IJBPAS, April, 2018, 7(4): 443-460

ISSN: 2277–4998

International Journal of Biology, Pharmacy and Allied Sciences (IJBPAS)

'A Bridge Between Laboratory and Reader'

www.ijbpas.com

INVENTORY OF MOST RARE AND ENDANGEREDPLANT SPECIES IN ALBAHA REGION, SAUDI ARABIA

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Received 17th Nov. 2017; Revised 15th Dec. 2017; Accepted 5th January 2018; Available online 1st April 2018

ABSTRACT

Rare and endangered plant species have been investigated based on intensive field work covering all ecological zones in Albaha region, Saudi Arabia. Different cross sections were placed randomly along different ecological sites. In each different habitat types plant species were recorded and sampled by using quadrates 25 by 25 m, and then most rare and endangered species were identified according to the percentage of frequency. In this investigation 46 rare and endangered plant species belongs to 33 families and 41 genera in which 10 endemic to Arabian Peninsula were identified and documented. Names of plants, frequency percentage and density per hectare were gathered. The distribution of rare species, patterns of some most rare and endangered plant species were mapped by using ARC-GIS techniques.

Keywords: Plant species, rare, endangered, endemic, near endemic, Albaha, Saudi Arabia

1. INTRODUCTION

Rare and endangered species are a species that faces extinction in all, or a part of its range (Avise, 2016). However, a species is considered endangered when one or more

of its populations have declined, rare species becoming extinct and extinction is a natural process (Starr *et al*., 2010). Biodiversity, including plant species diversity is threatened worldwide (Diaz *et al.*, 2006), as a result of anthropogenic pressures such as an increase of pollutants, human activities, human modifications of ecosystems and habitat destruction in addition to climate change (Baillie *et al.*, 2004, Kevin, 2016). The current millennium is experiencing a fast of extinction and species introduction posing a major threat to the biodiversity (Chaudhury and Khan, 2010). Over 8000 tree species, representing 10% of the planet's trees, are threatened with extinction due to the degradation, or destruction of woodland and forest habitat, or unsustainable timber production (Chaudhury and Khan, 2010). Rare species have a low frequency over habitat patches, and consequently a limited contribution to the community assembly process (Bossuyt *et al*., 2004).

The rate of extinction raised dramatically during a mass extinction when organism and habitats become extinct in relatively short period (Starr *et al.*, 2010), unlike past mass extinctions, caused by events like asteroid strikes, volcanic eruptions, and natural climate shifts, the current crisis is almost entirely caused by humans. In fact, there is 99 percent of currently threatened species are at risk from human activities, primarily those driving habitat loss, introduction of exotic species, and global warming (Endangered Species, 2009). However, nowadays the plant and animal species are disappearing worldwide at an accelerated pace. Based on recent trends, 21 % of global plant species are currently threatened with extinction according to the IUCN Red List Criteria (KEW, 2010). There are more than 300,000 known species of plants. The IUCN has evaluated only 12,914 species, finding that about 68 percent of evaluated plant species are threatened with extinction (Tilman *et al.*, 1994,Withrow, 2016), as many as half of the world's plant species may qualify as threatened with extinction under the World Conservation Union (IUCN) classification scheme (Nigel and Jørgensen, 2002). In 2012, the IUCN assessed a total of 63,837 species which revealed 19,817 are threatened with extinction. With 3,947 described as "critically endangered" and 5,766 as "endangered", while more than 10,000 species are listed as "vulnerable" (IUCN, 2016).

The percentage of rare and endangered species is very high in Saudi Arabia in comparison with other Middle Eastern countries. As there are about 2250 plant species in the Kingdom, 600 species are rare and endangered in their natural habitat (Al-Qurainy *et al*., 2013; Collenette, 1998, NCWCD, 1998). There is no complete red

list of plants or lists of threatened plants have been published for Saudi Arabia. The 1997 IUCN Red List of threatened Plants (Walter & Gillett, 1998) included 3 threatened species from Saudi Arabia and Eritrea, the 2003 Red List included five threatened plant species from Saudi Arabia, among them *Euphorbia ammak* (Miller, 1998), *Dracaena serrulata* (World Conservation Monitoring Centre. 1998) and *Juniperus procera* (Farjon, 2013) . Non-Red List literature sources however list 14 flowering plants as endangered, 11 vulnerable, 23 critically endangered, and 14 extinct from Saudi Arabia (First Saudi Arabian National Report on the Convention on Biological Diversity, 2005).

Albaha region, Saudi Arabia is one of the plant diversity hotspot region of the world, the region includes within the Eastern Afromontane hotspot area (Mallon, 2011). It has one of the richest plants in the Saudi Arabia; recent study (Al-Khulaidi, *et al.*, 2016) recorded 325 plant species (about 12 % of Saudi Kingdom's plants). The richness and density of the floral biodiversity have been noted by the authors, with many rare and endangered plant species. The region is not just rich in plant species but also in native populations of useful or economically important plants. Tree species are of particular importance in the region of *Juniperus procera* and *Acacia origena* forest and woodland.

The study aims to determine the initial population, the frequency percentage and the density per hectare of 46 most rare and endangered plant species of Albaha region, Saudi Arabia. The evaluation focused on the determining the conservation status, mapping the distribution and documenting the density and the frequency of each rare plant species. This study has been compiled using the recent study by the Authors on the distribution and abundance of plants species to Albaha.

1.1. **Site description**

Albaha region is located in the south western part of Saudi Arabia and lies between longitude 41/42E and latitude 19/20N (Fig. 1).

Topography

The topography consists of four main geographical units (Al-Khulaidi, *et al*., 2016): Tihama plain: undulating to almost sandy plain, the altitude ranges between 50 and 200 (350 m), Very steep to moderately steep slope foothills facing Tihama plain and ranges between 200 and 2100 m. High altitude mountains and range between 1700 and 2565 m. Eastern dry mountain and hills, and range between 1300 and 1700.

Average annual rainfall ranges between 142 (Al-Aqiiq), 300 to 316 (Albaha and Al-Mandaq), and 200 m at Al-Mukhwa.

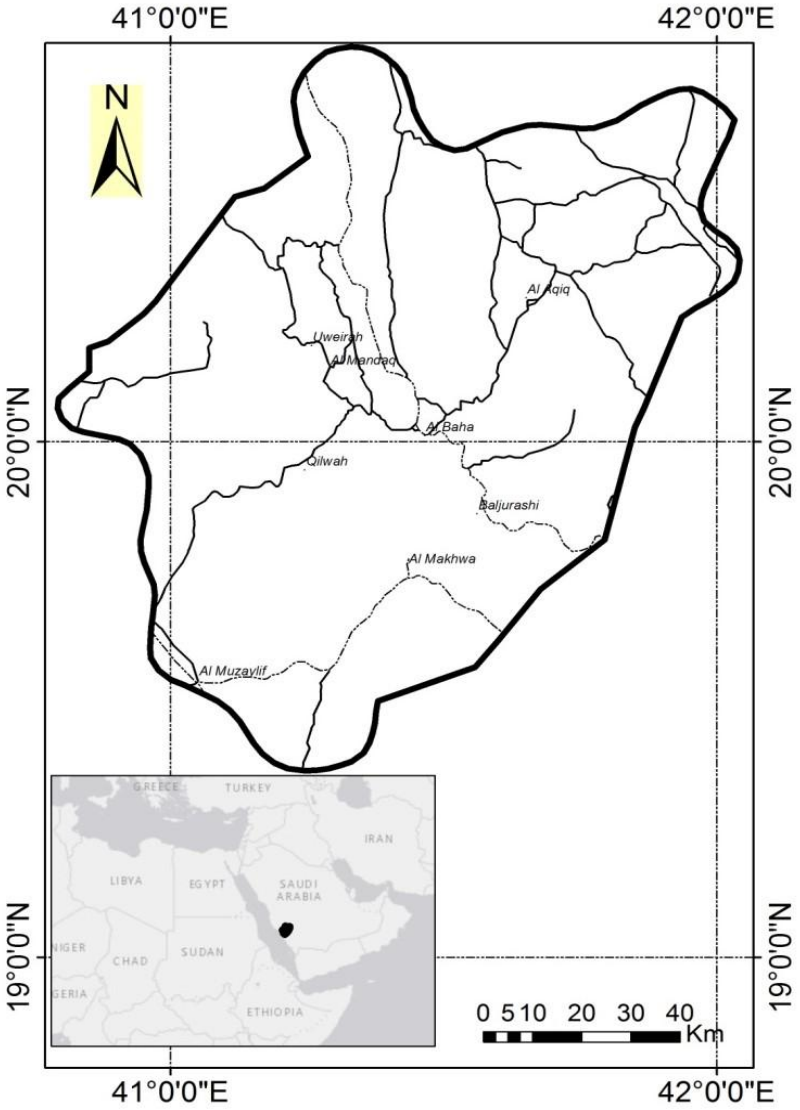

Figure 1: Location of the study area

2. MATERIALS AND METHODS

Different cross sections were placed randomly along different ecological sites. In each different habitat types plant species were recorded and sampled by using quadrates 25 by 25m, and then most rare and endangered species were identified according to the percentage of frequency of each plant. The survey was carried out during the month of May 2017 to July 2017 on visited various ecological sites and observed distribution of plant species. On the basis of Inventory of rare, endangered and threatened plants identification and collection from different area of Albaha region as well as carefully documented. The plants are enumerated alphabetically with their botanical name with author citation and family name by using the experience of the authors, and referring to standard flora (Collenette, 1998; Qashash, 2007; Chaudhary, 1999, 2000, 2001;

Gushash, 2007; Migahid, 1996). The voucher specimens were deposited in the Albaha University.

2.1. Data analysis

The distribution of each rare and endangered plant species were mapped using ARC-GIS techniques. Canonical Correspondence Analysis (CCA) was applied using MVSP (Multi-Variate Statistical Package) to study the relationship between the species and 3 variables (altitude, exposure and landforms). Frequency is used to describe the abundance and distribution of species. Frequency can be used to detect changes in plant species over time. It is typically defined as the number of times a species occurs in the total number of quadrats sampled, usually expressed as a percent. Frequency is one of the fastest and easiest methods for monitoring plant species because it is objective, repeatable, and requires just one decision. Frequency is a useful tool for comparing two plant communities; or to detect change within one plant community over time (Caratti, 2006; Al-Khulaidi *et al*., 2010).

The rarity and the scarcity of taxa present throughout the region of intervention were assessed from the calculation of relative frequency of each taxa. Frequency percentage was used to estimate the rarity degrees as the following: Relative frequency of plant species (in %), Very common ≥ 20 and 35 % , Common ≥ 12 and <20% , Fairly common ≥ 10 and <12% , Uncommon ≥ 5 and 10% , Rare ≥ 1 and 5 % and Very rare <1%

3. RESULTS

The results of this study have revealed 46 rare, endangered plant species belong to 33 families and 41 genera. Among them, there are 3 endemic and 7 near endemic species (Tables 1 and 2). All investigated plant species fall under very rare category with frequency percentage less than 1%. This study shows the maximum number of rare, endangered and threatened plant species in which belong to the family Aloeaceae (Xanthorrhoeaceae) as they cover 4 species, followed by Rubiaceae family with 3 species (Table 2 and Figure 2). The distribution of 46 species was mapped (Figure 3) using Arc Map. The concentration of rare species was high around Jabal Shada and Aqabat Huzna.

Table 1: Rare species with their frequency percentage and density per hectare				
Scientific name (* = endemic to Arabian Peninsula)	Family	Freq. %	Density /ha	Regional distribution
1) *Abrus precatorius* L.	Fabaceae	0.31	0.05	
2) *Adenia venenata* Forssk.	Passifloraceae	0.63	0.15	
3) *Aloe castellorum* J. R. I. Wood. *	Aloeaceae	0.94	7.85	Saudi Arabia &YemenCollenette, 1998; Al-Khulaidi, 2013)
4) *Aloe pseudorubroviolacea* Lavranos & Collen. *	Aloeaceae	1.25	1.25	Saudi Arabia (Collenette, 1998)
5) *Aloe sabaea* Schweinf. *	Aloeaceae	0.31	0.2	Saudi Arabia & Yemen (Collenette, 1998; Al-Khulaidi, 2013)
6) *Aloe shadensis* Lavranos & Collen.*	Aloeaceae	0.63	0.15	Saudi Arabia (Collenette, 1998
7) *Anagyris foetida* L.	Fabaceae	0.94	0.4	
8) *Barleria hochstetteri* Nees ex DC.	Acanthaceae	0.31	0.15	
9) *Caralluma tuberculata N.E.Br.(syn.Borealluma tuberculata (N.E.Br.)Plowes)*	Apocynaceae	0.63	0.35	
10) *Boscia angustifolia* A. Rich.	Capparaceae	0.94	0.15	
11) *Breonadia salicina* (Vahl) Hepper & J. R. I. Wood	Rubiaceae	0.31	0.1	
12) *Buddleja polystachya* Fresen	Loganiaceae	1.56	1.25	
13) *Capparis decidua* (Forssk.)Edgew.	Capparaceae	0.63	0.15	
14) *Celtis africana* Burm.f.	Ulmaceae	1.56	0.45	
15) *Centaurothamnus maximus* (Forssk.)Wagen. &Dittr *	Asteraceae	0.94	0.4	Saudi Arabia & Yemen (Collenette, 1998; Al-Khulaidi, 2013)
16) *Commiphora gileadensis* (L.) Christ.	Burseraceae	0.94	0.15	
17) *Commiphora kua* (R. Br. ex Royle) K. Vollesen	Burseraceae	1.56	0.45	
18) *Convolvulus asyrensis* Kotschy *	Convolvulaceae	0.63	0.25	Saudi Arabia (Collenette, 1998)
19) *Cordia monoica* Roxb.	Boraginaceae	1.56	0.65	
20) *Delonix elata* (L.) Gamble.	Caesalpiniaceae	0.31	0.15	
21) *Desmidorchis penicillata* (Deflers) Plowes (syn. *Caralluma penicillata* (Deflers) N. E. Br)	Apocynaceae	1.56	0.25	
22) *Diospyros mespiliformis* Hochst.ex DC.	Ebenaceae	1.25	0.7	
23) *Dobera glabra* (Forssk.)Poir.	Salvadoraceae	1.56	0.25	
24) *Dracaena serrulata*Baker.f.	Dracaenaceae	0.31	0.05	
25) *Ehretia obtusifolia* Hochst.ex DC.	Boraginaceae	1.56	0.25	
26) *Erica arborea*L.	Ericaceae	0.31	0.25	
27) *Euphorbia cuneata*Vahl	Euphorbiaceae	0.63	0.1	

28) Euphorbia parciramulosa Schweinf. *	Euphorbiaceae	0.31	0.6	Saudi Arabia & Yemen (Collenette, 1998; Al-Khulaidi, 2013)
29) Faidherbia albida (Delile) A. Chev.	Mimosaceae	1.25	3.6	
30) Ficus vasta Forssk.	Moraceae	1.25	0.2	
31) Grewia velutina (Forssk.)Vahl.	Tiliaceae	1.56	0.35	
32) Leucas alba (Forssk.) Sebald *	Lamiaceae	1.25	1.5	Saudi Arabia and Yemen (Collenette, 1998; Al-Khulaidi, 2013)
33) Melhania ovate (Cav.) Sprens.	Sterculiaceae	0.94	0.25	
34) Mimusops laurifolia (Forssk.)Friis	Sapotaceae	0.31	0.05	
35) Morella humilis (Cham. & Schltdl.) Killick	Myricaceae	0.63	0.15	
36) Moringa peregrine (Forssk.) fiori	Moringaceae	0.31	0.05	
37) Ochna inermis (Forssk.) Schweinf.	Ochnaceae	1.25	0.3	
38) Osyris quadripartite Salzm. ex Decne	Santalaceae	0.63	0.1	
39) Pandanus odorifer (Forssk.) Kuntze	Pandanaceae	1.25	1	
40) Pavetta longiflora Vahl. subsp. *longiflora* *	Rubiaceae	0.31	0.05	Saudi Arabia & Yemen Collenette, 1998; Al-Khulaidi, 2013)
41) Peganum harmala L.	Zygophyllaceae	0.31	0.05	
42) Plectranthus asirensis J. R. I. Wood. *	Lamiaceae	0.31	1.25	Saudi Arabia & Yemen Collenette, 1998; Al-Khulaidi, 2013)
43) Psydrax schimperiana (A. Rich.) Bridson	Rubiaceae	1.88	0.7	
44) Rhamnus staddo A. Rich.	Rhamnaceae	1.88	0.3	
45) Teclea nobilis Del.	Rutaceae	0.94	0.35	
*46) Ziziphus mucronata*Willd.	Rhamnaceae	0.31	0.1	

Table 2: Families with number of species, genera, endemic and near endemic species									
Family	*species*	*genera*	*endemic*	*near endemic*	*Family*	*species*	*genera*	*endemic*	*near endemic*
Acanthaceae	**1**	**1**			**Moraceae**	**1**	**1**		
Aloeaceae	**4**	**1**	**2**	**2**	**Moringaceae**	**1**	**1**		
Apocynaceae	**2**	**2**			**Myricaceae**	**1**	**1**		
Asteraceae	**1**	**1**		**1**	**Ochnaceae**	**1**	**1**		
Boraginaceae	**2**	**2**			**Pandanaceae**	**1**	**1**		
Burseraceae	**2**	**1**			**Passifloraceae**	**1**	**1**		
Caesalpiniaceae	**1**	**1**			**Rhamnaceae**	**2**	**2**		
Capparaceae	**2**	**2**			**Rubiaceae**	**3**	**3**		**1**
Convolvulaceae	**1**	**1**		**1**	**Rutaceae**	**1**	**1**		
Dracaenaceae	**1**	**1**			**Salvadoraceae**	**1**	**1**		
Ebenaceae	**1**	**1**			**Santalaceae**	**1**	**1**		
Ericaceae	**1**	**1**			**Sapotaceae**	**1**	**1**		
Euphorbiaceae	**2**	**1**	**1**		**Sterculiaceae**	**1**	**1**		
Fabaceae	**2**	**2**			**Tiliaceae**	**1**	**1**		
Lamiaceae	**2**	**2**		**2**	**Ulmaceae**	**1**	**1**		
Loganiaceae	**1**	**1**			**Zygophyllaceae**	**1**	**1**		
Mimosaceae	**1**	**1**			**33**	**27**	**22**	**3**	**6**

Endemic = only found in Saudi Arabia, Near Endemic = found in both Saudi Arabia and Yemen.

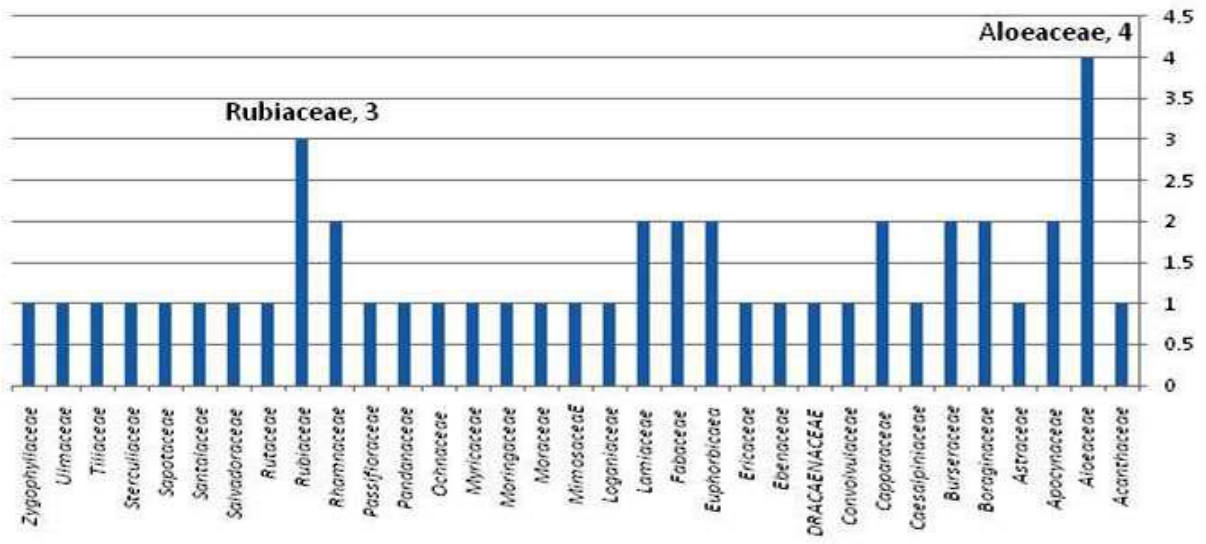

Figure 2: Plant families with number of rare species

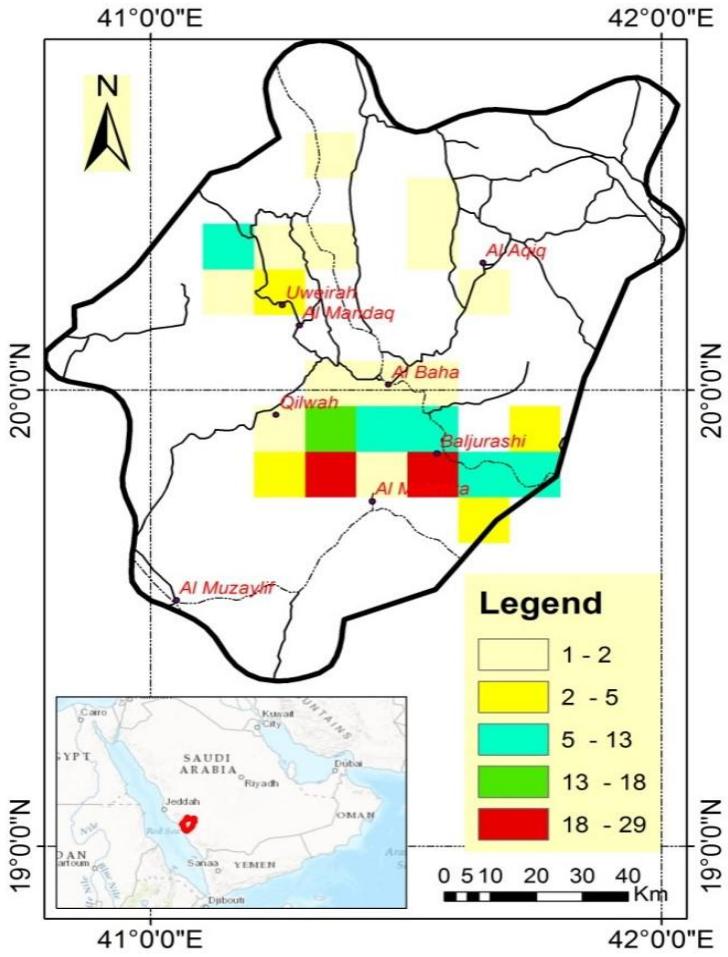

Figure 3: The distribution of rare and endangered plant species with their concentration rate in Albaha region. The distribution was high in JabalShada, South of Baljurashi and AqabatHuzna

Environmental data analysis of the plant species

The CCA axis (Fig. 4) shows that altitude increases along a gradient from the right to left and are strongly correlated with ordination axis 1. Altitude is the most important environmental variable. The CCA axis represents the following orders:

The species *Barleria hochstetteri* and *Pandanus odorifer*(top right) are found on drainage lines and fields facing South West at low altitude areas. The species *Abrus precatorius, Adenia venenata, Aloe shadensis, Boscia angustifolia, Breonadia salicina, Cordia monoica, Diospyros mespiliformis, Ehretia obtusifolia, Ficus vasta, Grewia velutina, Ochna inermis, Plectranthus asirensis, Psydrax schimperianum, Teclea nobilis* and *Ziziphus mucronata* (middle right) are found on rocky slopes and wadis between 800 and 1720 facing mainly North West.

The species *Aloe sp., Commiphora kataf, C. gileadensis, Delonix elata, Doberaglabra, Euphorbia cuneata, E. parciramulosa* (bottom right) are found on rocky slopes of low altitude area (between 400 and 815 m), mainly South, East, South East and South

West directions. The species *Convolvulus asirensis, Buddleja polystachya, Erica arborea, Pavetta longiflora* and *Peganum harmala* (top left) are found on terraces, wadis and rocky slope between 1400 an 2135 facing mainly South West and North west. The species *Aloe castellorum, A. pseudorubroviolacea, Celtis africana, Leucas alba, Osyris quadripartita, Rhamnus staddo* (middle right) are found on rocky slopes, rocky outcrops and terraces of high altitude areas (between 1800 and 2400m), mainly West, North West and South directions. The species *Desmidorchis penicillata, Melhania ovata* and *Morella humilis* (middle right) are found on rocky slopes, rocky outcrops and wadis at middle and high altitude areas (between 1400 and 2060 m.) mainly West and North West directions. The species *Anagyris foetida, Borealluma tuberculata, Centaurothamnus maximus* and *Faidherbia albida* (bottom right) are found at the middle and high altitude areas(between 1600 and 2400 m.) on rocky slopes, terraces and wadis mainly East and North East directions. The species *Commiphora kua and Dracaena serrulata*are found on rocky slopes between 815 and 1700 mainly South, and West directions. *The species Capparis decidua, Mimusops laurifolia* and *Moringa peregrina* are found on rocky slopes and wadis at middle altitude areas between 1370 and 1600 mainly north direction.

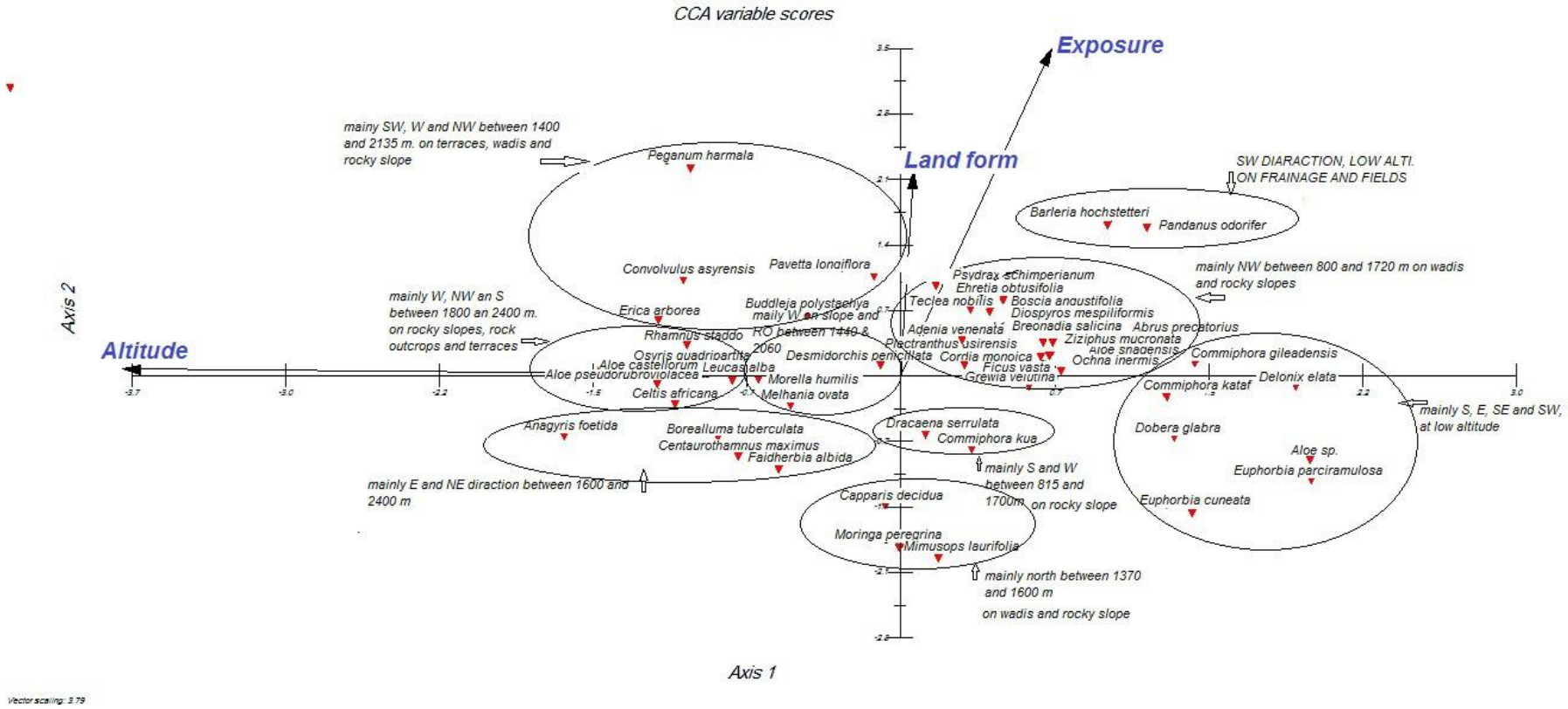

Figure 4: Canonical Correspondence Analysis (CCA) ordination biplot of plant species on main landforms and environmental variables (altitude, Exposure and land form). Altitude is the most important environmental variable

4. DISCUSSION

Rarity is common phenomena and occurs for different reasons. A species may be rare because it has a limited range of habitats, or because it has low populations, with scattered individuals, or a species may be rare because has an extreme habitat specialization (Dinerstein, 2013). Rare species, which might be at risk due to their small population size and narrow geographic range with increased vulnerability to disturbance can be endangered and threatened.

Few species characterized by total population that have just a few individuals with a narrow geographic range, these are the very rarest plants. For example, the following species were represented by only one single species restricted to one geographical area: *Abrus precatorius*, *Dracaena serrulata*, *Mimuso pslaurifolia*, *Pavett alongiflora* subsp. *Longiflora* and *Peganum harmala* or with few single species (2-4) restricted to one geographical area for instance: *Breona diasalicina*, *Ziziphus mucronata*, *Euphorbia cuneata*, *Osyris quadripartite*, *Aloe sabaea*, *A. shadensis*.

Other rare plants have many individuals, but these are crowded into a tiny area, like *Aloe pseudorubro violacea, A.castellorum, Centauro thamnusmaximus, Faidherbia albida* (Figure 5 and Figure 6).

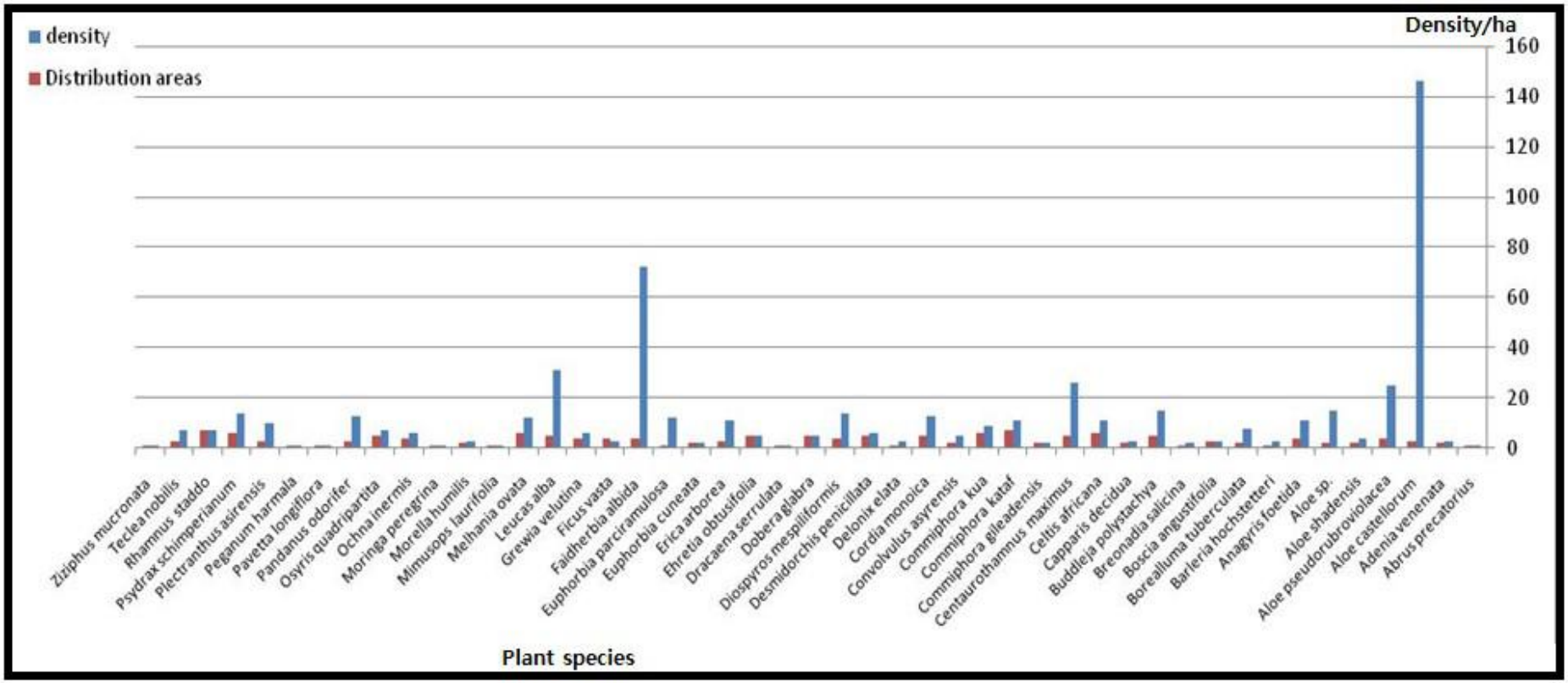

Figure 5: The density and the distribution areas of species. Few species have many individuals, but these are crowded into a tiny area, like *Aloe pseudo rubroviolacea, A. castellorum, Centauro thamnusmaximus, Faidherbia albida*, Other species were represented by only one single species restricted to one geographical area: *Abrus precatorius*, *Aloe sabaea, Dracaena serrulata*, *Mimusops laurifolia*, *Pavetta longiflora* subsp. *longiflora* and *Peganum harmala*

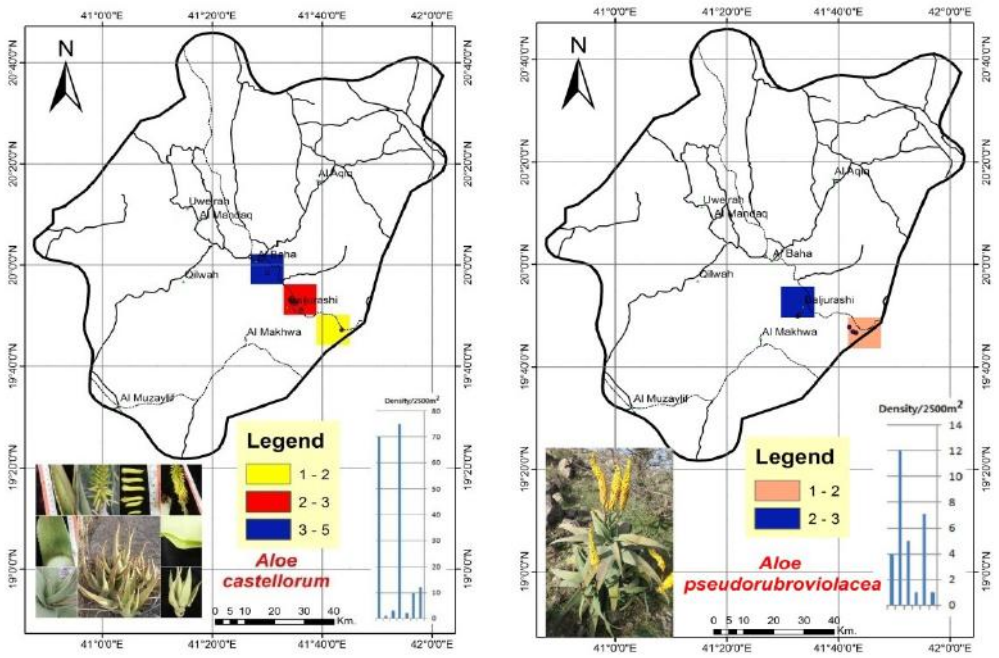

Figure 6: The distribution patterns of *Aloe castellorum* and *A. pseudorubroviolacea*
The charts show the patterns of individuals per 2500 m^2 of the plant. For *Aloe castellorum* the individual's patterns range between 4 to 75, for *A. pseudorubroviolacea* the individuals patterns range between 1 to 12

Few species were represented by single species with wide geographic range such as *Boscia angustifolia*, *Rhamnus staddo*, *Dobera glabra*, *Ehretia obtusifolia* and *Ficus vasta* (Figure 7).

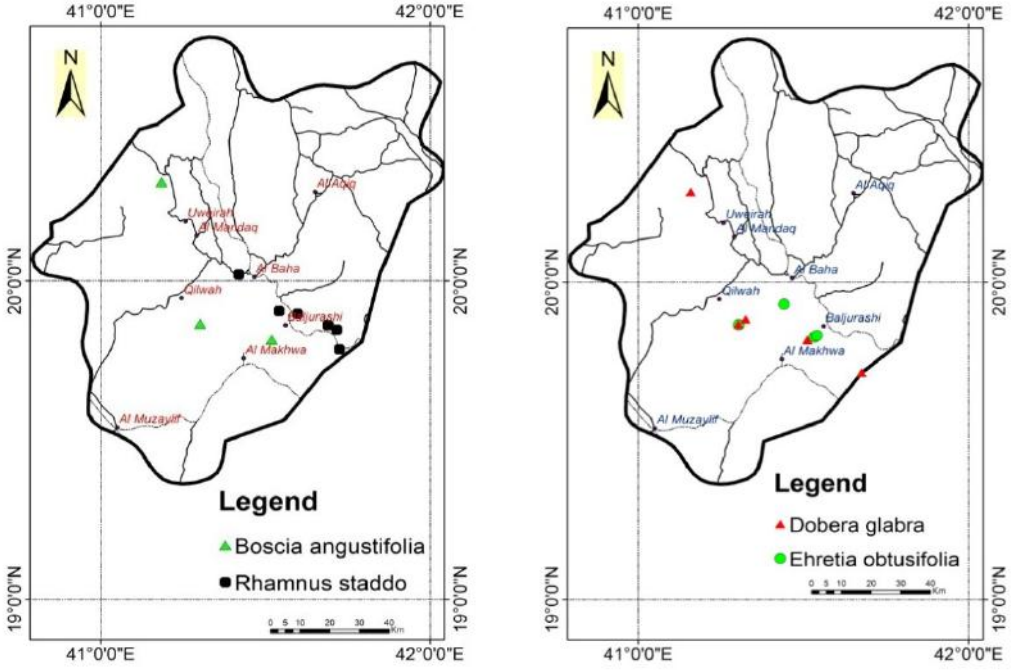

Figure 7: Rare plant species represented by single species with wide geographic range

Some rare plants occur sparsely over a broad area such as *Buddleja polystachya* and *Centauro thamnusmaximus* (Figure 8).

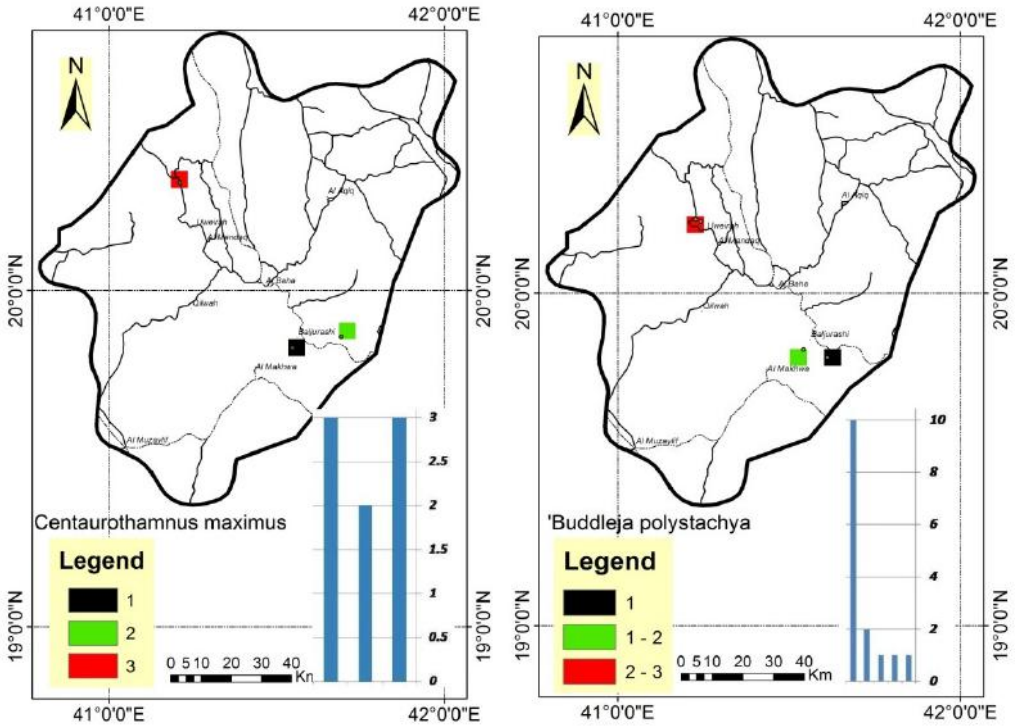

Figure 8: Rare plants occur sparsely over a broad area. The charts show the patterns of individuals of the plant per 2500 m^2

5. CONCLUSION

The findings of the present study documented 46 rare, endangered and threatened listed plant species in Albaha region. These species are closely contact with local community. Over exploitation of these species may cause the disappearing and destruction of habitats. Few species near the settlement areas such as the endemic *Aloe pseudo rubroviolacea* and *A.castellorum* are seriously threatened.

By conducting the awareness program among the local community we can promote the knowledge about importance of diversity and also can conserve the rare plants. We recommended advice to make a botanical garden and proper cultivation of threatened and important rare plants like, *Aloe pseudorubroviolacea, A. castellorum, Breonadia salicina, Delonix elata, Dracaena serrulata, Mimusopsl aurifolia, Moringa peregrina* and others.

The available information on endangered and threatened plant species are generally based on single collection reports and do not include any quantitative assessments of population sizes and total distribution or even the exact coordinates, so it is difficult to determine their status according to IUCN categories.

Aloe shadensis only known from Jabal Shada and Qilwa, no further information known on the occurrence of this endemic plant in other locations (data deficient), further field work is needed particularly as suspected to be threatened by collectors.

More investigation in Albaha region will reveal more rare and endangered plant species.

ACKNOWLEDGEMENTS

The researchers would like to express their thanks to the director of University of Al Baha, the Dean of College and the head of Biology department of Science and Arts, Baljurashi, Al Baha University (BU), for their help and assistance to fulfil this study.

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