Size Structure and Floristic Diversity of Acacia trees population in Taif Area, Saudi Arabia

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Abstract

Acacia trees are considered keystone species in many desert ecosystems and suffer from different anthropogenic effects. This study estimated the size structure of Acacia trees population in El-Taif area, which indicated that all the populations of Acacia present in El-Taif Area seems to be young as the proportion of small and medium individuals is greater than that of large individuals except the species Acacia albida. Absence of plant species under the canopy of Acacia trees may be due to the severe impact of grazing. In general, distribution of Acacia trees is controlled by physiographic features, and topographical irregularities. Phytosociologically, the area is inhabited by (79) species belonging to (59) genera and related to (26) families. The most characteristic family is Fabaceae (16 species) followed by Asteraceae (15 species). The life-form spectrum in the present study is characteristic of an arid desert region with the dominance of chamaephytes (43% of the recorded species) followed by phanerophytes (31%), therophytes (16%) and hemicyrptophytes (10%). The preponderance of annuals and shrubs reflects a typical desert flora, where it is closely related to topography. Phytogeographically, the shrub layer is composed mainly of the Saharo-Arabian with a Sudano-Zambezian focus on distribution. Pure Mediterranean taxa are not represented in the therophyte and chamaephyte layers, whereas they are represented in the bi- and pluriregional taxa. This may be attributed to the fact that plants of the Saharo-Arabian region are good indicators for desert environmental conditions, while Mediterranean species represent more mesic environments.

Keywords: Size classes; Acacia; Floristic diversity; El-Taif, Saudi Arabia

Introduction

In arid lands, the population size class structure and dynamics are related to species density as an evidenced to the correlation between the two characteristics over the population growth history [1]. Following the cessation of grazing, increasing population density is accompanied by a high-rate plant growth, where individuals attain a plant size above the average [2]. The role of individuals in the population can be expressed by their size, height, breadth and biomass; as these characteristics usually express their survival and reproductive possibilities. Due to the presence of various growth modifying agents, tree size differences may occur between even aged individuals in the same growth stage. These differences become much more conspicuous if the population has uneven-aged individuals, where the individual's size and biomass change with age [2,3]. The world's fast pace of urbanization has exerted profound pressure on urban trees [4].

The demography of tree species populations, particularly when dealing with field data including density, spatial distribution, size or age classes, seedling establishment, and mortality rates will support species management and conservation efforts [5-7]. The change in population tree size is characteristic of the species having high growth rates and high fecundity. Usually, these species possess functional properties which may cause the elimination of neighbors, for example, by occupying wider niche space as a factor, plays a significant role in population structure and dynamics [8-10], where some tree species may attain within a short time, an absolute dominance over other phytocoenotic components, by increasing their number and spatial distribution.

Population size may play a significant role in influencing the dynamic of plant populations [11,12]. Size differences may be caused directly or through differences in growth rates due to age differences, genetic variation, heterogeneity of resources, herbivory, and competition [10]. Little studies have been carried out on the size structure of tree populations such as [13-16].

Published demographic studies on subtropical trees don't enable an evaluation of vegetation climax stage [17]. The populations of Acacia trees, one of the most important tree components of the desert wadis in the central region of Saudi Arabia area subjected to tremendous pressure from human impacts. Apart from human caused changes in the unprotected habitats, other biotic and abiotic factors may also play a role in the decline of the plant population. This study aims to analyze the floristic diversity and the population size structure of Acacia sp within El-Taif area, Saudi Arabia.

Materials and Methods

The study area

Taif region lies south-east of Jiddah and the Holy City of Makkah and is situated in the central foothills of the western mountains at an altitude of approximately 2500 m above sea level (21°16' N - 40°25' E) (Figure 1). It is an important place for the people due to its scenic views and fertile valleys which support the growth of many fruits and vegetables. The geological units that outcrop in the Taif area from the
oldest to youngest are: Precambrian rocks, Tertiary sediments, Tertiary to Quaternary basalt, flows and Quaternary deposits.

Floristic analysis

The collected plant specimens were identified and named [18-20]. Species life forms were determined depending upon the location of the regenerative buds and the shed parts during the unfavorable season [21]. A chronological analysis of the floristic categories species was made to assign the recorded species to World geographical groups [22,23].

Population size structure

All the individuals of Acacia population were counted in the studied sites. Trunk diameter was measured at breast height (DBH). The size was estimated by measuring the height and mean crown diameter. The tree size was calculated as the canopy volume “V” following [24,25] according to the equation: \( V = \frac{4}{3} \pi a^2 b \), where “a” is the average canopy radius and “b” represents the canopy height. The size class values were then used to classify Acacia populations into 13 size-classes: the first <0.0050 m \(^3\) and second 0.0051–0.050 m \(^3\) classes were chosen to represent the established seedling and juvenile stages, respectively. The other classes (A1(1-20); A2(20-40); A3(40-60); A4(60-80); A5(80-100); A6 >100) separated the populations into different sizes. The frequency of individuals within each class was determined as relative values. Density was calculated as individuals per hectare. The mean and standard deviation of density, height and diameter of Acacia species were also calculated.

Results

Floristic composition

The recorded plant species (80) in the present study belonging to (59) genera and related to (26) families. Table 1 showed that, the family Fabaceae (15 species), followed by Asteraceae (15 species), Asclepiadaceae and Capparaceae (5 species, each), Lamiaceae (4 species), Chenopodiaceae, Solanaceae and Zygophyllaceae (3 species). 8 families with 2 species, other of them, Aizoaceae, Amaranthaceae, Boraginaceae, Cleomaceae, Cucurbitaceae, Malvaceae, Plantaginaceae and Resedaceae. The remain 10 families with one species only, other of them, Acanthaceae, Amaryllidaceae, Anacardiaceae, Caryophyllaceae, Brassicaceae, Cupressaceae, Poaceae, Rhamnaceae, Polygonaceae and Scrophulariaceae.

Life forms analysis of the study area revealed that 34 species (43%) of the total recorded species are Chamaephytes, followed by 25 species (31%) are Phanerophytes, 13 species (16%) are Therophytes and 8 species (10%) are Hemicryptophytes (Figure 2a).

Chorological analysis of the study area revealed that, 22 species (28%) of the total recorded species are Saharo-Arabian+Sudano-Zambezian. 14 species (18%) are Saharo-Arabian. 8 species (10%) are Sudano-Zambezian. Saharao-Arabia+Sudanian and Saharo-Arabian + Saharo-Arabian, Irano-Turanian-Sudano-Zambezian consists of 7 species (10.81%, each). 6 species (8%) are Irano-Turanian, The Mediterranean one with 3 species (4%). The remained chorological affinities represented by two or one species as in (Figure 2b).
| Family          | Species                                                                 | Life Form | Chorology |
|-----------------|-------------------------------------------------------------------------|-----------|-----------|
| Acanthaceae     | Blepharis ciliaris (L.) B.L.Burtt                                         | Ch        | SA+SZ+IT  |
|                 | Aizoon canariense L.                                                     | Th        | SA+SZ     |
|                 | Zaleya pentandra (L.) C.Jeffrey                                          | He        | SZ        |
| Aizoaceae       | Aerva javanica (Burm. f.) Juss. ex Schul.                                | Ch        | SA+SZ     |
|                 | Aerva lanata (L.) Juss. ex Schult.                                       | Ch        | TR        |
| Amaranthaceae   | Pancrentium sickenbergeni Ach.                                           | Th        | M+IT+SA   |
| Anacardiaceae   | Rhazya stricta Decne.                                                   | Ch        | SA+S      |
| Asclepiadaceae  | Asclipias sinaica (Boiss.) Muschli.                                      | Ch        | SA        |
|                 | Calotropis procera (Alton) W.T.Alton                                     | Ph        | SZ        |
|                 | Caralluma retrospeciens (Ehrenb.) N.E.Br.                                | Ch        | SA+SZ     |
|                 | Periploca aphylla Decne.                                                 | Ph        | SA+SZ     |
|                 | Pergularia tomentosa L.                                                  | Ch        | SZ        |
| Asteraceae      | Asteriscus graveolens (Forssk.) Less                                     | Ch        | SA        |
|                 | Asteriscus pygmaeus (DC.) Coss. & Dur.                                   | Th        | SA        |
|                 | Centaurea sinaica DC.                                                    | Th        | M         |
|                 | Cirsium vulgare (Savi) Ten.                                              | He        | IT        |
|                 | Crepis rueppelli Sch. Bip.                                               | Th        | IT        |
|                 | Echinops spinosissmus L.                                                 | He        | M         |
|                 | Euryops arabicus Steud.                                                  | Ch        | TR        |
|                 | Felicia dentata (A.Rich) Dandy.                                          | He        | SZ        |
|                 | Launaea sonchoides (Cass.) N. Kiliain                                    | Th        | SA        |
|                 | Launaea capitata (Spreng.) Dandy                                        | Ch        | SA+S      |
|                 | Osteospermum vaillantii (Decne.) Norl.                                   | Ch        | SA+SZ     |
|                 | Phagnalon sinaicum Bomm. & Kneck.                                        | Ch        | IT        |
|                 | Psidia punctulata (DC.) VATKE                                           | Ch        | SA        |
|                 | Pulicaria crispa (Forssk.) Oliv.                                        | Ch        | SA+S      |
|                 | Xanthium strumarium L.                                                   | Th        | M+IT      |
| Boraginaceae    | Arnebia hispidissima (Lehm.) DC.                                         | Ch        | SA+SZ     |
|                 | Trichodesma ehrenberghi Schweinf.                                        | Ch        | SZ        |
| Brassicaceae    | Savigrya parviflora (Del.) Webb. in Giorn.                              | Th        | SA        |
| Capparaceae     | Capparis decidua Ved.                                                   | Ph        | SA+SZ     |
|                 | Capparis spinosa L.                                                      | Ph        | SA        |
|                 | Maerua crassifolia Forssk.                                               | Ph        | SA+IT+SZ  |
|                 | Maerua oblongifolia (Forssk). A. Rich.                                  | Ph        | SA+IT+SZ  |
|                 | Morettia parviflora Boiss.                                               | Ch        | SZ        |
| Family            | Species                                                                 | Author(s)                                      | Flora Type |
|-------------------|-------------------------------------------------------------------------|-----------------------------------------------|------------|
| Caryophyllaceae   | Polycarpea repens (Forsk). Asch. & Sehweinf                             |                                               | Ch         |
|                   | *Bassia muricata* (L.). Asch.                                          |                                               | Ph         |
|                   | *Haloxylon salicornicum* (Moq.) Bunge                                   |                                               | Ch         |
|                   | *Salsola spinescens* Moq.                                               |                                               | Ch         |
| Chenopodiaceae    | *Bassia muricata* (L.). Asch.                                          |                                               | Ph         |
|                   | *Haloxylon salicornicum* (Moq.) Bunge                                   |                                               | Ch         |
|                   | *Salsola spinescens* Moq.                                               |                                               | Ch         |
| Cleomaceae        | *Cleome amblyocarpa* L.                                                 |                                               | Ch         |
|                   | *Cleome chilensis* DC.                                                  |                                               | Ch         |
| Cucurbitaceae     | *Citrullus colocynthis* (L.) Schrad                                    |                                               | He         |
|                   | *Cucumis prophetarum* L.var dissectus (Naudin) C. Jeffrey.              |                                               | He         |
| Cupressaceae      | *Juniperus procera* Hochst.                                             |                                               | Ph         |
| Fabaceae          | *Acacia gerrardii* Bent. var. gerrardii                                 |                                               | Ph         |
|                   | *Acacia gerrardii* Bent. Subsp. negevensis                              |                                               | Ph         |
|                   | *Acacia asak* (Forsk) willd.                                            |                                               | Ph         |
|                   | *Acacia etbaica* Schweinf.                                              |                                               | Ph         |
|                   | *Acacia hamulosa* Benth.                                                |                                               | Ph         |
|                   | *Acacia albida* (Delile) A.Chev.                                        |                                               | Ph         |
|                   | *Acacia origena* Hunde. (Hunde) Kyal. & Boatwr.                         |                                               | Ph         |
|                   | *Acacia nubica* Benth.                                                  |                                               | Ph         |
|                   | *Acacia ehrenbergiana* Hayne. (Forsk.) Schweinf.                         |                                               | Ph         |
|                   | *Acacia johnwoodii* Boulos                                              |                                               | Ph         |
|                   | *Acacia tortilis* subsp. raddiana Savi                                  |                                               | Ph         |
|                   | *Acacia tortilis* (Forsk.) Hayne. subsp. tortilis                       |                                               | Ph         |
|                   | *Astragalus sieberi* DC.                                                |                                               | Ph         |
|                   | *Indigofera spinosa* Forsk.                                              |                                               | Ph         |
|                   | *Lotus glinoides* Delile                                                |                                               | Ph         |
|                   | *Senna italic* Mill.                                                    |                                               | Ph         |
|                   | *Lavandula dentata* L.                                                  |                                               | Ph         |
|                   | *Lavandula pubescens* Decne.                                            |                                               | Ph         |
|                   | *Marrubium vulgare*                                                     |                                               | Ph         |
|                   | *Ostostegia fruticosa* (Forsk.) Penz.                                   |                                               | Ph         |
|                   | *Alcea rhyticarpa* (Trautv.)                                            |                                               | Ph         |
|                   | *Malva parviflora* L.                                                   |                                               | Ph         |
| Plantaginaceae    | *Plantago major* L.                                                     |                                               | Ph         |
|                   | *Plantago ciliata* Desf.                                                |                                               | Ph         |
| Poaceae           | *Stipagrostis plumosa* (L.) Munro ex T. Anderson                        |                                               | Ph         |
| Polygonaceae      | *Rumex vesicarius* L.                                                   |                                               | He         |
| Resedaceae        | *Ochradenus baccatus* Delile                                            |                                               | Ph         |
Reseda alba L.

Rhamnaceae
Ziziphus spina-christi (L.) Desf.

Scrophulariaceae
Kickxia floribunda (Boiss.) Täckh. & Boulou

Solanaceae
Lycium depressum Stocks.
Lycium shawi Roem. & Schult.
Solanum incanum L.

Zyegophyllaceae
Fagonia boveana (Hadidi) Hadidi & Garf
Fagonia indica Burm.f.

| Taxon                          | Size Class   |
|-------------------------------|--------------|
| Reseda alba L.                | Ph           |
| Rhamnaceae                    | Ph           |
| Ziziphus spina-christi (L.)   | Ph           |
| Scrophulariaceae              | Ch           |
| Kickxia floribunda (Boiss.)   | Ch           |
| Solanaceae                    | Th           |
| Lycium depressum Stocks.      | Th           |
| Lycium shawi Roem. & Schult.  | Ph           |
| Solanum incanum L.            | Ch           |
| Zyegophyllaceae               | Ch           |
| Fagonia boveana (Hadidi)      | Ch           |
| Fagonia indica Burm.f.        | Ch           |
| Tribulus terrestris L.        | Th           |

Table 1: List of species associated with the distribution of Acacia sp and in Taif area. Ph.=Phanerophytes; COSM=Cosmopolitan; H.=Hemicryptophytes; Th.=Therophytes; Ch.=Chamaephytes; PAL=Palaeotropical; TR.= Tropical M=Mediterranean; SA=Saharo-Arabian; IT=Irano-Turanian; E=Euro-Siberian; S=Sudanian and SZ=Sudano-Zambezian.

Population size structure

Size distribution analysis of Acacia population using canopy cover, tree height and Diameter (Figure 3) shows presence of juveniles in some of Acacia species such as Acacia gerrardii var. gerrardii, Acacia tortilis, Acacia ehrenbergiana, Acacia nubica, Acacia origena, Acacia hamulosa, Acacia asak and Acacia gerrardii subsp. negevensis, on the other hand it was absent in Acacia etabica, Acacia radiana and Acacia albida. A clear reduction in numbers of small and large categories and increasing in numbers of medium categories in Acacia johnwoodii and Acacia etabica. This pattern of distribution indicates the absence of recruitment to supplement the smallest size categories. In addition, human disturbance in the study area is responsible for high mortality, which is clear from the decline numbers of small and large trees.

The size structure of Acacia populations showed different size classes distribution. Five distribution models are shown in Figure 3: (1) Populations with continuous regeneration inputs, for example, Acacia johnwoodii and Acacia etabica where the percentage of individuals of young ages with crown size classes up to 20 m³ were represented; (2) Populations that lack regeneration where old individuals are sparsely represented with different size classes and young ages are not represented (e.g., Acacia albida; (3) Populations in serial successional stages as in Acacia hamulosa and Acacia ehrenbergiana. where the largest size classes are not represented; (4) Populations with young individuals as in Acacia tortilis, Acacia gerrardii subsp. negevensis and Acacia gerrardii var. gerrardii; and (5) Populations that almost reached extinction as in Acacia albida.

The relationships between the individual heights and diameters of Acacia trees population are simple linear (Figure 4). The result shows that the relation between height and diameter of trees was positive in all Acacia species except Acacia gerrardi (ger) and Acacia tortilis was negative. On the other hand, (Table 2) shows that the mean height to diameter ratio for both Acacia species was the highest in Acacia origena (60.0) and the lowest in Acacia hamulosa (1.6). Regarding the variation in the canopy size was the highest in Acacia albida (204.4) and the lowest in Acacia origena (13.6). Also, the height has the highest value (17.8 m) in Acacia albida and lowest (3.31 and 3.32 m) Acacia nubica and Acacia hamulosa, respectively. The diameter has the highest value (2.07 m) in Acacia hamulosa and lowest (0.1 m) in Acacia origena.

Figure 3: Tree crown size-class distribution of Acacia sp. in El-Taif Area. Acacia gerrardii (ger)=Acacia gerrardii var. gerrardii and Acacia gerrardii (neg)=Acacia gerrardii subsp. Negevensis.
Figure 4: The relationships between the individual heights and diameters of Acacia sp. in El-Taif Area. Acacia gerrardii (ger)=Acacia gerrardii var. gerrardii and Acacia gerrardii (neg)=Acacia gerrardii subsp. Negevensis.

Table 2: Simple correlations between the different variables of Acacia trees population in El-Taif Area. DBH= Diameter at Breath Height

Discussion

The area is inhabited by (79) species belonging to (59) genera and related to (26) families, the most characteristic families are Fabaceae and Asteraceae (15 species, each). The life-form spectrum in the present study is characteristic of an arid desert region with the dominance of chamaephytes (43% of the recorded species) followed by phanerophytes (31%), therophytes (16%) and hemicryptophytes (10%). The preponderance of annuals and shrubs reflects a typical desert flora, where it is closely related to topography [26,27]. On the other hand, they may be a response to the hot, dry climate and human and animal interferences. A comparison of the life-form spectra of the northern part of the Eastern Desert of Egypt [28] and those in the Tihama coastal plains of the Jizan region in south-western Saudi Arabia [29] showed the same results.

Phytogeographically, the shrub layer is composed mainly of the Saharo-Arabian with a Sudano-Zambezian focus on distribution. Pure Mediterranean taxa are not represented in the therophyte and chamaephyte layers, whereas they are represented in the bi- and pluriregional taxa. This may be attributed to the fact that plants of the Saharo-Arabian region are good indicators for desert environmental conditions, while Mediterranean species represent more mesic environments.

The results of the size distribution study indicated that all population of Acacia present in El-Taif Area seems to be young as the proportion of small and medium individuals is greater than that of large individuals except the species Acacia albida.

Acacia trees are considered keystone species in many desert ecosystems [30,31], due to the many provided services and goods, Thus, the conservation of Acacia trees is important particularly in arid and hyper arid deserts for regulating microclimate, improving conditions for survival of associated plant and animal species [32], providing direct benefits for local inhabitants, and for starting sustainable development [33]. Due to aridity and anthropogenic disturbances, floristic diversity of the study area is characterized by a paucity of trees and annuals. The canopy of Acacia shows negative influence on the understory vegetation. Most of the associated species were recorded between canopies.

The absence of plant species under the canopy of Acacia trees may be due to the severe impact of grazing. In no disturbed areas, [13] reported that A. tortilis has a positive influence on the understory herbaceous vegetation. In general, distribution of Acacia trees is controlled by physiographic features, and topographical irregularities, which all act through modifying the amount of soil water availability [34].
The height/diameter ratio gives an idea about the growth habit of the plant. In the present study, this ratio is less than unity for Acacia species which means that the individual diameter exceeds, the relation between height and diameter of trees was positive in all Acacia species except Acacia gerrardi and Acacia tortilis was negative tend to the two-species adapted to escarp from drought seasons. This may be a strategy of the desert plants to provide safe sites for their self-regeneration, as the horizontal expansion usually provides shade, which leads to decrease the severe heating effect and increase the soil moisture [35,36].

In conclusion, the total size structure of Acacia populations in El-Taif area is characterized by the preponderance of the young individuals comparing with the old ones, that we found continuously regeneration of most of Acacia population except one species named: Acacia albida which suffer from unregeneration due to some anthropogenic effects in the region.

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