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GIS Mapping of Main Pharmaceutical Plants in Al-Baha Region

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FOR THIS STUDY, we used geographic information systems (GIS) and ground surveys to map the important pharmaceutical plants in Albaha region of Saudi Arabia. We used GIS functions to generate distribution, richness, and density maps for 39 plants from 23 families and 25 genera. Three of these species are endemic to Saudi Arabia; two are found in both Saudi Arabia and Yemen, and five are found only in East Africa and the Arabian Peninsula. Five species belong to the family Xanthorrhoeaceae; four belong to each of the two families Euphorbiaceae and Burseraceae, and three belong to each of the families Amaranthaceae and Papaveraceae. For each species of a pharmaceutical plant, we calculated density per hectare and determined a frequency percentage. Our study area was in southwestern Saudi Arabia, between latitudes 16 and 21, and longitudes 40 and 41. This is the first study that uses GIS to show the distribution of pharmaceutical plants in this region and can be considered a basic resource for the mapping and domestication of all pharmaceutical plants in Saudi Arabia. This may contribute to cultivate the Pharmaceutical Plants on a commercial scale, with consequent economic benefits at both individual and national levels.

Keywords: Arabia, Albaha, GIS, Pharmaceutical plant, Saudi Mapping.

Introduction

Medicinal plants are considered one of the economic benefits of biodiversity (Rahman et al., 2004), and natural plant species provide a good source of a wide variety of secondary metabolites that exhibit valuable bioactivities including antiviral effects. (Maridass & Britto, 2008). In recent years, researchers have used scientific methods to demonstrate the efficacy of many medicinal plants and gain a better understanding of the mechanisms underlying their activities (Maver et al., 2018). Extracts of these plants are now widely used in medicinal industries and in the products of pharmaceutical companies worldwide (Hasan, 2014).

Since ancient times, native peoples almost everywhere have relied on natural vegetation resources for their medicinal needs. This indigenous knowledge has been passed down from generation to generation across the world (Jain & Sharma, 2000). In all regions, native plant species have formed the foundation of traditional or ethnic health systems, and they continue to play an important role in meeting the demands of traditional medicine markets (WHO, 2003), even as the use of old-style medicinal plants has greatly declined in developed countries (TITZ, 2004).

To date, many researchers have investigated the regional floras of Saudi Arabia in search of possible medicinal uses (Mandaville, 1990; Collenette, 1999; Chaudhary, 1999; Chaudhary, 2000a, b, c; Chaudhary, 2001); however, the identification and classification of medicinal plants have presented a major obstacle to researchers. Gaps remain in our knowledge of wild-plant identification, and of the distribution ranges and densities of most medicinal plant species. Even so, some valuable studies of

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medicinal plants have been carried out in Saudi Arabia. Awadh et al. (2017, 2019) identified a small number of medicinal plant species in Albaha region. Al-Said (1993) recorded 20 traditional medicinal plants and described their chemical composition. Rahman et al. (2004) studied promising medicinal plants from seven families. Yusuf et al. (2014) conducted similar work with plants from fifteen families, following the earlier study of Abulafatih (1987) of plants from four families. In the At-Taif area, Al-Sodany et al. (2013) identified 261 medicinal species belonging to 178 families. Finally, one recent study recorded 133 potentially medicinal plants belonging to fourteen families and twenty-eight genera in Albaha region (Al-Zandi et al., 2019).

Albaha region has distinct climatic and topographic characteristics which enrich its vegetation with great biodiversity (Al-Aklabi et al., 2016; Al-Khulaidi et al., 2018). Some local plants are still used by native people to treat a variety of diseases (Giday et al., 2003; Rahman et al., 2004; Mesfin et al., 2009; Alyemeni et al., 2010; Awadh et al., 2017, 2019).

By understanding the distribution pattern of medicinal plants, we can determine the effects of ecological and human interference and thus help formulate optimal utilization and conservation strategies. The accurate mapping of species distribution and abundance enables causes to be identified in the event of increased scarcity or declining numbers. Mapping the prevalence and richness of medicinal plant species in any study area provides a better awareness of conditions in those regions where the collection or conservation of medicinal plants is undertaken. To this end, we sought in this survey to identify all the pharmaceutical plants in Albaha region and provide maps of their distribution, richness, and density using GIS techniques. The paper deals with 39 wild plants from 23 families and 25 genera that are sources of chemicals used in important pharmaceutical drugs today. We provide sufficient information to initiate and continue research on important plant-based drugs and medicines found in Saudi Arabia.

Materials and Methods

Our study area was located in southwestern Saudi Arabia, between latitudes 16 and 21, and longitudes 40 and 41. (Fig. 1). We carried out a field study covering different ecological zones within the Albaha region, and identified 423 sample sites with dimensions of 20 by 20m. We selected pharmaceutical plants for study purposes based on data gathered from various pharmaceutical studies.

We used geographic information systems (GIS) with Arc Map software to generate maps of the distribution, density, and richness of the 39 pharmaceutical plants. During the vegetation survey, we recorded the number of plants of each species in each unit area to obtain a figure for plant density. The number of individuals in each site was expressed in per-hectare terms, obtained by dividing the total number of individuals by the total surveyed area of the various sample sites. We calculated frequency percentage by dividing the number of plots in which a species occurred by the total number of plots sampled, then multiplying by 100 (Al-Khulaidi et al., 2016; Al-Khulaidi et al., 2018; Al-Zandi et al., 2018) as follows:

Frequency percentage= [The number of plots in which a species occurred/ the total number of plots sampled] X 100

Results and Discussion

The data of the present study documented 39 pharmaceutical plant species of 23 families and 25 genera (Table 1). Six species were trees (11%), seven were succulents (12%), three were shrubs (20%), one was a climber (4%), and twenty-two were annuals (53%). Three species were endemic to Saudi Arabia; two were endemic to the Arabian Peninsula and found only in Saudi Arabia and Yemen; five were regionally endemic to East Africa and the Arabian Peninsula. Five species belonged to the family Xanthorrhoeaceae; four belonged to each of the two families Euphorbiaceae and Burseraceae; and three to each of the families Amaranthaceae and Papaveraceae (Figs. 2, 3 and Table 1). The most common plant species, i.e., those with a frequency percentage of more than 10%, were *Adenium obesum* (Forssk.) Roem. & Schult; *Aerva javanica* (Burm.f.) Juss. ex Schult.; *Blepharis edulis* (Forssk.) Pers.; *Lavandula dentata* L.; *Lavandula pubescens* Decne.; and *Withania somnifera* (L.) Dun. (Table 1).

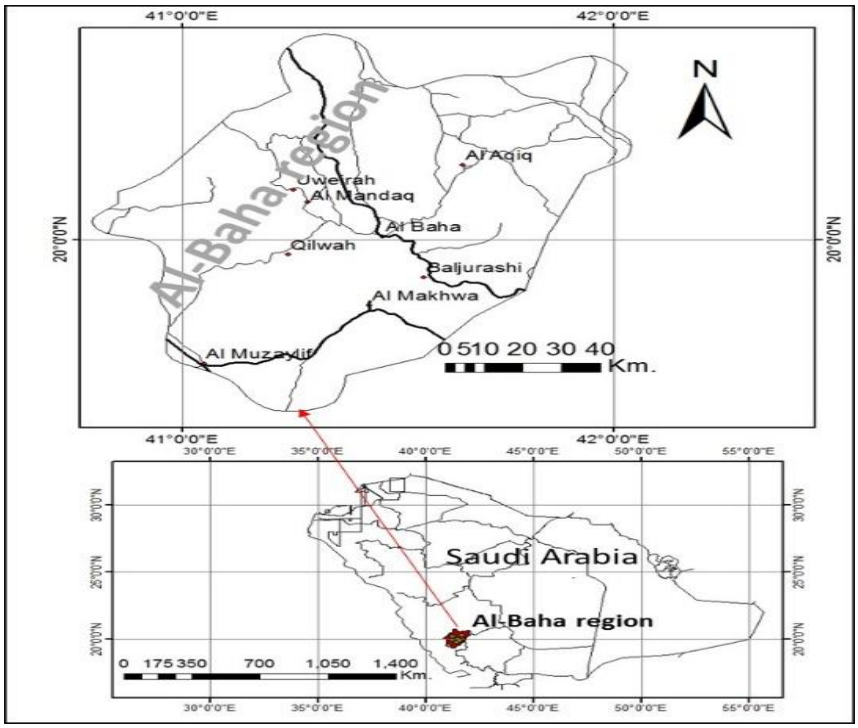


Fig. 1. Location of the study area

TABLE 1. The plant species with their life form, family and endemism

Plant name	Life form	Family	Endemism	Frequency %
Achillea biebersteinii Afan.	h	Asteraceae		5.65
Achyranthes aspera L.	h	Amaranthaceae		6.59
Adenium obesum (Forssk.) Roem. & Schult.	suc	Apocynaceae		12.24
Aerva javanica (Burm.f.) Juss. ex Schult.	h	Amaranthaceae		24.00
Aerva lanata (L.) Juss.	h	Amaranthaceae		5.88
Aloe castellorum J.R.I.Wood	suc	Xanthorrhoeaceae	Saudi Arabia & Yemen	1.65
Aloe pseudorubroviolacea Lavr. & Collen.	suc	Xanthorrhoeaceae	Saudi Arabia	1.65
Aloe sabaea Schweinf.	suc	Xanthorrhoeaceae	Saudi Arabia & Yemen	0.47
Aloe saudiarabica T.A.McCoy	suc	Xanthorrhoeaceae	Saudi Arabia	0.71
Aloe shadensis Lavranos & Collen.	suc	Xanthorrhoeaceae	Saudi Arabia	0.94
Ammi majus L.	h	Apiaceae		3.06
Argemone mexicana L.	h	Papaveraceae		1.88
Argemone ochroleuca Sweet	h	Papaveraceae		9.18
Blepharis edulis (Forssk.) Pers.	h	Acanthaceae		21.65
Brassica rapa L.	h	Brassicaceae		0.24
Calendula arvensis (Vaill.) L.	h	Asteraceae		2.35
Chenopodium ambrosioides	h	Chenopodiaceae		2.12
Cissus quadrangularis L.	suc	Vitaceae		4.94
Citrullus colocynthis (L.) Schrad.	h	Cucurbitaceae		4.47
Commiphora gileadensis (L.) C.Chr.	t	Burseraceae	East Africa and the Arabian Peninsula	1.88

TABLE 1. Cont.

Plant name	Life form	Family	Endemism	Frequency %
Commiphora kataf (Forssk.) Engl.	t	Burseraceae	East Africa and the Arabian Peninsula	2.12
Commiphora kua (R.Br. ex Royle) K.Vollesen	t	Burseraceae		2.12
Commiphora myrrha (Nees) Engl.	t	Burseraceae	East Africa and the Arabian Peninsula	6.12
Ephedra foeminea Forssk.	cli	Ephedraceae		3.53
Euphorbia hirta L.	h	Euphorbiaceae		0.24
Jatropha glauca Vahl	sh	Euphorbiaceae	East Africa and the Arabian Peninsula	2.12
Jatropha pelargoniifolia Courbai	sh	Euphorbiaceae	East Africa and the Arabian Peninsula	2.35
Lavandula dentata L.	h	Lamiaceae		11.53
Lavandula pubescens Decne.	h	Lamiaceae		17.65
Papaver decaisnei Hochst. & Steud. ex Boiss.	h	Papaveraceae		0.24
Ricinus communis L.	sh	Euphorbiaceae		6.59
Ruta chalepensis L.	h	Rutaceae		4.94
Salix mucronata Thunb.	t	Salicaceae		0.71
Salvadora persica L.	t	Salvadoraceae		2.59
Senna alexandrina Mill.	h	Caesalpiniaceae		2.59
Senna italica Mill.	h	Caesalpiniaceae		3.53
Tribulus terrestris L.	h	Zygophyllaceae		5.41
Urtica urens L.	h	Urticaceae		0.71
Withania somnifera (L.) Dun.	h	Solanaceae		10.12

t= Tree, sh= Shrub, cli= Climber, suc= Succulent, h= Herb

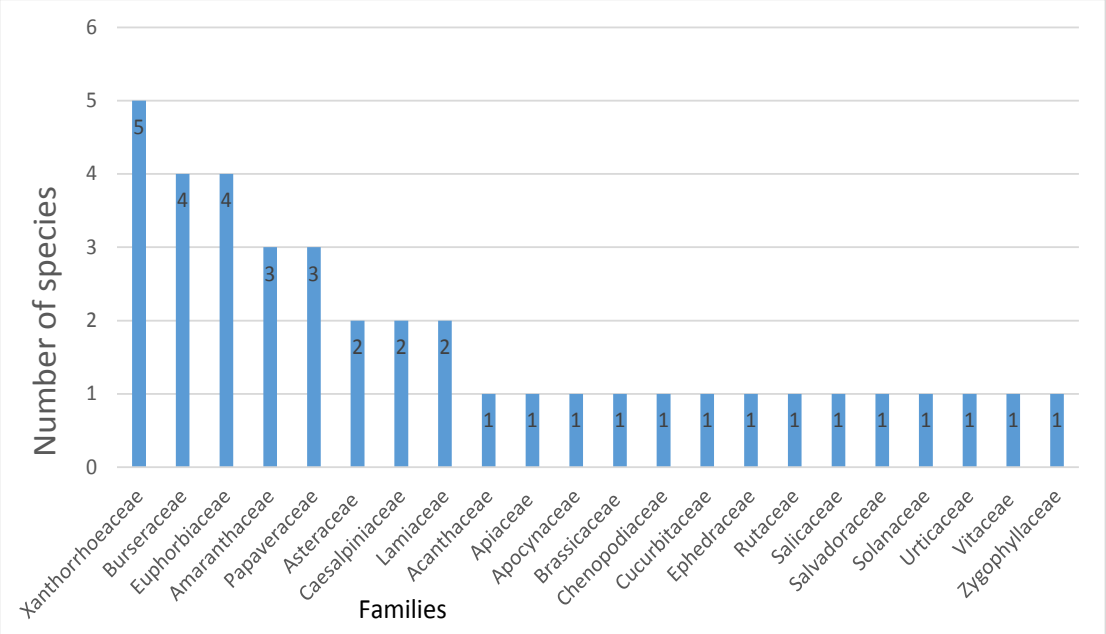


Fig. 2. Families with their number of species

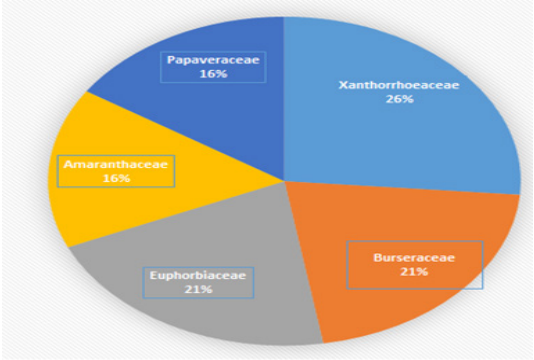


Fig. 3. The most-represented families with their numbers of species

Awareness of the geographical location of medicinal plants and of their natural habitat helps to determine the overall medicinal plant potential of any study area. The maps below depict 24 medicinal plants from Albaha that are currently used, or have previously been used, for pharmaceutical purposes. The maps (Fig. 4A–Q) depict their distribution and density.

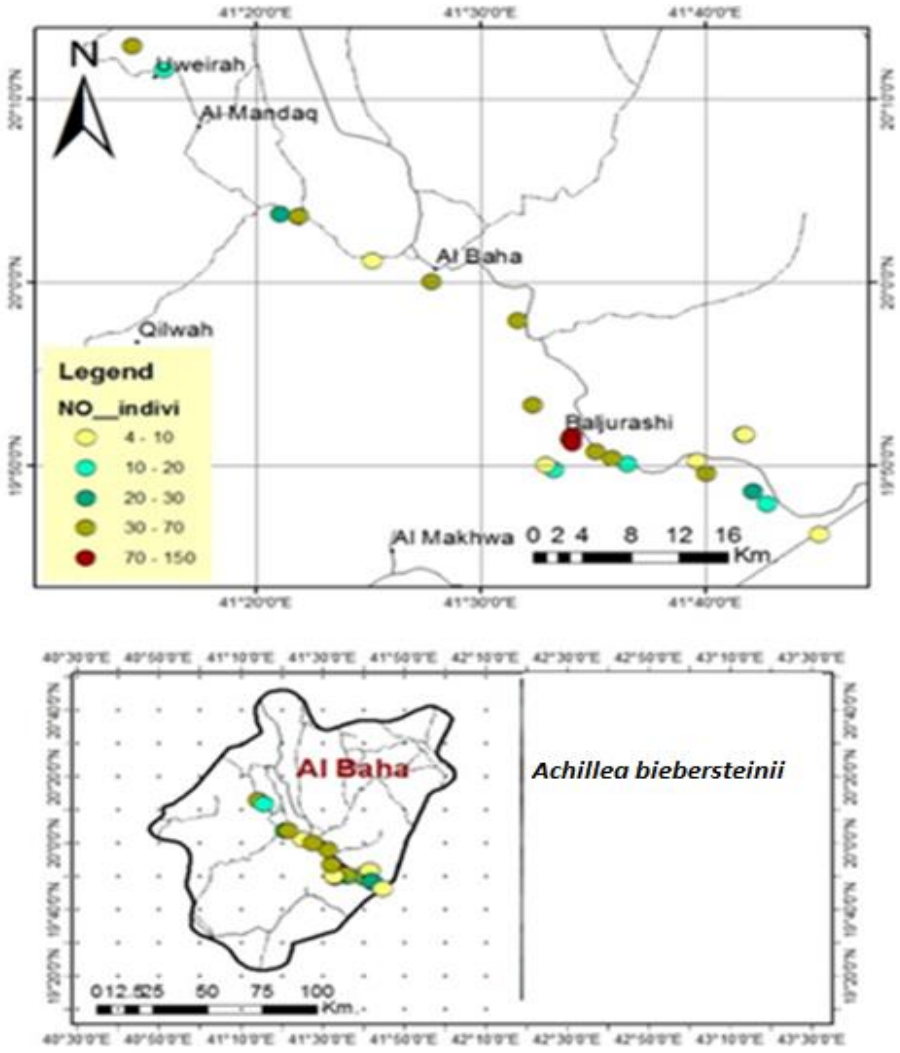


Fig. 4A. The distribution of Achillea biebersteinii. Annual species found in wet places of high altitude areas (over 1900m), in particular around Baljurashi, with individual ranges between 4 and 55 per sample site and reaches its peaks (130-150) under Vachellia origena woodland in wet neglected terraces

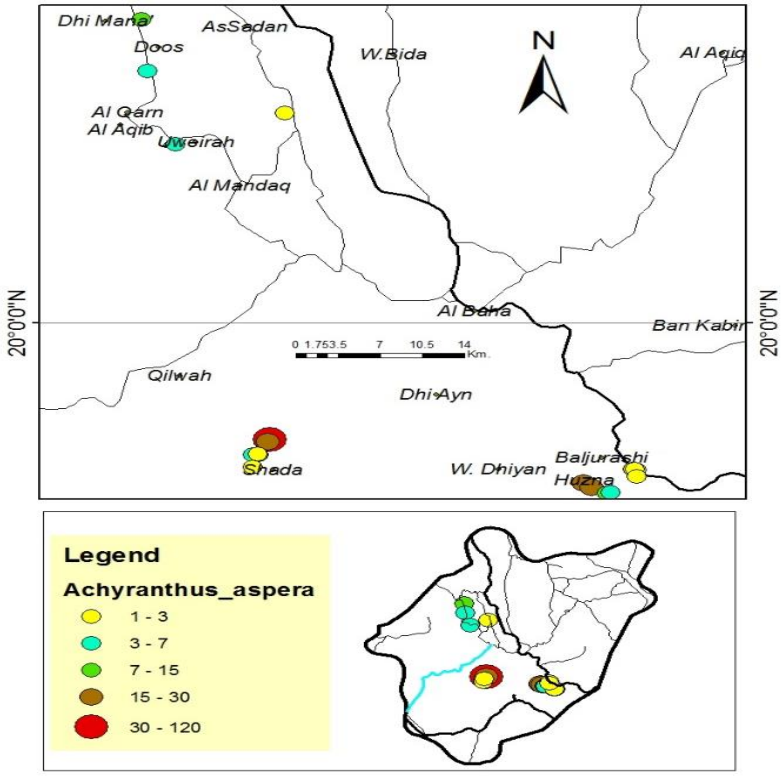


Fig. 4B. The distribution of Achyranthes aspera. It is found on wet sites, between 800 and 2050m in particular around Baljurashi, Huzna and J. Shada with individuals per sample site range between 1 – 120. Flowering periods: March, April, May

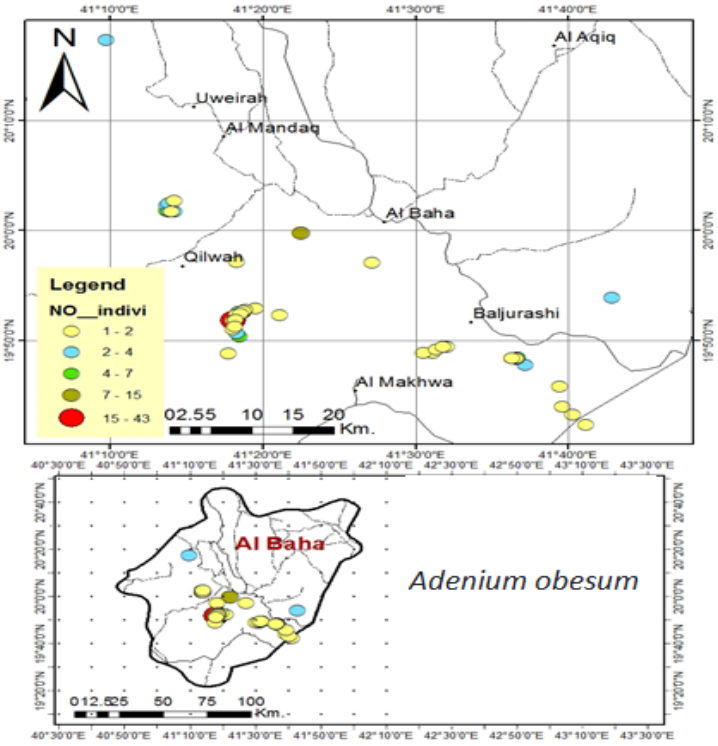


Fig. 4C. The distribution of *Adenium obesum.* It is found in dry exposed rocky slope, wadi beds and drainage lines between 500 and 1850m in particular in J. Shada with individual ranges between 1 and 15 per sample site and reaches its peaks (43) on dry Rocky outcrops dominated by Barleria bispinosa, at altitude of 1200 in J. Shada

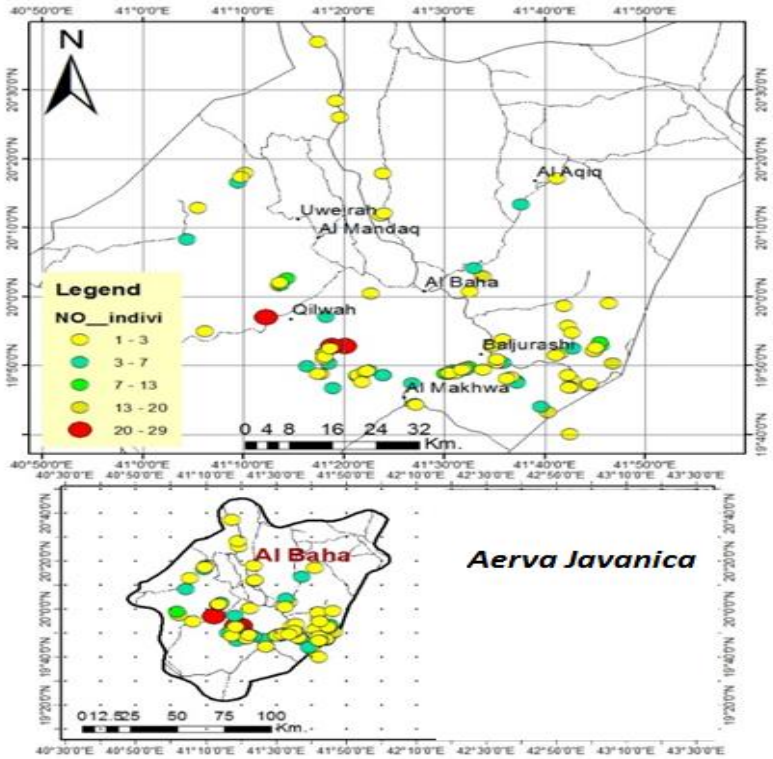


Fig. 4D. The distribution of *Aerva javanica.* Widespread species, found almost on all ecological sites between 150 and 2125m., with individual ranges between 1 and 29 per sample site

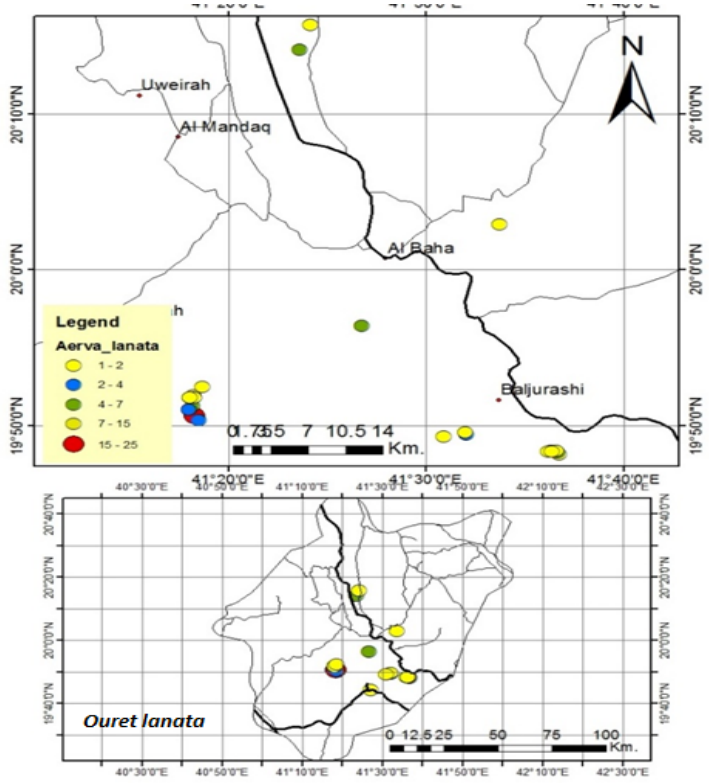
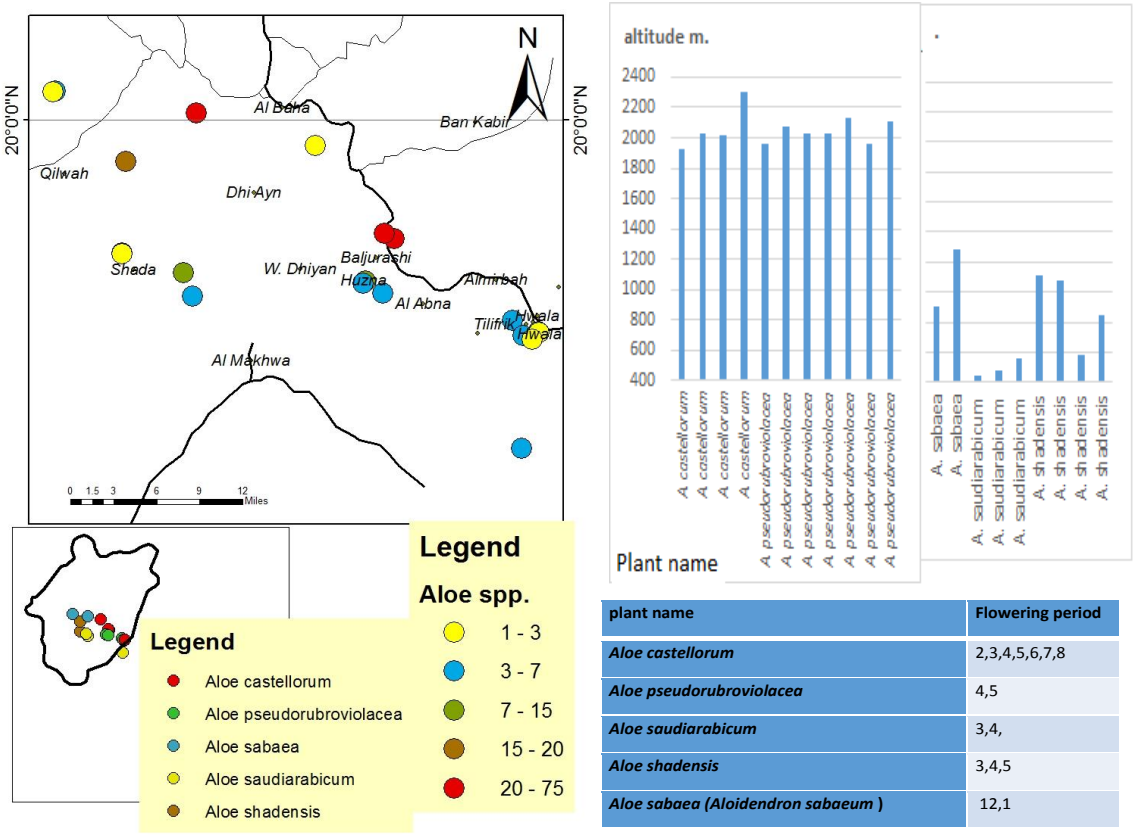


Fig. 4E. *Aerva lanata* (= *Ouret lanata*) found on rocky wadi beds, drainage lines, rock outcrops and rocky slopes between 300 – 1900m. The individuals range between 1 and 25 per sample site and reach its peaks (15-25 per sample site) on moderate altitude rocky drainage lines around J. Shada and Al Abna'



plant name	Flowering period
Aloe castellorum	2,3,4,5,6,7,8
Aloe pseudorubroviolacea	4,5
Aloe saudiarabicum	3,4,
Aloe shadensis	3,4,5
Aloe sabaea (Aloidendron sabaeum)	12,1

Fig. 4F. The distribution of fife *Aloe* species, 3 endemics to Saudi Arabia, 2 endemics to the Arabian Peninsula. The chart showing the altitude range of these 5 species. Two of them (*A. castellorum* & *A. pseudorubroviolacea*) are confined to high altitude areas (between 1925 and 2133, the rest of the species only found at low altitude areas west and SW of the region, in particular in J. Shada and around Qilwa, up to Wadi Reem and Aqapet Khalid where *A. sabaea* (*Aloidendron sabaeum*) forms a woodland. The individuals per sample site range between 1 to 75 for *A. castellorum*, 1 to 12 for *A. pseudorubroviolacea*, 7 to 70 for *Aloe sabaea* (*Aloidendron sabaeum*), 5 to 10 for *A. saudiarabicum* and 1 to 20 for *A. shadensis*

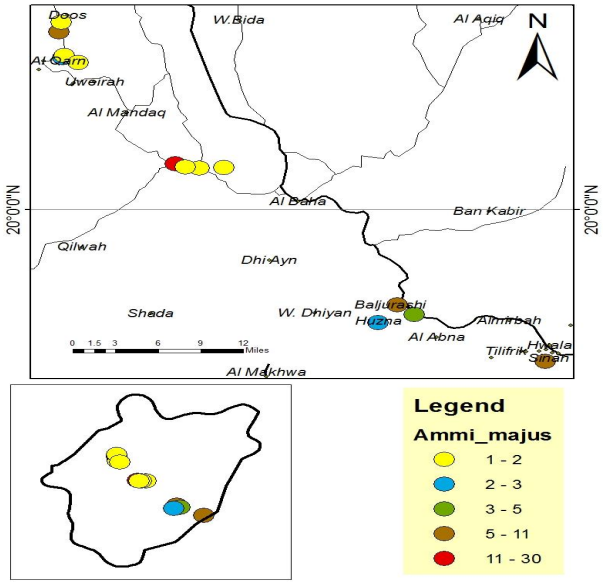
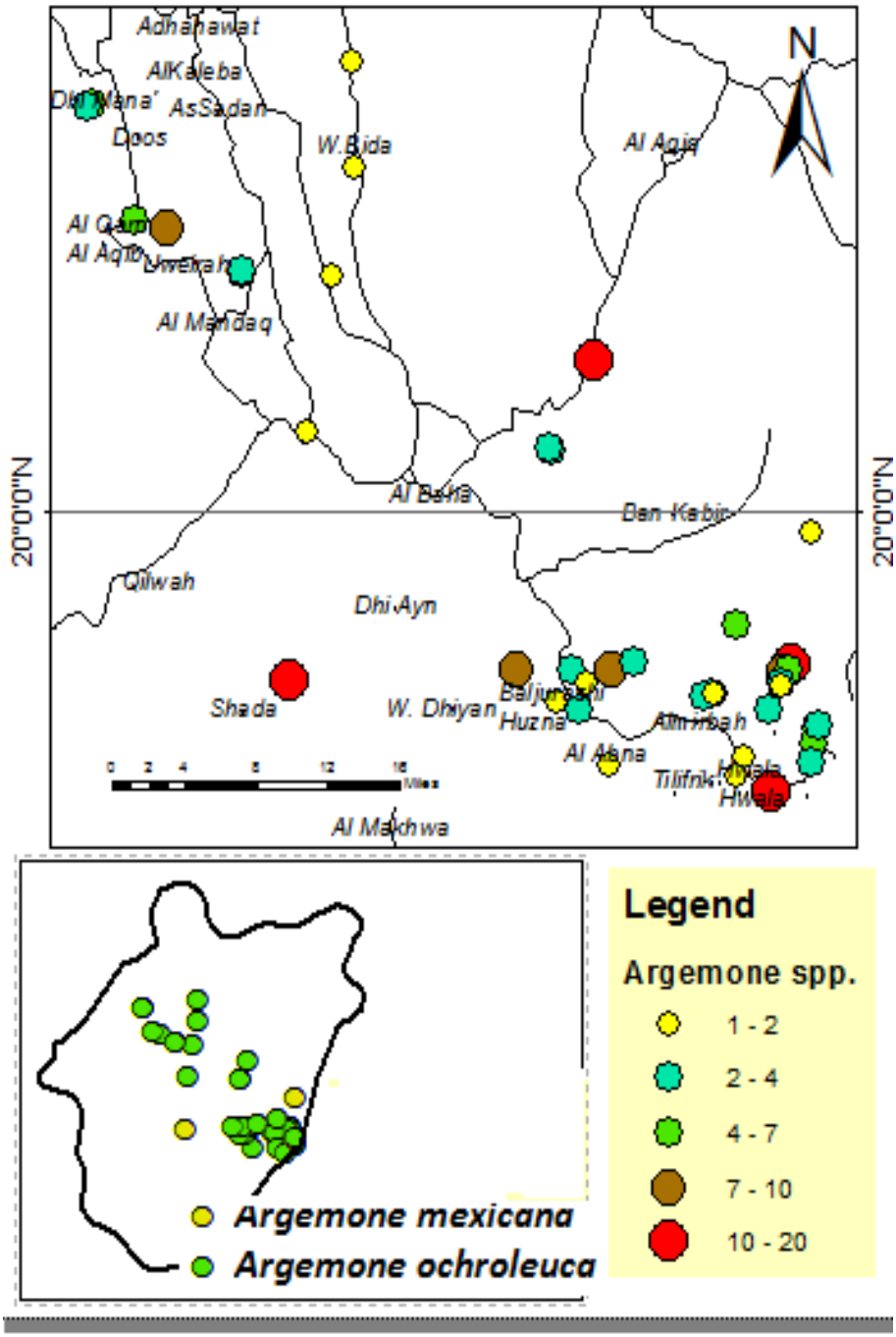


Fig. 4G. The distribution of *Ammi majus*. It is found on terraces and neglected fields at high altitude areas, between 1950 and 2245 with individuals per sample site range between 1 to 30. Flowering periods: April, May



ant name	Flowering period
rgemone mexicana	2,3,4
rgemone ochroleuca	1,2,3

Fig. 4H. The distribution of both *Argemone mexicana* and *A. ochroleuca*. The first is only found on low altitude areas around J. Shada (less than 600m. rarely reach 1600m. asl), the latter is found on high altitude areas (more than 1700m. asl), the individuals per sample site range between 1 to 20

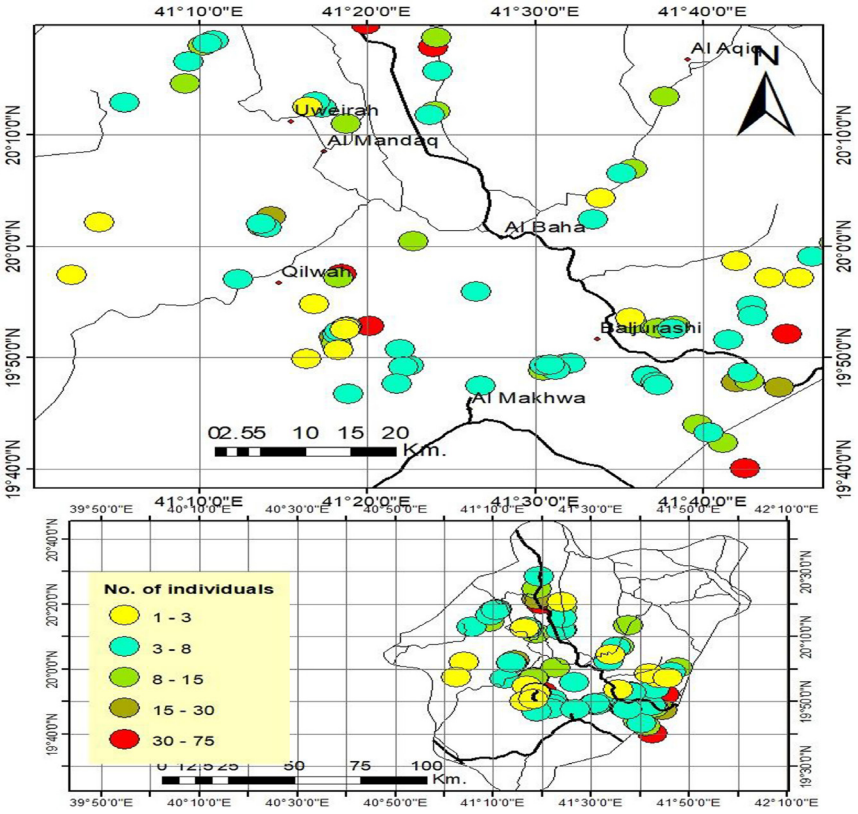


Fig. 4I. The distribution of *Blepharis edulis*. Widespread species, on dry habitats between 150 and 2040, such as wadi beds, rocky gently sloping and disturbing sites, the individuals per sample site range between 1 and 75. Flowering periods January, February, March, April, and October to November

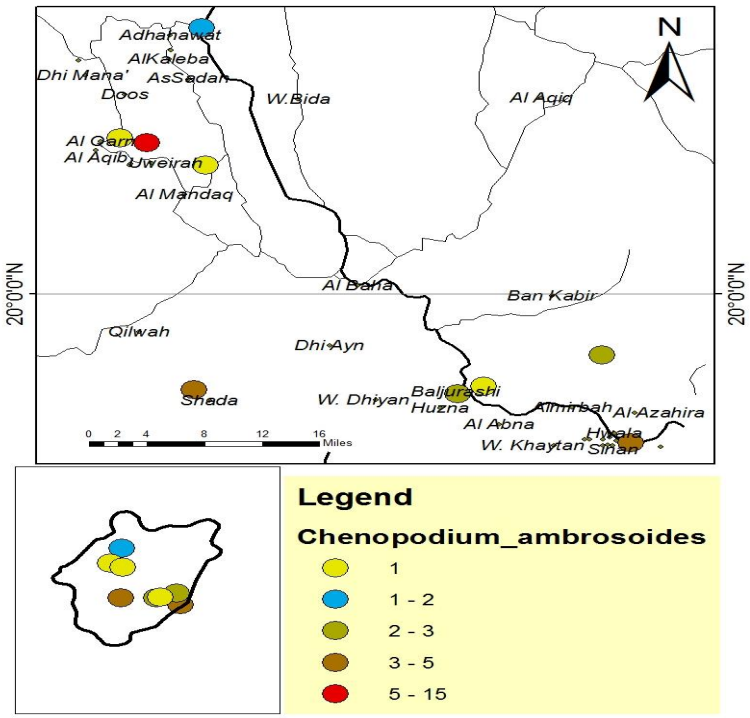


Fig. 4J. The distribution of *Chenopodium ambrosioides.* It is found on west sites, wadi beds and roadsides between 1330 and 2025m. The individuals range between 1 and 15. Flowering periods: 11,12,1,2,3,4

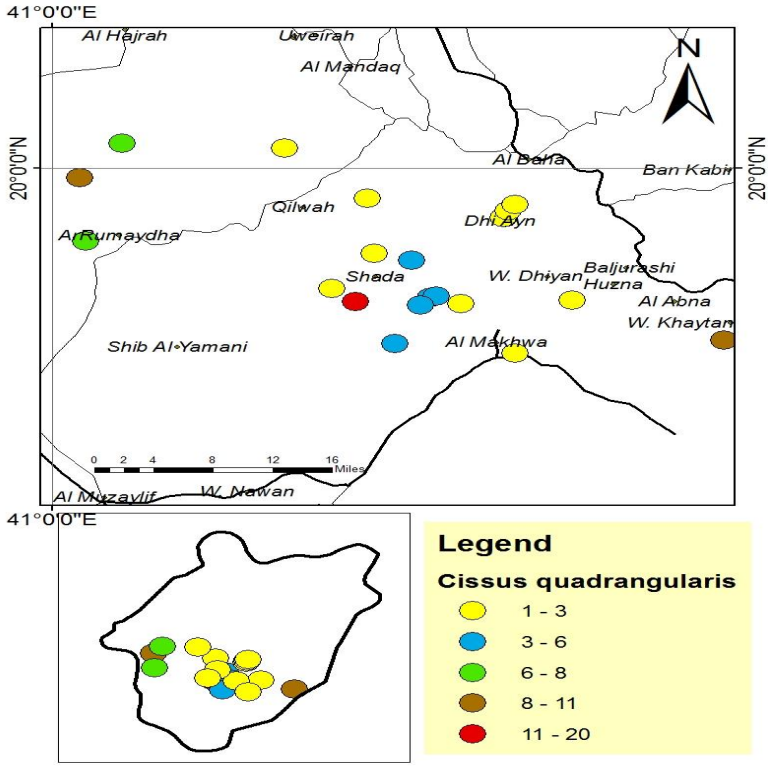


Fig. 4K. The distribution *Cissus quadrangularis* is found on wadi beds between 215 to 900 West and South West of the region in particular around wadi Al Khaytan and ArRumeidah, the individuals per sample site range between 2 and 20

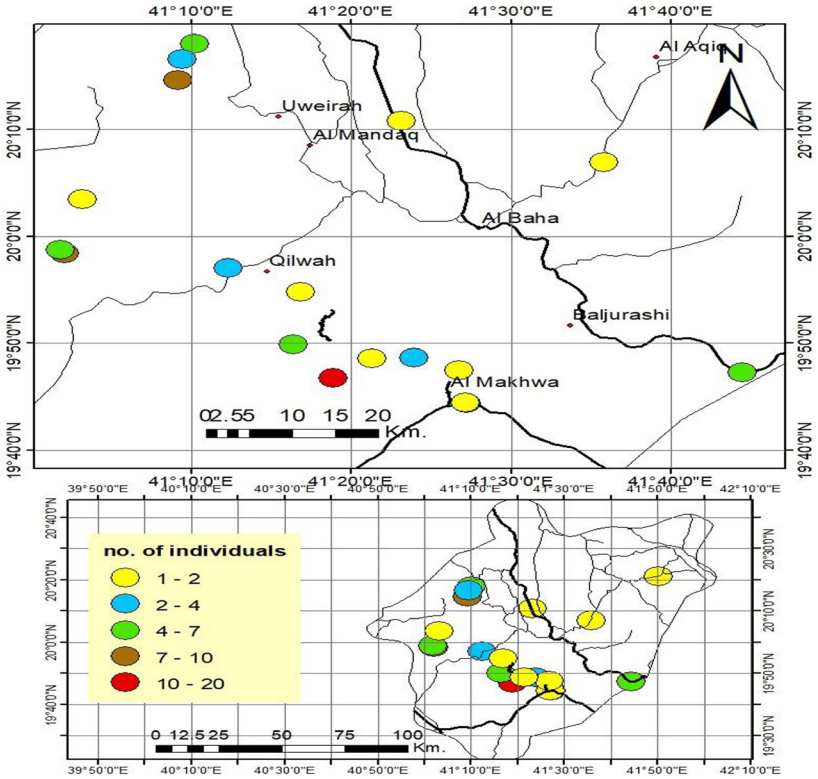
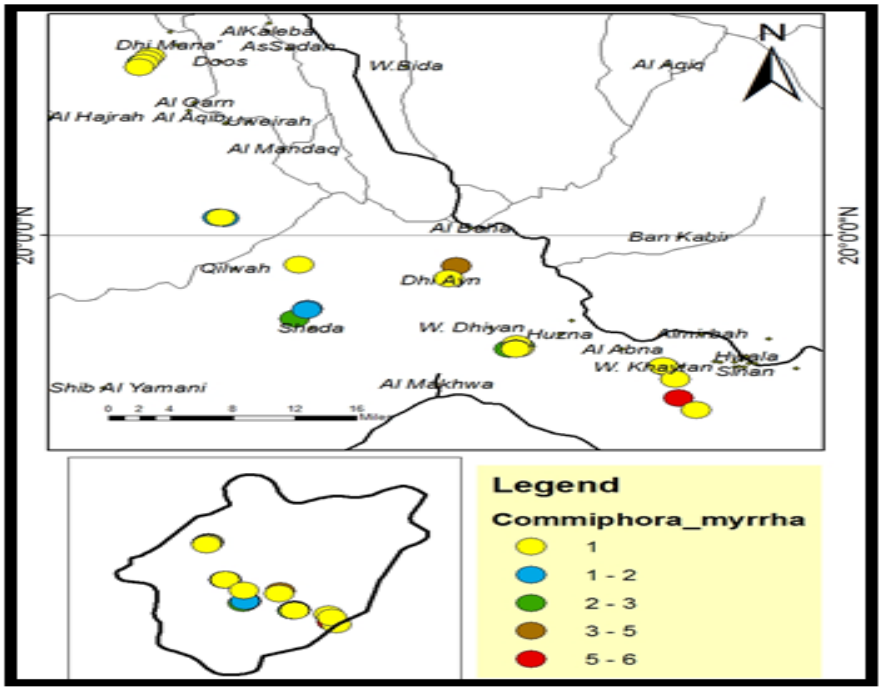
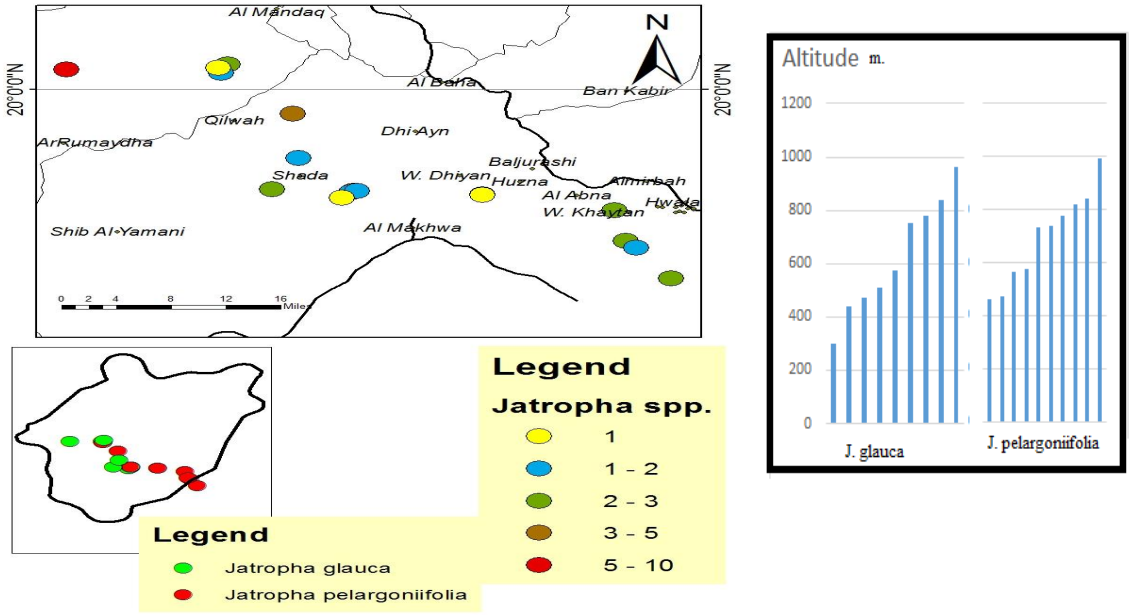


Fig. 4L. The distribution of *Citrullus colocynthis*. It is found in dry habitats between 300 and 935m. on wadi beds and sandy plain western part of the region and between 1400 to about 2000 on a dry plateau and sandy plain North East and East of the region. The individuals per sample site range between 1 to 20



Plant name	Flowering period
Commiphora myrrha	10,11,12

Fig. 4M. The distribution of *Commiphora myrrha*, it is found on dry rocky slopes facing west such as the bottom of Al Abna, descent, Dhi Ain and around J. Shada (between 500 and 985), the individuals range between 1 and 6



Plant name	*Flowering period*
Jatropha glauca	*8,9.10*
Jatropha pelargoniifolia	*3,4*

Fig. 4N. The distribution of both *Jatropha glauca* and *J. pelargonifolia,* both are found on wadi beds and rocky slopes, at low altitude areas SW and W of the region. The first is found between 230 and 962m., around Al Romaidah and Wadi Reem, with individuals per sample site range between 1 to 10. The letter is found between 472 and 995m., around wadi Khaytan, Qilwa and J. Shada, with individuals per sample site range between 1 to 5

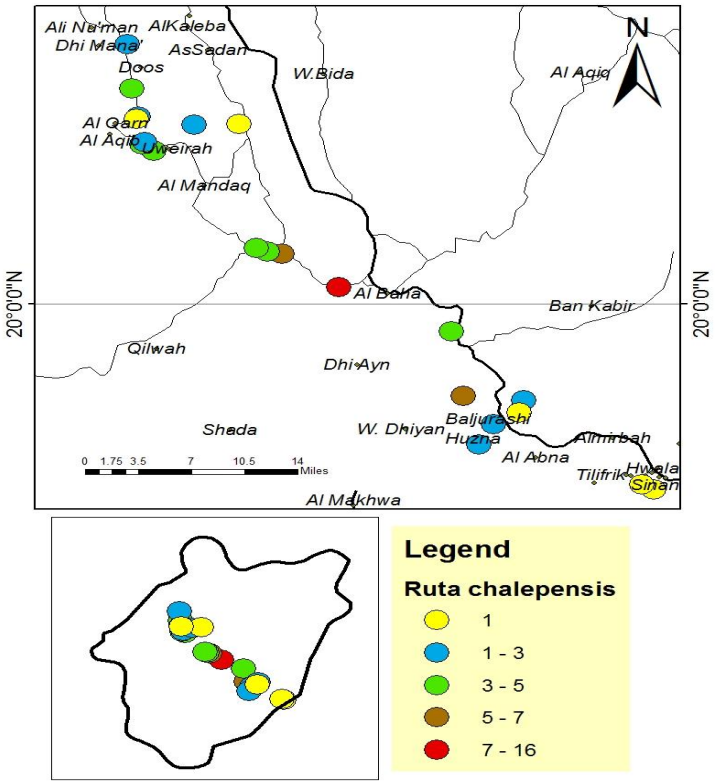
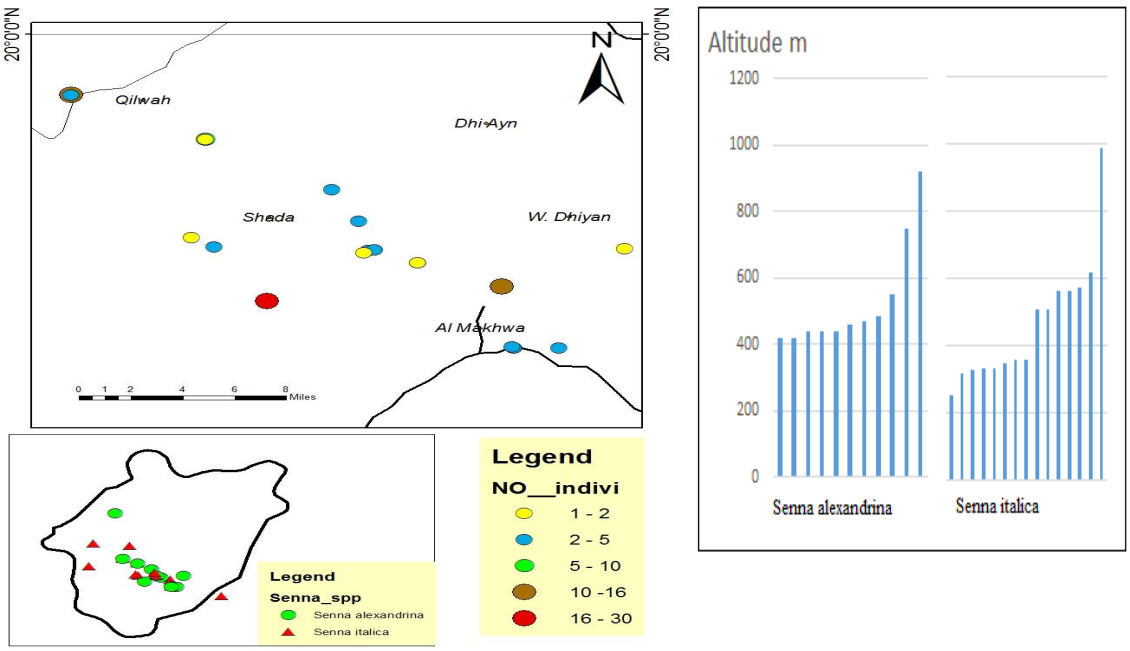


Fig. 4O. The distribution of *Ruta chalepensis.* It is found over 1700m, on terraces under Vachellia origena woodland. The individuals per sample site range between 1 to 16



Plant name	Flowering period
Senna alexandrina	4,5,11
Senna italica	1,2, 6,7,8

Fig. 4P. The distribution of *Senna* spp. (*Senna alexandrina* and *S. italica*), both species are found on wadi beds at low altitude areas western part of the region. The first is found between 417 and 920m. with individuals per sample site range between 1 to 15. The latter is found between 330 and 962m. with individuals range between 2 and 30

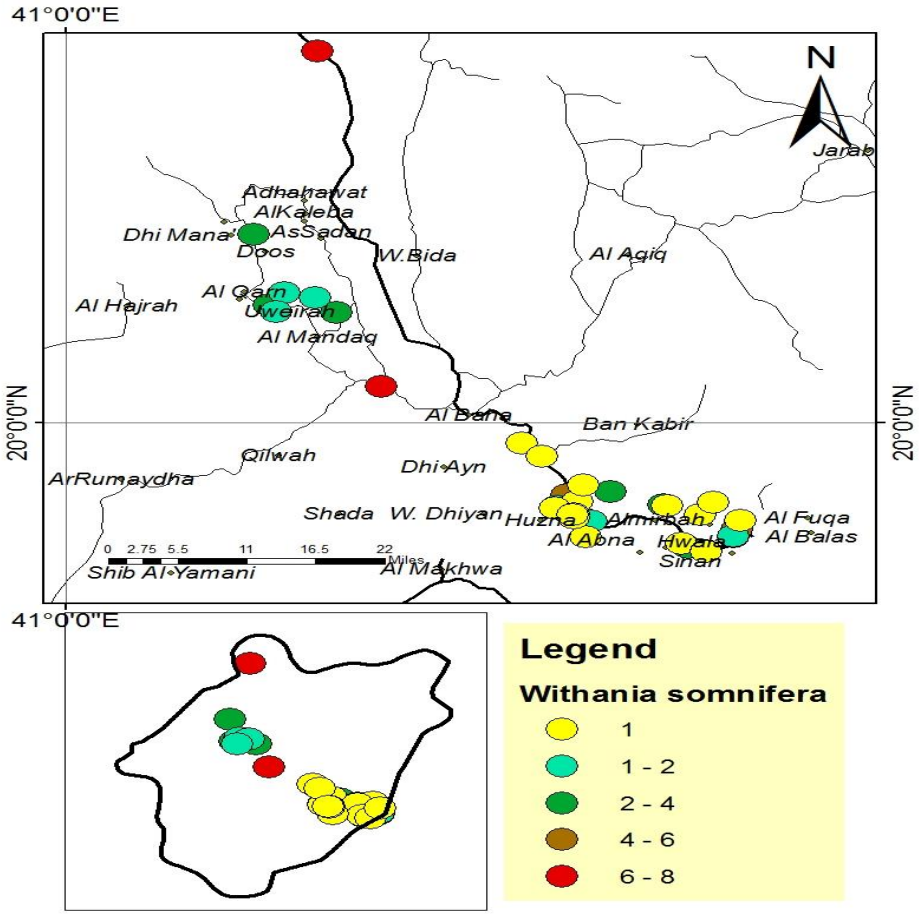


Fig. 4Q. The distribution of *Withania somnifera*. It is found on terraces, disturbed sites, drainage lines and rocky slopes, between 1300 and 2223m. The individuals per sample site range between 1 to 8. Flowering periods: 12,1,2,5

Conclusions

Mapping the spread and density of medicinal plants greatly assists in the development of conservation strategies and provides useful information on where conservation measures should be initiated and where collections should be conducted in the region.

The best way to support planned medicinal plant conservation is to display the distribution of these species on large-scale maps. As well as indicating the status of plant density and abundance, this type of information is of benefit when determining the causes of declining plant numbers and scarcity.

The collection of medicinal plants, particularly those whose chemical constituents have pharmaceutical uses, may provide economic benefits on a regional level. Awareness of the geographical location of such medicinal plants by means of accurate maps facilitates easy access to plants in their natural habitat and may also contribute to the discovery of new medicinal species in the region concerned. However, as of today, many plants in Saudi Arabia with documented usage in indigenous medicinal systems have still not been mapped properly. We hope the findings of our study contribute to future works to achieve this end.

Declaration of competing interest: The authors declare no competing interests.

Authors' contributions: Abdullah Alaklabi, 20%; Abdul Wali Al-Khulaidi, 60% and Nageeb A. Al-Sagheer, 20%.

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رسم خرائط باستخدام نظم المعلومات الجغرافية لأهم النباتات الصيدلانية في منطقة الباحة

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في هذه الدراسة ، استخدمنا نظام المعلومات الجغرافية (GIS) والمسوحات الأرضية لرسم خرائط لاهم النباتات الصيدلانية في منطقة الباحة بالمملكة العربية السعودية. استخدمنا وظائف GIS لإنشاء خرائط التوزيع والغنى النباتي والكثافة لـ 39 نوعا نباتيا تتبع 23 عائلة و 25 جنسًا. ثلاثة من هذه الأنواع النباتية يقتصر تواجدها على المملكة العربية السعودية فقط (متوطنة). واثنان سجلت فقط في كل من المملكة العربية السعودية واليمن. وخمسة انواع يقتصر تواجدها على الجزيرة العربية وشرق افريقيا.

تنتمي خمسة أنواع إلى الفصيلة Xanthorrhoeaceae ؛ وأربعة انواع تنتمي إلى الفصيلتين اللبينية Euphorbiaceae والبخورية Burseraceae ؛ وثلاثة ينتمون إلى كل من الفصيلة القُطيفيةAmaranthaceae والخشخاشية Papaveraceae لكل نوع من الأنواع النباتية الصيدلانية، قمنا بحساب الكثافة لكل هكتار وحددنا نسبة التكرار.

تقع منطقة الدراسة في جنوب غرب المملكة العربية السعودية، بين خطي العرض 16 و 21 ، وخطي الطول 40 و41. استخدمنا نظم المعلومات الجغرافية مع برنامج Arc Map من أجل إنشاء خرائط التوزيع والكثافة والثراء لكل من 39 مصنعًا للأدوية. هذه هي الدراسة الأولى التي تستخدم نظم المعلومات الجغرافية لإظهار توزيع مصانع الأدوية في هذه المنطقة، ويمكن اعتبارها مورداً أساسياً لرسم الخرائط وتدجين الجميع.

قد يساهم ذلك في زراعة النباتات الصيدلانية على نطاق تجاري، مع ما يترتب على ذلك من فوائد اقتصادية على المستويين الفردي والوطني.