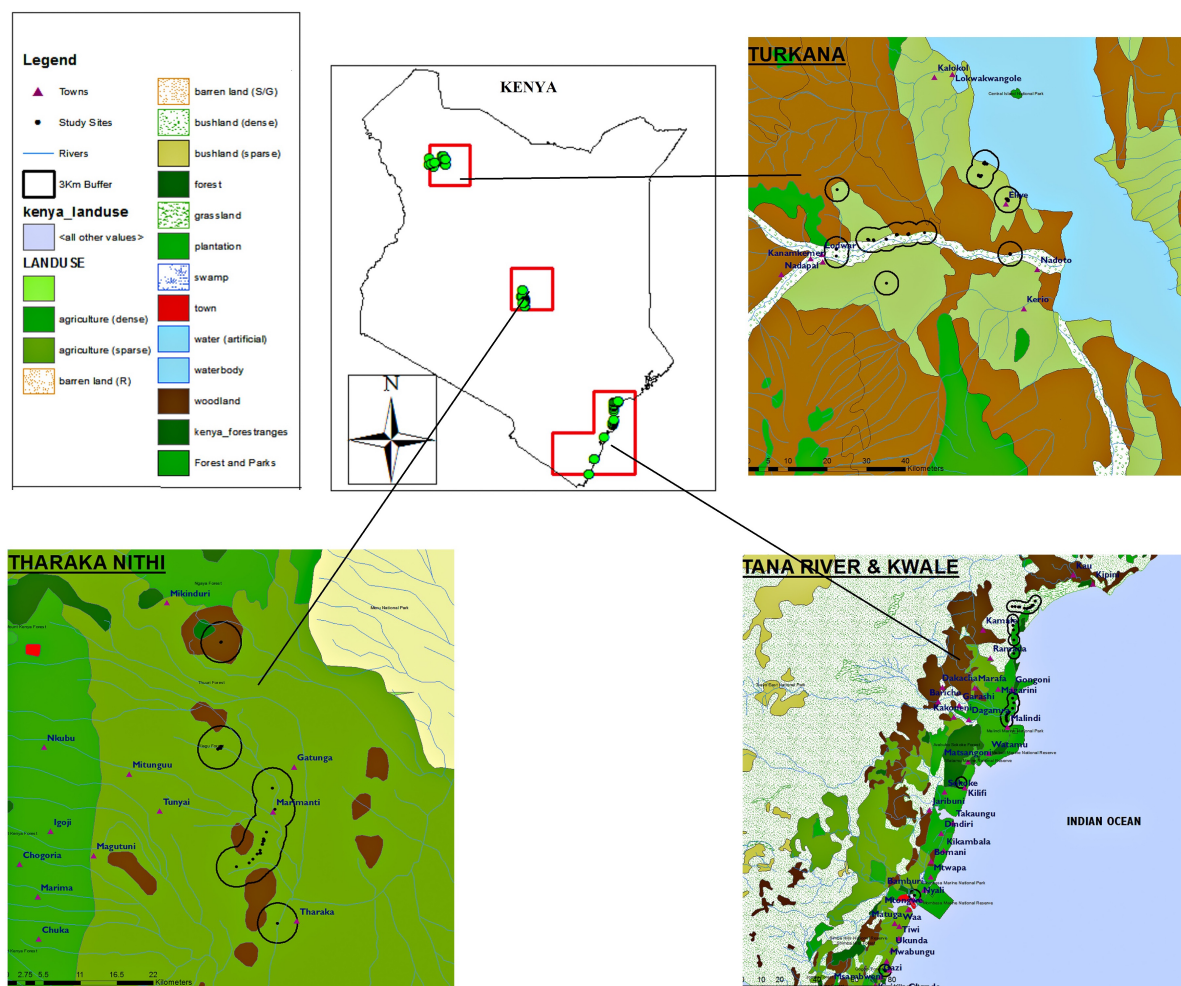


Figure 1. Map of Kenya showing sampling areas; Tharaka Nithi, Turkana, Tana River and Kwale counties in Kenya

Tharaka Nithi sub-county in Kenya is approximately 2610 km², with a population of 365,330 people. It has an annual rainfall of 500 to 800 mm per year and temperatures between 29°C to 36° C. The ethnic communities in Tharaka Nithi are, the Aatharaka and Nithi ethnic communities. The Tharaka Nithi people are agri-pastoralists specializing in food crops such as millet, sorghum, pigeon peas, green grams, and cowpeas and they keep dairy cattle, indigenous zebu cattle, goats, sheep and chicken (Icheria 2015). The main River Tana tributaries flowing through this area include Mutonga, Thingithu, Kathita, Thanantu, Thangatha, Kithinu and Ura rivers, which provide water for irrigation (County Government of Tharaka Nithi, 2017). The endowment with many rivers in the region is an impetus for fishing activities. The predominant vegetation cover consists of *Acacia* spp., with little drought-tolerant grass cover species (Gioto 2018). There are pockets of doum palm species on the mainland and along the rivers within the region.

Tana River County is classified as an ASAL, despite being home to the most important estuarine and

deltic ecosystem with a rich diversity of wildlife and plants in East Africa (<https://www.tanariver.go.ke/environmental-wildlife-and-natural-resources/>). The county has a mean temperature of 23°C and max of 33°C and rainfall of between 400 mm and 750 mm (Kenya inter-Agency rapid Assessment 2014). The rare species of monkeys called mangabey are only found here, and their main food is doum palm (Maundu & Tengnas 2005). It has a population of 240,735 under an area of 35375.8 km². Tana River people are agri-pastoralists specializing in food crops such as coconut, cowpea, green grams, cassava, cashew nuts, maize, mangoes and they keep goats and cattle (MoALF 2016). The county is classified as an acute food insecurity zone and they practice weaving and meal skipping to cope with the food stress (Kenya inter-Agency rapid Assessment 2014). The dominant ethnic groups are the Pokomo who are farmers, Orma and Wardey who are pastoralists. Other tribes include Waata and Boni who are hunters and gatherers, Wailwana, malakote and Bajuni (<http://www.tanariver.go.ke/about-us-2/>).

Kwale has a population of 649 931 and an area of 8270 km². The major economic activities include tourism, fishing and agriculture. The main communities here are the Mijikenda. They grow maize cassava, beans, cashew nuts, coconut, and mangoes and keep livestock such as the zebu cattle, goats and sheep (Kenya inter-Agency rapid Assessment 2014). The predominant vegetation cover consists of offshore mangrove forests along the Indian Ocean, wetland grass, coconut and doum palm.

Data collection

A total of 79 informants 38 (48.1%) women and 41(51.9%) men belonging to the four sampling areas were interviewed in this study. Women were the highly assessed gender in Turkana and Tana River while male were the most interviewed in Kwale and Tharaka Nithi (Table 1). The low number of

interviewees was partly due to scarcely populated areas and scarcity of key informants. The criteria for identifying the lead informants varied from one region to another. In Turkana field personnel of a Non-Governmental organization (NGO) known as Anglican Development Services guided the identification, location and led the interview administration. In Tharaka Nithi, Kenya Forestry Research Institute (KEFRI) personnel guided the survey, whereas in Tana River and Kwale, Kenya Nuts and Oil Crops Directorate personnel led the survey. The selection of informants was done using the snowball technique. Only customary users of *H. compressa* products were selected, interviewed and provided lead to the next interviewee. The lead question was on doum palm awareness (knowledge). The interviewed informants included farmers and businessmen.

Table 1. Number of informants across the four sampled counties in Kenya

County	Ethnic group	Local Name	Number of interviewees	Percentage of Women (%)	Percentage of Men (%)
Turkana	Rendile	<i>eng'ol</i>	27	51.9	48.1
Tana river	Pokomo	<i>Mkoma</i>	27	55.6	44.4
Kwale	Mijikenda	<i>Mkoma</i>	10	30	70
Tharaka Nithi	AaTharaka Nithi	<i>muruguju</i>	15	40	60

Personal observation, oral and semi-structured interviews were carried out to collect data on the four objectives of the study. The interview schedule used in this study had a mixture of closed and open-ended type of questions and was structured into four parts as shown in Table 2.

To gather unique and unanticipated information about doum palm ecology from the resident perspective, a couple of open-ended questions were included. In the same interview schedule, several closed-ended questions (dichotomous questions, Likert scale questions and fixed response questions)

were included to generate more information on the study objectives. Additionally, observational questions (Interviewer's opinion) were also included to generate the researcher's perception of biotic and abiotic stress assessment and distribution, domestication and maintenance of the palm. All responses to filled interview schedules were coded in SPSS under category type of questions and ordinal questions. During the interview, interpreters were used in cases where the respondents were not able to effectively communicate with the interviewer or were illiterate.

Table 2. Structure of the interview schedule used for sample collection

Part of Questionnaire	Aspects interviewed
Demographic information	Name, gender, County, Ethnic group of the informant
Distribution, domestication and maintenance	Number, Distribution and seasonality, Management practices, Cropping systems and Plants intercropped with <i>H. compressa</i>
Uses of doum palm	Plant parts uses (Leaves, stem, roots and fruits), special uses (Rituals, medicinal, religious), marketing of <i>H. compressa</i> products
Biotic/ abiotic stress	Pests and diseases affecting doum palm production, abiotic stresses on <i>H. compressa</i>

Data analysis

This study employed the following importance indices: Reported use (RU), Reported use Value Per Plant Part (RU Plant Part), Plant Part Value (PPV) in percentage and Fidelity Level (FL) in percentage (Hoffman and Gallaher 2007). Fidelity level is the

measure of how often a use report was mentioned (Salako *et al.* 2018).

$$FL(\%) = x/n \times 100$$

Where, x is the total number of informants who have mentioned a specific use and n is the total number of informants.

RU is the total number of uses reported for the plant.

RU Plant Part is the total number of uses for each plant part

Percentage PPV is the ratio between the total reported uses for each plant part and the total number of reported uses for the plant, that is

$$PPV = \frac{\sum RU \text{ Plant part}}{\sum RU} \times 100$$

For quantitative analysis of data, all weaving and derived products were grouped as handicrafts and construction and derived products as construction/building, to facilitate data analysis (Sadeghi & Kuhistani, 2014). Univariate analysis was done for appropriate categories. A data analysis strategy linked to research objectives was adopted. This strategy involved initial summarizing and describing the responses to each of the questions. Data on category type and ordinal questions were analyzed and presented in the form of the frequency of responses using percentages. Cross tabulation was used to determine the association between two category types of questions. Chi square was used to identify differences in the use values in the different regions sampled. This was done to test the hypothesis that doum palm uses are random with respect to the regions sampled.

Results

Distribution, domestication and maintenance of doum palm

A total of 26 (96.3%) out of 27 informants in Turkana reported having more than 15 doum palm trees in their farms. In Tana River, 51.9% of informants had between 1 and 5 plants in their farms. Turkana had the highest number in one farm compared to the rest of the sampling areas. The Residents of Kwale are well conversant with this plant. They were able to differentiate *H. compressa* into three varieties based on differences in morphological traits. They locally identified them as *Mkoma*, *Mbiye* and *Mkoko*. Only a few (20%) informants in Tharaka Nithi were able to differentiate the varieties but did not assign them any names. The informants from Tana River and Turkana could not differentiate the species/varieties.

More than half the respondents interviewed in Tharaka Nithi (53.3%), Tana River (55.6%), and Kwale (80%) supported domestication of *H. compressa*. Turkana had the least of respondents (11.1%) supporting domestication. The frequency of

intercropping doum palm and other crops was highest in Tharaka Nithi with 86.7% of informants intercropping at any stage of the palm's development and only 13.3% intercropping when it is mature (Fig. 2 A). Respondents from Kwale and Tana River do not intercrop *H. compressa* with other crops. However, in Turkana only 3.7% were willing to intercrop. All the Respondents from Tharaka Nithi practiced some form of maintenance, including pruning and weeding, whereas none in the other three counties undertook any maintenance.

Different crops such as pawpaws, bananas, mangoes, cowpeas, sorghum, millet, pigeon peas, green grams, oranges and cassava were intercropped with *H. compressa* in Tharaka Nithi (Fig. 2A, B). However, in Kwale, Tana River and Turkana counties, it occurs in the wild (Fig. 2 C, D). In Turkana, it is the main plant but other plants such as *Prosopis juliflora* and *Acacia* spp. are found to grow in the same locality. Coconut, cashew nuts, *Acacia* spp. and mangroves were observed to grow in the same ecological niche as *H. compressa* at the Kenyan coast (Kwale and Tana River).

Uses of doum palm

H. compressa leaves as food

Food uses of doum palm fruit were recorded in all the sampled regions as shown by the high-fidelity scores across all regions. Most (90%) of the informants who recorded fruit use were from Kwale followed by Turkana, Tana River and Tharaka Nithi. The fruit is consumed by humans by crushing and eating the flesh or drinking the water inside to quench thirst during drought (Figure 3A and 3B). The fruit can also be ground into powder and used as a food additive. The feed uses of this plant was recorded in all the regions sampled. The fruit is also eaten by animals in the ASAL (Table 3). They feed on the leaves and on fruits that are ripe and have fallen from the tree (Fig. 3C).

In Tharaka Nithi, the use of doum palm as food recorded the highest-fidelity score (80 %) while the use of fastening farm tools recorded the lowest score (6.7%). In Tana River County, uses of doum palm as food recorded the highest score (81.5 %) while medicine and fodder recorded the least (7.4%). In Kwale the most use was fruit as food (90%), while feed (leaves) recorded the least (10%). The most uses for Turkana was food (Fig. 3 A and 3B), while prevention of soil erosion was least, with the scores of 88.9 and 3.7% respectively. The use of leaves and fruits as animal feed was not as common as the use of the same for human food. This is supported by the lower fidelity for feed uses scores compared to food uses.



Figure 2. Doum palm intercropped with millet in Tharaka Nithi (A and B), doum palm growing in the wild in Tana River (C) and a bush of doum palm growing in Kwale (D)



Figure 3. A. *H. compressa* fruits, B. A Turkana woman eating *H. compressa* fruit, C. A donkey eating *H. compressa* fruits that have fallen from the tree

Medicinal uses of doum palm

Three medicinal uses were noted in this study. In Kwale the fruit powder is used as a painkiller for headaches and the crushed inflorescence is used to treat miscarriage. Only 7.4% of informants from Tana River recorded the use of crushed leaves for treating burns (Table 3).

H. compressa leaves for weaving

The leaves for weaving are collected from juvenile palms preferably those with long mid ribs (Fig. 4A

and B). Tharaka Nithi residents use leaves to make mats, baskets and brooms (Fig. 4 C, F, G and H). Weaving was noted to be done by women, men and children. However, women are frequent weavers (Fig. 4C). Local mat weavers in Turkana have modernized their baskets and mats by incorporating color and more articulate designs compared to Tharaka Nithi weavers (Fig.4 D and E). In Kwale County, doum palm leaves are used to make mats, baskets, ropes, fans and sieves (Fig. 4 I, J, K and L).

Table 3. Plant parts of doum palm used by different communities in Kenya and their fidelity levels

Plant Part	Use Category	Uses	Fidelity Level				P Value
			THK	TR	KW	TUR	
Fruit	Food	Fruit is crushed Water inside is taken Food additive	80	81.5	90	88.9	0.568
	Feed	Donkeys, Camels	26.7	18.5	10	48.1	0.046
	Fuel	Dry Husks are used	40	55.6	-	-	0.001
	Medicine	Powder as painkiller for headaches Inflorescence crushed and given to expectant mothers to prevent miscarriage	-	-	20	-	0.267
	Other uses	Fasten Farm tools-The husk is put at the fulcrum for support.	6.7	-	-	-	0.229
Leaves	Handicrafts	Weaving mats, brooms, ropes, fishing nets, sieves, hats	53.3	70.4	60	74.1	0.589
	Medicine	Leaf ashes for treating burns	-	7.4	-	-	0.267
	Roofing	Thatching houses	33.3	74.1	70	-	0.033
	Feed	Donkeys, Camels, goats	26.7	7.4	10	22.2	0.396
Stem	Construction	Furniture, houses, boats	73.3	20	80	66.7	0.834
	Wine making	Apical meristem is cut to tap wine	-	37.03	40	-	0.000
	Ornamental	As hedge	20	-	-	-	0.004
	Other uses	Building Pet Houses	26.7	-	20	-	0.013
Roots	Prevention of Soil erosion	Prevent soil erosion	-	-	-	3.7	0.583

***H. compressa* for construction material**

Doum palm log is cut and used for construction (Fig. 5A). In Tharaka Nithi, doum palm trunk and leaf petioles are used as material for house/granary construction and pet house construction (Fig. 5 C, E). The petioles are used for making furniture (Fig. 5 D). In Tana River, doum palm is the predominant material for house construction (Fig. 5B). The local communities use palm leaves for thatching mud houses. In Turkana, the residents use doum palm trunks to construct boats for fishing. They make boats by cutting 3 to 5 medium size trunks and tying them together using ropes woven from doum palm leaves.

Other uses of *H. compressa*

The fruit is also used for fastening farm tools. This is done by inserting the husk to the fulcrum of the hoe (Fig. 5 F). Wine tapping was indicated in Tana River and Kwale (Fig. 5G and H). The residents tap the sap from the apical meristem to make wine. The tapping

of wine was observed to be destructive. In some instances all the branches are cut leaving the plant with no leaves.

Biotic and abiotic stress in H. compressa

The most observed biotic stress was human interference and pest infestation, while the observed abiotic stress was drought and salinity (Table 5, Figure 6). Doum palm in Tharaka Nithi recorded the highest biotic stress, including pest infestation (Fig. 6D) and human interference. In Tharaka Nithi harvesting is destructive to juvenile palms making them stunted (Figure 6A and B). The observed biotic stress in Turkana, Kwale and Tana River consisted mainly of Human interference (30%, 25% and 20% respectively). Turkana and Tana River county recorded severe drought effects on doum palm plants while Tharaka Nithi and Kwale the drought effects were moderate (Table 5). Turkana, Tana River and Kwale displayed symptoms of salinity effects on doum palm (Table 5, Fig. 6C).



Figure 4. Handcraft from *H. compressa*; Woman from Tharaka collecting *H. compressa* leaves for weaving (A), Leaves ready for weaving in Tharaka Nithi (B), woman weaving baskets in Tharaka Nithi (C), Modernized baskets made from *H. compressa* by women in Turkana (D and E), mats, baskets and brooms made by people from Tharaka Nithi (F, G and H), baskets, fans, ropes and mats by women from Kwale (I, J, K and L).

Table 4. Reported Use value per plant part and Plant part value of *H. compressa* among four counties in Kenya

Plant Part	Overall		Tharaka Nithi		Tana River		Kwale		Turkana	
	RU _{Ppt}	PPV	RU _{Ppt}	PPV	RU _{Ppt}	PPV	RU _{Ppt}	PPV	RU _{Ppt}	PPV
Fruit	5	35.7	4	40	3	33.3	3	33.3	2	28.6
Leaves	4	28.6	3	30	4	44.4	3	33.3	3	42.8
Stem	4	28.6	3	30	2	22.2	3	33.3	1	14.3
Roots	1	7.1	-	-	-	-	-	-	1	14.3
RU	14		10		9		9		7	

RU_{Ppt} is Reported use per plant part, RU: Reported use, PPV: Plant Part Value in percentage

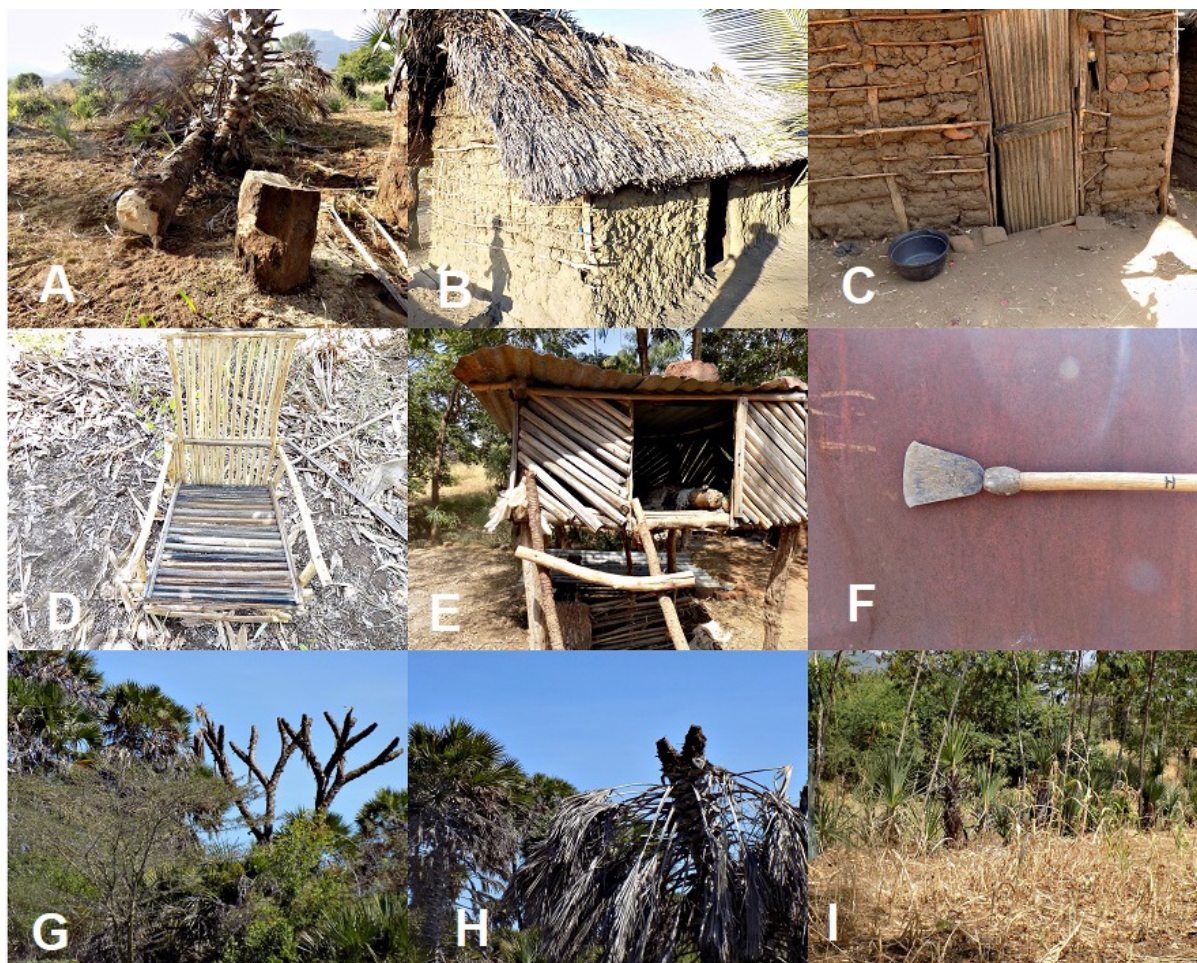


Figure 5. Construction and other *H. compressa* uses; log of *H. compressa* ready for use in Tharaka Nithi (A), Mud hut roofed with *H. compressa* leaves in Tana River (B), door made of *H. compressa* in Tharaka Nithi (C), Chair in Kwale (D), pet house in Tharaka Nithi (E), hoe arm fastened using *H. compressa* fruit in Tharaka Nithi (F), Stem cut for tapping wine by the coastal communities in Tana River and Kwale respectively (G and H) and doum palm used as a hedge (I).

Table 5. Biotic and abiotic stress as recorded in the sampled areas

Sample Area	Biotic stress		Abiotic stress	
	Morphological descriptor	Percentage (%)	Descriptor	Range
Tharaka Nithi	Leaf rust/pest infestation	73	Drought	Moderate
	Human interference (Overharvesting, logging, burning and clearing for human settlement)	60		
Turkana	Leaf rust/pest infestation	11	salinity	Severe
	Human interference (logging and burning)	30	Drought	
Kwale	Human interference (leaf overharvesting, wine tapping, logging and burning)	25	Salinity Drought	Moderate
Tana River	Human interference (leaf overharvesting, wine tapping, logging and burning)	20	Salinity Drought	Severe

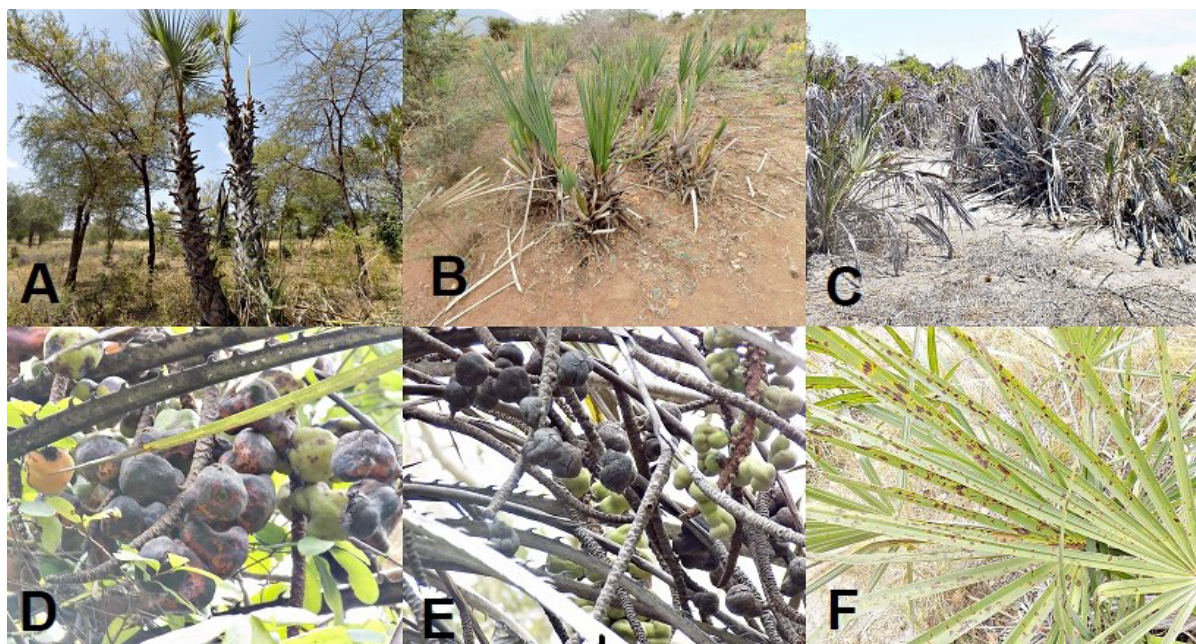


Figure 6. Biotic and abiotic stress of *H. compressa*; Overharvesting of leaves in Tharaka Nithi (A and B), effects of high salinity in Tana River (C), fruit infection in Tharaka and Kwale (D) and leaf rust in Turkana (E)

Discussion

This study highlights the importance of *H. compressa* to the local communities living in ASAL of Kenya. It is one of the few perennial plants that grows in these areas. Farmers in Tharaka Nithi do not clear it from the field during land preparation. They prune, weed and intercrop it. According to Vodouhè *et al.* (2011), the first step to domestication of wild plants includes maintenance in the field due to established uses and sustenance. In the second step, farmers are now interested in the plant and they weed and protect it. A domesticated plant is one that is fully dependent on man for its survival (Clement, 1992) and by this definition, *H. compressa* is therefore a semi domesticated plant. The motivation for its maintenance in Tharaka Nithi has been noted to be leaf production, high population density in Tharaka Nithi and the industrious nature of its residents (Amwatta 2004, Icheria 2015). Most weavers purchase bundles of leaves from farmers who have it on their farms. The farmers in turn continue to maintain it as a source of income. The need for maintenance in Tharaka Nithi is an indication that it could be losing its diversity which has adverse implications on conservation. On the other hand, Turkana had the highest *H. compressa* density of all the regions sampled and some little intercropping albeit with no maintenance activities. The lack of maintenance and propagation among the Turkana is partly due to the high population of *H. compressa*. The trees which grow along the rivers are the most predominant vegetation and thus considered to be the forests of Turkana (Turkana County government, 2013). The Turkana also depend on humanitarian aid and food relief from various government and

NGO which has possibly influenced their attitude towards the maintenance of *H. compressa* (Ng'asike & Swadener 2015).

The presence of many NGOs in Turkana that support agricultural activities is a likely cause for the existence of observed intercropping activities aimed at supplementing the wild fruits, livestock products and relief food (Ng'asike & Swadener 2015). Due to the heightened tourism activities in Kwale, the demand for doum palm products is high and hence the reason for high willingness to domesticate the plant (Kenya inter-Agency rapid Assessment 2014). Tana River residents expressed a high willingness to domesticate the plant due to the destructive process of tapping wine. Earlier studies reported that doum palm was an important plant in ancient Egypt, yet there is poor evidence of domestication (Clement 1992, Venugopal *et al.* 2017, Janick 2014).

This study documented 14 uses of doum palm. Fruits were the most used plant parts followed by leaves, stems and roots. In contrast, in an earlier study done on *H. compressa*, the leaves were the most used plant part (Amwatta, 2004). The present study observed that its most important use was human food for the people living in Tharaka Nithi, Turkana, Kwale and Tana River as indicated by the use index. The findings are in agreement with previous studies on palms which reported food being one of the important uses of *Borassus aethiopum*, coconut and date palm (Salako *et al.* 2018, Sadeghi and Kuhestani 2014, Stauffer *et al.* 2014). In all the sampled regions, the fruit mesocarp is used as food and feed. However, other peculiar uses of the fruit

were also documented. For example, in Turkana, residents drink fruit sap as a beverage and also mix crushed mesocarp with livestock blood and use it as a meal (popularly known as 'lokot'). Residents of Tharaka Nithi use dry fruits as fuel and dry endocarp to fasten farming tools while residents of Kwale use crushed mesocarp as a food additive and as a herbal painkiller. Worth noting was the use of immature inflorescence by Kwale community as herbal medicine for expectant mothers to prevent miscarriage. Previously, Maundu *et al.* (1999) reported the use of doum palm fruit as food (*lokot*) among the residents of Turkana. The Turkana are a minority community in Kenya who are nomadic, a state which makes them vulnerable to persistent poverty (Ng'asike & Swadener 2015). The area also experiences long seasons of drought necessitating alternative nourishment. During this time, they only have their livestock and plenty of doum palm fruits. In a study by Lokuruka (2008) doum palm fruit was shown to have high content of unsaturated fatty acids and are considered healthier than those from coconut or palm kernel oils. Earlier ethnobotanical studies on the palm family reported diverse medicinal utilities including but not limited to anti-inflammatory, anti-diabetic, anti-biotic and anti-neoplastic agents (Gruca, *et al.* 2014, Nagata *et al.* 2011, Venugopal *et al.*, 2017). *Hyphaene thebaica* fruits have been shown to be sources of effective antioxidants (Hsu *et al.* 2006). In Egypt, doum palm is used in the treatment of various ailments including hypertension (El-Rashad & Hassan 2005). Doum palm can thus be explored further for medicinal properties.

The doum palm fruit is a major food source for animals like donkeys, camels and goats in all the four sampled areas. This is similar to previous findings which also noted that *H. compressa* fruits are food sources to other animals like elephants, baboons, monkeys and Mangabey (Maundu & Tengnas 2005). Apart from *H. compressa* fruits being a source of feed, *H. compressa* leaves are always evergreen in these environments offering sufficient fodder for the livestock.

The common leaf uses in all the regions include weaving mats and trays, making brooms, thatching houses and animal feed. In Tana River, leaf ash is used to treat burns while in Kwale it is used to make fans, hats, sieves, ropes, and fishing nets. In Turkana, the leaves are used to make baby coats, food warmers and fishing nets. Due to their nomadic nature Turkana, residents use leaf petioles to make temporary huts called *manyattas*. On the other hand, in Tharaka Nithi, Kwale and Tana River leaves are used for thatching mud houses. Amwatta (2004) reported similar doum palm leaf uses. Whereas the

present study determined human food to be the most important use of doum palm, a recent review reported leaves as the most important doum palm part used in making various woven products like mats, brooms, ropes and baskets (El-Beltagi 2018). Tana River and Kwale reported the least use of leaves as feed. This could be due to the fact that they belong to the humid agroecological zones due to the Indian Ocean where there is some variety of vegetation for animal feed while Tharaka Nithi and Turkana are in the dry semi arid and arid zones.

Doum palm stem is used for the construction of houses, granaries and fences. The stem is also tapped for wine in Kwale and Tana river. Only Turkana residents acknowledged the importance of doum palm roots in soil erosion prevention. In some regions, wood prepared from male doum palm trees is considered better than that from the female (El-Beltagi 2018). There were differences in doum palm uses as feed, fuel and roofing across all the sampled regions.

The existing doum palm plants in the studied regions exhibited symptoms of biotic and abiotic stress. For instance, there was overharvesting of doum palm leaves and insect infestation in Tharaka Nithi. Tana River and Kwale regions are saline and prone to drought. Doum palm is one of the few perennial plant species found in saline soils and can withstand erratic hostile climate conditions (Orwa *et al.* 2009, Venugopal *et al.* 2017). Previous studies have indicated that Kenyan coastal saline soils are rich in sodium carbonates and chlorides while Turkana saline soils are rich in sodium chloride (Mugai, 2004). High salinity is a soil feature prevalent in the arid and semi-arid areas. The tapping of wine from this plant, among other uses, was the predominant biotic stress recorded in Kwale and Tana River. This is because wine tapping is destructive to the apical meristems of the plant.

Conclusions

This study shows that part of doum palm growing in the ASAL of Kenya is semi- domesticated. Its maintenance practices include pruning and weeding particularly in Tharaka Nithi. The most important use of doum palm is food from the fruit. Human interference, salinity and drought are the most stresses of this plant. There was difference in doum palm uses as feed, fuel and roofing across all the sampled regions. This plant has economic uses in Kenya despite its limited species/variety information. The rising exploitation of doum palm in Kenya calls for concerted *in situ* and *ex situ* conservation efforts.

Declarations

List of Abbreviations: KW Kwale; PPV Plant Part Value; RU Reported Use; RU_{Plant Part} Reported use per plant part; THK Tharaka Nithi County; TR Tana River County; TUR Turkana County

Ethics approval and consent to participate: Research permit and approval was granted by the Kenya National Commission for Science, Technology and innovation (NACOSTI). A prior informed consent was presented to the respondents stating clearly the objectives of the research and the potential impacts or output of the research. Those who consented to the research were the only ones allowed to participate. They were also informed that they had the right to refuse to be interviewed at any stage of the interview.

Consent for publication: Signed informed consent for publication was obtained from individuals in Figure 3 and 4.

Availability of data and material: All data generated or analyzed during this study are included in this published article

Competing interests: The authors declare that there are no conflicts of interest

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Authors' contributions: CM, JN and NLMB conceived the work, CM, JN and AO collected the data, AO analyzed the data, AO prepared the manuscript with assistance from CM, JN, NLMB and RG. All authors read and approved the final manuscript.

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Questionnaire for Recording Ethnobotany Data

GPS Coordinates of sampling sites.....

1. DEMOGRAPHIC INFORMATION

- a) Description of the farmer
 - a. Name of the farmer.....
 - b. Gender.....
- b) County.....
- c) Date.....
- d) Ethnic group.....

2. DISTRIBUTION AND DOMESTICATION OF DOUM PALM

- a) Do you know doum palm? Respondent to show the interviewee a doum palm tree in his farm
 - Yes
 - No
- b) Seasonality
 - Available only in season
 - Available throughout the year
- c) How many trees of Doum palm are in in your farm
 - 1-5
 - 5-10
 - 10-15
 - More than 15
- d) Have you observed any varietal differences in doum palm?
 - Yes
 - No
- e) If yes, how many varieties of doum palm can you identify?-----
- f) Name them.....
- g) What is the distribution of doum palm
 - widely distributed
 - Limited
 - Endangered
- h) Is it worthy to domesticate doum palm?
 - Yes
 - No
- i) Cropping System
 - 1. Monoculture
 - 2. Intercropping
- j) Does it allow intercropping?
 - Yes
 - No
 - Only when mature

- k) Plants intercropped with doum palm.....

- l) Do you do any form of maintenance of doum palm on the farm?
 o Yes
 o No
- m) How do you maintain doum palm in your farm?.....

3. USES OF THE PLANT

- a) How do you use the doum palm fruit?
- b) How do you use doum palm leaves.....
- c) How do you use doum palm stem.....
- d) How do you use doum palm roots.....
- e) Are there special uses of doum palm
 1. Feasts
 2. Religious purpose
 3. Medicine

If yes, describe the use.....

- f) Economic uses
 1. Export
 2. Local consumers
 3. Traditional industries
 4. Handicrafts

4. BIOTIC AND ABIOTIC STRESS

- (a) Is doum palm affected by pests
 If yes describe the pest.....
- (b) Is doum palm affected by diseases
 If yes describe the disease.....
- (c) Human interference (Harvesting by farmers, logging, clearing)
 1. High
 2. Moderate
 3. No/ low
- (d) browsing by animals
 1. High
 2. moderate
 3. Low
- e) Signs of Salinity stress.....
- f) Signs of Drought Stress.....