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Local knowledge and attitudes of frankincense communities in northeastern Somalia

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ABSTRACT

The global understanding of Traditional Ecological Knowledge related to the management and conservation of frankincense trees in Somalia remains limited, particularly considering the highly context-specific nature of TEK. This research aims to contribute to the advancement of knowledge by enhancing our understanding of the role played by Traditional Ecological Knowledge in the management and governance of frankincense fields in northeastern Somalia. The primary objective of this study is to identify and describe the key components of local knowledge that regulate harvesting practices, with the overarching goal of ensuring the long-term survival and productivity of frankincense trees in the country. Additionally, the study explores the attitudes of local communities towards traditional harvesting and conservation practices in frankincense fields. The findings highlight valuable insights into the interplay between local knowledge and the conservation of frankincense trees in northeastern Somalia, bridging the gap between scientific understanding and indigenous wisdom.

1. Introduction

African woodland ecosystems play an essential role in maintaining biodiversity, regulating water systems, preserving soil quality, and storing carbon (Cisse et al., 2020; Manlay et al., 2020; Ouedraogo et al., 2020). Many local communities rely heavily on the utilization of various products obtained from both the woody and nonwoody components of many plant species found in African woodland ecosystems (Félix et al., 2018; Hassan et al., 2011). These products encompass a diverse range of items, such as fibers, pharmaceutical materials, fodder, fuel wood, resins, and various others, all of which hold substantial socioeconomic importance (Sabo et al., 2022). However, the increasing demand for both subsistence and commercial use of these products is partially responsible for the unsustainable management of tree species, which in turn leads to the loss of forest ecosystems (Rasmussen et al., 2017). In fact, many traditional natural products have recently become popular in international markets, resulting in a significant increase in economic value and global attention (Fritsche and Rösch, 2020; Gogoi et al., 2020). Given that the commercialization of forest resources is not inherently detrimental, these challenges raise a thought-provoking inquiry into whether the existing scientific knowledge that influences our lives and guides the conservation of forest resources is adequately equipped to establish a genuinely sustainable future (Newton, 2008; Sinthumule and Mashau, 2020).

The literature indicates that sustainable forest management requires more than just scientific knowledge; it encompasses a broader range of knowledge and wisdom (Sinthumule and Mashau, 2020). There is a need for a comprehensive approach to conservation that

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extends beyond traditional biological perspectives and the conventional norms of modern science (Robertson and Hull, 2001). Local communities who have relied on their local environments for an extended period of time have a vested interest in conserving and promoting biodiversity (Agrawal and Gibson, 1999). The conservation practices of indigenous communities were established based on a set of empirical guidelines that were likely developed through a long history of trial and error (Gadgil et al., 1993). Moreover, indigenous communities possess extensive knowledge about various aspects of biodiversity, including habitat preferences and species behaviors (James et al., 2020). This knowledge contributes to conservation of natural resources (Agrawal and Gibson, 1999). The significance of Traditional Ecological Knowledge (TEK) practices and systems in facilitating the sustainable utilization and conservation of ecosystem services has garnered increasing attention (Ens et al., 2015; Mavhura and Mushure, 2019). TEK is often used interchangeably with other terms such as Traditional Knowledge (TK), Local Knowledge (LK), Indigenous Knowledge (IK), Indigenous Knowledge Systems (IKS), Peasants' Knowledge, Indigenous Technical Knowledge, and Folk Knowledge (Hunn, 1993; Reid et al., 2002; Mavhura et al., 2013; Tharakan, 2015; Boafo et al., 2016). These terms refer to accumulated knowledge, practices, and systems developed by local communities, often passed down through generations, for understanding and interacting with their environment in a sustainable manner. This knowledge is dynamic, culturally embedded, and often contextually specific, shaped by local traditions, practices, folklore, myths and taboos, and has the potential to play a pivotal role in forest resource management and conservation (Pei et al., 2009; Berkes et al., 2000, 2017).

The United Nations Convention on Biological Diversity explicitly highlights the importance of respecting, preserving, and maintaining the innovation and practices of indigenous and local communities in relation to the sustainable use of biological diversity (United Nations, 1992). The Aichi Targets (Target 18) also acknowledge the vital role of indigenous communities worldwide, their traditional ecological knowledge, and their significant contributions toward achieving the strategic plan for biodiversity 2011–2020. The World Bank in (1998) and the Millennium Ecosystem Assessment (MEA) report in (2005) both recognized the contributions of TEK in the context of sustainable forest management. This recognition underscores the value of TEK in biodiversity conservation efforts at the international level (Sinthumule and Mashau, 2020). While extensive studies exist on TEK and its role in resource management and conservation globally (Ghazanfari et al., 2004; Ramakrishnan, 2007; Nimachow et al., 2011; Osei-Tutu, 2017), insufficient attention has been given to understanding the role of TEK in the context of the Somali frankincense sector. Hence, our understanding of TEK related to the management and conservation of frankincense trees in Somalia is currently limited, especially considering that TEK is highly context specific (Stephenson and Moller, 2009). This gap in knowledge hampers the development of effective conservation strategies that integrate local knowledge and cultural practices. Thus, to achieve comprehensive and inclusive conservation of plant species, it is necessary to understand the prior knowledge of indigenous peoples (Mishra, and Tiu et al., 2004, 2007). Therefore, this study aims to enhance understanding of the role of Traditional Ecological Knowledge in the management and governance of frankincense fields in northeastern Somalia. This involves identifying and describing key traditional knowledge that regulates harvesting practices to ensure long-term survival and productivity of frankincense trees in northeastern Somalia. Additionally, the study investigates local communities' attitudes toward traditional harvesting and conservation practices in frankincense fields.

The remainder of this paper is broadly organized into three sections. The first describes study area and research methodology. The second section presents the findings and discussions of the study. The final section presents the conclusion of the study.

2. Methods

2.1. Study area

The study was conducted in the districts of Ufeyn and Alula, situated in the Bari and Gardafu regions of Puntland, Federal Republic of Somalia. Frankincense trees are known to thrive in four regions of Puntland. In this study, a purposive selection was made, focusing on two of these four regions, with one district chosen from each region.

Puntland is a major producer of frankincense, along with various other aromatic resins. The name "Puntland" is derived from the term "Land of Punt" mentioned in ancient Egyptian history (Thulin, 2020). Although the exact location of this fabled territory remains unknown, it is commonly believed to be in Somalia or Eritrea (Groom, 1981). Despite the uncertainty surrounding the precise location of this legendary land, many inhabitants of the frankincense regions of northeastern Somalia firmly believe that this area corresponds to the Land of Punt, with the early trade of incense in the region often romanticized, as depicted in the poem on the front flyleaf (Thulin, 2020).

The occurrence of frankincense trees is primarily observed in the Bari, Sanaag, Gardafu and Karkaar regions of Puntland. The frankincense areas are vast landscapes characterized by rugged and undulating mountains known as "Golis". The ecology of this zone is semidesert, and the livelihood of the local population is primarily a combination of livestock husbandry, crop production and fishing, supplemented by harvesting of frankincense and collecting honey (FSNAU, 2016). The area experiences a moderate climate in contrast to the majority of Puntland regions (FSNAU, 2016). Average annual temperatures within the Golis mountains vary from 24 °C to 28 °C (FSNAU, 2016).

Northeastern regions of Puntland are renowned for hosting Boswellia sacra Flück (syn B. carteri Birdw.) and Boswellia frereana Birdw. Boswellia sacra and Boswellia carteri are often considered the same species from a botanical perspective; however, the trees found in Somalia are commonly referred to as B. carteri, while those in the Arabian Peninsula are known as B. sacra (Thulin and Warfa, 1987). Therefore, the author will henceforth refer to Boswellia sacra as Boswellia carteri. These species are characterized as deciduous to semideciduous, typically reaching a maximum height of 8 m (DeCarlo. et al., 2020).

Moqor-libaax and Guban frankincense fields are part of the montane xeric woodlands that dot the Golis mountain chain. This area is characterized by its rugged terrain, which includes a succession of barren mountain peaks separated by saddles and valleys. In both the

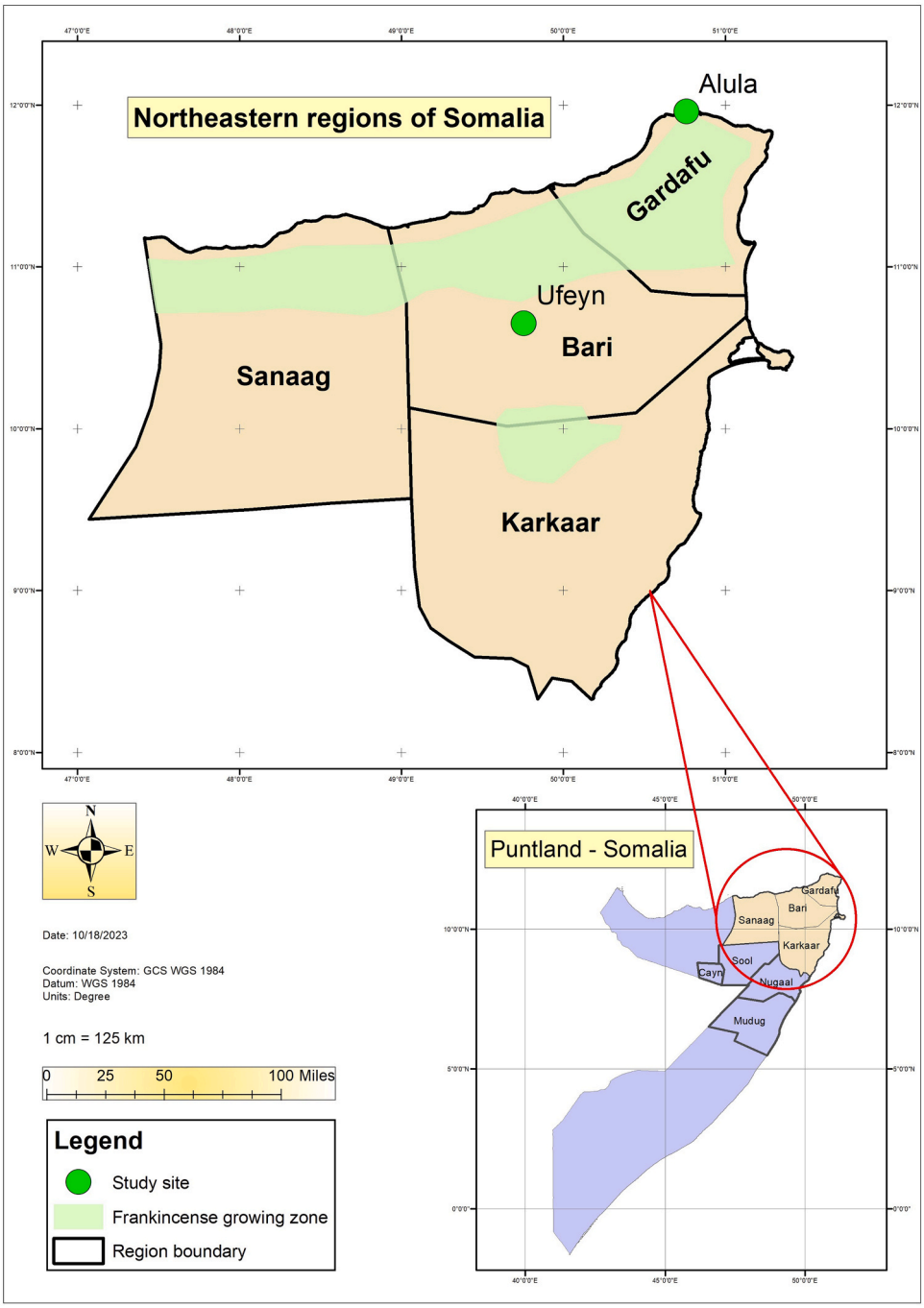

Fig. 1. Map of Puntland showing frankincense growing areas and administrative regions of the enterprise.

Moqor-libaax and Guban fields, various different species of plants and animals coexist with the frankincense trees. The Moqor-libaax fields host a diverse avian population. I observed various bird species in the area, including migratory birds such as *Columba oliviae, Warsangeli linnet, Hirundo aethiopica, Tudos ludoviciae,* and Somali Thrushes. Notably, the endemic Somali species, *Numida meleagris somaliensis* also known as the *helmeted guinea fowl,* was among the bird species present. The upper canopy of these fields was characterized by tree species including *Acacia hankokib, Acacia tortilillis, Ziziphus mauritania, Salvadora persica, Cadabra heterotricha, Commiphora erythraea,* and *Mimusops laurifolia*. These trees reached heights between 8 and 15 m, with some remarkable *Mimusops laurifolia* trees in Guban reaching up to 15 m. In Guban, I have also observed *Juniperus procera* and *Juniperus excelsa,* in the higher

canopy along with open shrubs of *Buxus hildebrandtii and Dodonea viscose* trees. In the lower part of the Guban field, I observed *Aloe megalacantha, Acacia edgeworthi, Buxus hildebrandtii, Euphorbia abyssinica,* and *Euphorbia balsamifera* among the shrubs in the area.

2.2. Data collection and analysis

Prior to the commencement of the study, the Ufeyn and Alula District Ethics Committees approved the research. Authorization letters issued by the office of the district commissioner helped to introduce the researcher to the study participants. All participants were introduced to the objectives and scope of the research. Written informed consent was also obtained from all the participants before participating in the study.

Data collection lasted from May 2021 to December 2022 and was performed through (i) key person interviews administered through questionnaires and (ii) field observations using field observation checklists. There were no available population data for the target population. Therefore, the study adapted Cochran's sample formula to determine an appropriate sample size that could represent an unknown population size. Through this formula, the study determined a random sample of 192 of the target population with a 95% confidence level and ± 5% precision level. A semistructured questionnaire was administered to 192 respondents from the frankincense communities in Ufeyn and Alula districts. The respondents were selected using systematic random sampling, with each district having 96 participants. The demographic characteristics of participants are described in Table 1. Following methods employed by previous studies (Ceriaco et al., 2011; Sinthumule and Mashau, 2020; Ramstad et al., 2007; Huntington, 1998), the questionnaire utilized a mix of open-ended and closed-ended formats, including multiple-choice questions with an option to provide comments or additional categories. In accordance with the approach proposed by Jacoby and Matell (1971), the study also utilized a three-point Likert scale to evaluate the attitudes of the participants. The survey questions aimed to gather data regarding participants' knowledge, myths, and customs utilized in the context of resource exploitation and harvesting practices and field management. Moreover, custodians were subject to targeted inquiries concerning their customary responsibilities in overseeing field governance, supervising resource exploitation, and implementing conservation activities within their frankincense fields. Each interview lasted 45 min and was moderated by the researcher.

The interviews data were entered into Microsoft Excel, and key phrases were highlighted using different colors to categorize them accordingly. The data were then grouped into different categories using codes, following Attride-Stirling (2001) and Walliman's (2011) methods. This approach enabled the research to obtain a concise summary of the main points and find repeated meanings present in the data. Subsequently, tabulated data underwent thematic content analysis, a qualitative analytical method that involves identifying, analyzing, and reporting themes present within the data (Braun and Clarke, 2006).

The author also conducted field observations, assisted by two research assistants to gain a general understanding of the situation in the Moqor-Libaax and Guban frankincense fields in Ufeyn and Alula, respectively, complementing the data collected through the interviews. The research assistants, who were residents of Ufeyn and Alula towns, possessed extensive knowledge of the frankincense fields and traditional ecological knowledge. Field observations focused specifically on human activities and the overall state of the frankincense fields. The exercise was conducted in July 2021 and December 2022, following the key informant interviews. By directly observing the fields, the researcher was able to acquire a first-hand understanding of the situation on the ground, thereby alleviating the reliance on second-hand information alone (Cohen et al., 2007). The analysis of the observed activities involved tallying the occurrences of "yes" and "no" responses in relation to the activities listed in Table 4. Interviews data were corroborated by the author observations.

3. Results and discussion

3.1. Demographic characteristics of respondents

No women were involved in the frankincense sector; all respondents were male. Most respondents (71.9%) had informal education. A smaller portion (17.7%) had formal educational experience, with only (11.5%) of this group had completed secondary school. A minority (0.5%) held university degrees. Additionally, 10% of the participants were identified as illiterate. A majority of participants (67%) were aged 40 or above, while the remainder were below 40.

Regarding participant roles, the study encompassed a diverse range of stakeholders. The largest group consisted of harvesters (37.5%), who are responsible for tapping the frankincense trees and collecting resin. Custodian committees (23.4%) also made up a significant portion, representing those responsible for the protection and management of the frankincense fields. These individuals were selected due to their significant traditional knowledge and indispensable role in fulfilling customary obligations concerning field governance, supervision of resource exploitation, and conservation activities. Traders (16.1%) formed another important group involved in the commercial aspect of the frankincense trade, while renters (16.7%) play a vital role in ensuring adherence to field conservation regulations. While it is widely held that local communities often exhibit caution towards government representatives and external parties, districts authorities (6.3%) play significant role in upholding 'Xeer' enforcement, particularly in the diligent implementation of sentences against individuals found in violation of the 'Xeer', as detailed in subsection 3.2.3. Majority of participants (80%) had strong knowledge and familiarity with trees and conservation regulations. This suggests a good understanding of the subject matter and the importance of environmental conservation practices. Twenty percent of respondents expressed low familiarity with these topics, indicating a potential gap in knowledge or awareness.

Table 1
Demographic profile of the respondents (n = 192) in the study area.

Characteristics	Frequency		%
Age	Ufeyn	Alula	
< 30 years	13	10	12
31–40 years	20	21	21.4
41–50 years	37	35	37.5
51–60 years	15	18	17.2
> 61 years	11	12	12
Educational background			
University	0	1	0.5
Secondary school	9	13	11.5
Primary and intermediate school	6	5	5.7
Other (informal education)	71	67	71.9
Illiterate	10	10	10
Familiarity with trees and conservation regulations			
Knowledgeable	72	81	80
Not knowledgeable	24	15	20
Participant roles			
Traders	17	14	16.1
Custodian committees	22	23	23.4
Districts officials	5	7	6.3
Harvesters	37	35	37.5
Renters	15	17	16.7

3.2. Local ecological knowledge

3.2.1. Governance and resource management

Frankincense grows wildly, and the only human input is through land owned. Every frankincense tree stand in the frankincense regions belongs to a clan, and ownership is inherited from forefathers through a strictly patrilineal line of inheritance, excluding female family members. While official records may lack specific delineations of field boundaries, the owners themselves possess precise knowledge regarding the boundaries of their fields (DeCarlo et al., 2020). Clan elders representing communal owners of frankincense fields take on the role of selecting a dedicated custodian committee. This committee is responsible for governing the ownership, tenure, and utilization of the fields. It is composed of male elders chosen for their extensive knowledge and experience in the frankincense sector. The committee is responsible for performing equitable division of stewardship among communal owners, following a practice known as 'Gaafeysi'. This ensures that each communal owner has their turn to exploit the fields. People from communal owners and willing to harvest the trees request permission from the custodian committee at the beginning of the harvesting season. The committee gives the first priority to those who requested first, provided they possess the necessary skills in harvesting practices and knowledge of 'Xeer' regulations. The committee manages the leasing of the fields when no one from the communal owners is willing to harvest the trees. In such case, the committee leases the fields to individuals outside the Gaafeysi circle. Those who are willing to rent the fields are prioritized based on who requested first and who possess the required skills in traditional harvesting practices and understanding of the ' Xeer' regulations outlined in subsection 3.2.2. Furthermore, the custodian committee's duties extend to reconciling resource-use conflicts, and overseeing responsible exploitation of the trees.

3.2.2. Frankincense customary law (Xeer)

The Somali people have ancient customary regulations, locally known as 'Xeer' (pronounced Heer), that regulate the frankincense sector (Farah, 1996). The development of the frankincense Xeer and establishment of frankincense land custody lack clear documentation regarding their origins and the specific individuals involved. Earlier research suggested that a charismatic leader like King Mohamoud Hawaadane who reigned over the northeastern regions from 1809 to 1818 made substantial contributions to the establishment of this 'Xeer' (PDRC, 2003). This social code 'Xeer' was developed to reduce and prevent natural resource tenure conflict, exploitation, and abuse, as well as manage the frankincense industry. The 'Xeer' is unwritten and has been passed down orally from generation to generation. In this section, we discuss only the regulations that are related to the conservation of frankincense trees.

3.2.2.1. Regulations for assessing trees' readiness for sustainable exploitation. These regulations necessitates conducting field observations before exchange of stewardship from one communal owner or renter to another at the inception and end n of one's stewardship. The custodian committees walk through the fields, observing the physical condition of each tree to determine if it is injured or overtapped. The custodian committees in both regions also impose restriction on trees that have been injured or overharvested to facilitate their recovery and ensure their health. Trees can be put under protection for anywhere between 1 and 3 years, depending on the nature of the injury sustained by the tree. Additionally, the custodian committee mandated consistent oversight during the harvesting season. Respondents in both regions confirmed the practice of these regulations.

Frankincense communities in Gardafu have an additional regulation to ensure the tree's readiness for harvesting. As part of the initial field observation, the custodian committee is also entrusted with verifying the suitability of the trees for tapping at the beginning of each harvesting season. This involves evaluating tree health and capacity to produce resin. This process incorporates a pre-harvest

tapping referred to as 'Godlin', which constitutes a critical aspect of the entire procedure. During the Godlin tapping, each tree undergoes 1–2 trial incisions, followed by a waiting period of two weeks before the recommended harvesting seasons commence. The outcomes of this process determine the potential for the exploitation of the frankincense tree in that particular season. Trees that exude a creamy resin with optimal moisture and aromatic properties demonstrate that they have sufficiently recovered from previous harvests, making them suitable for harvesting in the upcoming season. In contrast, trees producing reddish resin are deemed not ready for harvesting and should not be exploited during that specific harvest period. Resumption of harvesting occurs when the tree has fully recovered.

Trees deemed ready for harvesting should be closely monitored throughout the tapping process, as their initial positive readiness indicators may change over time. For instance, a tree initially displaying favourable sings of harvest readiness might exhibit adverse indicators after undergoing several tapping cycles. As a result, the tapping process must be executed with meticulous attention to how each individual tree responds to the tap in each tapping cycle.

Vigilant observation of the tree's responses is essential, enabling the determination of the optimal number of tapping cycles for each specific tree. This adaptive approach is crucial due to the potential variability in the number of cuts and tapping cycles, which can be influenced by the tree's distinct responses and recovery patterns from previous tapping seasons.

3.2.2.2. Regulations on harvesting trees colonized by parasitic plants. Most respondents (67%) stated that parasitic plants should be removed from infected trees, and harvesting from the tree should occur three weeks later. The parasitic plants should be promptly removed upon detection. Respondents from both Alula and Ufeyn districts acknowledged the existence of a locally recognized parasitic plant referred to as "Qobdhac or Qadow" possibly Loranthus spp. (Loranthaceae) which can exert various effects on Boswellia trees. Loranthus is a genus of parasitic plants that falls under the family Loranthaceae (Balle et al., 1960). These parasitic species thrive on the branches of woody trees and have been observed in the Golis mountains, where frankincense trees grow (Mumuli et al., 2010). Qobdhac occurs on the branches of Boswellia trees, and local people believe it has potential to weaken the tree's immune system, making it more vulnerable to diseases, as they draw nutrients and water from the tree and may reduce its resin production capacity.

3.2.2.3. Regulations for tapping patterns and incision methods. As revealed by the respondents, the harvesting practices for frankincense trees are characterized by a discernible seasonal pattern contingent on their geographical location. In the both regions, the harvesting of B. frereana trees occurs over 10 months (August to June). This finding corroborates the conclusions reached in a prior study conducted by Farah (1996). After undergoing two consecutive tapping seasons on B. frereana trees, harvesters are required to observe a mandatory resting period, referred to as "Gaaxin," for one tapping season before any further tapping can occur. The rest period facilitates trees recovery. Resting trees is consistent with findings of other studies (e.g. DeCarlo et al., 2020; PDRC, 2003). In the Gardafu region, the tapping of B. frereana trees comprises 7–11 tapping cycles, whereas in the Bari region, the trees undergo 5–9 tapping cycles, as outlined in Table 2.

Boswellia carteri harvesting occurs from April/May to November, covering 2–8 tapping cycles. After two consecutive tapping seasons, each B. carteri tree is rested for one tapping season.

In the Bari region, the approach for B. carteri trees differs. These trees afford an opportunity for tapping during two distinct harvesting seasons. The first season spans from September to January, and the second extends from November to April, both comprising 2–7 tapping cycles with 14–18 days of interval between each tapping cycle. In cases where harvesters may miss tapping during one of these designated seasons, they can opt to tap the trees during the subsequent harvesting season. Tapping should not occur during both of the defined harvesting seasons for the same tree. Additionally, a one-season respite should be afforded to B. carteri trees following the end of a tapping season. Tapping the trees outside the designated seasons is prohibited.

As confirmed by the respondents in both Alula and Ufeyn, the initial incision should not exceed dimensions of 2 × 3 cm, commonly referred to as " Xubin iyo bar/badh" in the local terminology. As the tapping process progresses through consecutive cycles, the size of the incision expands. The ultimate dimensions of the wound must align with a height of 6 cm and a width of 9 cm, ensuring that the depth remains within 0.5 cm. Notably, the dimensions for the incision slightly vary from those documented in the western Sanaag region by DeCarlo et al. (2020), although the depth of the incision is consistent. The respondents unanimously emphasized the importance of confining incisions to the outer layer of the tree's bark, with a meticulous avoidance of any intrusion into the inner bole. This regulation protects trees from deep incisions that go past the tree bark, a practice conducted by harvesters to extract a large amount of resin from the tree during the harvesting period. Such a violation could be fined between 1 and 10 million Somali Shillings, which is equivalent to $30–300 US dollars, depending on the age and size of the frankincense tree. Another violation that this regulation prevents is careless resin collection after the tapping cycles have been completed, referred to as "Jagayn and Candhagoyn" (PDRC, 2003; Farah, 1996). The regulation prohibits the careless scraping of exuded resin from the tree wound, which can cause

Table 2
Traditional harvesting practices for frankincense trees.

Tree type	Region	Tapping season	Tapping cycles	Tapping interval	Rest period
B. frereana	Bari & Gardafu	August - June	Gardafu: 7–11 cycles. Bari: 5–9 cycles	15–20 days	1-tapping season after two consecutive tapping seasons
B. carteri	Gardafu	April/May - November	2–8 cycles	15–18 days	1-tapping season after two consecutive tapping seasons
B. carteri	Bari	September - January. November - April	2–7 cycles	14–18 days	1-tapping season

damage to the outer protective bark of the tree. When the outer bark is damaged, the tree becomes vulnerable to attack by a notorious pest that burrows into the inner bark of the tree and can cause rot and mortality to the tree. The insect is locally called 'Xorre, Xare or 'Dowsar' (likely a species of Cerambycidae or Buprestidae beetle), and it can only attack the frankincense tree when the outer bark below the wound has been damaged accidentally or during harvesting (DeCarlo. et al., 2020; Negussie et al., 2018; PDRC, 2003). Depending on the severity of the damage, fines are meted out to those responsible for rendering the tree vulnerable to pest attacks. Infestation by this insect is detrimental to the health and productivity of trees, and if left unattended usually results in tree mortality within 5-10 years, especially when they infest the lower sections of the tree trunk.

The harvesting process comprises multiple tapping cycles, involving several rounds of tree tapping throughout the harvesting season. Within each tapping cycle, the previously healed wounds on the tree are reopened to stimulate the exudation of additional resin (Eslamieh, 2017; Farah, 1996). Tapping intervals are observed between each of these tapping cycles within the season. This carefully spaced timing ensures that the trees have sufficient time to exudate resin and gradually adapt to the process, allowing for the optimal exudation of resin during subsequent cycles. This interval duration is determined by various factors, including the prevailing climate conditions and the overall health status of the tree. Notably, well-hydrated and rested trees tend to expel sap more rapidly, potentially within the designated interval period. Consequently, if the trees exhibit sluggish resin secretion, exceeding the stipulated interval duration, and yield reddish resinous material over the tapping cycles, this serves as an adverse indication. It suggests that the tree is not sufficiently prepared for tapping, warranting a suspension of the tapping process.

While there are noticeable differences in the tapping schedules and cycles between the two regions, it's important to highlight that these variations extend beyond just these regions. The findings also underscore distinctions when compared to the tapping patterns and cycles observed in the western Sanaag region of Somaliland, as highlighted by DeCarlo et al. (2020). Furthermore, the tapping patterns and cycles documented by the (PDRC, 2003), which conducted a similar study in Puntland, also contributed to this broader spectrum of tapping practices. These collective observations emphasize that the tapping patterns of frankincense trees are influenced by a complex interplay of geographical, ecological, and cultural factors.

3.2.2.4. Regulations for tree tapping. These regulations dictate the tapping process based on the tree's age at commencement, as well as the number of incisions per tree, as described in Table 3. As the trees mature, each one undergoes a specific period of tapping preparation to ensure their full adaptation to the tapping process. In contrast to the trees observed in Somaliland, as indicated by DeCarlo et al. (2020), the Boswellia trees in the Bari and Gardafu regions initiate the tapping process at the age of 12 years. The first tapping usually occurs at a 'dhudhun' (30–40 cm) above the center of the trunk. At this stage, the tree is christened 'Hal-hogle' meaning 'single-holed.' The 'Hal-hogle' status is maintained for up to three years to allow the tree to adapt to the incision process. During these initial three years, the custodian committees and harvesters as well carefully observe how the trees react to the incision. For example, if the tree's leaves discolor or leaves are shed earlier than usual as a response to the stress, tapping should be suspended until the next tapping season. The status of the tree will remain 'Hal-hogle' until it is observed that the tree has fully adapted to the incision.

If the tree exhibited positive indicators during the prior incision, then in the subsequent tapping season, a point 'dhudhun' above the initial incision or on the opposite side of the trunk is selected for the second incision, and the tree's status is elevated to 'Labo-hogle' meaning 'double-holed'. The duration for which the 'Labo-hogle' status is sustained fluctuates, contingent upon the response of each individual tree during its preceding incision, commonly extending over a span of up to two years. Subsequently, the third incision is executed just above the location of the second incision. This action denotes the last category. From this point onward, the tree is referred to as 'Irmaan', which signifies that the tree has been properly conditioned and is prepared for harvesting.

Unlike the temporary statuses of 'Hal-hogle' and 'Labo-hogle' the designation of 'Irmaan' remains constant throughout the tree's lifespan. The 'Irmaan' status does not possess distinct identifying traits. The number of incisions that an 'Irmaan' tree carries varies based on its height. An 'Irmaan' tree could have anywhere between 3 and 8 incisions, each spaced approximately 30 cm or 'dhudhun' above each other.

Understanding the categorization of frankincense trees holds significance for tree conservation. A frequent error seen among individuals unfamiliar with the distinction between trees undergoing preparation and those classified as 'Irmaan' pertains to field renters. They often make numerous cuts on 'Hal-hogle' or 'Labo-hogle' trees in an attempt to extract more resin, inadvertently causing harm to the tree in the process.

I do not argue that the 'Xeer' alone is sufficient to address the conservation of frankincense trees and tackle the growing global environmental challenges and deforestation. However, I strongly believe that the conservation regulations of the 'Xeer' provide

Table 3
Classification of frankincense trees.

Tree status	Age	Duration of the status	Number of incisions	Placement of the incision
Hal-hogle	12 years	2–3 years	1 incision	The incision should be vertically positioned on the trunk of the tree.
Labo-hogle	14–15 years	2 years	2 incisions. Should be spaced 30–40 cm apart	The incision should be vertically positioned on the trunk of the tree.
Irmaan	17 years	Remains constant	3–8 incisions and each should be spaced 30–40 cm apart.	The incisions should be vertically positioned on the trunk of the tree.

valuable insights and prospects for sustainable natural resource management and have the potential to be integrated into conventional approaches to natural resource management. This further underscores the significance of integrating traditional ecological knowledge into scientific approaches for the purpose of achieving sustainable resource management (Haq et al., 2023; Mohammed et al., 2017).

3.2.3. Enforcement of the 'Xeer' verdict

Social governance among Somali people is structured based on kinship and social contracts (Xeer). The implementation and enforcement of customary law is a shared responsibility among community members. Among the community members are people engaged in the exploitation of trees for frankincense, frankincense traders, field owners, field renters and community members in the frankincense growing area and surrounding towns and villages.

In instances of violations against traditional harvesting regulations, the custodian committee raises concerns regarding such transgressions. Subsequently, the case is addressed through a voluntary and remedial process facilitated by an independent committee. The selection of this committee is contingent upon the nature and circumstances of the case, with traditional elders playing a role in its appointment. The committee is similar to a customary court. Usually, they comprise notable elderly members of the community believed to possess knowledge and wisdom of frankincense trees, their ecosystem, and the accepted procedure for their exploitation. The appointment procedure is transparent and open to public scrutiny and review. If found guilty of bias, customary committees are fined heavily, shamed, and shunned by the community. However, there are instances where the application of the regulations can be misinterpreted or incorrectly applied, especially when there is a general social acceptance of such actions. This often occurs in systems of oppression or discrimination. Punishments may be disproportionately imposed on wrongdoers. For instance, if the wrongdoer is from outside the circle of communal owners or belongs to minority clans, it is likely that a greater penalty will be imposed compared to when the offender is from within the circle of communal tree owners. Additionally, the committee may occasionally face significant influence from paramount clan chiefs, such as Ugaas, Beeldaaje, Boqor, or Suldaan. Leaders of these large clans, who reside in the frankincense-growing regions, can influence the decisions of the customary court, particularly in cases where the wrongdoer is a relative. This can deter the rigorous implementation of traditional practices. Due to the substantial influence held by these traditional authorities in matters pertaining to their respective societies, the committee, offenders, tree owners, and the broader populace typically acquiesce to the determinations or resolutions put forth by the paramount chiefs (Aden, 2011; Höhne, 2006). If the person found guilty fails to fulfill the requirements of the judgment, the person's next of kin or his or her traditional chief (nabaddoon) are required to do so in the form of collective punishment or collective compensation. In the event of punishment, the judgment is handed over to the police for enforcing of the sentence; usually this leads to imprisonment.

3.2.4. Local myths and taboos

In Somalia, the frankincense industry has been shrouded in myths that originated in ancient times, with an unknown date spanning millennia. The existence of myths has played a significant role in the conservation of frankincense fields in northeastern Somalia. In general, Somalis believe that trees are living beings that pray to Allah or God (the creator). They believe that since trees do not sin, their purity from sin causes their prayers to be answered immediately. Therefore, they believe that if they harm the tree, the tree will curse them and stop producing resin. They believe that the person who harms the tree will be cursed and will be inflicted with disease and poverty. One old taboo is the taboo of harvesting frankincense trees at night. Local communities believe that Jinns [Jinn, a spirit believed by Muslims to be one of the creations of Allah (SWT)], (spirits) inhabit the trees and possess the trees at night. Breaking the branches of a tree is considered a bad omen. A widely circulated tale from 1998 recounts the story of a young boy who broke a small branch or twig from a Boswellia carteri tree to brush his teeth. According to the testimony of one of the respondents, the young boy's hand suffered an incurable infection, eventually resulting in its amputation after a few months. Incidents such as this encourage belief in the supernatural or spiritual protection of the trees. The incident has been a key reference for local conservationists and parents advising their young ones to protect them from the curse of the frankincense tree. The evil spirit that inhabits the tree at night is called the Cirfiid, a powerful spirit of Jinn creation. Key informants reported that the spirit of the Cirfiid, who appears in the shape and form of a dragon spewing flames, guards the frankincense trees in the Moqor-Libaax area and the surrounding frankincense fields in the Al-miskat ranges (east Golis mountains). As one elder whom I interviewed in Ufeyn town explained, "*If you enter this frankincense fields in the general Almiskat areas with bad intentions, you will be confronted by and chased by the Cirfiid ''*.

Many people believe that Jinns inhabit frankincense trees. Hence, breaking a branch from a frankincense tree, cutting the tree, or even burning a frankincense tree is considered a bad act that could lead to chronic illness, paralysis, or even death. The Somali people also believed that women should not interact with frankincense trees. Women are not allowed to be part of frankincense harvesting teams and should not touch or live near frankincense trees under any circumstance. They believe that certain energies emitted by the bodies of women can harm the health and productivity of frankincense trees; hence their exclusion from all frankincense-related activities. Women, unless as the sole heir, are excluded from inheriting frankincense fields from their father. This has been a controversial subject, debated and condemned in vain as un-Islamic by local religious scholars. In support of this myth, a traditional elder I spoke to had this to say: A man with many daughters, who stubbornly ignored warnings against letting his daughters follow him on harvesting trips, lost his trees to severe lightning strikes that decimated half of the trees in his 'Kob' (a field of approximately 300 Boswellia trees). Another urban dweller in Alula called this incident of lightning a coincidence and went on to explain the logic, saying, "*This is just a smart and greedy way of ensuring that the trees stay within the ownership of the clan*". If women inherit them, then their children, who could be from other clans, could inherit the trees, causing conflict over these valuable heirlooms. While another explained this as a clever conservation idea, the trader from Ufeyn town said, "*The human beings were reproducing quicker than the frankincense trees*". As a result, the elderly decided to match the reproduction of the trees with the reproduction of human heirs by coding a male-only inheritance regulation. The trees would not have been conserved for thousands of years if this regulation had not

protected them from female ownership. He added, "*In these areas, we have a greater number of women than men ''*. The respondents believed that if women were to be part of the inheritance, they would not have frankincense today.

Frankincense communities have a taboo against grazing livestock in frankincense ranges, and this taboo is reinforced by a myth. They believe that livestock grazing in the frankincense field causes the trees to produce less resin and that the owners of the livestock will be stricken by poverty. Similarly, it is taboo to settle in frankincense fields or construct roads. It is believed that pollution from human settlements and emissions from cars are detrimental to the health, regeneration, and productivity of frankincense trees. As a result, the fear and respect of these myths have protected the Moqor-Libaax and Guban frankincense fields and surrounding areas. Mainly because of cultural preservation and fear, the fields have remained intact because people are afraid of being confronted by the Cirfiid or harmed by the evil Jinns that inhabit the trees.

3.2.5. Attitudes toward the frankincense 'Xeer'

The participants in the study demonstrated a positive attitude toward the utilization of the Somali frankincense Xeer, myths, and taboos as tools for the protection of the fields. A significant majority of respondents (80%) of those aware of the fields' value, recognized that these traditional practices played a crucial role in safeguarding the fields. The Xeer was particularly highlighted as an important mechanism employed by traditional custodians to ensure the conservation of frankincense resources. The integration of religious beliefs was also mentioned as another aspect contributing to the protection of the fields. It signifies recognition of the importance of indigenous knowledge and traditional systems in promoting sustainable resource management.

The participants' endorsement of these practices suggests a strong desire to uphold and transmit these cultural values to future generations. However, there is a contradiction, as participants acknowledged that they are not actively passing on these practices to their own children. This discrepancy raises questions about the factors or challenges that may prevent the transmission of cultural values from one generation to the next.

The observations conducted in the Moqor-Libaax and Guban frankincense fields were primarily based on human behavior and the general situation observed in the fields. Information on the number of wounds per tree and their alignment with the prescribed guideline were not collected during the study. Both DeCarlo et al. (2020) and Farah (1996) identified deviations from the Xeer practices in their respective study sites in Somaliland and Puntland. Therefore, further research is needed to better understand how well TEK contributes to sustainable resource use in northeastern regions of Puntland.

The researcher did not observe any signs of deforestation in either the Moqor-Libaax or Guban frankincense fields. Throughout the observation period, no tree stumps or broken branches were seen, indicating that the trees were not being excessively harvested or damaged. These observations suggest that the traditional practices and customary rules in place may be effectively contributing to the conservation of frankincense trees in these fields.

During the observation period, no individuals were observed visiting the frankincense fields to gather firewood. Similarly, we observed no forms of human disturbance near the frankincense fields. In close proximity to the Moqor-Libaax fields, a road was present; however, no human settlement was observed in the area. When queried about the road, the harvesters explained that it served as a route for vehicles involved in collecting the resins gathered from the field. Harvesters temporarily pitch their seasonal harvest camps and store their harvests in makeshift storage structures or caves on the slopes of the Moqor-Libaax and Guban ridges, locally known as "Gale Xiji". When asked about their commitment to implementing traditional harvesting practices and other Xeer regulations, the harvesters expressed their happiness and strong dedication to adhering to these practices for the purpose of conserving the trees. Most of respondents (78%) expressed the opinion that TEK should be combined with scientific knowledge to enhance the conservation of frankincense trees. This suggests a strong belief in the value of integrating traditional practices with modern scientific approaches for the sustainable management of frankincense resources.

In Guban fields, the research team observed a significant regeneration of Boswellia frereana, with a considerable number of robust seedlings apparent. In Moqor-Libaax, we also counted 50 trees that had been decommissioned from tapping for that season. The most surprising thing to the research team was that neither field had any fencing around it. However, there were no reports or signs of thieves tapping the trees or stealing the resins exuded from the trees. The researcher found no evidence of livestock grazing in the fields; there was no dung from camels, goats, sheep, cows, or even chickens in the Moqor-Libaax and Guban frankincense fields. In fact, we observed a large amount of donkey dung in the area outside the Moqor-Libaax frankincense fields. We did not meet any custodians during the observation exercise; however, the researcher observed field renters supervising harvest teams very closely during the harvest.

Table 4
List of observed activities in Moqor-Libaax and Guban frankincense fields.

Checklist	Guban		M. Libaax	
	Yes	No	Yes	No
Evidence of human disturbance in the frankincense fields		✔		✔
Presence of fencing, guards, or field rangers in the frankincense fields		✔		✔
Sign of off-road driving in frankincense fields		✔	✔	
Any evidence of forest degradation		✔		✔

4. Conclusion

This study demonstrates valuable insights into the traditional ecological knowledge and practices employed for resource management, exploitation, and conservation in the frankincense fields of northeastern Somalia. By uncovering and elucidating these practices, the study highlights their crucial roles in ensuring the long-term survival and productivity of frankincense trees. Furthermore, the examination of local communities' attitudes toward traditional harvesting and conservation practices revealed their significance in both the cultural survival and conservation of frankincense resources in Somalia. The traditional regulations governing tapping patterns, incision methods, and their regional variations within frankincense growing areas contribute significantly to our comprehension of local knowledge in harvesting practices and resource management policies within the frankincense industry. By acknowledging and, whenever feasible, incorporating these practices into conventional scientific approaches to natural resource management, stakeholders can play a role in conserving frankincense resources while also honoring the cultural heritage and traditions of the local communities engaged in these practices.

Declaration of Competing Interest

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

Data availability

No data was used for the research described in the article.

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Research ethics and consent

Ethics approval for the research tool was obtained from the Ufeyn and Alula Districts Ethics Committees prior to commencing the study. Informed consent was also obtained from all study participants, including permission for the publication of the information provided herein.

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