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Vegetation Analysis and Species Diversity Along an Altitudinal Gradient in the Central Hijaz Mountains of Saudi Arabia

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ABSTRACT. The study deals with the distribution, habitats, and ecological characteristics of natural vegetation along a transect crossing the central part of Hijaz Mountains, Saudi Arabia. Fifty stands were classified on the basis of leading dominant species, using agglomerative cluster analysis, into five distinct and recognizable vegetation groups (vegetation types). A total of 86 plant species were recorded. The present study provides evidence that the vegetation shows discernible zonation. The annuals increase, and the biennials and perennials decrease along the elevation gradient from lower to higher elevations. This appears to be correlated, at least partly, with altitude. Species diversity varies from one vegetation group to the other as well as between stands of the same group. The vegetation type of *Ficus salicifolia* is the most widespread, diversified and consequently, the most stable vegetation cover in the study area; it, therefore, represents the climatic climax community. Human interference has a prominent role in changing the physical environment and inevitably destroys the precarious balance among the components of the ecosystem. The environment has deteriorated, and retrogressive changes in the vegetation are recorded.

Keywords: Plant communities, diversity, altitudinal gradient, vegetation, Hijaz Mountains, Saudi Arabia.

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A number of investigations of the flora and vegetation have been conducted in the general study area, amongst others: Mandaville (1965), Migahid (1978 and 1988-90), Batanouny and Baeshin (1983), Collenette (1985), Fayed and Zayed (1989), Abd El-Ghani (1993). Ecological work in the highlands has been mostly restricted to general surveys: Abulfatih (1979, 1984, 1992), Zayed and Fayed (1987), Chaudhary *et al.* (1988), Abd El-Ghani (1996). However, little attention has been paid to plant species diversity. Studies of highlands and mountainous rocky vegetation has been made elsewhere in the neighbouring arid and semi-arid regions, *e.g.*, Kassas (1956), Boulos (1982), El-Hadidi (1969), Auerbach and Shmida (1993).

The present study is an analysis of the vegetation along altitudinal gradient on the slopes of the central part of the Hijaz Mountains; between Makkah and Al Hada crossing the mountains; investigating the relations of species and communities to one another in the vegetation pattern, describing the characteristic plant communities, and comparing them in terms of species composition, diversity and life form structure. Multivariate techniques and species diversity indices were used in order to asssess the relation between the vegetation types and the environmental variation.

Location and Climate

Makkah-Al Hada road is about 80 km long, of which ca 40 km crossing the mountains; representing a sector in the central part of the Hijaz Mountains in the south-eastern direction to Makkah and situated between Lat. 21° 22' – 21° 40' N and Long. 40° 60' – 40° 22' E, with a sharp rise from about 277 m above sea level at Makkah to 1650 m above sea level at Al Hada summit near Taif city. Granite and granite-gneisses prevail in this area which is a part of the Arabian Shield (Zahran 1983) and frequently occur as extensive areas of exposed rock. This massive granite belongs primarily to the Pre-Cambrian and Cambrian formed mainly of crystalline and metamorphic basement materials, and volcanic rocks (Brown 1972).

The climate of the study area represents a transition between the hyper-arid climate with winter rains in the north and west (where Makkah is located), and semi-arid climate with summer (Monsoon) rains predominant in the southeast, south and east (where Taif is located). Monsoon rains are usually expected during August, and it seems that in elevations from 300 m upwards these may be tolerably reliable. At higher elevations, 1200 m and above, especially around summits where the climate is somewhat cooler, they may accompanied by considerable incidence of cloud: orographic precipitation that enhances plant growth. Precipitation appears to be fairly regular during August and continues during September and October. The mountain rains have more than local importance because they may cause extensive floods. The second rainy season occurs during the end of the year (from December to April) and is presumably related to the cyclonic rains of the winter season. The climatic features of the study area are summarized in Table 1.

Table 1. Annual average (15 years) of some general climatic features at Makkah and Taif (after Zahran 1983, Fayed and Zayed 1989)

Climatic factor **Altitude (m ASL)**	**Makkah** **300**	**Taif** **1457**
Rainfall (mm)	86.6	208.4
Max. air temperature (°C)	36.6	28.8
Min. air temperature (°C)	26.5	15.2
Mean air temperature (°C)	33.1	22
Relative humidity (%)	47	38.7

It is to be noted here that during the winter months, Al Hada summit is frequently swathed in clouds for weeks, and this is the case also in the southern part of the Sarawat Mountain chains (as in Al-Baha and Abha). This entails considerable orographic precipitation which is more marked in higher elevation, and which supplies the vegetation with valuable water resources.

Methods

Vegetation samples were set to form a grid of transects showing relations of vegetation to topographic moisture gradients in 200 m elevation intervals from the base of the mountains (downslopes) to the summit (upslopes) near Al-Hada.

For the present study, which was undertaken from spring 1990 to spring 1993, fifty stands (10 in each of the five elevation intervals covering the entire elevation range) were set to represent variation in vegetation. The largest number of stands were taken from areas accessible by way of Makkah-Al Hada highway. Each stand was characterized by a reasonable degree of visual physiographic and physiognomic homogeneity. The size of the stand varied according to the richness of vegetation and the terrain of the area. The density, frequency and cover were expressed for each species as a percentage for all species in each stand. These three relative values were then summed to provide an importance value (IV) for each species ranging from 0.0 to 300. An altimeter was used to determine elevation above sea level.

Table 2. Means of importance values of the common associated perennials (occurring in at least 12 stands) in different vegetation groups resulting from the agglomerative classification. The number between brackets indicates the number of occurrences. For abbreviations of vegetation types see text

Vegetational groups		**A**	**B**	**C**	**D**	**D**
Altitudinal range (m)		300-500	550-750	800-1000	1050-1250	1300-1500
Number of stands sampled		10	10	10	10	10
Sample area (m)		100	100	100	100	100
Mean height of vegetation (m)		0.5-1.5	0.4-1.5	0.3-2	0.6-1.5	0.3-2.5
Total number of species recorded		56	51	49	46	42
Vegetation type		At-Lp	Ap-Is	Fs	Ae-Ec	Aas
Total cover (%)		10-15	20-25	25-35	25-30	30-35
Aerva javanica	(36)	30.19	7.05	12.32	1.09	3.39
Cenchrus ciliaris	(30)	40.53	18.10	21.53	20.71	1.31
Fagonia bruguirei	(33)	29.44	15.38	38.09	14.78	7.81
Fosskalea tenacissimia	(39)	29.06	13.41	1.18	7.35	1.56
Stipagrostis plumosa	(29)	7.29	26.76	29.20	37.09	14.66
Abutilon pannosum	(16)	27.61	**70.85**	4.73	25.12	–
Acacia torilis subsp. *raddiana*	(17)	**112.13**	20.17	31.18	11.10	–
Ficus salicifolia	(19)	19.20	33.00	**192.61**	11.37	–
Lavandula pubescens	(12)	7.62	4.21	13.15	40.30	–
Lycium shawii	(18)	23.13	25.03	4.43	12.71	–
Ochradenus baccatus	(13)	39.31	13.05	9.76	0.78	–
Pergularia daemia	(19)	0.16	10.71	1.93	3.78	–
Indigofera spinosa	(24)	22.78	**56.01**	3.43	–	–
Leptadenia pyrotechnica	(18)	**89.09**	20.08	7.10	–	–
Solamum incanum	(26)	14.26	16.61	4.07	–	–
Calotropis procera	(19)	28.65	14.89	–	49.71	–
Acacia asak	(13)	–	–	20.17	31.24	**84.00**
Acacia gerrardii	(12)	–	–	2.08	10.18	31.06
Caralluma quadrangula	(12)	–	–	37.20	12.29	7.15
Hyperrhenia hirta	(14)	–	–	19.06	48.67	2.71
Otostegia fruticosa	(17)	–	–	15.89	60.41	19.52
Solenostema argel	(15)	–	–	10.25	11.71	15.09
Acacia ehrenbergiana	(29)	21.61	–	35.20	**121.37**	25.23
Cucumis prophetarum	(23)	–	42.18	40.73	1.60	–
Euphorbia cuneata	(14)	–	39.72	46.13	**89.04**	–
Capparis spinosa	(12)	4.71	–	8.83	14.03	–
Pluchea dioscoridis	(12)	–	–	0.77	17.44	–

Stands were classified by means of a within-group dispersion method of agglomerative clustering (Orloci 1967), using a computer program of Goldstein and Girgal (1972).

Species richness (alpha-diversity) for each elevation belt was calculated as the average number of species per stand. The extent of species replacement or biotic change along environmental gradients (beta-diversity or species turnover) was calculated as the ratio between the total number of species recorded in the belt as a whole (gamma-diversity) and its alpha-diversity (Whittaker 1972, Wilson and Shmida 1984). The Shannon-Weaver's index: $H' = \sum_{i=1}^{S} (Pi)(\log Pi)$; for relative evenness was calculated where S = total number of species and Pi = relative importance value (relative cover) for ith species (Pielou 1975).

Three soil samples (0 – 50 cm) were collected from each stand, air dried, thoroughly mixed, and passed through a 2 mm-sieve to separate gravel and debris. Samples finer than 2 mm were analyzed for texture, organic matter (OM), water holding capacity (WHC) and total soluble salts (TSS) according to the procedures described by the United States Salinity Laboratory Staff (1954).

Vascular plant voucher specimens were determined by the author, using the herbarium of the University of Cairo (CAI), and following Collenette (1985) and Migahid (1988-90). Two complete sets of specimens collected are deposited in the herberia of CAI and the Junior College for Teachers' in Makkah.

Results

The data from the phytosociological analysis that aim at providing a picture of the general composition of the perennial vegetation of the study area are given in Table 2. A total of 86 plant species were recorded. The most widespread perennials are *Cenchrus ciliaris, Aerva javanica, Acacia ehrenbergiana, Forsskalea tenacissima* and *Solanum incanum;* each is recorded in 50% or more of the fifty stands sampled in the present study. However, none of these species can be considered as a leading dominant in the whole study area; instead, each exerts local dominance or is distinctly more important in certain groups of stands. This becomes evident if the average importance value of each species in the different vegetation groups resulting from the application of agglomerative classification is examined (Table 2). The distribution of the different vegetation groups along the elevation gradient shows a stepwise segregation of groups with altitudinal zonation. The group of *Acacia tortilis* subsp. *raddiana-Leptadenia pyrotechnica* occupies the lower level of the gradient, and that of *Acacia asak* occupies the highest level.

Stands of group "A" are dominated by *Acacia tortilis* subsp. *raddiana* (IV = 112.13) and *Leptadenia pyrotechnica* (IV = 89.09). The dominant species in the stands of group "B" are *Abutilon pannosum, Indigofera spinosa,* and *Stipagrostis plumosa,* with importance values of 70.85, 56.01 and 26.76 respectively. Stands of group "C" are dominated by trees of *Ficus salicifolia* (IV = 192.61), and stands of group "D" are co-dominated by *Acacia ehrenbergiana* (IV = 121.37) and *Euphorbia cuneata* (IV = 89.04). *Acacia asak* dominates the stands of group "E" with IV value of 84.00. Subordinate species are *Cenchrus ciliaris, Ochradenus baccatus* and *Fagonia bruguirei* in group "A", *Cucumis prophetarum* and *Euphorbia cuneata* in groups "B" and "C", *Otostegia fruticosa, Hyperrhenia hirta* and *Lavandula pubescens* in group "D", and *Acacia gerrardii* and *Acacia ehrenbergiana* in group "E".

It is clear that Sorensen's similarity coefficients between the different vegetation groups are generally low (Table 3). Among the highest coefficients are those between group "C" and groups "D" and "E" (higher elevations). It is interesting to notice that group "A" (lower elevations) has the lowest similarities with group "E" and all other groups.

Table 3. Sorensen's similarity indices between the different vegetation groups presented in this study

Vegetation group	A	B	C	D	E
A (300-500 m)		6	8	10	3
B (550-750 m)			24	13	17
C (800-1000 m)				34	42
D (1050-1250 m)					20
E (1300-1500 m)					

Most soil characteristics exhibit wide range of variation (Table 4). In all stands the percentage of sand is higher than that of gravel, silt and clay. Stands of higher altitudes (group E) comprise soils with higher percentages of silt and clay, water holding capacity and total soluble salts. More sandy soils with higher percentages of organic matter content and lime prevail in lower altitudes (groups A and B). The

Table 4. The mean values of some soil variables (along altitudinal gradient) in the five vegetational groups resulting from the application of agglomerative classification. Each value is a mean of 3 samples

Soil variable		Vegetation group				
		A	B	C	D	E
Gravel	(%)	20.11	29.82	30.91	22.73	27.78
Sand	(%)	79.26	67.95	65.34	73.27	66.68
Silt + Clay	(%)	0.63	2.23	3.75	4.00	5.54
Water holding capacity	(%)	9.73	8.25	10.09	10.56	10.98
Organic matter	(%)	0.71	0.67	0.42	0.38	0.09
$CaCO_3$	(%)	2.41	4.53	1.36	1.24	1.70
Total soluble salts (meq/1)		0.03	0.14	0.05	1.06	1.27

content of total soluble salts (TSS) in stands of different vegetation groups reflects the arrangement of these groups along a salinity gradient (Table 4). On the other hand, calcium carbonate content reflects, more or less, an arrangement of these groups on the physiographic gradient starting with the higher elevations and ending with the lower one.

Regarding life form, there is a gradient of increasing number of annuals and decreasing number of biennial and perennial species associated with elevation gradient from lower to higher altitudes (Table 5). The total number of species, and to some extent, the species turnover decreased along the altitudinal gradient. For species richness and relative evenness, the vegetation types of group "C": *Ficus salicifolia* and that of group "D": *Acacia ehrenbergiana-Euphorbia cuneata* attain the highest values.

The simple linear correlation between the soil variables and the importance values for the dominant species has been calculated (Table 6). Vegetation types "D" and "E" show the greatest number and the highest magnitude of significant relationships with the different soil variables. It is also obvious that all the vegetation types (communities) show decidedly significant (positive) correlation with silt and clay, and altitude. In addition, communities of higher elevations (groups "D" and "E") are more positively correlated with organic matter than the others. There is no significant correlation (and negative when present) between water holding capacity and $CaCO_3$ and all the vegetation groups.

Table 5. Life form spectrum and diversity indices of the five different vegetation groups discerned in the present study. N = number of species; P = percentage of each life form in each vegetation group; S.E. = standard error

Life form	Vegetational group									
	A		B		C		D		E	
	N	P%	N	P%	N	P%	N	P%	N	P%
Annuals										
Grasses	6	10.7	4	7.8	7	14.3	10	21.7	12	28.6
Herbs	2	3.6	9	17.7	13	26.6	13	28.3	16	38.1
Total	**8**	**14.3**	**13**	**25.5**	**20**	**40.9**	**23**	**50.0**	**28**	**66.7**
Biennials	**7**	**12.5**	**5**	**9.8**	**5**	**10.2**	**3**	**6.5**	**2**	**4.8**
Perennials										
Grasses	7	12.5	5	9.8	3	6.1	3	6.5	3	7.1
Herbs	12	21.4	6	11.8	2	4.1	2	4.3	0	0.0
Shrublets	8	14.3	9	17.6	7	14.3	4	8.7	4	9.5
Shrubs	10	17.9	11	21.6	6	12.2	6	13.0	2	4.8
Trees	4	7.1	2	3.9	5	10.2	5	11.0	3	7.1
Total	**41**	**73.2**	**33**	**64.7**	**23**	**46.9**	**20**	**43.5**	**12**	**28.5**
Parasites	0	0.0	0	0.0	1	2.0	0	0.0	0	0.0
Total species	56		51		49		46		42	
Species richness ± S.E.	8.1 ± 0.052		7.8 ± 0.027		9.1 ± 0.013		8.7 ± 0.015		6.4 ± 0.162	
Species turnover	6.9		6.7		5.4		5.3		6.5	
Shannon - W.	0.78		0.71		1.20		0.96		0.53	

Table 6. Simple linear correlation coefficients (r) between the importance value of the dominant species in the different vegetation groups and the variations in soil characters. The asterisk denotes a significant correlation (at the 5.0% probability level)

Soil factor		Correlation coefficients (r)				
		A	B	C	D	E
Sand	(%)	+ 0.17	+ 0.02	+ 0.23	+ 0.14	– 0.08
Silt + Clay	(%)	**+ 0.43***	**+ 0.58***	**+ 0.67***	**+ 0.76***	**+ 0.61***
Water holding capacity	(%)	– 0.13	– 0.07	– 0.16	– 0.09	– 0.05
Organic matter	(%)	+ 0.12	+ 0.05	+ 0.22	**+ 0.51***	**+ 0.57***
$CaCO_3$	(%)	– 0.06	– 0.20	– 0.01	**– 0.44***	– 0.18
Total soluble salts (meq/l)		– 0.09	+ 0.17	– 0.06	– 0.03	– 0.01
Elevation (m)		**+ 0.71***	**+ 0.63***	**+ 0.41***	**+ 0.65***	**+ 0.69***

Discussion

In Saudi Arabia, Zayed and Fayed (1987), Chaudhary *et al.* (1988) and Zayed and El-Karemy (1989) enumerated several plant communities of higher altitudes, many of which are comparable to those described in the present study. The vegetation dealt with along an altitudinal gradient in the study area is classified by cluster analysis into 5 groups named after the dominant species (species with highest importance values) as follows: *Acacia tortilis* subsp. *raddiana-Leptadenia pyrotechnica* (At-Lp), *Abutilon pannosum-Indigofera spinosa* (Ap-Is), *Ficus salicifolia* (Fs), *Acacia ehrenbergiana-Euphorbia cuneata* (Ae-Ec) and *Acacia asak* (Aas). Most of these species have repeatedly been recorded as abundant in phytosociological surveys in various habitats in Saudi Arabia and other adjacent Arab Gulf countries (Batanouny and Turki 1983 and Batanouny 1987), and variations in their abundance have also been related to topographic and/or edaphic variations. However, these groups are not absolutely discrete. The members of each pair of groups are, in various degrees, linked together by having one or more of the dominant species in common. This, however, does not preclude the fact that these vegetation groups are well-defined and represent sociological entities recognizable in the field.

Calculations of the Sorensen's similarity coefficients indicate smooth species composition changes throughout the 5 different vegetation groups along the elevation gradient. The species composition of the *Ficus salicifolia* vegetation type is more similar to those of *Acacia ehrenbergiana-Euphorbia cuneata* and *Acacia asak* vegetation types (zones) than those of the other zones. This may be attributed to the comparable soil characters of these communities. This study provides evidence that the vegetation shows discernible zonation. Table 2 gives some of the noticeable differences between the zones and also some of the interzonal similarities. As expected, certain species have wide ranges of amplitude and hence may be found in several zones, others have more circumscribed ranges and are limited in their distribution.

Plant growth within this mountainous area shows remarkable seasonal and annual fluctuations. The notable aspects of these fluctuations are primarily due to the growth of annuals and ephemerals, that are drought evaders. They usually appear in late winter and early spring in profuse number of individuals. High up the mountains the plant growth may indicate conditions less arid than those indicated lower down the slope (Kassas and Zahran 1965). This may explain the increase of annuals along the elevation gradient, and in the different vegetation types recognized. The dominant perennials in this transect are the shrubs and shrublets as well as herbs (drought enduring), comprising more than 50% of the total perennials recorded in each zone. It may also be noted that both annuals and perennial species are more abundant on north-facing than on south-facing slopes. This may be due to the more favourable moisture balance and the higher content of silt and clay in the soil.

The cliffs, slopes and crevices of the metamorphic volcanic rocks met within the present study provide special habitat conditions in which chasmophytes may grow. These species are probably isolated individuals that do not form communities in the sociological sense. They often grow in, and may be confined to, places inaccessible to grazing animals *e.g. Acacia hamulosa, Capparis spinosa, Ephedra alte, Farsetia longisiliqua* and *Fagonia arabica.*

The high species richness and evenness of the vegetation type dominated by *Ficus salicifolia* could be related to the heterogeneity of its substrate, as it covers most of the environmental gradient from the mesophytic (open scrub), marginal communities (ecotones), natural depressions and rock crevices. This supports the view that increasing habitat heterogeneity increases species diversity (Ricklefs 1977 and Nilsson *et al.* 1991). Mellinger and McNaughton (1975) concluded that a higher level of species diversity would be brought about by a local differentiation in soil around individual plants, since heterogeneity of environments allow satisfaction of the varied requirements of many species with a community (Whittaker and Levin 1977). The *Acacia asak* community type has a distribution similar to those aforementioned types, however it attains a low species diversity. This could be due to the dense canopy of the tall growing species (*e.g. Acacia asak* and *Acacia gerrardii*) that makes germination and growth of other species more difficult (van Strien *et al.* 1991). In general, plant hight is an important factor in the competitive ability and hence the structure of vegetation (Nilsson *et al.* 1991). The higher species turnover values of *Acacia tortilis* subsp. *raddiana-Leptadenia pyrotechnica* and *Abutilon pannosum-Indigofera spinosa* vegetation types can be interpreted in terms of biotic changes and species replacement along environmental gradient (Whittaker 1972, Wilson and Shmida 1984), which are clear in the communities mentioned above. The lower species replacement of *Acacia ehrenbergiana-Euphorbia cuneata* may indicate that the floristic composition of this vegetation type is highly specific, and thus having a recurring habit from one stand to the next. This agrees with the results from related studies in Saudi Arabia (Shaltout and El-Halawany 1993).

In the present study, the relative stages of community stability for the different vegetational groups has been discussed on the assumption that community stability and high diversity are positively correlated (Pielou 1975). It is also based on the assumption that the diversity of an abstract community should be expressed as an average of the diversity measures for the different concrete units of the particular community, and consequently the lower the standard error of the diversity measure, the greater is the homogeneity of the community. The vegetation group of *Ficus salicifolia,* showing both high diversity and greater homogeneity may be considered, therefore, as the most stable community in the study area, that it represents the climatic climax stage of the region. Despite the relatively high diversity and homogeneity of the vegetation group dominated by *Acacia ehrenbergiana Euphorbia cuneata,* it has a relatively narrower distribution range.

The results obtained from the correlation analyses show that most vegetational variation is related to altitude. The altitudinal variation of the occurrence of the dominant species (see Tables 2 and 6) supports this conclusion. Thus, altitude is of great importance not only in the characterization of the five different communities (vegetation types), but also in the differentiation within individual communities. The altitudinal control of vegetation is due to interactions of several factors. At the highest altitudes, in this study, the air is about 10 °C cooler than it is at the lowest one, with greater diurnal and seasonal temperature fluctuations, more frequent mist, fog and cloud, and less evaporation. Soil that is rich in organic matter at lower altitudes counteracts with poorer soil at high altitudes. Thus, micro-climatically and edaphically, the higher altitudes represent less arid (more humid) habitats. The occurrence of *Argemone mexicana* (exotic species), *Onopordon ambiguum, Commelina forsskalei, Psiadia arabica, Verbesina enclioides* as well as some ferns (*e.g. Cheilanthes vellea* and *Ceterach officinarum*) mostly characteristic of less arid habitats, is further evidence of this.

The degree of human interference seems also to play a prominent role in forming the characters of vegetation. Human factors contribute to the disruption of the natural equilibrium among the components of the ecosystem, thus causing its deterioration (Batanouny 1976, 1979). Among the changes in the vegetation induced by human activities (disturbances) which lead to the retrogressive changes (Kassas 1970) in the study area, the following can be mentioned: (1) continued destruction of grass-cover due to uncontrolled grazing increases soil erosion and soil impoverishment, changes the soil's mechanical composition and water relations, and favours colonization by weeds especially in the middle elevations (Hajar 1993); (2) construction activities, especially digging and widening the roads, result in the removal of vegetation from vast areas and enhance erosion; and (3) severe cutting of trees and shrubs of *Acacia ehrenbergiana* either for fuel (charcoal production) or by over-grazing favours invasion of the habitat supporting this vegetation type by *Abutilon pannosum* and *Calotropis procera.* This may cause this plant, on the long-run to be endangered. The modification of species composition of the natural vegetation in the study area by continued human interference is inevitable and affects its diversity and potentiality.

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تحليل الغطاء النباتي وتباين الأنواع مع تدرج الارتفاع على المرتفعات الوسطى لجبال الحجاز بالمملكة العربية السعودية

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يتعلق هذا البحث بدراسة البيئة ، وتوزيع الغطاء النباتي وتنوعه مع التدرج في الارتفاع عن مستوى سطح البحر ، على طول امتداد قطاع يمثل الطريق بين مكة المكرمة ومنطقة الهدا عبر الجزء الأوسط من جبال الحجاز في الجزء الغربي من المملكة العربية السعودية ، ويبلغ طول القطاع الذي يقع داخل سلسلة جبال الحجاز حوالي ٤٠ كم وبارتفاع يتراوح بين ٣٠٠-١٥٠٠م فوق سطح البحر . تم اختيار ٥٠ موقعاً للدراسة ، أختيرت على أساس تتبع التغير في حالة الغطاء النباتي . وقد أمكن بتطبيق احدى طرق التحليل الاحصائي (Agglomerative cluster analysis) فصل خمس مجموعات خضرية رئيسية تسودها الأنواع النباتية ذات القيم العليا لمعامل الأهمية . وتمثل هذه المجاميع ، في الوقت نفسه ، العشائر النباتية الخمسة السائدة في منطقة البحث .

وقد توصلت هذه الدراسة إلى ما يلي :

١- ان زيادة أعداد النباتات الحولية وقلة أعداد ثنائيات الحول والمعمرة في المجاميع الخضرية له صلة وثيقة بالارتفاع ، كما أن عامل التدرج في الإرتفاع

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يرتبط ارتباطاً موجباً مع توزيع الأنواع النباتية السائدة في المجموعات الخضرية الخمس .

٢- ان المجموعة الخضرية التي يسودها نبات الأثب (*Ficus salicifolia*) هي أكثر المجاميع تنوعاً ونباتاً وأفضلها تجانساً ، ولهذا فهي تمثل الغطاء النباتي المناخي الذروي لمنطقة الدراسة .

٣- ان تدخل العامل البشري في تغيير البيئات الطبيعية للنباتات يفسد الاتزان بين مكونات النظام البيئي ، وبالتالي فقد سجلت بعض التغيرات الملحوظة الطارئة على الغطاء النباتي الطبيعي في منطقة الدراسة ، والتي يمكن أن تؤدي على المدى البعيد ، إلى اختفاء وربما انقراض بعض الأنواع النباتية الهامة .