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Ecosystem services of Hurri hills, a montane woodland ecosystem in the arid lands of northern Kenya

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ABSTRACT

Hurri hills (HH) is an ungazetted mountain range in the northern part of Kenya in Marsabit County, harbouring a diverse range of ecosystems. The mountain range has been experiencing land conversion for town expansion, agricultural production and settlements threatening ecosystem service (ES) provision. Sustaining ES provision under increasing anthropogenic pressures is one of the challenges of the HH community. We used focus group discussions (FGD) in seven locations targeting eighty-two participants to identify ES, their importance, perceived drivers of change and the potential impacts on these ES. Preference ranking and Content analysis were used to determine the frequency of ES and their threats. The Jaccard similarity coefficient (J) was used to compute the similarity in ES and their threats in different locations. The FGD identified over 40 ES categorised under provisioning, regulating, supporting and cultural services. The primary ES provided by HH includes water (both domestic and livestock), pasture, fuelwood, thatch grass, cultural sites, cultural material, wildlife habitat, agriculture /settlement, and climate regulation. The Jaccard index of similarity varied at 0.73 for ES, 0.27 for forage species, 0.52 for fuelwood species, 0.29 for medicinal species and 0.36 species for building purposes while the index for threats to ES provision was 0.91. The study established the presence of wildlife species of both local and international importance classified between, near threatened and endangered. Overgrazing, unsustainable utilisation of forest resources, deforestation and climate change were the main drivers impacting ES provision. These results underline the significance of HH as a biological and socio-economic system to the local population. These results further support the need for community centred participatory resource use planning that integrates the inherent threats to the provision of ES in the HH ecosystem. The study recommends undertaking a detailed baseline survey to establish the status and distribution of the main plant and animal taxa to advise the viability of establishing community conservancies in a bid to conserve the ecosystem.

1. Introduction

Forests and their associated systems around the world, which cover about 22% of the earth's surface, represent critical livelihood opportunities for many rural and urban populations providing cash income, fuelwood, timber, valuable medicines, and an improved groundwater supply (Tengö et al., 2017; Djenontin et al., 2018). They further play a crucial role in a host of regulating ecosystem services that play a critical role in several key economic sectors (Haurez et al., 2017). However, such roles of forests are being threatened by anthropogenic impacts and complex environmental issues (Ehlers Smith et al., 2017; Tindall and Robinson, 2017).

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The Millennium Ecosystem Assessment MEA (2005) defines ecosystem services (ES) as the goods and services local communities obtain from an ecological system for their well-being. These ES were further broken down into four distinct categories: provisioning services, regulating services, supporting services and cultural services (Díaz et al., 2006). However, continued demands for these forest resources have caused untold deterioration of terrestrial landscapes, leading to changes such as; deforestation, conversion of previous forest areas to agricultural land, over-abstraction of water, the introduction of exotic trees and grasses on the indigenous vegetation and increased settlements in the urban and peri-urban areas (Crafford et al., 2012).

The montane forests of Kenya produce direct economic value for its citizens and positively impact the rest of the economy, providing intermediate products and services for the industries downstream and providing goods for consumption by households (UNEP, 2012). However, despite their significance, deforestation in these forest systems between 2000 and 2010 amounted to an estimated loss of 50,000 (ha) of pristine forest, casting an uncertain future for these otherwise critical ecological systems. In northern Kenya, the population near montane forests has increased significantly in the last 40 years due to the droughts and war in neighbouring areas (Dietz et al., 2015). With increasing droughts, water scarcity and human population pressure especially in the drylands, conserving these fragile ecosystems is increasingly becoming a challenge (Cuni-Sanchez et al., 2016).

Hurri hills (HH) is an ungazetted montane woodland ecosystem range in the northern part of Kenya within the Marsabit County and harbours a diverse range of ecosystems providing ES critical to the people of the area (F.A.O, 1971; MCIDP, 2013–2017). However, there has been sustained destruction of HH over time through illegal extractive activities and human encroachment from adjacent dwellers (MCIDP, 2013–2017). Other anthropogenic factors include firewood collection, deforestation, charcoal burning, overgrazing, poaching (bush meat and sandalwood), impacts of climate change, increasing human population in the areas around the forest, and conversion of lands for settlement. The County Government of Marsabit (CGM), in their second integrated Development Plan (2018–2022), acknowledged the significance of forests in the county and the anthropogenic pressures they face amid a changing climate. They singled out the damage inflicted on HH woodlands through the historical burning of the rangeland before the onset of the seasonal rainfall to control ticks. According to MCIDP (2013–2017), this indiscriminate burning led to the destruction of over 30,000 ha of the evergreen forest by the 1980s, with only pockets of remnant trees remaining. There is therefore genuine concern from the CGM and other stakeholders that this destruction, if left unattended, will have huge consequences on the ability of the HH ecosystem to

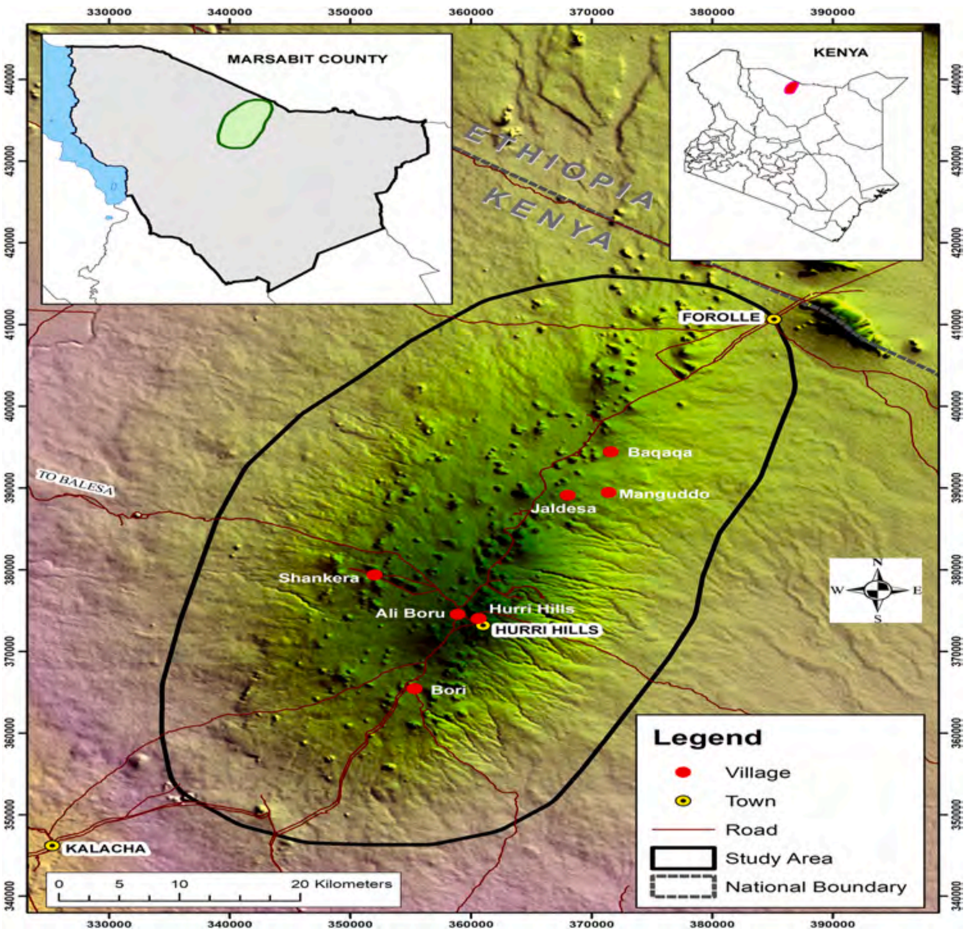

Fig. 1. Map showing the location of the study area in Kenya relative to the county and national setting.

sustainably supply ES.

Several authors have documented the significance of montane forests and their related ecosystems in the provision of ES in northern Kenya (Bussmann, 2006; Watkins and Imbumi, 2007; Jusu and Sanchez, 2013; Cuni-Sanchez et al., 2016; KWS, 2016; Delbanco et al., 2017; Muhati et al., 2018a, 2018b; Ouko et al., 2018; Dan et al., 2021). However, studies to establish the significance and role of the HH ecosystem in the provision of ES as defined by MEA (2005) have not been undertaken. Studies have shown that evaluating the interactions between communities and natural systems enhances understanding of the problems encountered for improved policy formulations contributing to sound environmental decision making (Grêt-Regamey et al., 2017; Ward et al., 2018).

It is, therefore, necessary to study the significance of HH in the provision of ES and how anthropogenic pressures might affect the continued ES provision. This will inform future intervention efforts for sustainable ES provision in HH. Therefore, the objectives of this study were (1) to identify the ecosystem services provided by HH as perceived by the local communities, (2) to rank the most important species providing provisioning ecosystem services, (3) to assess the perceived impacts of anthropogenic activities on ecosystem service provision.

2. Materials and methods

2.1. Study site

This study focused on HH ecosystem in the Marsabit County in northern Kenya, a remote region of large Pleistocene basaltic lava cones (Saggerson, 1969) (Fig. 1). HH is a dryland moist mountain tower comprising several undulating hills formed by volcanic activity extending from Kenya-Ethiopia plains at Furore town towards Chalbi desert in the South kilometres from Maikona- Kalacha junction (MCIDP, 2013–2017). They occur between latitudes (340,000–420,000) and longitudes (330,000 to −38000) with an area of approximately 2519 km^2 (MCIDP, 2013–2017). These hills rise about 300 m (985 feet) above the lava plateau, reaching 1524 m (5000 feet) above sea level (Sombroek et al., 1982). Rainfall is concentrated in two wet seasons, from March-May (Long) and from October–December (Short), and ranges between 800 and 1600 mm per annum though erratic and poorly distributed (F.A.O, 1971). The area is characterised by mist and fog, with temperatures ranging from a low of 15°C to 27°C at the highest.

Vegetation ranges from forested woodland pockets dominated by *Croton macrostachyus, Acacia tortilis, Acacia bussei, Commiphora africana, Acacia mellifera, Acacia senegal, Acacia seyal, Acacia reficiens* and *Combretum molle* found along the valleys and the southern slopes (Stiles and Kassam, 1991). The principal perennial grass species that dominate the higher altitudes of the ecosystem are *Themeda triandra, Chrysopogon plumulosus, Aristida* spp.*, Setaria incrassate, Chrysopogon plumulosus* and *Dichanthium insculptum,* with the low land dominated with *Aristida mutabilis* and *Aristida adscensionis* annual grassland (F.A.O, 1971).

HH has an estimated population of 18,720 persons (KNBS, 2019), with the Gabbra, the dominant community, with the minority being the Wayu. Good climatic conditions have offered a favourable environment for human settlement practising subsistence agriculture centred on food crops like maize, sorghum, millet, beans, fruits and vegetable crops (MCIDP, 2013–2017). The Gabbra also practice sedentary pastoralism, grazing livestock (cattle, goats, sheep, camels and donkeys) away from manyattas during the day and back in the evening (wet season) (KNBS, 2019). In contrast, during the dry season, they have grazing foras (temporary manyattas) moving from one to the other, looking for pasture.

2.2. Sampling framework and field data collection

To establish local communities' perceptions regarding the ES HH provides, focus-group discussions (FGDs) targeting nine to fourteen participants (eighty-two in total) were organised in seven permanent villages (Figs. 1,2) in September 2019 using an FGD guiding questionnaire (Annexe 1–3). After the aim of the study was explained to the local chiefs, they helped mobilise the village elders, opinion leaders and community volunteers who were users of the ES of HH to participate in the survey. In addition, the

Fig. 2. FGD at Bori village Hurri hills (Photo taken on 23:09:2019 by Rahma Dawe).

enumerators familiarised themselves with the various ES as defined by MEA (2005) (provisioning, regulating, cultural and supporting services) and interpreted to the local community the ES terminology in the local (Gabbra) language. Various studies have shown that the use of multiple FGD allows a researcher to assess the extent to which data saturation (i.e., repetition of information obviating the need for additional data that has interpretive usefulness) has been reached (Flick, 1998; Sandelowski, 2008; Saumure and Given, 2008). Consequently, non-permanent villages (*fora*) where local pastoralists emanating from the seven permanent villages migrated periodically in such of pasture, fodder and water for their livestock were not considered. The study faced challenges in accessing the seven villages which were well spread apart between undulating hills and valleys. This challenge was overcome by splitting the survey groups into the different villages so as to cover them at relatively the same time and over a shorter period. The language barrier challenge was overcome by engaging the local chiefs who were conversant with the Gabbra language and thus acted as a translators. Due to the perennial cases of insecurity in the study area compounded by the poor state of the roads, we employed the services of security teams from the Kenya Wildlife Service and Kenya Forest Service to facilitate access to the villages for FGD administration.

The first section of the FGD questionnaire centred on the importance of the HH ecosystem to the local communities, the ES provided, and the threats to the ecosystem. The second section centred on the ranking of plant species that were of importance to the livelihood (medicinal, fodder, firewood and pasture) of the communities and the potential impacts of anthropogenic threats to ES provision. Thirdly, participants were asked to identify the most important ES in each village, stating their reasons (Annexe 1). The most commonly observed wildlife species in the HH ecosystem were also recorded in the FGD meetings. FGD participants identified ecosystem benefits using traditional terminology which was later grouped according to the MEA (2005) classification of ES types. Comments captured in a respective FGD by an individual with respect to the study objectives and later validated by the FGD members were considered representative of the general sentiments of the entire village. The group sentiments, rather than the individual, was considered the unit of subsequent data analysis.

Table 1
Ecosystem services as perceived by the communities in the FGD in HH.

Categories of ecosystem services	Ecosystem service	Description
Provisioning services	Water provision	Water for livestock, humans and wildlife (Springwater, Rivers and water harvesting)
		Mist trapping
	Pasture provision	Pasture for livestock and wildlife
		Root tubers
	Energy	Wind energy
		Fuelwood
		Charcoal
		Solar energy
	Building materials	Thatch grass
		Timber
		Poles
		Tree buck
		Basaltic rocks
		Murram for building houses and roads
		Red soil
	Non-timber forest products	Bushmeat
		Wild fruits
		Wild pumpkin
		Wild honey
		Fragrance shrubs
		Medicinal plants for humans and livestock
	Raw materials	Stools, baskets, mats, toothbrush, milking container, gourd, headrest
		Dyes for skin and leather
		Wild skins for roofing of houses
		Camel bell
		Arms (spears, arrows, clubs)
		Carvings
		Arrow poison
		Ritual sticks
		Ceremonial plants
Regulating services	Climate regulation/rainfall attraction	Higher rainfall relative to the surrounding
		Cool temperatures all year
		Tree shade
		Fresh air
	Flood/stormwater control	Flood water control
Supporting services	Groundwater recharge	Aquifer recharge for springs in Maikona, Kalacha and North Horr
	Habitat for biodiversity	Home to wildlife
	Agriculture /settlement	Home to humans
	Soil formation	Support agricultural production
Cultural services	Spiritual values	Cultural sites
		Sacred sites
	Cultural identity	Hurri hills elicits a sense of pride and identity

2.3. Data analysis

The identified ES in the local dialect were translated into the English language and grouped into provisioning, regulating, cultural and supporting services, following the categorisation of the Millennium Ecosystem Assessment (MEA, 2005). Content analysis a systematic coding and categorising approach used for exploring verbal discussions to determine trends and patterns of words (Powers and Knapp, 2006; Gbrich, 2007) was used to establish the frequency of ES and their threats. Key ES and threats were assigned codes and their frequency quantified within and between the FGD. The data was analysed using the preference ranking approach by Martin (2004) and displayed in tables. The ranking identified the most frequently used tree species for livestock forage, medicinal uses and building construction per location as identified. The frequency of the most preferred species per location was then averaged and ranked to identify the most preferred species across the HH ecosystem. The species mentioned most times for a given ES was considered the most important while the most important species overall was the species with more uses and mentioned most times. The Jaccard similarity coefficient (J), (Eq.1) (Halkidi et al., 2002) was used to compute the similarity between ES and ES threats within and between FGD groups.

$$J(i,j) = sim(i,j) = \frac{a}{a+b+c} \tag{1}$$

where:

i. a is the number of attributes (presence /absence) that are equal for both objects i and j (ES/Threats),
ii. b is the number of attributes that equal 0 for object i but equal 1 for object j,
iii. c is the number of attributes that equal 1 for object i but equal 0 for object j.

A value of 1 indicates complete similarity, while 0 indicates complete dissimilarity. The conservation status of wildlife species observed by the communities was verified through the Wildlife Conservation and Management Act 2013 classification (GoK, 2013), IUCN Red List for conservation status (www.iucnredlist.org), and the CITES classification (The CITES species CITES).

3. Results

3.1. Ecosystem services as perceived by FGD

Eighty-two respondents from seven villages in HH identified over forty ES they were familiar with including, provisioning, regulating, supporting and cultural (Table 1). According to the ranking, the most significant ES provided by HH common across all the seven villages was water provision (both domestic and livestock), pasture provision, fuelwood provision, thatch grass, cultural sites, cultural material, wildlife habitat, agriculture /settlement and climate regulation/rainfall attraction (Annexe 4). In addition, over thirty commonly observed wildlife species were identified with *Struthio molybdophanes, Phacochoerus africanus, Hyaena hyaena, Acinonyx jubatus, Loxodonta africana, Equus grevyi, Lycaon pictus, Panthera pardus* and *Panthera leo* classified as between near threatened and endangered according to the 2013 Wildlife Act of Kenya and IUCN Red List Status 2017 (Annexe 5). The FGD identified deforestation, unsustainable utilisation of resources, overgrazing, climatic variability and the lack of active management as the main threats facing the sustenance of ES in HH (Table 2). The Jaccard index of similarity (J) varied for the various provisioning services with an index of 0.73 for ES provision, 0.27 for forage species, 0.52 for fuelwood species, 0.29 for medicinal species and 0.36 for tree species for building purposes. The Jaccard index for the first nine ES provided in the seven villages and the threats to ES provision was 1 and 0.91 respectively.

3.2. Community water sources

The FGD identified seventeen water points for domestic use, livestock and wildlife watering (Table 3).

Table 2
Threats to ES provision as perceived by local communities in the FGD.

Threats to ES provision	Villages								
	AB	BQ	SH	BR	HHC	JA	MN	Frequency	Rank
Deforestation,	√	√	√	√	√	√	√	7	1
Unsustainable utilisation of resources	√	√	√	√	√	√	√	7	1
Climatic variability	√	√	√	√	√	√	√	7	1
Overgrazing	√	√	√	√	x	√	√	6	4
Lack of active management	√	√	x	√	x	√	√	5	5

NB: Unsustainable utilisation of resources denotes overexploitation of thatch grass, fuelwood, medicinal plants, poles/timber/tree buck, ceremonial plants, bush meat (poaching), gum and resins.

3.3. Most important species providing provisioning ecosystem services

3.3.1. Forage species

Twenty-nine forage species of significance to the communities were identified with *Grewia* spp.*, Cordia quarensis, Pilliostigma thoningi, Olea africana, Erythrina abyssinica* and *Acacia mellifera* as the most preferred species (Annexe 6). The main grass species were, *Themeda triandra, Chrysopogon plumulosus, Aristida* spp.*, Setaria incrassate, Chrysopogon plumulosus* and *Dichanthium insculptum*. The significance of individual forage species varied across the seven villages.

3.3.2. Firewood provision

The FGD identified eighteen tree species for firewood provision: *Grewia trichocarpa, Grewia villosa, Acacia tortilis, Acacia mellifera* and *Acacia nilotica* were the most preferred (Annexe 7). The significance of individual forage species varied across the seven villages.

3.3.3. Medicinal plants

Twenty-five medicinal plant species of significance to the communities were identified, with *Carissa edulis, Echinops hispidus, Osyris compressa, Euphorbia tescorum* and *Aloe barbadensis* as the most preferred (Annexe 8). These medicinal plants treated various ailments, e.g., malaria, fever, wounds and stomach problems, among others (Table 4). The significance of individual forage species varied across the seven villages.

3.3.4. Construction material

The community used seventeen tree species for building purposes: *Grewia bicolor, Diospyros abyssinica, Olea africana, Haplocoelum foliolosum* and *Cordia ghafar* were the most preferred species (Annexe 9). Plants in this category were used to frame traditional houses and as poles, while *Euphorbia* spp. was used as live fences. *Sansevieria ehrenbergii, Aristida adscensionis* and *Paspalidium desertorum* grass species were the most preferred thatching grass, while basaltic rocks and red soil was used for walling. The significance of individual forage species varied across the seven villages.

4. Discussion

4.1. Ecosystem services as perceived by the FGD

These results demonstrate the significance of the HH ecosystem in the provision of at least 40 ES to the Gabbra community of Marsabit County. The ranking of water provision, pasture provision, fuelwood provision, thatch grass, cultural sites, cultural material, wildlife habitat, agriculture/settlement and climate regulation/rainfall attraction as the most significant ES underlines the significance of HH in the community's livelihood provision. The high Jaccard index of similarity (0.73) recorded between the seven villages and an index of 1 for the first nine ES provided in HH further suggests that the HH ecosystem is the livelihood of the local community. The 0.73 Jaccard index of similarity also suggests that different locations utilised/perceived ES provided by HH differently. This is in support of Cuni-Sanchez et al. (2016) who in a study of ES provision in forest islands in the deserts of northern Kenya concluded that ethnicity and location affect ES identification and importance ranking. Scholte et al. (2015) further concluded that communities value ES differently based on a set of factors, including: (i) social aspects (e.g., cultural background, social network) and personal (e.g., income, age, gender, education, location of residence) characteristics and also (ii) interactions among stakeholders and ES associated with use, perception and knowledge. It is therefore plausible to conclude, that locational differences, age variation, gender and cultural aspects observed in HH had a bearing on the variability of perception and utilisation of ES. Most of the provisioning, regulating, supporting and

Table 3
Community water sources in HH.

Water source	Description	Usage
Yaa Gala water pan	Man-made pan	Livestock watering/ human use
Blalat water pan	Man-made pan	Livestock watering/wildlife use/human use
Holo Gandile water pan	Man-made pan	Livestock watering/wildlife use/human use
Underground tank 1 (Jaldesa group)	Man-made tank	Livestock watering/wildlife use/human use
Underground tank 2 (Badda hurri group)	Man-made tank	Livestock watering/wildlife use/human use
Underground tank 3 (Hurri women group)	Man-made tank	Livestock watering/wildlife use/human use
Underground tank 4 (Nanok group)	Man-made tank	Livestock watering/wildlife use/human use
Underground tank 5 (Biliqa group)	Man-made tank	Livestock watering/wildlife use/human use
Borr dam	Man-made dam	Livestock watering/wildlife use/human use
Jatama dam	Man-made dam	Livestock watering/wildlife use/human use
Mboga dam	Man-made dam	Livestock watering/wildlife use/human use
Bori dam	Man-made dam	Livestock watering/wildlife use/human use
Shankera dam	Man-made dam	Livestock watering/wildlife use/human use
Tullu gab dam	Man-made dam	Livestock watering/wildlife use/human use
Baqaqa spring	Natural spring	Livestock watering/wildlife use/human use
Maddo katelo spring	Natural spring	Livestock watering/wildlife use/human use
El dola spring	Natural spring	Livestock watering/wildlife use/human use
River Dambito	Seasonal river	Livestock watering/wildlife use/human use

Table 4
Medicinal species as perceived by local communities in the FGD.

Common Names	Scientific Names	Treatment
Arsa	*Gnidia stenophylla*	Malaria, fever, stomach acid
Harkeena	*Euphorbia tescorum*	Fever, malaria, respiratory diseases, diarrhoea and sexually transmitted diseases (STIs)
Arges	*Aloe barbadensis*	Malaria, asthma, eye, glands, bones ache, stomach problems, STIs
Ejersa	*Olea Africana*	Malaria
Jijirmocho	*Ipomoea jonaldisonii*	Snakebite, cleans womb, malaria
Anchacha	*Arobanche minor*	Whooping cough, stomachache
Dag'ams	*Carissa eduliss*	Treats STIs, snake bites, bones ache, boils, cleans wombs, malaria, epilepsy, yellow fever
Mululach	*Populus ilicifolia*	Tongue wounds
Banya	*Blespharispermum pubescens*	Severe headache
Birres	*Terminalia kilimanduscharica*	Cleans womb, stomach ache, yellow fever
Iddi tiroftu	*Withania somnifera*	Snakebite, malaria
Burs	*Echinops hispidus*	Livestock constipation
Qorqodha	*Pavonia zeylanica*	Evil eye
Wanga	*Acacia nubica*	STIs
Awacho	*Albizia anthelmintica*	Worms, cleans womb, bone and joint pain, headache, stomach discomfort
Oda	*Ficus sycomorus*	Camel pus/wounds
Sotowes	*Platycelyphium voense*	Yellow fever, bone and joint pain
Gaddah	*Zanthoxylum chalybeum*	Treats throat infections
Walena	*Erythrina abyssinica (Roots, buck)*	Snakebites, malaria, sexually transmittable diseases such as syphilis and gonorrhoea, amoebiasis, elephantiasis, cough, liver inflammation, stomach-ache, colic and measles
Korobo	*Terminalia parvula*	Venereal diseases, diarrhoea, dysentery, colic, pneumonia, cough, skin diseases, schistosomiasis, gonorrhoea and problems with menstruation
Waraa	*Commiphora* spp.	Treat/dress wounds, relieve painful swelling, treat menstrual complications

cultural ES recorded in this study have been mentioned in various studies, e.g., Marsabit Forest Reserve (Githae et al., 2008; Cuni-Sanchez et al., 2016; Muhati et al., 2018a, 2018b), Mount Kulal and the Nyiro Mountains in northern Kenya (Cuni-Sanchez et al., 2016) and the five water towers in Kenya comprising the Mau Forest Complex, Mount Kenya, the Aberdares, Mount Elgon and Cherangani (UNEP, 2016). These ES have also been noted in other African forests (e.g., Dave et al., 2017; Ward et al., 2018; Cuni--Sanchez et al., 2019).

4.1.1. Water provision

Responses identifying water as one of the most important ES in HH was unsurprising considering that the HH ecosystem is located between Chalbi and Dida Galgalu desert and in a drought-prone area where water is a premium commodity. According to the FGD, HH is a wet season grazing area for livestock and wildlife and depends on River Dambito, a seasonal river for water needs. The natural springs, water pans and dams in HH are (Table 2) managed by appointed local elders known as Aba Herega. Aba Herega govern the overall management of all the water points by allocating watering days to pastoralists and setting by-laws. The association sets by-laws, e.g., closing the water points during the wet season, charging penalties for straying animals and unauthorised entry into the water pans. Water collected from mist condensed on tree branches (e.g., *Eucalyptus* spp., *Lucerne* spp.) funnelled along the trunk using plastic sheets in HH is an alternative water source for household use (Fig. 3). According to respondents, fog that lasts for 4 h can harvest over 200 litres of water per tree and is common around the HH township.

However, due to climate-related changes, the respondents observed that the duration of fog/mist occurrence has drastically reduced in hours per day over time, and thus this method of water harvesting is no longer as effective. Water is frequently the most important ES mentioned in drought-prone areas, such as southwest China (Allendorf and Yang, 2013) and in the desert in south Israel (Orenstein and Groner, 2014). Indeed, as observed in HH, water is the most important ES provided by the montane forests of Kenya, often known as Kenya's 'Water Towers' (UNEP, 2012).

Fig. 3. Collecting water for domestic use from fog trapping in Hurri hills (Photo taken by Cuni-Sanchez in October 2015).

4.1.2. Energy provision

Fuelwood provision ranked highly in all the seven locations around HH and was used by households daily for cooking and lighting purposes. With a poverty rate of 83.2% (CRA, 2014), the primary energy source in Marsabit County is fuelwood used by 98.6% of the residents for their fuel needs (KWS, 2016). Fuelwood provision is a critical ES provided by ecosystems in Kenya and is considered the main form of biomass energy, meeting the needs of over 64.5% of households, particularly in the rural setup (Wiesmann et al., 2014). This observation was validated by the MCIDP (2013–2017), which concluded that 96% of the Marsabit County population relied on fuelwood for their daily energy source for cooking and lighting purposes. This is partly attributed to the county's poverty levels, which is the largest and second poorest in Kenya, with a poverty rate of 83.5%, according to GoK (2011). The communities living in HH complement the use of fuelwood with a solar-powered system to light up their homes and operate various appliances (Fig. 4). The construction of the solar plant was funded by donors ensuring that the town runs on green energy and offering energy diversity.

Recent studies by Cuni-Sanchez et al. (2016), Muhati et al. (2018a, 2018b), Ouko et al. (2018), Dan et al. (2021) highlighting the importance of fuelwood as an energy source for the poor communities living around the island forests in northern Kenya are in support of our findings. Communities considered fuelwood a cheaper option to kerosene, liquified gas and charcoal imported from the neighbouring Maikona town and Marsabit and Moyale towns. The preference ranking for wood fuel species was based on the tree species' availability, distribution, and accessibility per location and could explain the low J index (0.52) computed in the study area.

4.1.3. Pasture and forage provision

Pasture and forage provision were considered essential ES for local communities considering that HH is a critical dry season pasture refuge for livestock and wildlife populations. The dominant *Themeda triandra* and *Chrysopogon plumulosus* grass species augmented by *Aristida* spp., *Setaria incrassate* and *Dichanthium insculptum* allowed the locals to breed livestock all year round, providing the much-needed milk and meat supplies. While pasture is the most preferred form of livestock forage in HH, given their free-range form of pastoralism, tree fodder is equally critical, particularly during the dry season when pasture is scarce. While the Aba Herega, responsible for rangeland management, do not encourage the felling of live trees for fodder purposes, respondents admitted to occasionally doing so to feed their livestock during the dry season. However, the use of pangas (machetes) to trim the branches of palatable forage trees to feed their livestock during the drought season and revert to the perennial grass when the conditions are favourable is tolerated. Various studies have considered fodder to be a critical ES complementing pasture among pastoralists in northern Kenya (Cuni-Sanchez et al., 2016, 2019; Muhati et al., 2018a, 2018b; Ouko et al., 2018). Communities ranking of fodder tree species was premised on its availability, accessibility, nutritional value and palatability. Considering the treacherous hilly terrain in HH, the most palatable forage species in proximity and readily available for livestock was most preferred to species of nutritious value but further off homesteads. This conclusion may explain the varied responses in forage species preference and ranking per location and hence the low J index (0.29) recorded.

4.1.4. Construction material

Construction material was considered a critical ES by the locals, particularly in the building of the roof structure in traditional houses, supply of poles, the framing of traditional houses and fencing of homesteads and cattle bomas. The house poles were made from various tree species (Annexe 9), with *Sansevieria ehrenbergii* (wild sisal) used for making ropes for fastening intersecting poles, doors and room partitions. The use of timber from ecosystems for housing needs has also been documented by Githae et al. (2008), Cuni-Sanchez et al. (2016), Muhati et al. (2018a) in the dry montane forests of Mt Marsabit, Mt Kulal and Mt Nyiro in northern Kenya. The roof and a section of the walls in the houses in HH are traditionally covered with thick grass-tufts made from *Sansevieria ehrenbergii, Aristida adscensionis* and *Paspalidium desertorum* perennial grasses, which occur notably in proliferation in HH (Fig. 5). *Commiphora* spp. was mainly used for constructing fences for ritual ceremonies and live fences in homesteads.

During the seasonal migration of livestock to the lowlands for pasture and water during the dry season, the Gabbra community put up temporary settlements (*fora)* where they barricade their camps and animal enclosures against predators using thorny branches from

Fig. 4. Solar plant at the HH centre (Photo taken on 26:09:2019 by Godwin Muhati).

Acacia tortolis and *Acacia rejiciens* shrubs. The Gabbra also constructed their houses using basaltic rock commonly found in HH, which is held firm with branches from various tree species. The locally available red soil was used as a form of local cement plastering the basalt rock and the poles together. These basaltic rocks were also used to construct livestock enclosures to prevent depredation from the hyenas (*Crocuta crocuta*) and other predators during the night. The roads in the HH area were also paved using basalt rocks and murram from the local quarries making the roads passable during the wet and dry seasons. According to the respondents the choice of construction material hinged on availability, abundance, accessibility and type of structure required in the different locations. These location-specific attributes influencing community preference may therefore explain the low J index (0.36) recorded for tree species for building purposes.

4.1.5. *Wildlife habitat*

Wildlife habitat features significantly as an ES despite HH being an ungazetted ecosystem and therefore does not enjoy protection status from the county or national governments. Respondents, however, had concerns about human-wildlife conflict and wildlife depredation, which was negatively impacting their livelihoods. Depredation of their livestock by lions *(Panthera leo)*, leopards *(Panthera pardus)*, wild dogs (*Lycaon pictus*), spotted hyenas *(Crocuta crocuta)* and stripped hyaenas (*Hyaena hyaena)*, coupled with crops destruction by the antelopes, have been a significant source of concern over the years. The nearest Kenya Wildlife Service office where such conflict is reported is in Marsabit town, which is inaccessible to the majority of the locals due to the long distance and poor roads. The respondents however appreciated the role the woodlands played as a habitat for wildlife conservation and hence its significance in the priority list. Of the wildlife species commonly observed by the respondents, *Struthio molybdophanes, Phacochoerus africanus, Hyaena hyaena, Acinonyx jubatus, Loxodonta africana, Equus grevyi, Lycaon pictus, Panthera pardus* and *Panthera leo* are classified as between near threatened and endangered according to the IUCN Red List Status 2017 and 2013 Wildlife Act (Annexe 5), cementing the significance of HH as a critical wildlife refuge. This observation qualifies conclusions by Ottichilo et al. (2000) and Western et al. (2009) that 70% of wildlife in Kenya is found outside protected areas. The respondents suggested that with the abundance of wildlife in HH, sections of the expansive ecosystem could be converted into community conservancies akin to the Northern Rangelands Trust approach (NRT, 2017, 2018) in northern Kenya for wildlife protection. The establishment of conservancies in Kenya has been considered a success in supporting wildlife management practices, increased income from revenue generated from tourism, pasture management for their livestock, physical security, environmental protection and community livelihood improvement, particularly in northern Kenya (Glew et al., 2010). This has been the case for the Songa Conservancy (109, 861 ha), Shurr Conservancy (425,183 ha), Jaldesa Conservancy (52, 078 ha) and Melako Conservancy (54,677 ha) in Marsabit, which augment wildlife conservation (NRT, 2017, 2018). Protected areas (PAs) initiated by national governments in various jurisdictions have been proven to be effective in restoring degraded ecosystems (Andrade and Rhodes, 2012). However, in the same breath due to resource and access restrictions, PAs do not always generate the desired benefits to the local population. Consequently, conservation approaches that integrate ecosystem conservation and natural resources management like the conservancy approach proposed by the communities, may be more effective. Respondents noted the decreasing population of various antelope species (*Tragelaphus scriptus*, *Nanger granti*, *Aepyceros melampus*, *Litocranius wallert, Madoqua guentheri* and *Eudorcas thomsonii)* relative to earlier years which they suggested was declining due to poaching for bushmeat consumption. For example, they observed that the last white rhinoceros (*Ceratotherium simum*) in HH was poached in 1984 for its ivory horns, extirpating the species in that region. The establishment of community conservancies in their opinion is expected to reign in on unsustainable utilisation of forest resources as well as the illicit bushmeat trade.

4.1.6. *Climate regulation/rainfall attraction*

Respondents considered climate regulation/rainfall attraction a critical ES sustaining livelihoods in the forest area. Respondents attributed the favourable climatic conditions for agro-pastoralism to the chain of hills at high altitude, which regulates the microclimate of the area compared to the surrounding desert-like conditions. HH residents being in a high-altitude area, enjoy rainfall of between 800 and 1000 mm, moderate temperatures ranging between 15ºC–27ºC with rich soil conditions relative to the lowlands

Fig. 5. Traditional house made of *Grewia* spp. with the roof made of *Aristida adscensionis* thatch (Photo taken on 24:09:2019 by Godwin Muhati).

where rainfall is between 200 and 250 mm with poor soils. This response corroborates studies by Cuni-Sanchez et al. (2016), Muhati et al. (2018a, 2018b) and UNEP (2016), citing regulating services such as local climate regulation as critical ES provided by the montane forests in Kenya. Carbon sequestration plays a significant role in carbon dioxide removal from the atmosphere and climate stabilisation (IPCC, 2014, 2021). However, this ES did not feature in the responses as critical in the HH ecosystem. All of the participants were unfamiliar with this ES, which may be attributed to the low literacy levels, lack of awareness and the fact that this ES is yet to be exploited in HH under the REDD+ framework. This observation was also made by Muhati et al. (2018a) in the Marsabit Forest Reserve where local communities were not conversant with this ES with the government agencies managing the forest barely familiar with the carbon sequestration mechanism. Given that HH is covered by 80% grassland (F.A.O, 1971) and acknowledging the significance of soils as a repository of soil carbon (IPCC, 2014; Mbaabu et al., 2020), studies on the quantification of carbon stocks in the HH ecosystem may be necessary.

4.1.7. Medicinal plants

The FGD considered medicinal plants a critical ES provision though not as prominent as water, forage, fuelwood and climate regulation. Gabbra traditional medicine is administered by traditional practitioners who take up this profession from their family lineage. Traditional medicine from the forested pockets of HH is collected in the form of roots, bulbs, fruits, latex, tubers, tree bark, leaves, branches and seeds, using them to treat various ailments (Table 3). The most common form of administering the remedies was through oral ingestion after boiling the medicine, as was the case for stomach ailments, malaria, asthma, stomach infections/bloating, whooping cough and STIs. Eye infections, snake bites, open wounds and skin infections were treated by direct application of herbal juice or latex, crushed extract, i.e., (*Aloe barbadensis*), while *Withania somnifera, Pavonia zeylanica,* and *Commiphora* spp. were burned before ingesting or applying the resulting ash. Diseases and other health problems were treated with single plants species only. However, if the patients condition was not improving, another plant of the same treatment category was applied. The importance of the medicinal plant use in HH is in support of previous studies in similar ecosystems in northern Kenya (e.g., Bussmann, 2006; Watkins and Imbumi, 2007; Jusu and Sanchez, 2013; Muhati et al., 2018a; Delbanco et al., 2017; Dan et al., 2021). Respondents ranked medicinal plant species based on their availability, abundance, location, and the type of illness to be treated. This may explain the varied responses in medicinal plant species used in the various locations in HH and thus the low J index (0.29) recorded. Due to limited access to health facilities, high poverty levels, poor infrastructure and long distances between health facilities, respondents acknowledged the significance of this ES in the rural areas.

4.2. Settlement/agriculture

Respondents indicated that the first settlers, predominantly the Gabbra community came to HH in 1976 from the low land areas of Forole, Maikona, Balesa and Turbi. Due to favourable soils, the early settlers practised agriculture and kept livestock for their daily needs. They grew crops such as maize, beans, wheat, teff, sorghum, khat, tobacco, kale, spinach and onions, among other crops (Fig. 6). They chose this location primarily because the climatic conditions were conducive for human habitation and had a montane climate with predictable rains relative to the surroundings. The forest provided them with fresh water and food in the form of wild fruits, nuts, vegetables, berries, mushrooms, honey and root tubers. The forest also provided them with raw materials required for house construction and making household accessories. Local communities utilised raw materials from the forest to make products like baskets, mats, stools, calabashes, gourds, toothbrushes, bowls, spoons, cups, headrests, cowbells, brooms, ritual sticks, spears, swords and clubs accessories required for their day to day social cultural and economic activities.

For example, mats were woven from *Commiphora* spp. and used as mattresses by women, children and the elderly for resting and occasionally sleeping. Stools were made from *Erythrina abyssinica* and *Commiphora* spp. and were used in the household, homesteads, were carried around for meetings in the village and also used during wedding ceremonies. (Fig. 7).

Fig. 6. Crop production for domestic use on the (left) maize production on the (right) beans production (Photo taken on 24:09:2019 by Godwin Muhati).

Toothbrushes were made from semi-mature branches of various tree species (*Lannea floccose, Acacia senegal, Commiphora* spp., *Teclea simplicifolia, Acacia reficiens* and *Acacia mallifera*). They were made by chewing the edge of a branch and used as a supplementary toothbrush to clean and strengthen the gums. Respondents observed that selected trees species used for making toothbrushes, e.g., *Commiphora* spp., also contained medicinal properties and as such, complemented dental hygiene with the management of other ailments (Fig. 8) (Table 4).

Cattle bells, fat storage containers, and milking containers were made from *Asparagus africanus* roots and *Delonix elata* (Fig. 9). In contrast, bowls, spoons, cups and calabash gourds were made from *Erythrina abbysinica* tree species.

Sandalwood (*Santalum album*) was used as a fragrance wood species for the body, clothing and house environment. It was prepared by burning in low temperatures to produce smoke rich in aroma, in which women hung their clothes to serve as a deodorant. In addition, the flowers and wood of sandalwood was harvested for the plant's fragrant essential oil. HH also provided spiritual and recreational services, which offered the early settlers opportunities for relaxation and aesthetic appreciation of the mountain relative to the surrounding desert-like environment. The mountain range also provided various sacred/cultural sites, which served as grounds for initiation rites, rites of passage and prayer sites enhancing their sense of place and spiritual purpose (Fig. 10).

From the responses, ceremonial/cultural plants use figured importantly in the Gabbra community. Different species had specific ceremonial significance, primarily associated with blessings, ages-rites and marriages. For example, *Acacia tortilis, Commiphora candula, Erythrina abyssinica, Olea Africana* and *Erythrina abyssinica* were used to make traditional stools used during marriage ceremonies. *Olea africana* and *Cordia africana* were used to make ritual sticks, while specific parts of *Acacia tortilis* was cut and put on the rooftop when a baby boy was born. During such ceremonies, spears, swords, clubs (rungus) and sticks were accessorised by men, usually indicative of their position in the society. Warriors carried bows and spears, clubs and arrows were used by young adults while the elders carried sticks. Straight branches of various *Acalypha* spp. were preferred for making arrows. *Tarenna abyssinica*, *Tarenna holstii* and *Olea africana* were the preferred species for rungus (warclubs), while *Dombeya goetzenii* and *D. rotundifolia* were in high demand for spear shafts. *Gnidia glauca* and *Acokanthora schimperii* were the only species used as arrow poison. In this case, the bark of the tree was boiled in water for several hours and the remaining residue smeared on arrow tips. From the discussions in the FGD, it was evident that indigenous knowledge systems were critical in the local management of the HH ecosystem. These systems formed the basis for community-level decision making in aspects of resource use, protection of cultural and sacred places, construction, food security, human and animal health, education and more importantly natural resource management. In the absence of KWS and KFS in wildlife and forest management respectively in the HH ecosystem, it is the indigenous knowledge systems transferred over generations that have sustained natural resource conservation.

5. Threats to ES provision in HH

5.1. Deforestation

The high Jaccard similarity coefficient index (0.91) recorded across the locations for the main threats to ES provision suggests that local communities had a common understanding of the main forcings affecting the ability of HH to sustain ES. FGD respondents expressed concern over the observed deforestation over time which had decimated the once forested HH ecosystem to the current grassland and pockets of high canopy forests in the laggas. Respondents asserted that livestock herders' intentional burning of the forest to kill ticks during the dry season in anticipation of seasonal rainfall had played a key role in reducing the forested landscape.

Fig. 7. Traditional stool made from *Erythrina abbysinica* (Photo taken on 26:09:2019 by Godwin Muhati).

Fig. 8. Traditional toothbrush made from *Commiphora* spp. (Photo taken on 26:09:2019 by Godwin Muhati).

Fig. 9. Livestock bell hanged on camel neck made from *Delonix elata* (Photo taken on 26:09:2019 by Godwin Muhati).

Fig. 10. Sacred site in HH (Photo taken on 26:09:2019 by Godwin Muhati).

According to the respondents, uncontrolled deforestation since the early 1960s had significantly reduced land occupied by the cloud forest to its current status affecting water provision over time. Deforestation and forest degradation negatively affects ES provision by reducing carbon capture and storage, reducing water retention and regulation and reduces biodiversity and species distribution due to natural habitats loss (Soh et al., 2019). Deforestation of montane forests negatively affects water yield, partially because of the loss in cloud water interception in these forests occurring at such high elevations (Bruijnzeel et al., 2011). Indeed, water is the most critical ES provided by the montane forests of Kenya, often known as Kenya's 'Water Towers' (UNEP, 2012). Forest loss, according to the communities, led to the dispersal of most of the larger species of mammals, like the lion (*Panthera leo*), the African elephant (*Loxodonta* *africana*), Black rhinoceros (*Diceros bicornis*), Grevy's zebra (*Equus grevyi*) and Giraffe (*Giraffa camelopardalis*). According to Anderson (1975), the evergreen forest in HH was destroyed by the Borana community carrying out a mixed agricultural/pastoral economy. However, F.A.O (1971) suggested that the forest probably never existed, but there is the possibility that it can exist given adequate protection from fire and cutting. A further study by Kihonge (2017) on LULCC trends in HH between 1973 and 2017 concluded that the area covered by the closed forest reduced significantly, with the most extensive forest cover change occurring between 1973 and 1984. However, the study was not conclusive on the hectarage of forest lost during the study period and as such, further studies to establish the extent of forest loss may be necessary.

5.2. *Unsustainable exploitation of forest resources*

Respondents decried the unchecked utilisation of forest resources as a significant threat to the continued provision of ES by the HH ecosystem. For example, in harvesting medicinal resources for treating various ailments, harvesting timber and forage for livestock, communities cut tree branches, the main stem, pluck leaves, cut down or uproot the whole tree, killing the entire plant. The removal of wood, roots or entire plants generally leads to the death of an individual, as does the cutting of the bark when ring debarking takes place (Cunningham, 1993). The selective harvesting and overexploitation of preferred tree species, e.g., *Olea africana*, *Santalum album*, *Acacia* spp., *Grewia* spp., *Diospyros abyssinica* and *Acacia seyal* used for various purposes (Annexe 6–9), could lead to population decline and eventual local extirpation. This also if left undeterred, could disproportionately affect the long-term livelihoods of the communities that depend on them (van Andel and Havinga, 2008). As highlighted by several authors (Fashing and Gathua, 2004; Githae et al., 2008; Asner, 2009; KWS, 2016; Cuni-Sanchez et al., 2016; Muhati et al., 2018b), tropical forests have the ability to self-maintenance. However anthropogenic disturbances such as selective logging of keystone species can alter their conservation value through local extirpation of species changing their structure. According to communities in HH, illegal firearms from neighbouring communities have fuelled the poaching of wildlife and the thriving bushmeat trade with reckless abandon. Bushmeat trade is considered a major threat to biodiversity conservation in Africa where it provides a critical source of protein and income to local communities (Fa et al., 2003). However, studies by Becker et al. (2013) and Lindsey and Bento (2012) have demonstrated that bushmeat trade around protected and non-protected areas, has negative ecological impacts leading to declines in wildlife species and local extirpation of endemic species. An increase in human-wildlife conflict, bushmeat trade and livestock depredation in HH coupled with delayed financial compensation to the afflicted by the relevant authorities have further dampened the local's conservation efforts.

5.3. *Overgrazing*

According to the FGD respondents, increased human and livestock populations have contributed immensely to overgrazing and habitat degradation. While the Gabbra tradition forbids illegal hunting, tree-cutting and or over-utilisation of the grazing range, it appears that due to the rapid growth of human and livestock populations in the region, considerable environmental damage was inevitable. Overgrazing is considered a huge threat to the continued provision of sustainable pasture for the local communities in HH. HH, both the eastern and western slopes, is a wet season grazing area and attracts an influx of livestock from Turbi, Bubisa, Kalacha, Maikona, Balesa and Forole towns due to the availability of surface water. Livestock grazing in the forests significantly affects soil physicochemical properties and ecosystem functions through grazing and browsing, trampling on soil, and nutrient cycling effecting soil organic carbon loss (Kikoti and Mligo, 2015). Disturbance through livestock grazing on natural ecosystems may also impact the soil structure through soil erosion after denudation of the vegetation occasioning changes in vegetation structure and floristic composition (FAO and ITPS, 2015). The respondents believe that overgrazing during the dry season impeded the growth of the forest understory through trampling of saplings and juvenile trees, uprooting of palatable saplings, consequently converting grasslands to bare land and increasing soil erosion through the loosening of topsoil.

5.4. *Climate change*

FGD respondents considered climate change an existential threat to the continued provision of ES in HH. Over the years, they assert that they have relied on rainwater and mist harvesting to sustain their subsistence farming and livestock keeping. However, due to the impacts of recurrent and sustained drought episodes, several wells and underground water tanks (both communal and private) have been drying up faster than envisaged exacerbating an already dire water shortage problem. According to them, the long rains (main planting season) have been irregular over time, poorly distributed and depressed in intensity, having a huge bearing on water storage potential and agro-pastoralism. This observation has been amplified by CGM (2013–2017), Muhati et al. (2018c) and Cuni-Sanchez et al. (2018) in studies in the Marsabit Forest Reserve, with potentially huge implications for agricultural activities in the main planting season. Climate change is likely to increase the pressures that forests are currently facing as tree dieback increases with depressed rainfall and increased incidences of pests and diseases with the likely increase in forest fires (IPCC, 2014, 2021). As suggested by IPCC (2021), the most cost-effective mitigation option for forest systems like HH is increasing their resilience through nature-based solutions like sustainable forest management. As noted by the communities, the lack of active management in the HH ecosystem, despite its significance as a habitat for plants and wildlife of significant socio-economic and biological importance, further compounds the challenges.

6. Conclusions and recommendations

The HH ecosystem represents a vital source of ES to the Gabbra community providing provisioning, regulating, supporting and cultural services. Of particular importance is the provision of water, pasture, agriculture/settlement, cultural material, cultural sites, wildlife habitat, medicinal plants, thatch grass, climate regulation and fuelwood for household energy needs. However, the ecosystem faces severe threats predominantly anthropogenic, which threaten the provision of these ES. They include; deforestation, climatic variability, overgrazing, lack of active management and unsustainable utilisation of forest products. Understanding how local communities use and value HH and its inherent threats jeopardising continued ES provision is essential to ensure that it is sustainably managed. These results support the need for participatory resource use planning that takes into account the inherent threats to the provision of ES in the HH ecological system. The resource use planning should endeavour to integrate indigenous knowledge and its best practices into contemporary environmental management systems in an attempt to bridge the gap between planning and implementation of conservation efforts at the local level. The study recommends undertaking a baseline survey to establish the status and distribution of the main plant and animal taxa, information that will form the basis for a comprehensive resource use plan. The results of the baseline survey will inform decision-makers on the viability of establishing community conservancies as suggested by the local communities.

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Authors Contribution

The author, Godwin Leslie Muhati, was involved in data collection, data analysis, manuscript writing, and proofreading.

Declaration of Competing Interest

The author declares the following financial interests/personal relationships which may be considered as potential competing interests, Godwin Leslie Muhati reports financial support was provided by French Development Agency. Godwin Leslie Muhati reports a relationship with Kenya Wildlife Service that includes: employment.

Data availability statement

The data used in the development of this manuscript are available from the corresponding author upon request.

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Annexe 1. Sample Questionnaire focus group discussions guiding questionnaire?

Introduction and explanation of the survey.
The current study is a research project whose overall objective is two-fold.
Part 1: To establish the ecosystem services the Hurri hills provides.
Part 2 Is to establish the threats afflicting ecosystem services and their provision in Hurri hills.
The language of facilitation; Gabbra.
Part 1: To establish the ecosystem services the Hurri hills provides.
The Hurri hills and the services it provides.

1) Do you have any knowledge about Hurri hills?
2) Do you believe this is an area of special interest to the community?
3) Of these goods and services, which are the most important to the community?
4) What are the goods and services that the forest provides to you? (Facilitator extensively introduces the terminology ecosystem services to the respondents and the different categorisation). (i.e., water, fuelwood, pasture, medicinal plants, cultural site, wildlife habitat)
5) Which tree species are extracted from the forest for forage use? (Local and scientific names)
6) Which tree species are extracted from the forest for medicinal use? local and scientific names)
7) Which tree species are extracted from the forest for building use? local and scientific names)
8) Which are the most common wildlife species observed in the area?

9) What are the community water sources available in the forest and their usage in Hurri hills? (Take pictures, GPS positions and name the sites)

Part 2: Threats afflicting ecosystem services in Hurri hills.

1) Is there any issue that you may wish to add concerning the Hurri hills resources and their utilisation?

2) If yes, what is the most important issue of concern in the Hurri hills? (e.g., land-use change, overexploitation of resources, climate change, overgrazing, logging, over-abstraction of water, poaching etc.).

3) What are the driving forces that fuel this issue of concern? (i.e., the triggers that fuel question).

4) What are the impacts of forest threats to ecosystem goods and services?

The answers provided will be kept confidential and used only for scientific purposes. No unauthorised person will gain access to the information.

Annexe 2. Focus Group Discussion Session Plan/Schedule on The Ecosystem Services Hurri Hills, Provides for the seven villages

Item	STEPS	TIME ALLOCATION	RESPONSIBLE PERSON	FGD VILLAGE MEETING SCHEDULE
	THE OPENING ENGAGEMENT			1) Hurri hills centre, 20:09:2019 2) Jaldesa 21:09:2019 3) Bori Village 23:09:2019 4) Baqaqa 24:09:2019 5) Manguddo25:09:2019 6) Ali Boru 26:09:2019 7) Shankera, 27:09:2019
1	Welcoming the community group and ushering them into the venue of the meeting	5 min	Research lead /Local chief	
2	Word of Prayer led by one of the local participants	5 min	Research lead /Local chief	
3	Formal introductions of the facilitator, research team and participants.	5 min	Research lead /Local chief	
4	The facilitator explains to the participants the following; i. Objective/purpose of the study/survey/FGD. 1: To establish the ecosystem services the Hurri hills provides. 2: To establish the threats afflicting ecosystem services and their provision in Hurri hills i. How the participants were selected to be part of that FGD and the future use of the data. ii. The roles of facilitator, notetaker and participants. iii. The expected duration of the discussion. iv. The ground rules (e.g., mobile phones off) how the discussion will progress, emphasizing the importance of participants' honest responses, interaction, and that there are no right or wrong answers. v. Ethical considerations, including confidentiality and its limitations, voluntary participation. vi. Obtaining the participants' written or oral consent.	10 min	Research lead /Local chief	
5	**Context of the FGD** The lead researcher makes a short presentation to situate the workshop /FGD within the survey objectives.	10 min	Research lead /Local chief	
	THE EXPLORATION SECTION			
6	The facilitator asks participants questions as well as possible probing questions, in a logical sequence based on the guiding FGD questionnaire (See questionnaire)	90 min	Research lead /Local chief	
	THE CLOSING SECTION			
7	i. The facilitator invites participants to provide further information or input if they want to. ii. Participants provided with contact information, affirmation of how the data will be used is made. iii. The facilitator affirms when the survey will be complete and findings disseminated.	15 min	Research lead /Local chief	
8	Word of Prayer led by one of the local participants.Facilitator and the survey team thanks the participants and leave at their pleasure.	5 min	Research lead /Local chief	

Annexe 3. Profiles of the respondent in the focus group discussions, their names are withheld for ethical reasons

Hurri Hills centre.
The language of facilitation; Gabbra.

S/no	Name	Village	Occupation	Gender	Age
1	Community member	Hurri hills centre	Farmer	Male	54
2	Community member	Hurri hills centre	Pastrolist	Male	39
3	Community member	Hurri hills centre	Farmer	Female	42
4	Community member	Hurri hills centre	Farmer	Male	30
5	Community member	Hurri hills centre	Herbalist	Female	45
6	Community member	Hurri hills centre	Farmer	Male	38
7	Community member	Hurri hills centre	Farmer	Female	25
8	Community member	Hurri hills centre	Pastrolist	Male	40
9	Community member	Hurri hills centre	Herberlist	Male	66
10	Community member	Hurri hills centre	Pastrolist	Male	54
11	Locational chief	Hurri hills centre	Chief/Facilitator	Male	48

Ali Boru location.
The language of facilitation; Gabbra.

S/no	Name	Village	User group	Gender	Age
1	Community member	Ali Boru	Pastrolist	Male	45
2	Community member	Ali Boru	Pastrolist	Female	41
3	Community member	Ali Boru	Pastrolist	Male	35
4	Community member	Ali Boru	Pastrolist	Male	54
5	Community member	Ali Boru	Honey collectors	Female	32
6	Community member	Ali Boru	Pastrolist	Female	29
7	Community member	Ali Boru	Pastrolist	Male	37
8	Community member	Ali Boru	Pastrolist	Male	46
9	Community member	Ali Boru	Pastrolist	Male	35
10	Community member	Ali Boru	Pastrolist	Male	46
11	Community member	Ali Boru	Chief/facilitator	Male	43

Bori location.
The language of facilitation; Gabbra.

S/no	Name	Village	User group	Gender	Age
1	Community member	**Bori**	Pastrolist	Male	47
2	Community member	**Bori**	Pastrolist	Female	35
3	Community member	**Bori**	Pastrolist	Male	46
4	Community member	**Bori**	Pastrolist	Male	48
5	Community member	**Bori**	Herberlist	Male	71
6	Community member	**Bori**	Honey collectors	Male	23
7	Community member	**Bori**	Pastrolist	Male	20
8	Community member	**Bori**	Pastrolist	Female	49
9	Community member	**Bori**	Pastrolist	Male	52
10	Community member	**Bori**	Pastrolist	Male	62
11	Community member	**Bori**	Chief/facilitator	Male	44
12	Community member	**Bori**	Pastrolist	Male	46
13	Community member	**Bori**	Pastrolist	Female	51
14	Community member	**Bori**	Pastrolist	Male	48

Shankera location.
The language of facilitation; Gabbra.

S/no	Name	Village	User group	Gender	Age
1	Community member	Shankera	Pastrolist	Female	41
2	Community member	Shankera	Pastrolist	Male	51
3	Community member	Shankera	Pastrolist	Male	39
4	Community member	Shankera	Pastrolist	Male	58
5	Community member	Shankera	Herberlist	Male	71
6	Community member	Shankera	Pastrolist	Male	44
7	Community member	Shankera	Honey collectors	Female	47
8	Community member	Shankera	Pastrolist	Male	28
9	Locational chief	Shankera	Chief/facilitator	Male	47

Baqaqa location.
The language of facilitation; Gabbra.

S/no	Name	Village	User group	Gender	Age
1	Community member	Baqaqa	Pastrolist	Male	58
2	Community member	Baqaqa	Pastrolist	Male	48
3	Community member	Baqaqa	Pastrolist	Female	38
4	Community member	Baqaqa	Pastrolist	Male	48
5	Community member	Baqaqa	Herberlist	Male	55
6	Community member	Baqaqa	Pastrolist	Female	41
7	Community member	Baqaqa	Pastrolist	Female	28
8	Community member	Baqaqa	Herbalist	Male	69
9	Community member	Baqaqa	Pastrolist	Male	41
10	Community member	Baqaqa	Pastrolist	Male	51
11	Community member	Baqaqa	Pastrolist	Male	48
12	Community member	Baqaqa	Pastrolist	Male	43
13	Locational chief	Baqaqa	Chief/facilitator	Male	51

Jaldesa location.
The language of facilitation; Gabbra.

S/no	Name	Village	Occupation	Gender	Age
1	Community member	Jaldesa	Farmer	Male	44
2	Community member	Jaldesa	Pastrolist	Female	50
3	Community member	Jaldesa	Farmer	Female	51
4	Community member	Jaldesa	Farmer	Male	48
5	Community member	Jaldesa	Herbalist	Female	45
6	Community member	Jaldesa	Farmer	Male	42
7	Community member	Jaldesa	Farmer	Female	39
8	Community member	Jaldesa	Pastrolist	Male	40
9	Community member	Jaldesa	Herberlist	Male	61
10	Community member	Jaldesa	Pastrolist	Male	54
11	Community member	Jaldesa	Pastrolist	Male	42
12	Community member	Jaldesa	Pastrolist	Male	44
13	Locational chief	Jaldesa	Chief/Facilitator	Male	43

Manguddo location.
The language of facilitation; Gabbra.

S/no	Name	Village	Occupation	Gender	Age
1	Community member	Manguddo	Pastrolist	Male	44
2	Community member	Manguddo	Pastrolist	Female	38
3	Community member	Manguddo	Pastrolist	Female	52
4	Community member	Manguddo	Pastrolist	Male	41
5	Community member	Manguddo	Pastrolist	Female	52
6	Community member	Manguddo	Pastrolist	Male	42
7	Community member	Manguddo	Pastrolist	Female	49
8	Community member	Manguddo	Pastrolist	Male	53
9	Community member	Manguddo	Herberlist	Male	59
10	Community member	Manguddo	Pastrolist	Male	41
11	Locational chief	Manguddo	Chief/Facilitator	Male	54

Annexe 4. ES provision as perceived by local communities in the FGD

Ecosystem services	Villages								
	AB	BQ	SH	BR	HHC	JA	MN	Freq	Rank
Water provision	√	√	√	√	√	√	√	7	1
Fuelwood provision	√	√	√	√	√	√	√	7	1
Agriculture /settlement	√	√	√	√	√	√	√	7	1
Cultural material	√	√	√	√	√	√	√	7	1
Cultural /Sacred sites	√		√	√	√	√	√	7	1
Wildlife habitat	√	√	√	√	√	√	√	7	1
Climate regulation/rainfall attraction	√	√	√	√	√	√	√	7	1
Pasture provision	√	√	√	√	√	√	√	7	1
Thatch grass	√	√	√	√	√	√	√	7	1
Medicinal plants	√	×	√	√	√	√	√	6	10
Fresh air	√	√	×	√	√	√	√	6	10
Poles/Timber/Tree buck	√	√	×	√	√	√	√	6	10
Cultural identity	×	√	×	√	√	×	√	4	13
Ceremonial plants	×	√	×	√	×	√	√	4	13
Tree shade	×	√	×	√	×	√	√	4	13
Bushmeat	×	√	×	√	×	√	√	4	13
Wild honey	×	√	×	√	×	√	√	4	13
Fragrance	×	√	×	×	√	√	√	4	13
Groundwater recharge	×	√	×	×	√	×	√	3	19
Root tubers	×	√	×	√	×	×	√	3	19
Solar energy	×	√	×	×	√	×	√	3	19
Flood water control	×	×	×	√	×	√	√	3	19
Wild pumpkin	×	×	×	√	×	×	√	2	23
Wind power	×	×	×	×	√	×	×	1	24
Charcoal	×	×	×	×	×	×	√	1	24

Note: AB= Ali Boru, BQ= Baqaqa, SH= Shankera, BR= Bori, HHC= Hurri hills centre, JA= Jaldesa, MN= Manguddo.

Annexe 5. List of common animals observed by the local communities in the FGD

Common name	Scientific name	IUCN Red List Status 2017	CITES classification	2013 Wildlife Act classification
African Buffalo	*Syncerus caffer*	Least Concern	Not Listed	Not Listed
Spotted Hyena	*Crocuta coffer*	Least Concern	Not Listed	vulnerable
Thomson's gazelle	*Eudorcas thomsonii*	Least Concern	Not Listed	Not Listed
Striped Hyaena	*Hyaena hyaena*	Near Threatened	Appendix III	Endangered
Somali ostrich	*Struthio molybdophanes*	Near Threatened	Not Listed	Endangered
Desert warthog	*Phacochoerus aethiopicus*	Near Threatened	Not Listed	Endangered
Common warthog	*Phacochoerus africanus*	Near Threatened	Not Listed	Endangered
Black-backed Jackal	*Canis mesomelas*	Least Concern	No Special Status	Not Listed
Somali lesser galago	*Galago gallarum*	Least Concern	Appendix II	Least Concern
Bushbuck	*Tragelaphus scriptus*	Least Concern	Not Listed	Not Listed
Bush duiker	*Sylvicapra grimmia*	Least Concern	Not Listed	Not Listed
Olive Baboon	*Papio anubis*	Least Concern	Appendix II	Not Listed
Grant's Gazelle	*Nanger granti*	Least Concern	Not Listed	Not Listed
African elephant	*Loxodonta africana*	Vulnerable	Appendix I	Endangered
Common Zebra	*Equus burchelli*	Near Threatened	Not Listed	Not Listed
Impala	*Aepyceros melampus*	Least Concern	Not Listed	Not Listed
Lesser kudu	*Tragelaphus imberbis*	Near Threatened	Not Listed	vulnerable
Greater kudu	*Tragelaphus strepsiceros*	Least Concern	Not Listed	vulnerable
Guenthers Dik-dik	*Madoqua guentheri*	Least Concern	Not Listed	Not Listed
Leopard	*Panthera pardus*	Vulnerable	Appendix I	Endangered
Aardvark	*Orycteropus afer*	Least Concern	Not Listed	Not Listed
Grevy's Zebra	*Equus grevyi*	Endangered	Not Listed	Endangered
Beisa oryx	*Oryx beisa*	Near Threatened	Not Listed	Not Listed
Vervet Monkey	*Chlorocebuss pygerythrus*	Not Listed	Not Listed	Not Listed
Reticulated Giraffe	*Giraffa camelopardalis*	Vulnerable	Not Listed	Not Listed
African Lion	*Panthera leo*	Vulnerable	Appendix II	Endangered
Syke's monkey	*Cercopithecus mitis*	Least Concern	Appendix II	Not Listed
Grey duiker	*Sylvicapra grimmia*	Least Concern	Not Listed	Not Listed
Common warthog	*Phacochoerus africanus*	Least Concern	Not Listed	Not Listed
Wild dog	*Lycaon pictus*	Endangered	Endangered	Endangered
African Hare	*Lepus victoriae*	Least Concern	Not Listed	Not Listed
Gerenuk	*Litocranius wallert*	Near Threatened	No Special Status	Not Listed
Cheetah	*Acinonyx jubatus*	Critically Endangered	Appendix I	Endangered

Annexe 6. Ranking of forage species as perceived by local communities in the FGD

Common Name	Scientific Name	Villages								
		AB	BQ	SH	BR	HHC	JA	MN	Freq	Ranking
Aroressa	*Grewia* spp.	√	√	×	×	√	√	√	5	1
Mad'er	*Cordia quarensis*	√	√	×	×	×	√	√	4	2
Abbarra tapp'ata	*Pilliostigma thoningi*	×	√	×	√	√	×	×	3	3
Ejersa	*Olea africana*	×	√	×	√	√	×	×	3	3
Walenna	*Erythrina abysinica*	√	×	×	√	√	×	×	3	3
Sapansa	*Acacia mellifera*	×	×	×	√	×	√	√	3	3
Banya	*Blespharispermum pubescens*	√	×	×	√	×	×	×	2	7
Barbaresa	*Plectranthus ignarius*	√	×	×	√	×	×	×	2	7
Biqa	*Pappea capensis*	×	√	×	×	×	√	×	2	7
Makannis	*Croton macrostachyus*	×	√	×	×	√	×	×	2	7
Sigirso	*Acacia reficiens*	√	×	×	√	×	×	×	2	7
Ammarresa	*Acacia brevispica*	×	√	×	×	×	×	√	2	7
Ogumdi	*Grewia villosa*	×	√	×	×	×	×	√	2	7
Deeka looni	*Grewia tenax*	×	√	×	×	×	×	√	2	7
Waachu	*Acacia seyal*	×	×	×	√	×	×	√	2	7
Chana	*Haplocoelum foliolosum*	×	×	×	×	√	√	×	2	7
Sukella	*Delonix elata*	×	×	×	×	√	×	√	2	7
Dadacha	*Acacia tortilis*	×	×	×	√	×	×	×	1	18
Hallo	*Acacia bussei*	×	×	×	√	×	×	×	1	18
Ammess	*Commiphora* spp.	×	×	×	√	×	×	×	1	18
I'd'dado	*Acacia senegal*	×	×	×	√	×	×	×	1	18

(*continued on next page*)

(*continued*)

Common Name	Scientific Name	Villages							Freq	Ranking
		AB	BQ	SH	BR	HHC	JA	MN		
Qalqalcha	*Maerua angolensis*	×	×	×	√	×	×	×	1	18
Doqa	*Cadaba glandulosa*	×	×	×	√	×	×	×	1	18
Abunne	*Bidens hildebrantii*	×	×	×	√	×	×	×	1	18
Garri	*Heeria reticulata*	×	×	×	×	×	√	×	1	18
Agarsu	*Commiphora Africana*	×	×	×	×	×	×	√	1	18
Qorrobbo	*Terminalia parvula*	√	×	×	×	×	×	×	1	18
Burquqe	*Acacia nilotica*	√	×	×	×	×	×	×	1	18
Shisha	*Baleria acanthoides*	×	×	×	×	×	×	√	1	18

Annexe 7. Ranking of tree species for fuelwood provision as perceived by local communities in the FGD

Common Names	Scientific Names	Villages							Freq	Ranking
		AB	BQ	SH	BR	HHC	JA	MN		
Aroressa	*Grewia trichocarpa*	√	√	√	√	√	√	√	7	1
Ogumdi	*Grewia villosa*	√	√	√	√	√	√	√	7	1
Dadacha	*Acacia tortilis*	√	√	√	√	√	×	√	6	3
Sapansa	*Acacia mellifera*	√	√	√	√	√	×	√	6	3
Burquqe	*Acacia nilotica*	√	√	×	√	√	√	√	6	3
Sigirso	*Acacia reficiens*	√	√	√	√	×	×	√	5	6
Ammarresa	*Acacia brevispica*	√	√	×	√	×	√	√	5	6
I'd'daado	*Acacia senegal*	√	√	×	√	√	×	×	4	8
Waachu	*Acacia seyal*	√	√	×	×	×	×	√	3	9
Hallo	*Acacia bussei*	×	×	×	√	×	√	√	3	9
Qorrobbo	*Terminalia parvula*	×	√	√	×	×	√	×	3	9
Ammessa	*Commiphora africana*	×	×	×	×	√	√	×	2	12
Mad'er	*Cordia quarensis*	×	×	×	×	×	√	√	2	12
Qalqalcha	*Maerua angolensis*	×	×	×	×	×	×	√	1	14
Dakkara	*Boswellia hildebrantii*	√	×	×	×	×	×	√	1	14
Agarsu	*Commiphora erythrea*	√	×	×	×	×	×	×	1	14
Sukella	*Delonix elata*	×	×	×	√	×	×	×	1	14
Ejersa	*Olea europea*	√	×	×	×	×	×	×	1	14

Annexe 8. Ranking of medicinal species as perceived by local communities in the FGD

Common Names	Scientific Names	Villages							Freq	Ranking
		AB	BQ	SH	BR	HHC	JA	MN		
D'agamsa	*Carissa edulis*	√	√	×	√	√	×	√	5	1
Burs	*Echinops hispidus*	√	√	×	×	√	√	√	5	1
Wato qayya	*Osyris compressa*	√	×	×	√	×	√	√	4	3
Harkeena	*Euphorbia tescorum*	√	√	×	√	×	×	√	4	3
Arges	*Aloe barbadensis*	√	√	×	√	×	×	√	4	3
Jijirmocho	*Ipomoea donaldisonii*	×	√	×	√	×	×	√	3	6
Hiddi tiroftu	*Withania somnifera*	√	√	×	×	√	×	×	3	6
Awacho	*Albizia anthelmintica*	×	√	×	×	×	×	√	2	8
Sotowes	*Platycelyphium voense*	×	√	×	×	×	×	√	2	8
Okolle	*Asparagus africanus*	√	√	×	×	×	×	×	2	8
Anchacha	*Arobanche minor*	×	×	×	√	×	×	√	2	8
Mululach	*Populus ilicifolia*	×	×	×	√	×	×	√	2	8
Birres	*Terminalia kilimanduscharica*	×	×	×	×	√	×	√	2	8
Luqa luke	*Steganotaenia araliacea*	×	√	×	×	×	×	×	1	14
Finchiris	*Jatropha parvifolia*	×	√	×	×	×	×	×	1	14
Illam	*Lawsonia inermis*	×	√	×	×	×	×	×	1	14
Banya	*Blespharispermum pubescens*	×	×	×	√	×	×	×	1	14

(*continued on next page*)

(*continued*)

Common Names	Scientific Names	Villages								
		AB	BQ	SH	BR	HHC	JA	MN	Freq	Ranking
Qorqodha	*Povonia zeylanica*	×	×	×	×	×	×	√	1	14
Wanga	*Acacia nubica*	×	×	×	×	×	×	√	1	14
Odaa	*Ficus sychomorus*	×	×	×	×	×	×	√	1	14
Rukesa	*Combretum molle*	×	×	×	×	√	×	×	1	14
Gaddah	*Zanthoxylum chalybeum*	×	×	×	√	×	×	×	1	14
Walena	*Erythrina abyssinica*	×	×	×	×	√	×	×	1	14
Korobo	*Terminalia parvula*	×	×	×	×	√	×	×	1	14
Waraa	*Commiphora* spp.	×	×	×	√	×	×	×	1	14

Annexe 9. Ranking of tree species for building purposes as perceived by local communities in the FGD

Common Name	Scientific name	Villages								
		AB	BQ	SH	BR	HHC	JA	MN	Freq	Ranking
Arores	*Grewia bicolor*	√	√	×	×	√	√	√	5	1
Looko	*Diospyros abyssinica*	√	√	×	×	×	√	√	4	2
Ejers	*Olea africana*	√	√	×	√	√	×	×	4	2
Ch'ana	*Haplocoelum foliolosum*	√	√	×	×	√	√	×	4	2
Adaama	*Euphorbia* spp.	√	×	√	×	√	√	×	4	2
Mad'er	*Cordia ghafar*	×	√	×	√	×	√	√	4	2
Amares	*Acacia brevispica*	√	√	×	×	×	×	√	3	7
Korkorres	*Tarenna graveolens*	×	√	×		√	√	×	3	7
Gaale	*Kedrostis gijef*	√	×	×	×	×	√	×	2	9
Hallo	*Acacia bussei*	×	√	×	√	×	×	×	2	9
Haddessa	*Dodonaea angustifolia*	√	×	×	×	×	√	×	2	9
Biqa	*Pappea capensis*	×	√	×	×	×	√	×	2	9
Bal safi	*Eucalyptus* spp.	×	×	×	×	√	×	×	1	13
Ogomdi	*Grewia villosa*	×	×	×	×	×	×	√	1	13
Daddaca	*Acacia tortilis*	×	√	×	×	×	×	×	1	13
Algge	*Sansevieria ehrenbergii*	×	×	√	×	×	×	×	1	13
Buuyyo biila	*Aristida adscensionis*	×	×	×	√	×	×	×	1	13
Ciira	*Paspalidium desertorum*	×	×	×	×	×	×	√	1	13

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