Main vegetation types and plant species diversity along an altitudinal gradient of Al Baha region, Saudi Arabia

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Received 8 November 2015; revised 2 February 2016; accepted 4 February 2016
Available online 3 March 2016

1. Introduction

The vegetation types of Al Baha region have not been studied in detail before, and this study is the first comprehensive one on the entire vegetation communities across altitudinal gradient in Al Baha region. A few studies have been carried out...
on the vegetation of Al Baha and focused on the recording of few or individual plant species and vegetation (Alaklabi et al., 2014; Al-Zahrani and Elhag, 2005; Collenette, 1985; El-Karemy and Zayed, 1996; Hajar, 1993; Hassan and Al-Hemaid, 1995; Zayed and Fayed, 1987).

Al Baha region characterized by high diverse vegetation, Juniperus procera woodland and forest found there in abundance beside other communities. The high mountains of Al Baha are considered as one of most significant plant diversity zones in Saudi Arabia. Although Al-Baha is a small area in Kingdom of Saudi Arabia, recent studies estimated about 230 plant species (about 12% of the total plant species of the Kingdom). The flora of Al Baha is a mixture of the tropical African, Sudanian plant geographical region (Paleotropical origin) and the with very few of Saharo-Sindian or Saharo-Arabian region (Holarctic origin) and Mediterranean regions (Al-Khulaidi, 2013). Most of Al Baha’s flora belongs to Sudanian region of Eritreo-Arabian province of Sudanian region (Zohary, 1973) or Somalia-Masai region center of endemism, (White, 1983). The Sudanian element dominates the western mountains and parts of the high land plains which are characterized by relatively high rain fall. The Mediterranean region element dominates the high mountain areas. The Saharo-Arabian element dominates the coastal plains, eastern mountain and the eastern and northern desert plains.

Much of the work on vegetation classification comes from European and North American ecologists (Van Der Maarel, 2004; Feldmeyer-Christie et al., 2005). They have fundamentally different approaches. In North America, vegetation types are based on a combination of the following criteria: climate pattern, plant habit, phenology and/or growth form, and dominant species. In the current US standard (adopted by the Federal Geographic Data Committee (FGDC), and originally developed by UNESCO and the Nature Conservancy, the classification is hierarchical and incorporates the non-floristic criteria into the upper (most general) five levels and limited floristic criteria only into the lower (most specific) two levels (Van Der Maarel, 2004). In Europe, classification often relies much more heavily, sometimes entirely, on floristic (species) composition alone, without explicit reference to climate, pheno-ology or growth forms (Feldmeyer-Christie et al., 2005). It often emphasizes indicator or diagnostic species which may distinguish one classification from another.

The aim of vegetation classification in this study is to group the plant species together on the basis of their floristic composition into vegetation types (communities) generally known as plant phytosociological units using MVSP software and following the method of Braun-Blanquet ordination methods.

2. Site description

Al Baha region (Fig. 1) is located in the south western part of Saudi Arabia. It is situated between longitude 41/42E and latitude 16/20N. The study area is located along environmental gradients with an elevation of 130–2450 m above sea level. It is a transition zone between dry coastal plain, Rocky mountains that face west and semi desert mountains that face east. It has a wide variety of woodland, shrubland, grassland, and forest habitats accompanied by many plant species.

2.1. Topography

Al Baha region composes of three main ecosystems as in Fig. 2. Tihama plain: it is a sandy flat to undulating plain, ranging from 50 to 150 (200 m) and narrowing toward northwest slopes and touching the foothills at 350 m. The plain is intersected by many valleys mainly wadi Nawan, wadi Al Hasaba, wadi Malal, wadi Nabira and wadi Uleib.
The foothills facing Tihama: it is a medium to steep slope intersected by valley gullies, descending gradually toward the west, the altitude ranges from 200 (400) to 2001 and 2200 west of Al Baha city and Uwera and between 2000 and 2100 m west of Baljurashi.

High-altitude mountains: in some parts with almost flat and undulating plateaus, the altitude ranges between 1700 to the east and from 2000 to 2500 m toward the west at Jabal Alzzrayeb, rising up to 2565 m at Al Hamd (north-east of Al Baha city).

The eastern mountains and plateaus: gradually descend toward the east and north-east, dissected by several valleys such as the wadi Jazab and wadi Ayna. The altitude ranges between 1300 and 1700 m.

2.2. Climate

The Orographic rise of air masses from the onshore wind provides an effective cooling mechanism, which causes rainfall. For example, areas exposed to the sea such as the southern slopes, receive more rainfall than the zones facing the interior plateau. Local topographic features cause similar effects, at correspondingly smaller scales. According to Koppen’s climate classification system (1936), dry and semiarid climates (BWh) predominate in Arabian Peninsula. Almost the entire area of Al Baha belongs to the climate class BWh of tropical/subtropical desert (Ayele and Al Shadily, 2000).

The climate of Al Baha region is influenced by its varying topography. It is generally moderate in summer and cold in winter, with average temperature ranging between 12 and 23 °C. The climate is comparatively cold in winter (10–22 °C) and mild in summer (22–32 °C). Average rainfall in Al-Aqiq and Al-Mikhwah areas is 100-200 mm, temperature is 20–37 °C in winter and 36–51 °C in hot summer (Ibrahim, 2010; Aref et al., 2011). Records from 7 stations show that annual average rainfall of the Al Baha area ranges from 142 mm to 316 mm. The annual rainfall reaches 142 mm at Al Aqiq (1650 m), 300 mm at Baljurashi (2062 m), 316 mm at Al Mandaq (1948 m), and 200 mm at Al Mikhwah (600 m) (Aboulabbes, 2013).

3. Materials and methods

After preliminary reconnaissance, transects were located along Elevation Gradients in Al Baha region, Saudi Arabia, consistently correlated mainly with elevation and topography. Transects were chosen to cross the region and identify major vegetation communities in the different landforms (Fig. 3). A total of 59 plant species which stratified, randomly-placed quadrats (25 × 25 m) were sampled along this transect. With the use of vegetation data sheet, the following variables were measured and recorded in the field: Terrain (land form by field observation according to the categories, slope direction; latitude and longitude using Geographical Positioning System (GPS) and vegetation cover, expressed as number of each species in the sample site.

The following methods were used to survey the plant cover based on the Zurich–Montpellier (Kent and Coker, 1992) or Braun-Blanquet school (Zonneveld, 1989):

1. Plant species were identified and entered in rows and sample plots were entered in columns of an initial matrix.
2. Number for each plant species and environmental data such as altitude, topography, exposure for each sample plot was added.

Figure 2 Topography of Al Baha region.

Figure 3 Cross section along the study area.

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(3) Sample plots with a high similarity of plant species composition were placed side by side.
(4) Plant species with similar patterns in quadrat plots were aggregated.

Using MVSP Two-way indicator species analysis and Canonical Correspondence Analysis (CCA) were used to analyze the relationships between vegetation and environmental variables.

The number of plant species in each quadrat, as well as the number of individuals of each species was recorded to calculate plant density per hectare. ArcGIS (Arc Map) was used to create a raster plant density map along the cross section (Silverman, 1986).

4. Results and discussion

4.1. Plant species density

The 190 plant species belonging to 59 families were recorded along the cross section. These plant species formed 15 vegetation types that primarily correspond mainly to different combinations of elevation, and topography. These types are representative of the vegetation in different ecosystems. Each type had a different vegetation structure, topography and environment (Table 1). The variation types were significantly related to elevation, topography, and aspect. The highest species diversity appeared in the fog affected mountain slopes facing Tihama coastal area under medium disturbance intensity. Factors such as fogs, elevation, slope, aspect, moisture, soil and topography were strongly correlated with species composition.

Plant species density is the number of plant species and abundance of each species that are found in the study area. ArcGIS (Arc Map) was used to create a raster plant density map along the cross section. Plant density appears to peak at high altitude areas (around Aqabat Hizna and Baljurashi) and declines gradually toward south west (coastal plains) and north east (around Al Aqiq) as rainfall decreases and temperature increases (Fig. 4).

Using MVSP software and following the method of Braun-Blanquet ordination methods (Braun-Blanquet, 1932), the sample plots were arranged to similarities and then combined with 15 vegetation types (Fig. 6 and Table S1). A number of each plant species were entered in the matrix. Species with similar distributions were grouped together in the table and association-analysis final groups were re-arranged to consolidate patterns in the table as much as possible. The matrix shows a diagonal clusters where the boundaries of vegetation types in rows and sociological species groups in columns can be detected visually through the absence or presence of different plant species. Vegetation types are labeled by the dominant species (the second name) and by the species almost exclusively occurring in the vegetation type (the first name) (see Figs. 5 and 7).

4.2. Description of main vegetation types

4.2.1. Tamarix aphylla – Salvadora persica type

This type forms woodland and is restricted to wadis. The vegetation cover ranges between 30% and 36%. The topography is composed of flat wadis. The altitude ranges from 150 to 160 m above sea level. The most common species are T. aphylla and S. persica.

4.2.2. Acacia ehrenbergiana – Acacia tortilis type

This type forms sparse woodland and is found on rocky slopes adjacent to wadis and fallow lands. The altitude ranges from 136 to 275 m above sea level.

The vegetation cover is very poor ranging between 2% and 9%. The average tree cover is 20%, the average shrub cover is 1%, and the average herbaceous cover is 1%. Association plant species are S. persica, Calotropis procera and Abutilon pannosum.

4.2.3. Commiphora myrrha – Maerua crassifolia – Acacia asak type

This type forms woodland to shrubland and grassland. The vegetation cover ranges between 8% and 110%. The average tree cover is 13%, the average shrub cover is 9%, and the average herbaceous cover is 25%.

The topography is composed of steep to moderate steep slope and rock outcrops. The altitude ranges from 700 to 990 m above sea level. The dominant species is A. asak. The most common species that always occur are A. asak, Anisotes trisulcus. The following species are rare and found only in this type: Barleria acanthoides, Barleria hochstetteri, Boscia angustifolia, Commelina forsskalaei, Commicarpus sp., Commiphora kua, Dobera glabra, Ecbolium viride, Euphorbia cuneata, Indigofera spiniflora, Portulaca oleracea, Pulicaria sp., Salsola sp., Sarcostemma viminalis, Suueda aegyptica.

4.2.4. Nicotiana glauca – A. asak type

This type represents the degraded sites of type 3 that occur in the same ecological zone and in the same type of land formation but at a higher altitude. The vegetation cover ranges between 5% and 24%. The average tree cover is 5%, the average shrub cover is 2%, and the average herbaceous cover is 4%. The most common species that always occur are A. asak and N. glauca. The following species are rare and found only in this type Forskaokea tenacissima and Acacia hamulosa.

The topography is composed of a moderate steep slope. The altitude ranges from 1127 to 1756 m above sea level.

4.2.5. Flueggea virosa – A. asak type

This type forms woodland. The vegetation cover ranges between 70% and 80%. The topography is composed of a steep to moderate steep rocky drainage line. The altitude ranges from 1700 to 1750 m above sea level.

The most common plant species are: A. asak, Cissus rotundifolia, Crotalaria sp., Ficus cordata, Ficus ingens, F. virosa, Grewia trichocarpa, Grewia villosa, Lantana sp., Triumfetta flavescens.

4.2.6. Panicum turgidum – Acacia tortilis type

This type forms woodland and shrubland. The vegetation cover ranges between 18% and 65%. The average tree cover is 19%, the average shrub cover is 13%, and the average herbaceous cover is 9%. The topography is composed of wadis. The altitude ranges from 415 to 736 m above sea level.

The most common species and always occur are A. tortilis, Aerva javanica, Indigofera spinosa. The following species are
| Vegetation type | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------------|---|---|---|---|---|---|---|---|
| Plant density   | 42 | 17 | 12 | 14 | 11 | 103 | 71 | 292 |
| Richness        | 3  | 3  | 3  | 4  | 13 | 8  | 16 | 12  |
| Exposure        | S  | S  | SW | SW | SE | SW | SE | SW |
| Rainfall        | 90 | 90 | 90 | 250| 250| 250| 250| 250 |
| Trees %         | 35 | 2  | 7  | 7  | 5  | 10 | 10 | 10  |
| Shrub %         | 1  | 0  | 0  | 5  | 10 | 3  | 2  | 5  |
| Herb %          | 0  | 0  | 2  | 4  | 0  | 1  | 0  | 0  |
| Total           | 36 | 2  | 9  | 5  | 17 | 12 | 7  | 6  |
| Altitude m      | 158| 136| 275| 990| 805| 870| 782| 875 |

| Vegetation type | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|-----------------|---|----|----|----|----|----|----|
| Plant density   | 123| 31 | 14 | 17 | 16 | 16 | 16  |
| Richness        | 17 | 13 | 3  | 10 | 17 | 16 | 23  |
| Exposure        | S  | S  | NW | SW | S  | S  | S  |
| Rainfall        | 300| 300| 200| 200| 300| 300| 300  |
| Trees %         | 7  | 3  | 6  | 10 | 10 | 10 | 10  |
| Shrub %         | 25 | 5  | 40 | 8  | 2  | 5  | 2  |
| Herb %          | 5  | 30 | 70 | 5  | 35 | 35 | 40  |
| Total           | 57 | 38 | 170| 12 | 19 | 67 | 52  |
| Altitude m      | 2020| 2014| 2026| 2031| 1902| 2200| 2383 |

Table 1: Relationship between the vegetation types and different environmental factors.
4.2.7. Combretum molle – Cyphostemma digitatum type

This type forms woodland to grassland. The vegetation cover ranges between 25% and 55%. The average tree cover is 15%, the average shrub cover is 2%, and the average herbaceous cover is 20%. The topography is composed of rocky slopes and rock outcrops. The altitude ranges from 1440 to 1490 m above sea level.

The most common species and always occur are Abutilon fruticosum and C. molle. The following species are rare and found only in this type: C. molle, Coptosperma graveolens, C. digitatum, Psydrax schimperiana, Talinum portulacifolium, Echium gymnostachyum, Ocinum filamentosum, Rhynchosis sp., Aerva lanata.

4.2.8. Achillea biebersteinii – Acacia origena type

This type forms woodland to grassland. The vegetation cover ranges between 40% and 132%. The average tree cover is 33%, the average shrub cover is 5%, and the average herbaceous cover is 70%. The topography is composed of fallow lands and wadis. The altitude ranges from 2025 to 2177 m above sea level.

The most common plant species are of this type are: A. origena, A. biebersteinii, Asphodelus fistulosus, Halothamnus bottae, Onopordum heteracanthum, Verbena encelioides. The following species are rare and found only in this type: Chenopodium ambrosioides, Marrubium vulgare, Mirabilis jalapa, Phragmanthera austroarabica, Rumex steudelii, Ruta chalepensis, Xanthium spinosum.

4.2.9. Maytenus parviflora – Hyparrhenia hirta – J. procera type

This type forms forest, shrubland and grassland. The vegetation cover ranges between 12% and 170%. The average tree cover is 16%, the average shrub cover is 16%, and the average herbaceous cover is 24%. The topography is composed of rock outcrops, wadis and rocky slopes. The altitude ranges from 1900 to 2085 m above sea level.

The most common plant species of this type are: J. procera, H. bottae, H. hirta, A. origena. The following plant species are rare and only found in this type: Periploca somalensis, Farsetia longisiliqua, Celtis africana, Phyllanthus sp., Astragalus atropilosulus and Centaurothamnus maximus.

4.2.10. Lavandula dentata – Themeda triandra – J. procera type

This type forms forest, woodland and grassland. The vegetation cover ranges between 52% and 67%. The average tree cover is 18%, the average shrub cover is 3%, and the average herbaceous cover is 40%. The topography is composed of rocky slopes. The altitude ranges from 2015 to 2383 m above sea level.

The most common plant species of this type are: J. procera, T. triandra, Micromeria imbricata, Sageretia thea. The following plant species are only found in this type: Cluitia lanceolata, Lavandula dentate and rarely Gomphocarpus fruticosus, Hypoestes forskalei, Meriandra bengalenisa, Salvia aegyptiaca, Conyza pyrrophopapp, Cymbopogon sp., Ephedra aphylla.

4.2.11. Barbeya oleoides – Olea europaea – J. procera type

This type forms shrubland and grassland. The vegetation cover ranges between 38% and 90%. The average tree cover is 10%, the average shrub cover is 28%, and the average herbaceous cover is 25%. The topography is composed of steep to moderate steep rocky slopes and rocky wadis. The altitude ranges from 1700 to 2065 m above sea level.

The most common plant species of this type are: Jasminum grandiflorum, J. procera, Lavandula pubescens, O. europaea, Psiadia punctulata. The following plant species are rare and only found in this type: Opuntia ficus-indica, Pentas lanceolata.

4.2.12. Ochradenus baccatus – Dodonaea viscosa type

This type forms forest, shrubland and grassland. The vegetation cover ranges between 38% and 90%. The average tree cover is 10%, the average shrub cover is 28%, and the average herbaceous cover is 25%. The topography is composed of steep to moderate steep rocky slopes and rocky wadis. The altitude ranges from 1700 to 2085 m above sea level.

The most common plant species of this type are: Acacia ebaica, D. viscosa, O. europaea, P. punctulata. The following plant species are rare and only found in this type: Phoenix caespitosa, S. aegyptiaca.

4.2.13. Rhazya stricta – Lycium shawii type

This type forms woodland and shrubland. The vegetation cover ranges between 6% and 66%. The average tree cover is 13%, the average shrub cover is 8%, and the average herbaceous cover is 6%. The topography is composed of steep to
moderate steep rocky slopes plains, hills and wadis. The altitude ranges from 1378 to 1746 m above sea level.

The most common plant species of this type are: A. ehrenbergiana, A. etbaica, A. tortilis, L. shawii, Ziziphus spina-christi. The following plant species are rare and only found in this type: Aizoon canariensis, Desmidorchis penicillata (= Caralluma penicillata), Caralluma quadrangular (= Monoloma quadrangular), Chrozophora oblongifolia, Euphorbia granulate, Hibiscus micranthus.

4.2.14. Kleinia odora – Acacia etbaica type
This type forms woodland and shrubland. The vegetation cover ranges between 22% and 60%. The average tree cover is 11%, the average shrub cover is 11%, and the average herbaceous cover is 13%. The topography is composed of wadis and foot slopes. The altitude ranges from 1805 to 2020 m above sea level.

The most common plant species of this type are: A. etbaica, Acacia gerrardii, D. viscosa, Fagonia indica, Solanum incanum, Ziziphus spina-christi. The following plant species are rare and only found in this type: K. odora, Boerhavia elegans, Asparagus africanus.

4.2.15. Kanahia laniflora – Bacopa monnieri type
This type forms grassland. The vegetation cover reaches 86%. The average tree cover is 5%, the average shrub cover is 1%,
and the average herbaceous cover is 80%. The topography is composed of springs. The altitude ranges from 1800 to 1810 m above sea level.

The most common plant species of this type are: *Argemone ochroleuca*, *B. monnieri*, *K. laniflora*, and *Pluchea sp.*

### 4.3. Environmental data analysis

#### 4.3.1. The sampling plots
Altitude and rainfall are the most important environmental variables and increase along a gradient from the right to the left. There is a strong relationship between the distribution of sample plots of vegetation types 8–12 (left) with altitude and rainfall and between the sample plots of eastern mountain slopes, Tihama foothills and coastal plains (right) with landform. The sample plots of wadis and fallow lands (types 1, 2 and 6) are negatively correlated with altitude and moisture, while the sample plots of vegetation types 8–10, are positively correlated with altitude and rainfall. Sample sites of vegetation type 13 with variable landforms are negatively correlated with rainfall. Sample sites of wadis (type 6) are negatively correlated with rainfall and altitude.

#### 4.3.2. Plant species
The CCA axis (Fig. 8) shows that altitude and rainfall increase along a gradient from the right to left and are strongly correlated with ordination axis 1. The CCA axis represents the following orders:

Species more commonly associated with high altitude areas and high rainfall (bottom left) and more commonly associated with fallow lands e.g. *A. origena*, *A. biebersteinii*, *A. fistulosus*, *Withania somnifera*, or commonly associated with rocky slopes e.g. *Echinops sp.*, *Ficus palmata*, *H. bottae*, *M. parviflora*, *Nepeta deflersiana*, *O. heteracanthum*, *Osteospermum vaillantii*, *Polygala abyssinica*, *V. encelioides*.

Species more commonly associated with high altitude areas and relatively high rainfall and rocky areas (top left) e.g. *Anagyris foetida*, *Anarrhinum forsskaolii*, *Caylusea hexagyna*, *Centaurea pseudosinaica*, *H. hirta*, *J. procura*, *M. parviflora*, *M. imbricate*, *O. vaillantii*, *Periploca aphylla*, *P. abyssinica*, *Rumex nervosus*, *S. thea*, *T. triandra*.

Species negatively correlated with rainfall and altitude (bottom right) and more commonly associated with wadis e.g. *A. ehrenbergiana*, *C. colocynthis*, *P. turgidum*, *Desmidorchis retrosiciens*, *C. quadrangular*, *S. persica*, *E. reticulata*, *J. glauca*, *T. aphylla* or more commonly associated with rocky slopes e.g. *Acacia johnwoodii*, *Adentum obesum*, *A. trisulcus*, *A. asak*, *M. crassifolia*, *Commiphora gileadensis*, *C. myrrha*, *Acacia johnwoodii*, *Adentum obesum*, *A. trisulcus*, *A. asak*, *M. crassifolia*, *Commiphora gileadensis*, *C. myrrha*, *Cadaba farinosa*, *Cadaba glandulosus*, *Grewia erythraea*, *Grewia tenax*, *I. spinosa*, *Premna resinosa*, *Pennisetum setaceum*, *Sarcostemma sp.*

Species more commonly associated with middle to low altitude, relatively low rainfall and rocky areas or wadis and drainage lines (middle right) e.g. *C. molle*, *C. graveolens*, *C. digitatum*, *Ehretia obtusifolia*, *F. ingens*, *F. virosa*, *Grewia tembensis*, *G. trichocarpa*, *G. villosa*, *Hibiscus delfsii*, *P. schimperiana*. The species *A. etbaica*, *Acacia gerrardii*, *B. oleoides*, *C. molle*, *C. graveolens*, *C. digitatum*, *Ehretia obtusifolia*, *F. ingens*, *F. virosa*, *Grewia tembensis*, *G. trichocarpa*, *G. villosa*, *Hibiscus delfsii*, *P. schimperiana*. The species

![Figure 6 MVSP similarity result data.](image-url)
Figure 7  Canonical Correspondence Analysis (CCA) ordination biplot of sampling points on main landforms and environmental variables (altitude, rainfall and land form). Arrows represent the environmental data and point in the direction of maximum change of the environmental variable across the diagram. Altitude and rainfall are the most important environmental variables. Altitude and landform are strongly correlated with ordination axis 2. There is a very clear segregation between vegetation types 8 to 12 (left) and of the other vegetation types (right). The first group is strongly correlated with altitude and rainfall, and the second group is strongly correlated with the landforms.

Figure 8  Canonical Correspondence Analysis (CCA) ordination biplot of plant species and 3 environmental variables. Altitude and moisture (rainfall) are the most important environmental variables.
The life form spectrum in Tihama and eastern part of the study area reflects a typical desert flora, the majority of species being therophytes and Chamaephytes. These results agree with the spectra of vegetation in desert habitats in other parts of Saudi Arabia (El-Demerdash et al., 1995; Collenette, 1999; Chaudhary, 1999, 2000, 2001; Al-Turki and Al-Qlayan, 2003; Fahmy and Hassan, 2005; El-Ghanem et al., 2010). It may also be stated that the Saharo Arabian species which are restricted in their distribution to the south western strip of Saudi Arabia are more abundant in habitats of more favorable micro-environmental conditions and those providing better protection (Zohary, 1973; Ghazanfar and Fisher, 1998; El-Ghanem et al., 2010).

The present study is the first systematic survey of the vegetation of the region. Previous studies concentrated on compiling floristic checklists or on general descriptions of the vegetation communities found in selected habitats without following any consistent scientific methodology. It is intended that the present research should form the basis for any future management plants for the region.

Human activities and climate change have changed the natural environment over time; in particular they have tipped the ecological balance resulting in a fragmentation of habitats. For example, the increases of invasive N. glauca, rapidly can result in detrimental effect on indigenous species. Infrastructure around the main cities has resulted in damaging the vegetation communities, in particular A. origena and J. procera communities.

The study evaluated the vegetation types, the structure of plant communities and their distribution, the plant species composition, plant biodiversity and areas with the greatest plant diversity.

Fog-affected seaward-facing mountain slopes occur in the mountains above Aqabat Hizna and around Baljurashi, these landscapes support dense deciduous woodland dominated by the tree J. procera, together with A. origena. As the influence of fog decreases further north-east or south-west, forest and woodland is replaced by sparse woodland or shrubland dominated by A. asak, A. tortilis and A. ehrenbergiana. Beyond this, the vegetation becomes sparser and finally gives way to open semi-desert.

The main threats to the vegetation in Al Baha are from the direct and indirect impacts of human activities. In general, these relate to changes in the traditional land management practices which in the past have protected the vegetation. In particular the vegetation in the region has been directly and indirectly changed by the recent rapid economic growth. Direct threats of development include the taking of land for infrastructure; this is widespread on the high altitude areas such as around Baljurashi where it will potentially affect important J. procera and A. origena communities.

The building of new roads affects the vegetation in various ways: by changing watersheds and creating micro-niches along the roadsides. Human activities in the study area, have allowed invasive species, such as N. glauca, to rapidly spread with a resultant detrimental effect on the abundance of native species. This plant becomes the dominant species in many parts of the study area forming a pure stand of open woodland. Pure stands of N. glauca trees are common now in the river beds of the main Wadi, road sides and neglected agricultural land.

5. Summary

Primarily, this study will improve the understanding of the distribution and ecology of plant taxa in the region. However, it also emphasizes that vast areas in this remarkable region are still botanically un-explored very well. The research is the first detailed vegetation survey to be completed in Al Baha region and provides data which can be used as a baseline for monitoring change. The methods and protocols developed during the study can be used as a basis for carrying out similar studies in other parts of Saudi Arabia and for helping to devise management and conservation programs. In the study area, the major vegetation types, their composition and biodiversity were identified and vegetation maps generated.

The result of Braun-Blanquet and MVSP analyses revealed 15 vegetation types and demonstrated several distinct patterns of species distribution such as:

1. Species found over wide range of ecological sites.
2. Species distributed mainly on wadi beds.
3. Species only found on rocky slopes facing the Red sea.
4. Species only seen on high altitude mountains.
5. Species only seen on coastal plain and semi-desert areas.

Due to the varied topography over the study area, several important microhabitats were identified, including runnels, west facing mountains, wet sites, coastal plains, and semi desert areas. Each of these microhabitats supports special types of vegetation, each with a characteristic floristic composition and distinct physiognomy.

Human activity has exploited the plant resources of the entire area but has preferentially targeted particular types of vegetation. There is a clear evidence of overgrazing in the wadis, the collection of firewood from certain trees (e.g. J. procera, A. tortilis). There has been obvious direct targeting of the natural resources, for instance, the clearing of the forest and woodland in high altitude areas for infrastructure.

Further study on the factors that influence the distribution of plant species of Al Baha region and the possible effects of climate change on the distribution patterns is needed. It would be helpful if vegetation surveys could be combined with data or Abiotic factors such as altitude, aspect, soil, moisture and other environmental factors and biotic factors such as human and other living organisms to get a better and clear idea on the distribution, abundance and composition of plants in particular rare, endemic and near-endemic species. Detailed vegetation as well as topography and land use mapping of the whole region of the Al Baha using the modern softwares such as ArcGIS and ERDAS is recommended.

Acknowledgements

We like to express our gratitude to King Abdulaziz City for Science and Technology for providing the research grant. The researchers also express their thanks to Dr. Abdullah Mohammed Al-Zahrani, the director of University of Al Baha and the Dean of Applied Studies and Continuous Education.
University of Al Baha for their great help and assistance to fulfill this study.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.sjbs.2016.02.007.

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