Abstract

Plant hotspot areas are the areas that are very rich in plant species diversity. These areas have a priority for conservation. To highlight the plant diversity for nature conservation purposes a case study in Al Baha region, Saudi Arabia is presented, in which the importance of the natural vegetation and flora of one of the hotspot areas of Saudi Arabia is evaluated through the explanation of its natural plant species. A survey study has been conducted in an area of 167.6 km², a 97 sample each with 20X20 m were laid out covering the whole ecological zones of the study site. Data of flora, vegetation cover and topography were gathered from each sample site. The study revealed about 319 plant species belonging to 228 genera and 75 families. Two species were found endemic to Saudi Arabia, 14 were endemics to Arabian Peninsula, and five were regional endemics that are only found in East Africa and Arabian Peninsula, while 39 species are rare and endangered.

1. Introduction

The Mountains in southwestern Saudi Arabia (i.e. Sarawat), are considered as one of the richest biodiversity areas in the Arabian Peninsula and comprises a large number of endemic, endangered and threatened plant species (Abuzinada et al. 2005; Qushas, 2007). Biodiversity hotspots play a leading role in international and national nature conservation strategies (Hobohm et al., 2016). The study area is located on the Sarawat Mountains and within The Eastern Afromontane Hotspot area (Mallon, 2011). This area has rich biodiversity and is considered as one of the richest plant diversity areas in the Arabian Peninsula (Al-Aklabi et al. 2016; Al-Zandi et al. 2018). It also supports high rates of endemism, large numbers of rare species and a few endangered plant species with restricted distributions on inaccessible slopes facing the Red Sea (Al-Khulaidi et al. 2018). Some of the monotypic trees can be remnants of past forests and ancient heritage (Aronson et al. 2016), where many forest elements have destroyed and declined due to climate change and human activities.

Many studies on plant diversity of ecological sites in Saudi Arabia were conducted (e.g. Ghazanfar and Fisher 1998; Hegazy et al. 1998; Chaudhary and Al-Jowaid 1999; Hall et al. 2011; El-Sheikh, 2013; Alatar et al. 2015). The outcome of some of them (e.g. Collenette 1985, 1999; Thomas et al. 2017) takes into account the endemism and endangered plant species. However, a few of them highlighted the important areas of plant diversity in Saudi Arabia (e.g. Al-Abbas et al. 2010; Llewellyn et al. 2010; Hall et al. 2010, 2011; Thomas et al. 2017).

The flora and the vegetation of the study area are a mixture of different climatic conditions and of different elements of Saharo-Arabian or Saharo-Sindian, Sudanian region, and Mediterranean region (Al-Khulaidi 2013; Al-Aklabi et al. 2016). This due to a variation in rainfall from dry at low altitude and relatively wet at high altitude and due to different types of landscape and altitude ranges from 650 to 2350 m. (Fig. 2). Few vegetation studies were conducted in Al-Baha region covering part of the study area (Al-Aklabi et al. 2016; Al-Zandi et al. 2018; Al-Khulaidi et al. 2018a; Al-Robai et al. 2019).
In this study, we aim to highlight the important plant area in Albaha region. Our research will include an inventory for the plant diversity of the targeted study area. In addition, the study aims to highlight the hotspot areas that have the highest plant species richness and further plant biodiversity among the studied zones.

2. Materials and methods

2.1. The study area

The study was conducted in the period from April 2017 to July 2018, near Baljurashi city in the southwest of Al-Baha region, (between 19.41: 19.50 North and between 41.29 and 41.44 East). The study area covers the ecological zones located around Hawala, Jabal Uthrob, Al Abna and Huzna areas (Fig. 1). These areas stretch parallel to Tihama plain and extend for approximately 68 km. from Assollubat fault in the south to Huznah escarpment in the north. The altitude ranges between 300 and 2350 m above sea level (masl). The slopes and the plateaus directed sharply to Tihama plain, and become lower and gradually slope eastward. Deep wadis and drainage lines cut the mountains, and flow toward the Tihama foothills. Tihama foothills area border the eastern and western sides of Jabal Uthrub escarpment, which is covered by rocks, gravels, and rock outcrops.

In general, the Arabian Shield, where the study was conducted is composed of a stable Craton of predominantly late Precambrian metavolcanic and plutonic rocks. Its surface is composed of around 50% plutonic rocks, and 50% volcanic sedimentary rocks. Granit consists of about 70% of plutonic rocks. Most rocks in Hawalah area are Amphibolite, Biotite, Tonalite, Gabbro, Andesite, and Granite (Brown et al., 1989).

The landscape variation strongly influences the flora, composition, structure of the vegetation communities and vegetation types. The variation of landscape in particular that facing the west and effected by fog provides a vegetation edge microclimate ecosystem...
(Young and Mitchell, 1994), which supports unique flora, vegetation composition and structure with endemic, rare plant species. The altitude of the study area ranges between 600 and 2240 masl (Fig. 2). The terraces are confined nearly to the high altitude areas, most of these terraces are neglected for years, and as a result, they became covered by natural vegetation dominated by Vachellia origena (=Acacia origena) with associated species such as Juniperus procera, Asphodelus fistulosus, Achillea biebersteinii, Nepeta deflersiana, Tripteris vaillantii, Hyparrhenia hirta, Eragrostis papposa and others.

The Geographic Information System GIS (Arc Map software) was used to generate maps of the endemic, near-endemic, rare, endangered species, plant density and plant richness throughout the study area. Diversity indices were applied using a MultiVariate Statistical Package (MVSP) software and by using Simpson’s and Shannon’s method to identify the more diverse sample sites. The total number of samples was 97 samples, each with a size of 20X20 m. and dispersed randomly in an area of 167.6 km², with the assurance that the samples covered all ecological zones and topographic units of the study area.

2.2. Plant population parameters

2.2.1. Density: Number of individuals of each species counted in each sample site

The numbers of individuals of each species in each site were then converted to a number of individuals per hectare. This is achieved by dividing the total number of individuals by the total areas surveyed in the different landforms.

2.2.2. Frequency: Frequency was calculated by dividing the number of plots in which a species occurs into the total number of plots sampled

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2.2.3. Endemism: The endemic plant species is defined for this study as the plant that only occurs in Saudi Arabia; the near-endemic species are those that occur only in the Arabian Peninsula (mainly Saudi Arabia and Yemen).

The distribution of endemic and near-endemic species are based on Collenette 1985; Wood 1997 and Al-Khulaidi 2013. The Regional endemics in the study area are the plants that occur only in the Arabian Peninsula and East Africa (Somalia, Ethiopia, Djibouti, Sudan, Kenya, Uganda, Tanzania) (Fig. 3).

Fig. 2. The altitude of the study area.

Fig. 3. Eastern Africa, 1 Somalia, 2 Ethiopia, 3 Djibouti, 4 Sudan (North & South), 5 Uganda, 6 Kenya, 7 Tanzania.
of regional endemic plants was based on information from (Thulin 1993- Volume 1, 2, 3 and 4, Thulin 2008, Edwards et al. (2000); Hedberg and Edwards (1989) as well as Wood (1997).

3. Results

In total, 319 plant species belonging to 75 families and 228 genera were found in the surveyed area (Appendix 1). Two species are endemic to Saudi Arabia, 14 are endemic to Arabian, 5 regional endemic only found in East Africa and Arabian Peninsula and 39 are rare and endangered, most of them were concentrated around Jabal Uthrub, Hawala, and at the top of Al Abna and Huzna descents (Fig. 4).

The family Asteraceae is represented by the highest number of species (35 species) followed by the Poaceae (27 species), Lamiaceae (19 species), Fabaceae (15 species), Acanthaceae (12 species), Apocynaceae (11 species), Euphorbiaceae and Mimosaceae (10 species) (Fig. 5). The previous prominent eight families together contribute 139 plant species (44% of the overall total species). Twenty-eight families (29% of the overall total) are represented by only a single species, with the most common ones being Barbeyaceae (*Barbeya oleoides*), Ericaceae (*Erica arborea*).

3.1. Plant population parameters

3.1.1. Frequency

About 82% of the total plant species were categorized in the lowest frequency class, whereas 11% of the plants were distributed in the second frequency class. With a frequency of 49%, *Juniperus procera* is the most frequent species followed by *Maytenus parviflora* (41%) and *Senegalia asak* (=*Acacia asak*) with frequency.
(39%). Most abundant species with a frequency of more than 20% are shown in Fig. 6. Many species were very rare and endangered, with a frequency between 1 and 2%. The most important and rarest species were Boscia angustifolia, Periplocha aphylla, Commiphora kua, Euphorbia cuneata, Kleinia odora, Psitacia falcata, Salvia merjanie, Teclea nobilis, and Jasminum fluminense with a frequency 1% (Table 1).

3.1.2. Endemism
The study area contains a remarkable number of endemic plant species. These are estimated to be about 16% of the vascular flora of the study area, in which endemic (two species), near endemic (14 species) and regional endemic (34 species) (Table 2). Fig. 3 shows the distribution of endemism, rare and endangered plant species of the study area.

3.1.3. Plant density
The Majority of high-density plants were grasses. These grasses are confined mainly to high altitude areas namely Hyparrhenia hirta and Themeda triandra. Further annual species such as Asphodelus fistulosus and Osteospermum vaillantii were also recorded as high-density species; both species appear along road margins and disturbed sites in the summertime. Among trees, Juniperus procera was a high-density tree and forms woodland of varies vegetation and structure types (Fig. 7).

3.1.4. Plant diversity
The most diverse sample sites were: 371, 367, 420 and 423 (Table 3 & Fig. 8). These sample sites were located on the high-altitude areas facing mainly South and South West such as the top of Al Abna descent and on Jabal Uthrub (Hawala).

4. Discussion
There are 29 rare and endangered plant species in the study area, with a frequency of less than 2% (Table 1). Many plant species in the world are threatened with extinction due to climate change and intensive human activities (Chaudhary and Khan, 2010). A recent study estimates 46 rare and endangered plant species in Al Baha region (Al-Khulaidi et al. 2018b). Species richness, endemism, or rarity are paramount criteria in selecting important plant areas (IPAs) for conservation strategies (Sánchez de Dios et al., 2017), single plant families can be worth to adding them as one criterion in selecting IPA. Two rare species with single plant families Barbeya oleoides and Erica arborea are found in the study area (Fig. 9).

The topographic factor in some areas, especially those facing the Red Sea, such as areas that located around Hawala, Jabal Uthrum (East) as well as at the top of Al Abna descent and around Huzna village (West), where there are waves of fog, helped to enrich these areas with plant diversity (Fig. 10). Generally, these areas are characterized by both a high density of vegetation and a high number of plant species (i.e. species richness). In terms of conservation, these areas have to be protected and managed properly so that their rich plant diversity resources are preserved.

Barbeya oleoides, is found only in 7 locations around Huzna and at the top of Al Abna descent, the most dominants were found between 1454 and 1768 masl, on drainage lines facing South West and North East. The plant is an endemic of the eastern Afromontane escarpment of the Ethiopian plateau, horn of Somalia, Eritrea, between 1200 and 2900 masl (Rendle 1916; Friis, 1983; Thulin 2008). Thus, it is forming part of the transition element between Afromontane and Somalia-Masai regions (Hall, 2008), and SW of Arabian Peninsula mountains, between 700 and 2135 masl (woad, 1997; Collenette, 1985). This species forms a vegetation type with Olea europaea and Juniperus procera on steep to moderate rocky slope and wadis between 1700 and 2065 masl. (Al-Aklabi et al., 2016). This species recorded also at about 1540 masl in Taif region that characterized by monthly temperature ranges from 13.7 °C to 30.9 °C and an annual rainfall of about 208 mm (Ragab, et al., 2005). This rare plant is considered as one of the medicinal plants of Saudi Arabia (Zakaria, 2010).

Furthermore, Barbeya oleoides has been evaluated by the International Union for Conservation of Nature IUCN as Least Concern and is considered a monotypic tree family that is represented by
a single genus and single species. Thus, this species is important
taxonomically, and in terms of phytogeography and phylogenetic
studies (Rana, and Ranade 2009; Sarwar and Araki, 2010). Some
of the monotypic trees can be remnants of past forests and ancient
eritage (Aronson et al. 2016), where many forest elements have
destroyed and declined due to climate change and human activities.
The rare tree Erica arborea is only found in three locations over
2000 m east of the study area (Jabal Uthrub), on habitats of rock
heritage (Aronson et al. 2016), where many forest elements have
destroyed and declined due to climate change and human activities.

![Image](image.png)

**Fig. 6.** Most abundant species with their percentage frequency.

| Table 1 | Rare and endangered plant species, with a frequency between 1 and than 2%. |
|---------|--------------------------------------------------------------------------|
| Plant name | Freq.% | Plant name | Freq.% | Plant name | Freq.% |
| Acacia oerfota (=Vachellia oerfota) | 2 | Lycium shawii | 2 | Boscia angustifolia | 1 |
| Aloe castelorum | 2 | Monolluma quadrangula | 2 | Periplocha aphylla | 1 |
| Barleria acanthoides | 2 | Pentas lanceolata | 2 | Commiphora kua | 1 |
| Capparis spinosa | 2 | Phoenix caesipitosa | 2 | Euphorbia cuneata | 1 |
| Celtis africana | 2 | Pulicaria petiolaris | 2 | Kleinia odora | 1 |
| Cordia monoica | 2 | Rhamnus staddo | 2 | Psitacia falcata | 1 |
| Cynoglossum bottae | 2 | Silene yemensis | 2 | Salvia merjamie | 1 |
| Dobera glabra | 2 | Tamarix nilotica | 2 | Teuclea nobilis | 1 |
| Euclea racemosa | 2 | Grewia velutina | 1 | Jasminum fluminense | 1 |

| Table 2 | Endemic, near endemic and regional endemic of the study area. |
|---------|--------------------------------------------------------------------------|
| Plant name | Endemism | Plant name | Endemism | Plant name | Endemism |
| Aloe pseudorubroviolacea | * | Felicia abyssinica | *** | Felicia dentata | *** |
| Plectranthus asirnensis | * | Acacia ethica (=Vachellia ethica) | *** | Grewia velutina | *** |
| Acacia johnwoodii (=Vachellia johnwoodii) | ** | Acacia hamulosa (=Senegalia hamulosa) | *** | Kickxia pseudoscoparia | *** |
| Aloe castelorum | ** | Acacia origena (=Vachellia origena) | *** | Kleinia odora | *** |
| Barleria bispinosa | ** | Anisotes trisulcus | *** | Lavandula atriplicifolia | *** |
| Centaurothamnus maximus | ** | Barbeyia oleoides | *** | Lavandula pubescens | *** |
| Crinum album | ** | Buddleja polystachya | *** | Minuartia filifolia | *** |
| Cynoglossum bottae | ** | Caralluma retrospiens | *** | Phoenix caesipitosa | *** |
| Gymnosporia parviflora | ** | Carissa spinarum | *** | Pistacia falcata | *** |
| Leucas alba | ** | Cometes abyssinica | *** | Pulicaria schimperi | *** |
| Monolluma quadrangula | ** | Commiphora gileadensis | *** | Searsa retinorhoea | *** |
| Nepeta deflersiana | ** | Commiphora kua | *** | Rumex nervosus | *** |
| Orbea wisssmannii var. eremastrum | ** | Commiphora kua | *** | Seddera arabica | *** |
| Phragmanthera austroarabica | ** | Commiphora myrrha | *** | Silene yemensis | *** |
| Picris scabra | ** | Cordia monica | *** | Solanum schiperianum | *** |
| Teucrium yemense | ** | Cyphostemma digitatum | *** | Tryamfetta flavescens | *** |

**KEY Endemism.**
* Endemic, ** near endemic, *** regional endemic found in Eritrea, Djibouti, Ethiopia, Sudan, Kenya, Tanzania.

![Table](table.png)
outcrops and with relatively deep soil terraces facing North West. Studies conducted in the region considered this species as one of the rare and endangered taxa (Al-Khulaidi, 2018a; Al-Khulaidi, et al., 2016). According to IUCN categories, the species is considered as Least Concern (Harvey-Brown and Barstow, 2017; Rivers, et al., 2019). The plant is native to the Mediterranean, Tropical African Mountains, and Arabian Peninsula (Harvey-Brown and Barstow, 2017). The plant forms a community on mountains with loam; moderate fine granular located between 2800 and approximately 3250 masl South-eastern Highlands of Ethiopia (Yimer, 2007). The plant forms a community in Mediterranean regions of Turkey, where the temperature ranges between 14 and 18 °C with high humidity in summers (Yildirim and Yilmaz, 2005), and ranges in altitudes from 660 to 820 masl, and slope gradient is between 14 and 55%. And in southwest Sardinia where the predominant soils are Leptosols, with average annual rainfall 1056–1072 mm, and average annual temperature in the area 13 °C (Vacca, 2017). Generally, the plant grows and forms communities in areas with high rains and low temperatures in the world, such as the Mediterranean and East Africa regions.

Teclea nobilis, Boscia angustifolia are remarkable species found only in East Africa, Saudi Arabia and Yemen (Thulin 2008). Both are very rare species with a single tree in the habitat (i.e., the study area), the first only seen at 1734 masl, on drainage line facing SW, while the latter is only seen in two locations, inaccessible rocky slope between altitudes 900 and 1650 masl. The two species generally are rare in Al Baha region (Al-Khulaidi et al., 2018a) (Fig. 11). The tree Faidherbia albida is only seen in one location, this rare tree is considered as one of the enigmatic old tree species of great cultural significance in the Middle East (Aronson et al. 2016). Still few rare plant species need to be investigated in detail. These rare and remarkable plant species need taxonomic evaluation, documentation, and conservation, and also need special attention from the preservation and conservation points of view, the extinction of these species, would represent a big loss of plant diversity. The rarity of this plant may be due to the low rain and fog. However, these rare trees may have been introduced in the past, but have not spread, and have thus remained isolated (Rana, and Ranade 2009).

### Declaration of Competing Interest
The authors declared that there is no conflict of interest.
Fig. 8. The most diverse sample sites are around Hawala and at the top of Al Abna descent.

Fig. 9. Rare species representing a family with a single species. The latitude and altitude points and the scale are for enlarged map.
Fig. 10. Number of species (Richness) per sample site (20 by 20 m.) top and density of plant species per km². Below.
Appendix: Surveyed plant species list with density and frequency for each species.

| Plant name | Frequency | Density/ha | Relative density | Relative frequency | Plant name | Frequency | Density/ha | Relative density | Relative frequency |
|------------|-----------|------------|------------------|-------------------|------------|-----------|------------|------------------|-------------------|
| Abutilon fruticosum | 7.2 | 9.5 | 0.240 | 0.354 | Hibiscus micranthus | 2.1 | 0.5 | 0.013 | 0.101 |
| Abutilon sp. | 6.2 | 8.8 | 0.221 | 0.303 | Hibiscus vitifolius | 3.1 | 2.1 | 0.052 | 0.152 |
| Acalypha fruticosa | 9.3 | 9.8 | 0.247 | 0.455 | Huernia sp. | 1.0 | 1.3 | 0.032 | 0.051 |
| Achillea arabica (=Achillea biebersteinii) | 7.2 | 36.1 | 0.910 | 0.303 | Hyparrhenia hirta | 38.1 | 273.5 | 6.895 | 1.870 |
| Achyranthes aspera | 10.3 | 24.7 | 0.624 | 0.505 | Hypoestes forskoali | 11.3 | 61.9 | 1.560 | 0.556 |
| Adenium obesum | 18.6 | 10.6 | 0.266 | 0.910 | Iffoga spicata | 3.1 | 3.6 | 0.091 | 0.152 |
| Aerva javanica | 27.8 | 32.0 | 0.806 | 1.364 | Indigofera sp. | 3.1 | 16.2 | 0.409 | 0.152 |
| Aerva lanata | 10.3 | 11.1 | 0.279 | 0.505 | Indigofera spiniflora | 2.1 | 1.0 | 0.026 | 0.101 |
| Aizoon canariense | 4.1 | 7.5 | 0.188 | 0.202 | Indigofera spinosa | 18.6 | 57.0 | 1.436 | 0.910 |
| Aloe castellorum | 2.1 | 4.9 | 0.123 | 0.101 | Jasminum fluminense | 1.0 | 0.5 | 0.013 | 0.051 |
| Aloe pseudorubroviolacea | 5.2 | 7.7 | 0.195 | 0.253 | Jasminum grandiflorum | 20.6 | 17.5 | 0.442 | 1.011 |
| Alyssinum desertorum | 2.1 | 1.0 | 0.026 | 0.101 | Jatropha glauca | 2.1 | 2.8 | 0.071 | 0.101 |
| Amaranthus sp. | 1.0 | 0.8 | 0.019 | 0.051 | Jatropha pelargonifolia | 5.2 | 2.6 | 0.065 | 0.253 |
| Ambrosia maritima | 2.1 | 64.9 | 1.638 | 0.101 | Juniperus procera | 49.5 | 137.1 | 3.457 | 2.426 |
| Ammi majus | 2.1 | 3.4 | 0.084 | 0.101 | Justicia flava | 5.2 | 4.6 | 0.117 | 0.253 |
| Anarrhinum forskohlii subsp. forskohlii (=Anarrhinum orientale) | 1.0 | 4.1 | 0.104 | 0.051 | Justicia odora | 1.0 | 0.5 | 0.013 | 0.051 |
| Anchusa ovata | 1.0 | 0.3 | 0.006 | 0.051 | Kickxia pseudoscoparia | 6.2 | 2.3 | 0.058 | 0.303 |
| Andropogon distachyos | 12.4 | 35.1 | 0.884 | 0.606 | Kleinia odor | 1.0 | 0.3 | 0.006 | 0.051 |
| Andropogon sp. | 1.0 | 2.6 | 0.065 | 0.051 | Lactuca dissecta | 2.1 | 2.1 | 0.052 | 0.101 |
| Anisotes trisulcus | 17.5 | 52.6 | 1.326 | 0.859 | Lamarkia aurea | 2.1 | 18.0 | 0.455 | 0.101 |
| Argemone ochroleuca | 4.1 | 6.2 | 0.156 | 0.202 | Lantana sp. | 3.1 | 1.5 | 0.039 | 0.152 |
| Argyrolobium arabicum | 6.2 | 4.4 | 0.110 | 0.303 | Launea sp. | 4.1 | 1.5 | 0.039 | 0.202 |

Fig. 11. The distribution of Teclea nobilis, Boscia angustifolia.
### Appendix (continued)

| Plant name                              | Frequency % | density/ha | Relative density | plant name                              | Frequency % | density/ha | Relative density |
|-----------------------------------------|-------------|------------|------------------|-----------------------------------------|-------------|------------|------------------|
| Aristida adscensionis                  | 35.1        | 147.2      | 3.711            | Lavandula atriplicifolia               | 2.1         | 0.5        | 0.013            |
| Arthraxon sp.                           | 1.0         | 0.5        | 0.013            | Lavandula coronopifolia                | 4.1         | 3.1        | 0.078            |
| Asparagus africanus                     | 1.0         | 0.5        | 0.013            | Lavandula dentata                      | 19.6        | 37.6       | 0.949            |
| Asphodelus fistulosus                  | 10.3        | 114.2      | 2.879            | Lavandula pubescens                    | 16.5        | 9.8        | 0.247            |
| Astragalus pelecinus (=Biserrula pelecinus) | 1.0         | 0.5        | 0.013            | Lavandula sp.                          | 2.1         | 2.1        | 0.052            |
| Atractylis cancellata                  | 1.0         | 0.5        | 0.013            | Leucas alba                            | 2.1         | 6.4        | 0.162            |
| Avena barbata                           | 1.0         | 2.6        | 0.065            | Leucas glabrata                        | 6.2         | 5.9        | 0.149            |
| Avena sp.                               | 9.3         | 17.0       | 0.429            | Lindernbergia indica                   | 1.0         | 1.0        | 0.026            |
| Barbeya oleoides                        | 12.4        | 3.9        | 0.097            | Lolium multiflorum                     | 2.1         | 5.2        | 0.130            |
| Barleria acanthoides                   | 2.1         | 0.8        | 0.019            | Lotus sp.                              | 1.0         | 0.5        | 0.013            |
| Barleria bispinosa                     | 7.2         | 7.7        | 0.195            | Lycium shawii                          | 2.1         | 0.8        | 0.019            |
| Barleria hochstetteri                  | 1.0         | 0.8        | 0.019            | Lysimachia arvensis subsp. arvensis (=Anagallis arvensis) | 8.2         | 30.9       | 0.780            |
| Barleria sp.                            | 3.1         | 1.5        | 0.039            | Maerua crassifolia                     | 5.2         | 1.3        | 0.032            |
| Bidens biterata                         | 1.0         | 0.8        | 0.019            | Malva parviflora                       | 1.0         | 0.5        | 0.013            |
| Blepharis edulis                        | 19.6        | 53.9       | 1.358            | Mentheus sp.                           | 3.1         | 1.0        | 0.026            |
| Boerhavia diffusa                      | 2.1         | 0.8        | 0.019            | Medicago minima                        | 1.0         | 14.2       | 0.357            |
| Boerhavia elegans                      | 1.0         | 0.3        | 0.006            | Medicago polymorpha                    | 1.0         | 0.5        | 0.013            |
| Boscia angustifolia (=Boscia integrifolia) | 1.0         | 0.3        | 0.006            | Melhania ovata                         | 2.1         | 0.8        | 0.019            |
| Brachiaria sp.                          | 1.0         | 1.3        | 0.032            | Melilotus indicus                       | 1.0         | 6.4        | 0.162            |
| Brassica rapa                           | 1.0         | 1.8        | 0.045            | Micromeria imbricata                   | 21.6        | 36.1       | 0.910            |
| Brassica tournefortii (=Coenya tournefortii) | 4.1         | 27.6       | 0.695            | Micromeria sp.                         | 26.8        | 45.1       | 1.137            |
| Bromus rigidus                          | 1.0         | 3.1        | 0.078            | Minuarta filifolia                     | 8.2         | 4.6        | 0.117            |
| Buddleja polystachya                    | 3.1         | 0.8        | 0.019            | Misopates orontium                     | 1.0         | 0.5        | 0.013            |
| Cadaba farinosa                         | 3.1         | 1.3        | 0.032            | Monolluma quadrangula (=Ceropogia quadrangula) | 2.1         | 0.5        | 0.013            |
| Cadaba glandulosa                       | 3.1         | 1.0        | 0.026            | Nepeta deflersiana                     | 5.2         | 10.8       | 0.273            |
| Calendula arvensis                      | 1.0         | 6.4        | 0.162            | Nicotiana glauca                       | 14.4        | 10.8       | 0.273            |
| Calotropis procera                      | 11.3        | 5.4        | 0.136            | Notoceras bicornes                      | 1.0         | 9.0        | 0.227            |
| Campanula edulis                        | 1.0         | 0.5        | 0.013            | Nuxia oppositifolia                    | 5.2         | 3.9        | 0.097            |
| Capparis cartilaginea                   | 4.1         | 1.0        | 0.026            | Ochradenus buccatus                     | 1.0         | 0.3        | 0.006            |
| Carduus pycnocephalus                   | 1.0         | 0.5        | 0.013            | Oeimium filamentosum                   | 2.1         | 2.6        | 0.065            |

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### Plant name Frequency density/ha Relative density Relative frequency plant name Frequency density/ha Relative density Relative frequency
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| Plant name                      | Frequency % | density/ha | Relative density | Relative frequency | Plant name                      | Frequency % | density/ha | Relative density | Relative frequency |
|---------------------------------|-------------|------------|------------------|-------------------|---------------------------------|-------------|------------|------------------|-------------------|
| Carissa spinarum               | 9.3         | 7.2        | 0.182            | 0.455             | Ocimum forskoelei               | 2.1         | 4.4        | 0.110            | 0.101             |
| Caroxylon imbricatum (=Salsola imbricata) | 2.1       | 4.6        | 0.117            | 0.101             | Olea europaea                   | 30.9        | 34.3       | 0.864            | 1.516             |
| Caryosyke hexagyna              | 1.0         | 0.8        | 0.019            | 0.051             | Onopordum heteracanthum         | 3.1         | 1.3        | 0.032            | 0.152             |
| Celtis africana                 | 2.1         | 0.5        | 0.013            | 0.101             | Opuntia ficus indica            | 4.1         | 13.1       | 0.331            | 0.202             |
| Cenchrus ciliaris               | 26.8        | 187.1      | 4.718            | 1.314             | Osteospermum vaillantii (=Tripteris vaillantii) | 23.7        | 116.0      | 2.924            | 1.162             |
| Cenchrus setaceus (=Pennisetum setaceum) | 28.9       | 47.7       | 1.202            | 1.415             | Osyris quadripartita (=Osyris lanceolata) | 3.1         | 1.3        | 0.032            | 0.152             |
| Cenchrus sp. (=Pennisetum sp.)  | 3.1         | 12.6       | 0.318            | 0.152             | Centaurea pseudosaica           | 2.1         | 2.1        | 0.052            | 0.101             |
| Centauranthus maximus           | 1.0         | 0.8        | 0.019            | 0.051             | Oxalis corniculata              | 3.1         | 1.5        | 0.039            | 0.152             |
| Cheilanthes pteridioides        | 3.1         | 9.5        | 0.240            | 0.152             | Panicum turgidum                | 1.0         | 0.3        | 0.006            | 0.051             |
| Chenopodium album               | 3.1         | 4.9        | 0.123            | 0.152             | Paronychia sineaica             | 3.1         | 4.4        | 0.110            | 0.152             |
| Chenopodium murale              | 1.0         | 0.3        | 0.006            | 0.051             | Phleum lanceolata               | 2.1         | 1.5        | 0.039            | 0.101             |
| Chrozophora oblongifolia        | 1.0         | 0.3        | 0.006            | 0.051             | Pentacolus lanceolata           | 2.1         | 1.3        | 0.032            | 0.152             |
| Chrysoptocum plumulosus         | 6.2         | 5.4        | 0.136            | 0.303             | Periplaca aphylla               | 19.6        | 11.1       | 0.279            | 0.960             |
| Chrysoptocum sp.                | 3.1         | 5.2        | 0.130            | 0.152             | Periplaca somaliensis           | 13.4        | 5.9        | 0.149            | 0.657             |
| Cissus quadrangula              | 3.1         | 3.9        | 0.097            | 0.152             | Phagnalon stenolepis            | 8.2         | 12.9       | 0.325            | 0.404             |
| Cissus rotundifolia             | 13.4        | 20.6       | 0.520            | 0.657             | Phoenix caespitosa              | 2.1         | 0.5        | 0.013            | 0.101             |
| Citrullus colocynthin           | 1.0         | 1.3        | 0.032            | 0.051             | Phragmanthera austroarabica     | 3.1         | 1.3        | 0.032            | 0.152             |
| Clematis hirsuta                | 5.2         | 2.8        | 0.071            | 0.253             | Phyllanthus sp.                 | 1.0         | 0.5        | 0.013            | 0.051             |
| Cleome gynandra (=Cynandropsis gynandra) | 1.0       | 0.5        | 0.013            | 0.051             | Picris scabra                    | 4.1         | 5.7        | 0.143            | 0.202             |
| Cleome scapos                   | 1.0         | 0.5        | 0.013            | 0.051             | Pistacia falcata                | 12.4        | 3.9        | 0.097            | 0.606             |
| Cleome sp.                      | 3.1         | 1.0        | 0.026            | 0.152             | Plantago afrif                    | 1.0         | 6.4        | 0.162            | 0.051             |
| Clusia lanceolata               | 12.4        | 6.2        | 0.156            | 0.606             | Plantago ovata                   | 3.1         | 22.4       | 0.565            | 0.152             |
| Cocccinia grandis               | 8.2         | 9.5        | 0.240            | 0.404             | Pluchea dioecoris               | 1.0         | 2.8        | 0.071            | 0.051             |
| Cocculus pendulus               | 1.0         | 0.3        | 0.006            | 0.051             | Polyxcarbon tetrathyllum         | 1.0         | 0.5        | 0.013            | 0.051             |
| Coleus aridicus (=Plectranthus asirensis) | 3.1       | 6.2        | 0.156            | 0.152             | Polygala abyssinica              | 11.3        | 6.4        | 0.162            | 0.556             |
| Combretum molle                 | 14.4        | 17.8       | 0.448            | 0.707             | Portulaca oleracea              | 1.0         | 0.3        | 0.006            | 0.051             |
| Cometeb abyssinica              | 2.1         | 0.8        | 0.019            | 0.101             | Portulaca quadsirata            | 1.0         | 0.8        | 0.019            | 0.051             |
| Plant name                  | Frequency % | density/ha | Relative density | Relative frequency | Plant name                  | Frequency % | density/ha | Relative density | Relative frequency |
|-----------------------------|-------------|------------|-----------------|-------------------|------------------------|-------------|------------|-----------------|-------------------|
| Commelina forskalolii       | 4.1         | 2.8        | 0.071           | 0.202             | Premma resinoso         | 4.1         | 4.6        | 0.117           | 0.202             |
| Commelina sp.               | 2.1         | 1.0        | 0.026           | 0.101             | Psidia punctulata       | 26.8        | 64.7       | 1.631           | 1.314             |
| Commicarpus grandiflorus    | 4.1         | 2.6        | 0.065           | 0.202             | Psydrax schimperianus   | 3.1         | 2.6        | 0.065           | 0.152             |
| Commicarpus plumbagineus    | 7.2         | 3.4        | 0.084           | 0.354             | Pulicaria petiolaris    | 3.1         | 1.3        | 0.032           | 0.152             |
| Commicarpus sp.             | 3.1         | 1.0        | 0.026           | 0.152             | Pulicaria schimperi     | 5.2         | 2.1        | 0.052           | 0.253             |
| Commiphora gileadensis      | 3.1         | 0.8        | 0.019           | 0.152             | Pulicaria undulata      | 11.3        | 19.3       | 0.487           | 0.556             |
| Commiphora katu             | 3.1         | 1.8        | 0.045           | 0.152             | Pupalia lappacea        | 18.6        | 26.0       | 0.656           | 0.910             |
| Commiphora kua              | 1.0         | 0.5        | 0.013           | 0.051             | Rhamnus studdo          | 2.1         | 0.5        | 0.013           | 0.101             |
| Commiphora myrrha           | 12.4        | 6.2        | 0.156           | 0.606             | Rhus chalepensis sp.    | 4.1         | 3.1        | 0.078           | 0.202             |
| Conyza stricta              | 18.6        | 25.0       | 0.630           | 0.910             | Ricinus communis         | 3.1         | 2.3        | 0.058           | 0.152             |
| Coptosperma graveolens      | 4.1         | 2.1        | 0.052           | 0.202             | Ruellia patula          | 2.1         | 1.5        | 0.039           | 0.101             |
| Cordia monoica              | 2.1         | 0.5        | 0.013           | 0.101             | Rumex nepalensis (=Rumex steudelanius) | 1.0         | 0.8        | 0.019           | 0.051             |
| Crassula schimperi          | 4.1         | 3.4        | 0.084           | 0.202             | Rumex nervosus          | 11.3        | 7.0        | 0.175           | 0.556             |
| Crepis sp.                  | 3.1         | 12.1       | 0.305           | 0.152             | Rumex vesicarius        | 10.3        | 17.3       | 0.435           | 0.505             |
| Crinum album                | 3.1         | 1.0        | 0.026           | 0.152             | Ruta chalepensis        | 3.1         | 1.0        | 0.026           | 0.152             |
| Crotalaria sp.              | 17.5        | 18.8       | 0.474           | 0.859             | Saccharum spontaneum    | 1.0         | 1.0        | 0.026           | 0.051             |
| Cucumis sp.                 | 1.0         | 0.3        | 0.006           | 0.051             | Sageretia thea          | 24.7        | 18.6       | 0.468           | 1.213             |
| Cymbopogon sp.              | 1.0         | 0.8        | 0.019           | 0.051             | Salsola tragus          | 9.3         | 11.3       | 0.286           | 0.455             |
| Cynanchum viminalae (=Sarcostemma viminalae) | 10.3     | 6.4        | 0.162           | 0.505             | Salvadora persica       | 1.0         | 0.8        | 0.019           | 0.051             |
| Cynodon dactylon            | 6.2         | 146.9      | 3.704           | 0.303             | Salvia aegyptica        | 8.2         | 46.4       | 1.170           | 0.404             |
| Cynoglossum bottae          | 2.1         | 1.8        | 0.045           | 0.101             | Salvia dianthera (=Meriandra bengladensis) | 1.0         | 1.3        | 0.032           | 0.051             |
| Cynoglossum sp.             | 1.0         | 1.3        | 0.032           | 0.051             | Salvia merjami          | 1.0         | 0.3        | 0.006           | 0.051             |
| Cyperus sp.                 | 2.1         | 2.1        | 0.052           | 0.101             | Sansevieria forskaliana (=Dracaena forskaliana) | 1.0         | 1.5        | 0.039           | 0.051             |
| Cyphostemma digitatum       | 7.2         | 11.1       | 0.279           | 0.354             | Scandix pectenvernus     | 1.0         | 2.6        | 0.065           | 0.051             |
| Dactyloctenium aegyptium    | 1.0         | 1.3        | 0.032           | 0.051             | Searisia glutinosa (=Rhus abyssinica) | 2.1         | 0.8        | 0.019           | 0.101             |
| Desmidorchis retrosicriens (=Caralluma retrosicriens) | 9.3     | 3.6        | 0.091           | 0.455             | Searisia natalensis (=Rhus natalensis) | 1.0         | 0.5        | 0.013           | 0.051             |
| Digitaria velutina          | 3.1         | 9.8        | 0.247           | 0.152             | Searisia retinorrhoea (=Rhus retinorrhoea) | 19.6        | 11.3       | 0.286           | 0.960             |
| Dobera glabra               | 2.1         | 0.5        | 0.013           | 0.101             | Seddera arabica         | 5.2         | 6.2        | 0.156           | 0.253             |
| Dodonaea viscosa subsp.     | 35.1        | 38.4       | 0.968           | 1.718             | Seddera sp.             | 1.0         | 0.3        | 0.006           | 0.051             |
| angustifolia                |             |            |                 |                   |                         |             |            |                 |                   |
| Dysphania ambrosioides (=Chenopodium ambrosioides) | 1.0     | 1.0        | 0.026           | 0.051             | Senegalia asak (=Acacia asak) | 39.2        | 31.4       | 0.793           | 1.920             |

(continued on next page)
| Plant name | Frequency | density/ha | Relative density | Relative frequency | Plant name | Frequency | density/ha | Relative density | Relative frequency |
|------------|-----------|------------|------------------|-------------------|------------|-----------|------------|------------------|-------------------|
| Dysphania schraderiana (=Chenopodium schraderianum) | 13.4 | 41.0 | 1.033 | 0.657 | Senegalía hamulosa (=Acacia hamulosa) | 3.1 | 0.8 | 0.019 | 0.152 |
| Ecboïlium gymnastachyum | 1.0 | 1.0 | 0.026 | 0.051 | Senna alexandrina | 1.0 | 0.3 | 0.006 | 0.051 |
| Ecboïlium viride | 1.0 | 0.8 | 0.019 | 0.051 | Silene sp. | 5.2 | 3.1 | 0.078 | 0.253 |
| Echinops sp. | 12.4 | 10.6 | 0.266 | 0.606 | Silene yemensis | 2.1 | 11.9 | 0.299 | 0.101 |
| Ecbobolium gymnostachyum | 1.0 | 26.3 | 0.663 | 0.101 | Sisymbrium erysimoides | 1.0 | 7.7 | 0.195 | 0.051 |
| Ehrelietra obtusifolia | 3.1 | 0.8 | 0.019 | 0.152 | Sisymbrium irio | 1.0 | 0.8 | 0.019 | 0.051 |
| Ephedra foliata | 4.1 | 1.0 | 0.026 | 0.202 | Sisymbrium erysimoides | 1.0 | 7.7 | 0.195 | 0.051 |
| Eragrostis papposa | 29.9 | 172.9 | 4.361 | 1.466 | Solanum incanum | 32.0 | 23.2 | 0.585 | 1.567 |
| Erica arborea | 3.1 | 2.8 | 0.071 | 0.152 | Solanum sp. | 2.1 | 0.5 | 0.013 | 0.101 |
| Erigeron bonariensis (=Conyza bonariensis) | 1.0 | 0.3 | 0.006 | 0.051 | Solanum villosum | 6.2 | 4.6 | 0.117 | 0.303 |
| Erodium cicutarium | 6.2 | 9.3 | 0.234 | 0.303 | Sonchus alarceus | 5.2 | 3.9 | 0.097 | 0.253 |
| Erodium malacoides | 5.2 | 10.8 | 0.273 | 0.253 | Spargularia bocconeii | 1.0 | 1.3 | 0.032 | 0.051 |
| Erodium moschatum | 1.0 | 1.3 | 0.032 | 0.051 | Stipagrostis ciliata | 11.3 | 99.5 | 2.508 | 0.556 |
| Eucalyptus tricarpa | 1.0 | 1.3 | 0.032 | 0.051 | Stipagrostis obtusa | 1.0 | 0.3 | 0.006 | 0.051 |
| Euphorbia cuneosa | 1.0 | 0.3 | 0.006 | 0.051 | Tamarix nilotica | 4.1 | 5.4 | 0.136 | 0.202 |
| Euphorbia schimperiana | 4.1 | 6.4 | 0.162 | 0.202 | Tamarix nilotica | 2.1 | 0.5 | 0.013 | 0.101 |
| Euphorbia serpens | 1.0 | 0.3 | 0.006 | 0.051 | Tetrapogon tenellus | 3.1 | 4.9 | 0.123 | 0.152 |
| Euphorbia sp. | 2.1 | 0.5 | 0.013 | 0.101 | Tetrapogon villosus | 4.1 | 5.4 | 0.136 | 0.202 |
| Fagonia indica (=Zygophyllum indicum) | 13.4 | 12.6 | 0.318 | 0.657 | Trichodesma sp. | 4.1 | 2.3 | 0.058 | 0.253 |
| Faidherbia albida | 3.1 | 5.7 | 0.143 | 0.152 | Urostelium parviflorum | 2.1 | 1.0 | 0.026 | 0.051 |
| Fassettia longisiliqua | 6.2 | 4.1 | 0.104 | 0.303 | Urostelium parviflorum | 2.1 | 1.0 | 0.026 | 0.051 |
| Felícia abyssinica | 8.2 | 18.8 | 0.474 | 0.404 | Urostelium parviflorum | 2.1 | 1.0 | 0.026 | 0.051 |
| Felícia dentata | 5.2 | 3.9 | 0.097 | 0.253 | Urostelium parviflorum | 2.1 | 1.0 | 0.026 | 0.051 |
| Ficus cordata subsp. salicifolia | 20.6 | 7.2 | 0.182 | 1.011 | Urostelium parviflorum | 2.1 | 1.0 | 0.026 | 0.051 |
| Ficus ingens | 15.5 | 5.4 | 0.136 | 0.758 | Urostelium parviflorum | 2.1 | 1.0 | 0.026 | 0.051 |
| Ficus palmata | 7.2 | 2.3 | 0.058 | 0.354 | Urostelium parviflorum | 2.1 | 1.0 | 0.026 | 0.051 |
| Ficus sycomorus | 11.3 | 5.4 | 0.136 | 0.556 | Urostelium parviflorum | 2.1 | 1.0 | 0.026 | 0.051 |
| Flueggea virosa | 8.2 | 5.2 | 0.130 | 0.404 | Urostelium parviflorum | 2.1 | 1.0 | 0.026 | 0.051 |
| Forsskaolea tenacissima | 9.3 | 7.0 | 0.175 | 0.455 | Urostelium parviflorum | 2.1 | 1.0 | 0.026 | 0.051 |
| Fumaria abyssinica | 3.1 | 1.8 | 0.045 | 0.152 | Urostelium parviflorum | 2.1 | 1.0 | 0.026 | 0.051 |
| Galium setaceum | 1.0 | 0.5 | 0.013 | 0.051 | Urostelium parviflorum | 2.1 | 1.0 | 0.026 | 0.051 |
| Galium sp. | 2.1 | 1.0 | 0.026 | 0.101 | Urostelium parviflorum | 2.1 | 1.0 | 0.026 | 0.051 |
| Plant name          | Frequency | density/ha | Relative density | Relative frequency | Frequency | density/ha | Relative density | Relative frequency |
|---------------------|-----------|------------|------------------|--------------------|-----------|------------|------------------|--------------------|
| Geranium sp.        | 8.2       | 30.4       | 0.767            | 0.404              | 5.2       | 2.3        | 0.058            | 0.253              |
| Gladiolus daleni    | 1.0       | 2.6        | 0.065            | 0.051              | 18.6      | 22.2       | 0.559            | 0.910              |
| Glinus lotoides     | 1.0       | 0.5        | 0.013            | 0.051              | 5.2       | 3.9        | 0.097            | 0.253              |
| Gomphocarpus fruticosus | 11.3     | 6.7        | 0.169            | 0.556              | 7.2       | 6.7        | 0.169            | 0.354              |
| Grewia erythreae    | 5.2       | 1.3        | 0.032            | 0.253              | 2.1       | 1.5        | 0.039            | 0.101              |
| Grewia tembensis    | 9.3       | 6.2        | 0.156            | 0.455              | 30.9      | 35.1       | 0.884            | 1.516              |
| Grewia tenax        | 7.2       | 5.2        | 0.130            | 0.354              | 9.3       | 7.0        | 0.175            | 0.455              |
| Grewia trichocarpa  | 18.6      | 11.9       | 0.299            | 0.910              | 1.0       | 0.3        | 0.006            | 0.051              |
| Grewia velutina     | 1.0       | 0.3        | 0.006            | 0.051              | 9.3       | 7.5        | 0.188            | 0.455              |
| Grewia villosa      | 5.2       | 2.6        | 0.065            | 0.253              | 3.1       | 3.1        | 0.078            | 0.152              |
| Gymnosporia parviflora (=Maytenus parviflora) | 41.2 | 47.7 | 1.202 | 2.021 |
| Helichrysum glumaceum | 9.3    | 10.8       | 0.273            | 0.455              | 3.1       | 2.6        | 0.065            | 0.152              |
| Helichrysum sp.     | 1.0       | 5.2        | 0.130            | 0.051              | 1.0       | 0.5        | 0.013            | 0.051              |
| Heliotropium sp.    | 3.1       | 2.1        | 0.052            | 0.152              | 1.0       | 0.5        | 0.013            | 0.051              |
| Hibiscus aponeurus  | 2.1       | 0.5        | 0.013            | 0.101              | 5.2       | 1.8        | 0.045            | 0.253              |
| Hibiscus aponeurus  | 1.0       | 0.3        | 0.006            | 0.051              | 2.1       | 2.3        | 0.058            | 0.101              |
| Hibiscus deflersii  | 9.3       | 7.7        | 0.195            | 0.455              | 11.3      | 4.4        | 0.110            | 0.556             |

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