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RESEARCH ARTICLE

VEGETATION MAPPING AND DEVELOPMENT OF A METHOD FOR THE VEGETATION TYPIFICATION IN THE ARABIAN PENINSULA

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Abstract

The study aims to generate vegetation mapping for the study area's existing vegetation and apply a vegetation typification approach that can be used to identify the vegetation structure of any region in the Arabian Peninsula. To highlight the plant diversity and the vegetation communities for nature conservation purposes, a case study in Albaha region, Saudi Arabia is presented, in which the natural vegetation communities and vegetation types of one of the Important Plant Species Areas (IPSA) of Saudi Arabia is evaluated. In an area of 167.6 km2, 97 samples, each with 20X20 m were laid out covering the whole ecological zones of the study area. Data on flora, vegetation cover and topography were gathered from each sample site using Braun-Blanquet method. ITC approach of vegetation typification according to three dimensions (trees, shrubs, and herbs) is applied to identify the structures of each vegetation type. The results showed 319 plant species belonging to 228 genera and 75 families. These species were analyzed and classified into three plant communities and 14 different vegetation types using multivariate analysis program (MVSP) software. Using the percentage of trees, shrubs and herbs, the three-dimensional graphics of vegetation structure presented in this study can be used to determine the vegetation structure of any region in the Arabian Peninsula.

Keywords: IPSA, Vegetation community, Vegetation type, Vegetation mapping, Saudi Arabia, Vegetation typification.

Introduction

The Sarawat Mountains, which start in the north of the Arabian Peninsula, and extend to Yemen are very rich in biodiversity compared to other habitats in the Arabian Peninsula, these mountains comprise a large number of endemic, endangered and threatened plant species [1,2,3]. The study area which is located in the Sarawat Mountains and within The Eastern Afromontane Hotspot area [4], has very rich biodiversity and is considered one of the richest plant diversity in the al Baha region. [5, 6].

The vegetation of the study area is a mixture of different climatic conditions and different elements of mainly Sudanian region, with little Saharo-Arabian or Saharo-Sindian, and the Mediterranean region [7, 5]. This is because of variations in rainfall and altitude ranges from 650 to 2350 m. [1] (see Fig. 2).

Some vegetation cover studies have been carried out in the region. These studies covered part of the current study area, Among the most important of these studies are [5, 6, 8, 9, 1].

Mapping of plants is an important task of presentation of information and scientific data on plant distribution in relation to environmental conditions [10]. In this study, we aim to highlight the main vegetation types that characterized the study area. Besides, the study aims to generate vegetation mapping for the existing vegetation in the area and apply an approach of vegetation typification that can be used to identify the vegetation structure of any region in the Arabian Peninsula.

Materials and Methods

The study Area

The study area is located in the southeast of Albaha region, Saudi Arabia, between a latitude19.41: 19.50 and

a longitude 41.29 and 41.44 East) (see Figure 1). These areas stretch parallel to Tihama plain and extend for approximately 68 km. Deep wadis and drainage lines cut the mountains, and drift toward the Tihama foothills and coastal plains [1]

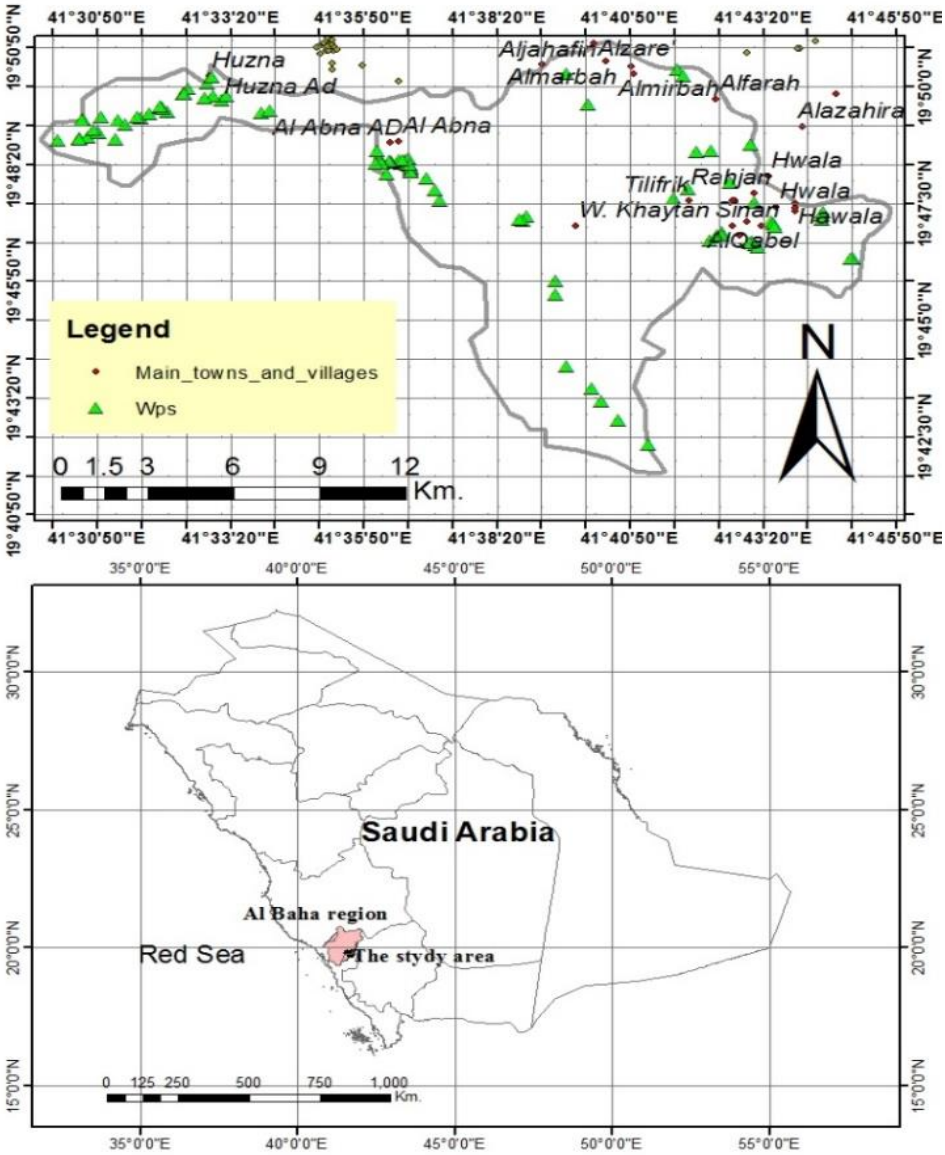

Fig.1: The location of the study area showing also the waypoints (after [1])

The landscape difference strongly influences the structure of the vegetation communities and vegetation types. The variation of landscape in particular that faces the west and is affected by fog provides a vegetation edge microclimate ecosystem [11], which supports unique vegetation composition and structure with endemic, rare plant species. The altitude of the study area ranges between 600 and 2240 m. above sea level (Figure 2). The terraces are confined nearly at high altitude areas, and most of these terraces are neglected for years (figure 3), as a result, they became covered by vegetation similar to vegetation type 3d natural, which is dominated by *Vachellia origena* with associated species such as *Asphodelus fistulosus, Juniperus procera,* and others.

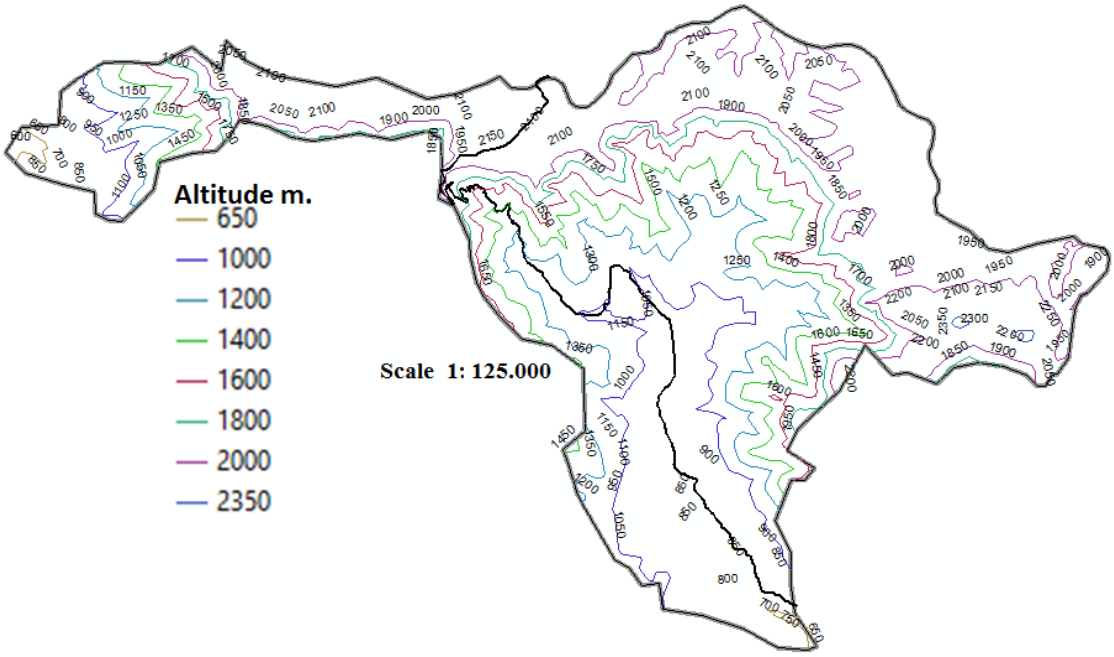

Fig. 2: The altitude of the study area (after [1])

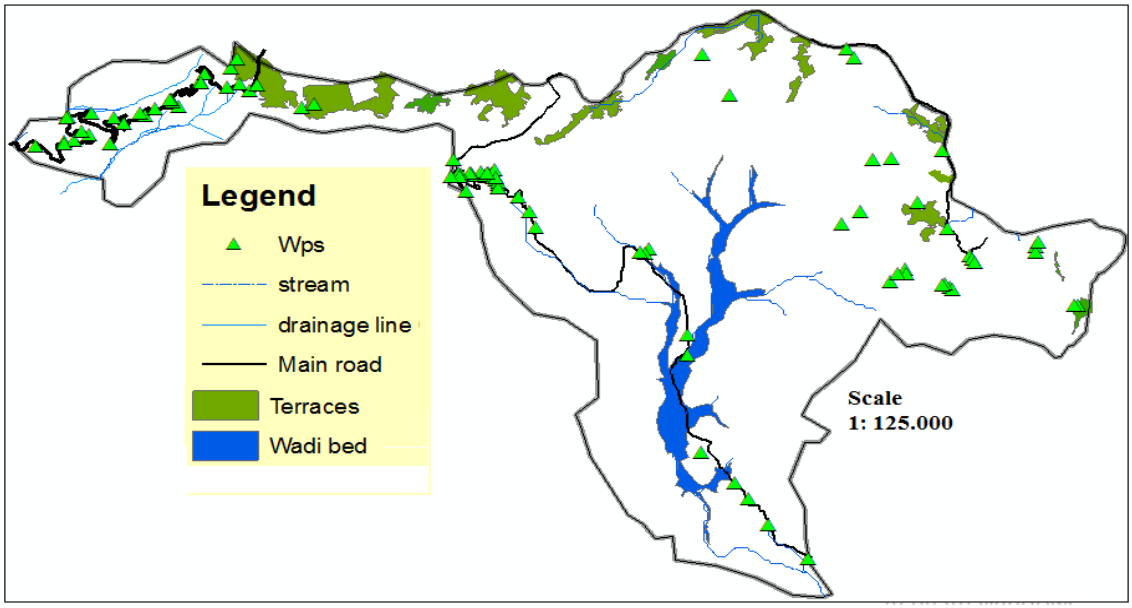

Fig. 3: Topography of the study area with the sample sites.

Vegetation Classification

Vegetation classification aims to group the plant species based on their floristic composition into plant communities generally known as plant phytosociological units [12]. Following the method of Braun-Branquet, the sample plots were arranged to similarities and then combined in 3 vegetation communities (figure 5) and 14 vegetation types.

Vegetation Structure

Woody plants taller than 1 m were considered trees; woody plants shorter than 1 m were considered shrubs; and woody plants shorter than 0.5 m were considered sub-shrubs or dwarf shrubs. The herbaceous stratum consisted of non-woody plants (grasses and ground cover herbs).

To identify the structures of each vegetation type, the ITC approach [13,14,15] of vegetation typification according to three dimensions (trees, shrubs, and herbs) is used (Table 1 and Figure 4). The vegetation communities and vegetation types were generated using MVSP software and the Braun-Blanquet method. The main feature of the vegetation mapping was the altitude range.

The total number of samples was 97 samples, each with a size of 20X20 m. These samples were distributed randomly in an area of 167.6 km 2, with the assurance that they have covered all ecological zones and topographic units of the study area.

Table 1: Vegetation structure types (rows) versus percentage cover of vegetation (After [15]

Vegetation Structural type	Percent cover per layer		
	Trees	Shrub	Grasses
Forest	>60	n.a.	n.a.
Woodland	>25	n.a.	n.a.
Woodland-shrubland	15-25	<10	n.a.
shrubland- woodland	5 - 25	>10	n.a.
Shrubland	<5	>20	<20
Shrubland grassland	<5	>20	>20
Wooded grassland	5 - 15	<10	>5
Grassland	<5	<20	>50
Sparsely vegetated land	<5	<5	<50

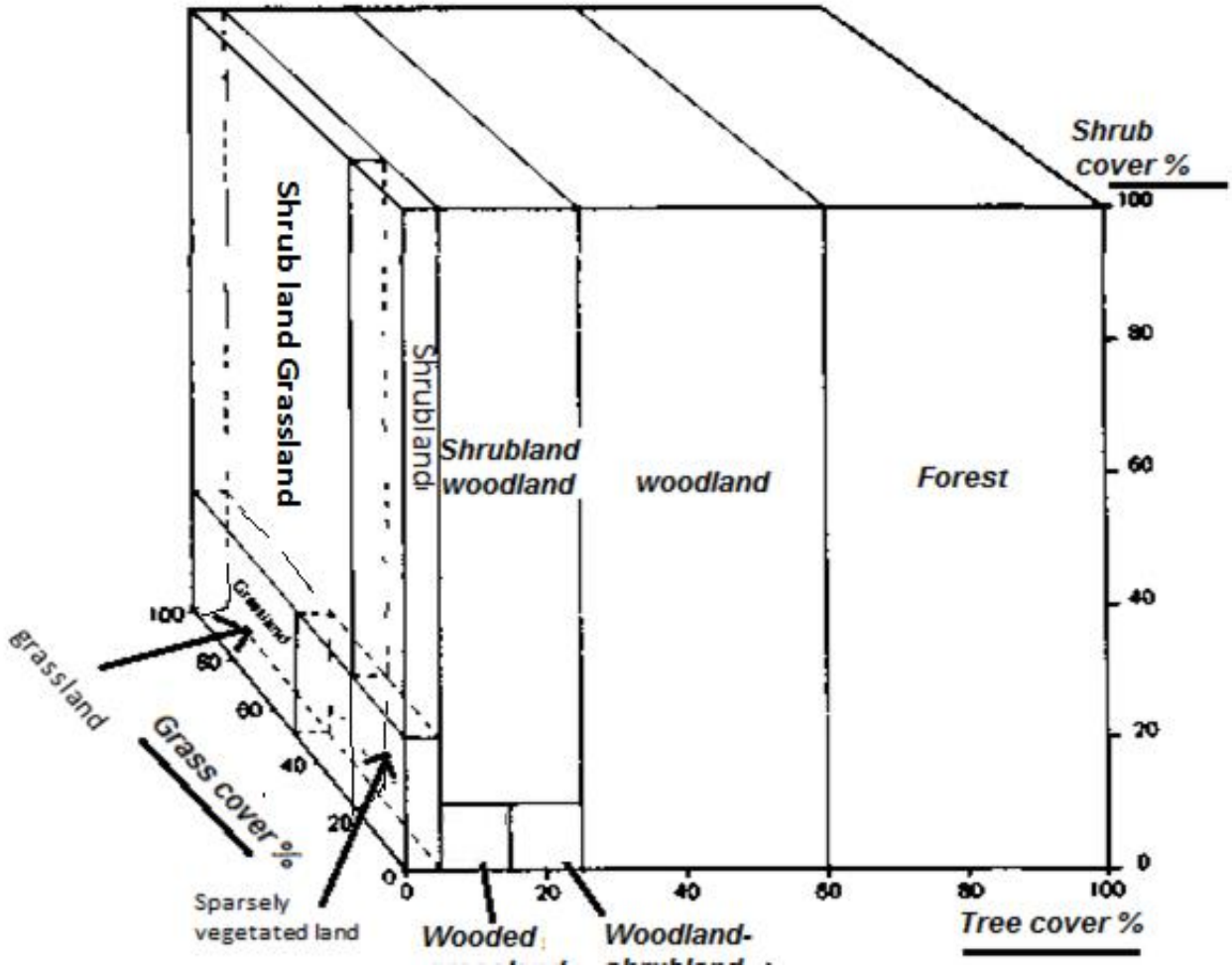

Fig. 4: Three dimensional graphic representation of vegetation structural (After [15]

Vegetation Communities

In total, 319 plant species were tabulated and analyzed using MVSP software to generate three vegetation communities consisting of 3 vegetation communities and 14 different vegetation types. The communities and their relationships to environmental factors were analysed by Canonical Correspondence Analysis (CCA), using the statistical software of MVSP version 3.1 (Figure 3.5). Data were available on: altitude. Canonical Correspondence Analysis (CCA) ordination biplot of sampling points on environmental variables (altitude) were done using MVSP software (Figure 6).

Results

In total, 319 plant species were tabulated and analyzed using MVSP software to generate three vegetation communities and 14 different vegetation types (Figure 5 and 6)

Three vegetation communities were identified in the study area, namely: *Anisotes trisulcus community* (between 600 and 1000 m.), *Senegalia asak (Acacia asak*) community (between 1000 and 1700 m.) and *Juniperus procera* community (over 1700 m).

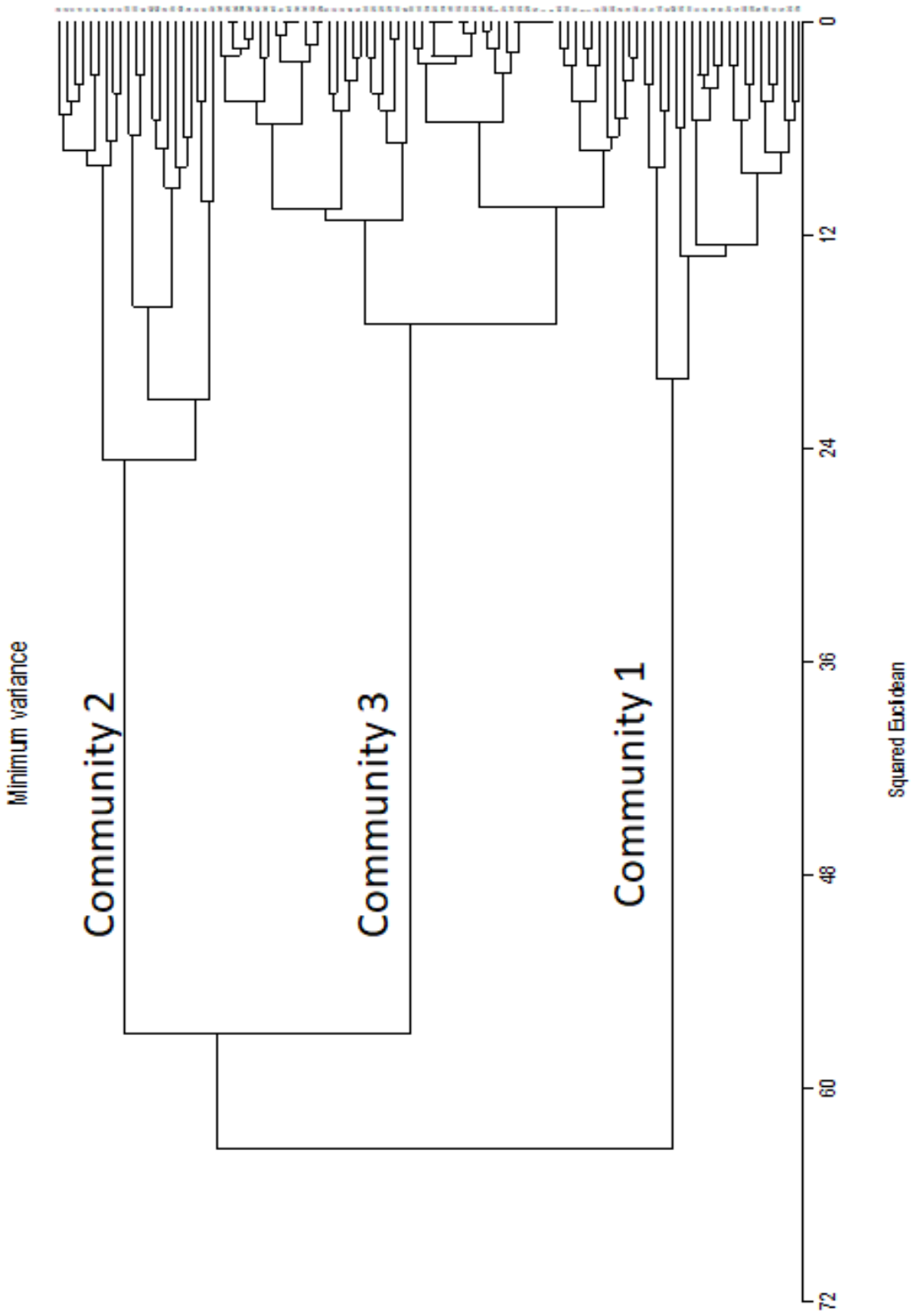

Fig. 5: Main vegetation communities using MVSP software

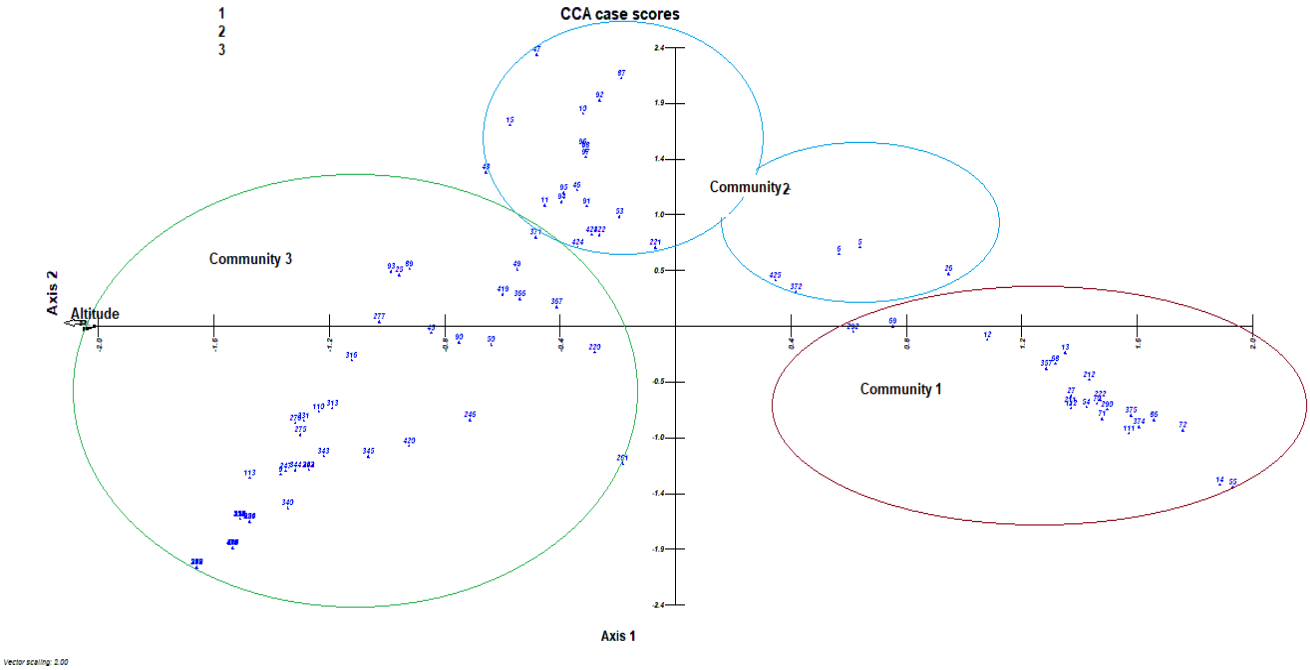

Fig. 6: Ordination biplot of sampling points on environmental variables (altitude) using Canonical Correspondence Analysis (CCA). The altitude is represented by arrows, and the sample sites are represented by points. The most important environmental variable is altitude. The altitude arrow is pointing in the direction of the greatest change in the environmental variable across the diagram. Community one confides in low altitude, the second in moderate altitude, and the third in high altitude.

1- Anisotes Trisulcus Community

This community occurs at low altitude areas (from 600 to 1000 m.), on rocky slopes, drainage lines and wadis. The community comprises 5 vegetation types (from A to E). The community forms a variety of vegetation structures. A woodland dominated by *Vachellia flava (Acacia ehrenbergiana)* was seen on drainage lands and wadi beds facing South and South East, shrubland dominated by *Anisotes trisulcus* was seen on wadis facing south and on rocky slopes facing east, a grassland dominated by *Stipagrostis obtuse* was seen on rocky slopes facing South and South West. 7 vegetation structures are noticed in this habitat, the most vegetation structures of this habitat are shrubland- woodland (30%), Woodland-shrubland (20%) and Grassland (15%) (fig. 7a).

Total vegetation ranges between 15 and 48 % on rocky slopes and between 60 and 77% on drainage lines and wadis. The average percentage of trees was 12%, shrubs 17% and herbs 16%. The number of individual plants ranges between 5 and 19, the number reaches 24 on rocky slopes facing South and South West. The most common plants beside *Anisotes trisulcus* are *Senegalia asak, Vachellia flava, Aristida adscensionis, Blepharis edulis, Indigofera spinosa,* and *Stipagrostis obtuse.*

2- Senegalia Asak Community

This community occurs at a moderate altitude area (from 1120 to 1660 m), on rocky slopes, drainage lines, rock outcrops and wadis, mainly facing West. North West and South West. The community comprises 5 vegetation types (from A to E). The community forms a woodland and grassland, a woodland dominated by *Senegalia asak and Combretum molle* was found on drainage lines facing south and on a rocky slope facing North West, *Aristida adscensionis, Stipagrostis obtusa* and *Cenchrus ciliaris* grasslands are the dominant vegetation structure of this community. 6 vegetation structures are noticed in this habitat, the most vegetation structure of this habitat is shrubland- woodland (32%), Woodland-shrubland (21%), and Grassland (18%) (fig. 7b).

Total Vegetation cover ranges between 7 and 40 % on rocky slopes and between 60 and 95% on the drainage lines and wadis. The average percentage of trees is 15%, shrubs 5% and herbs 10%. The number of plants ranges between 5 and 43. The most common plants beside *Senegalia asak are Aristida adscensionis, Blepharis edulis, Cenchrus ciliaris, Combretum molle, Indigofera spinosa, Pennisetum setaceum* and *Stipagrostis obtuse.*

3- Juniperus Procera Community

This community occurs at a moderate altitude area (from 1700 to 2147 m), on rocky slopes, drainage lines, rock outcrops, terraces, and wadis, mainly facing West. North West and South West. The community comprises 4 vegetation types (from A to D). The community forms a woodland and grassland. A woodland dominated by *Juniperus procera* was found on rocky slopes and wadis facing West and North West, a woodland. The

vegetation of this zone is characterized by a combination of trees and grasses. 8 vegetation structures are noticed in this habitat, the most vegetation structure of this habitat is woodland (31%), Shrub grassland (19%) and wooded grassland (14%) (fig. 7c). A forest structure is only found in this zone with 6%.

Total Vegetation cover ranges between 8 and 90 %, the cover exceeds 100% on rocky slopes and wadis that are dominated by grasses. The average percentage of trees is 22%, shrubs 11% and herbs 38%. The number of plants ranges between 8 and 48. The most common plants beside *Juniperus procera* are grasses such as *Aristida adscensionis, Cenchrus ciliaris, Eragrostis papposa, Hyparrhenia hirta,* and *Themeda triandra*. Vegetation dominated by *Vachellia origena* is also found in old terraces and neglected fields. *Hyparrhenia hirta, and Themeda triandra* grasslands are found on rocky slopes and drainage lines.

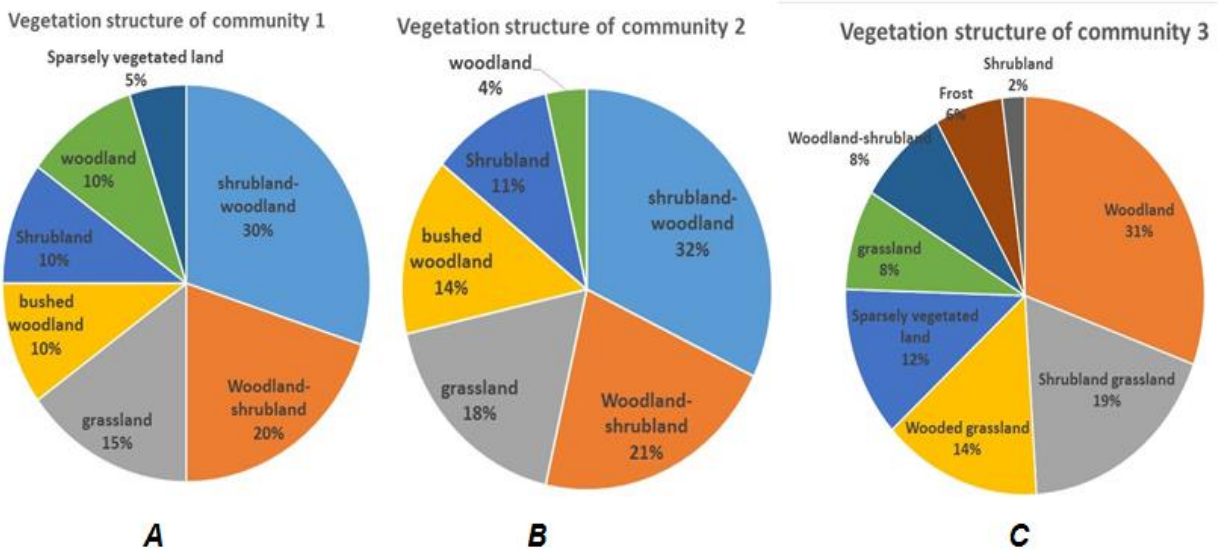

Fig. 7: Vegetation structures of the three main communities with their percentages

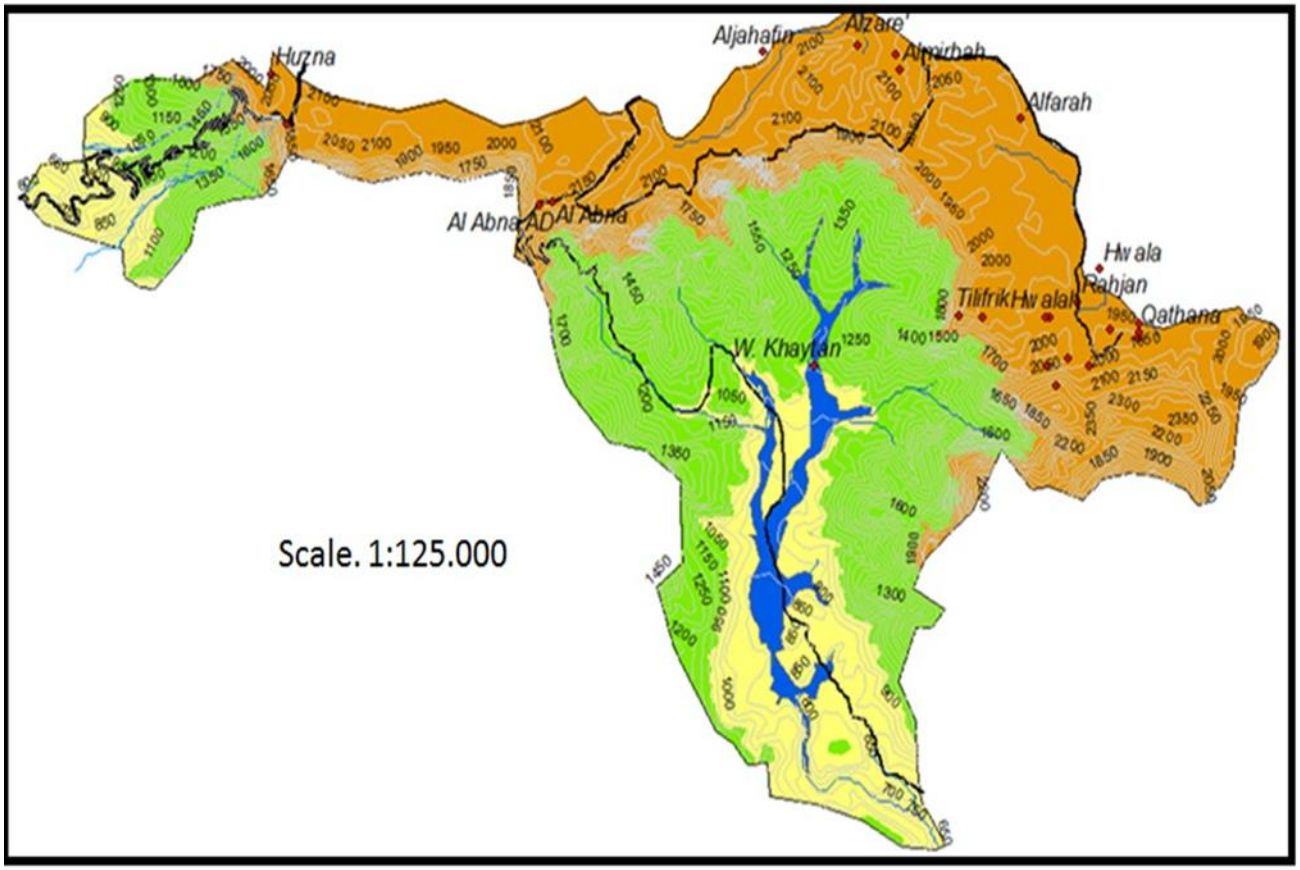

Fig. 8: A map of main vegetation communities

Table 2: Key to main Vegetation communities and types in Hawala – Al Abna - Huzna as shown in figures 5 and 6

Altitude m.	Vegetation community	Vegetation types	Altitude range m.	structure	Land form	exposure	Main associate Species with its percentage	No of species	% of the type
300 -1000	1- Anisotes Trisulcus Community	A- *Salsola imbricata- Anisotes trisulcus*	605-840	Woodland, shrubland- woodland (average trees 4%, shrub 7% & herbs 12%)	Drainage line and rocky slope	S,SE	*Anisotes trisulcus (27)* *Blepharis edulis (9)* *Indigofera spinosa (9)* *Vachellia flava (6)* *Salsola imbricata (6)* *Fagonia indica (3)*	15-19	10
		B-*Commiphora kataf- Vachellia johnwoodii*	820-995	Shrubland, shrubland- woodland, Sparsely vegetated land (average trees 23%, shrub 13% & herbs 6%)	Rocky slopes & wadis	S,NE,W	*Anisotes trisulcus (27)* *Indigofera spinosa (13)* *Aerva javanica (10)* *Vachellia johnwoodii (7)* *Aristida adscensionis (10)* *Commiphora kataf (5)* *Vachellia flava (6)* *Cissus quadrangula (6)* *Jatropha pelargoniifolia(3)* *Blepharis edulis (3)*	9-12	15
		C- Ziziphus spina-christi- Vachellia flava - Indigofera spinosa	736-1000	Woodland - shrubland- woodland (average trees 19%, shrub 30% & herbs 5%)	Wadis and rocky slope	S,NE,W	*Indigofera spinosa (41)* *Anisotes trisulcus (14* *Vachellia tortilis (3)* *Vachellia flava (16)* *Commiphora myrrha (3)* *Caralluma retrospiciens(3)* *Vachellia johnwoodii (3)*	8-13	20
		D- Maerua crassifolia - Premna resinosa- Senegalia asak	700-875	Woodland – shrubland, bushed woodland, shrubland, grassland (Average trees 11%, shrub 14% & herbs 18%)	Rocky slope	S,E,W,SW,NE,	*Stipagrostis obtusa (35)* *Anisotes trisulcus (8)* *Aristida adscensionis (7)* *Blepharis edulis (4)* *Indigofera spinosa (4)* *Senegalia asak (3)* *Aerva javanica (3)* *Fagonia indica (3)* *Andropogon distachyos (3)*	5-24	45
		E- Barleria hochstetteri- Ecbolium viride- Stipagrostis obtusa	920 - 999	shrubland- woodland , Grassland (Average trees 7%, shrub 5% & herbs 43%)	Rocky slope	SW	*Stipagrostis obtusa (27)* *Cenchrus ciliaris (9)* *Pennisetum setaceum (6)* *Aerva javanica (5)* *Blepharis edulis (5)* *Sarcostemma viminale (5)* *Aristida adscensionis (3)* *Forsskaolea tenacissima (3)* *Senegalia asak (3)* *Ruellia patula (3)*	19-24	10

1000-1700	2- Senegalia asak community	A- *Grewia velutina - Stipagrostis obtusa*	1127 - 1320	Wooded grassland, Grassland, Sparsely vegetated land (average trees 6%, shrub 3% & herbs 17%)	Rocky slope	W,S,SW, NW	*Stipagrostis obtusa (16)* *Halothamnus bottae (12)* *Senegalia asak (9)* *Nicotiana glauca (9)* *Indigofera spinosa (8)* *Aerva javanica (8)* *Pennisetum setaceum (7)* *Blepharis edulis (6)* *Calotropis procera (3)* *Vachellia etbaica_ (3)*	4-8	21
		B- *Psydrax schimperianum - Combretum molle*	1450 - 1488	Woodland, shrubland- woodland (average trees 20%, shrub 10% & herbs 16%)	rocky slopes & rock outcrops	NW	*Combretum molle (11)* *Cyphostemma digitatum (11)* *Abutilon fruticosum (8)* *Psiadia punctulata (6)* *Leucas glabrata (5)* Hibiscus deflersii (5) *Senegalia asak (4)* *Cenchrus ciliaris (3)* *Psydrax schimperianum (3)* *Hypoestes forskalei (3)*	9 - 32	11
		C: *Tamarix nilotica -Stipagrostis obtuse*	1338-1440	Grassland, Sparsely vegetated land (Average trees 3%, shrub 2% & herbs 40%)	Rocky slopes	S, NW	*Stipagrostis obtusa (25)* *Cenchrus ciliaris (15)* *Blepharis edulis (9)* *Indigofera spinosa (3)* *Fagonia indica (3)* *Forsskaolea tenacissima (3)* *Pupalia lappacea (3)* *Lavandula pubescens (3)*	18-26	7
		D: *Olea europaea- Ficus sycomorus - Coccinia grandis -*	1550-1660	Woodland, grassland (Average trees 10%, shrub 5% & herbs 37%)	Rocky slope	E,W,SW	*Aristida adscensionis (13)* *Coccinia grandis (13)* *Faidherbia albida (8)* *Crotalaria sp. (6)* *Rumex nervosus (6)* *Senegalia asak (6)* *Lavandula pubescens (6)* *Dodonaea viscosa (5)* *Ficus sycomorus (4)* *Olea europaea (4)* *Pennisetum setaceum (4)* *Combretum molle (4)*	10-16	18
		E: *Cissus rotundifolia -Acalypha fruticosa- Senegalia asak*	1394 - 1550	Woodland. Shrubland, Wooded grassland, shrubland- woodland, grassland, Sparsely vegetated land (Average trees 16%, shrub 7% & herbs 28%)	Wadis and drainage lines	W,S,SE, SW	*Pennisetum setaceum (6)* *Cissus rotundifolia (6)* *Andropogon distachyos (5)* *Hyparrhenia hirta (5)* *Aristida adscensionis (5)* *Cenchrus ciliaris (5)* *Senegalia asak (3)* *Crotalaria sp. (3)* *Blepharis edulis (3)* *Pupalia lappacea (3)* *Indigofera spinosa (3)*	8-43	43

1700 - 2350	3- Juniperus Procera Community	*A-* *Barbeya oleoides – Ficus cordata- Themeda triandra*	1700 - 1800	shrubland- woodland, Woodland-Shrubland, Wooded grassland, Shrubland- grassland, Shrubland, Sparsely vegetated land (Average trees 9%, shrub 14% & herbs 42%)	Drainage lines and rocky slopes	W, SW, SE	*Themeda triandra (7)* *Hyparrhenia hirta (7)* *Pupalia lappacea (5)* *Pennisetum setaceum (5)* *Cenchrus ciliaris (4)* *Eragrostis papposa (4)* *Psiadia punctulata (3)* *Jasminum grandiflorum (3)* *Chrosopogon sp. (3)* *Helichrysum sp. (3)*	8 -52	16
		B- *Ficus palmate - Vachellia gerrardii - Hyparrhenia hirta*	1900- 2147	Woodland, Wooded grassland , Wooded grassland, shrubland- woodland (Average trees 16%, shrub 6% & herbs 18%)	Rocky slopes, drainage lines, wadis and fallow land	S, W, E, SW, NW	*Juniperus procera (9)* *Hyparrhenia hirta (6)* *Achillea biebersteinii (5)* *Aristida adscensionis (4)* *Pennisetum sp. (3)* *Themeda triandra (3)* *Eragrostis papposa (3)* *Opuntia ficus-indica (3)* *Andropogon distachyos (3)* *Hypoestes forskalei (3)*	7-20	25
		C- *Minuartia filifolia -- Psiadia punctulata - Themeda triandra*	1877 - 2135	Forest, Woodland, shrubland- woodland, grassland, Sparsely vegetated land (average trees 26%, shrub 13% & herbs 40%)	Rocky slope, rock outcrops, cliff, drainage line and terraces	W, NW, NE, SE, S, E	*Themeda triandra (11)* *Hyparrhenia hirta (7)* *Tripteris vaillantii (5)* *Cynodon dactylon (5)* *Cenchrus ciliaris (4)* *Aristida adscensionis (4)* *Eragrostis papposa (4)* *Juniperus procera (3)* *Psiadia punctulata (3)* *Hypoestes forskalei (3)*	21 - 44	37
		D- *Achillea biebersteinii - Vachellia origena - Asphodelus fistulosus*	194 - 2350	Forest, Woodland, shrubland- woodland. Grassland, Sparsely vegetated land	Rocky slope, Wadi, terraces, fallow land	SE, W, NW, E	*Hyparrhenia hirta (11)* *Asphodelus fistulosus (10)* *Eragrostis papposa (9)* *Cenchrus ciliaris (8)* *Cynodon dactylon (6)* *Juniperus procera (5)* *Chenopodium schraderianum (4)* *Salvia aegyptiaca (3)* *Aristida adscensionis (3)* *Tripteris vaillantii (3)*	15 - 48	22

Discussion

Vegetation is an essential component of ecosystems and the environment all over the world, serving as the foundation for terrestrial food webs and animal habitats. It also produces oxygen, aids in the cycling of energy and nutrients throughout an ecosystem, improves water quality, and aids in the mitigation of flooding and land erosion. Our climate can even be influenced by vegetation cover.

The study demonstrates how vegetation communities and structure are distributed, what species they are made up of, and what type of topography they cover. Variation and change in the structure of these vegetation communities and their vegetation types can occur naturally, as a result of environmental stressors, or as a result of human activities such as deforestation and land use change.

The lack of fog that characterized the area in the past may have contributed to the change in vegetation structure. Monitoring of the vegetation community is required to determine the status and trends in plant species abundance, coverage, diversity, and distribution in this remarkable area [16].

This study provides sufficient information about species composition, topography, and structure of vegetation that may require educated planning and management of the flora and vegetation of the study area. The physical environment that supports and maintains forest biodiversity is provided by vegetation structure, which has been identified as a significant biodiversity indicator [17].

ITC approach of vegetation typification and three dimensional graphic that applied in this paper can be used to identify the vegetation structure of any region in the Arabian Peninsula.

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مقالة بحثية

رسم خرائط الغطاء النباتي وتطوير طريقة لتحديد التركيب النباتي لنباتات شبه الجزيرة العربية

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المُلخّص

تهدف الدراسة إلى ابراز خرائط للغطاء النباتي للنباتات الموجودة في منطقة الدراسة وتطبيق نهجا لطبقات الغطاء النباتي يمكن استخدامه لتحديد بنية الغطاء النباتي لأي منطقة في شبه الجزيرة العربية. لتسليط الضوء على التنوع النباتي والمجتمعات النباتية لأغراض الحفاظ على الطبيعة، تم تقديم دراسة حالة في منطقة الباحة بالمملكة العربية السعودية، حيث تم تقيم المجتمعات النباتية وأنواع الطرز النباتية لإحدى مناطق الأنواع النباتية الهامة (IPSA) في المملكة العربية السعودية. في مساحة 167.6 كيلومتر مربع ، تم مسح 97 عينة دراسية، مساحة كل منها 20 × 20 مترًا تغطي المناطق البيئية بأكملها في منطقة الدراسة. تم جمع البيانات عن النباتات والغطاء النباتي والتضاريس من كل موقع عينة باستخدام طريقة براون بلانكويت. تم تطبيق نهج المعهد الدولي لعلوم المعلومات الجغرافية ورصد الأرض (ITC) لتصنيف الغطاء النباتي وفقًا للأبعاد الثلاثة (الأشجار والشجيرات والأعشاب) لتحديد التركيب النباتي لكل طراز من الطرز النباتية. أظهرت النتائج 319 نوعاً نباتياً تنتمي إلى 228 جنساً و 75 عائلة. تم تحليل وتصنيف هذه الأنواع الى ثلاث مجتمعات نباتية و 14 طرازا نباتيا مختلفًا وذلك باستخدام برنامج MVSP. باستخدام النسبة المئوية للأشجار والشجيرات والأعشاب، يمكن استخدام الشكل الثلاثي الأبعاد لهيكل الغطاء النباتي الواردة في هذه الدراسة لتحديد بنية الغطاء النباتي لأي منطقة في شبه الجزيرة العربية.

الكلمات المفتاحية: مناطق الانواع النباتية الهامة (IPSA)، المجتمع النباتي، الطراز النباتي، رسم خرائط الغطاء النباتي، المملكة العربية السعودية، طبقات الغطاء النباتي.

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