

Original Research Article

Risk assessment mapping of *Acacia tortilis* subspecies *raddiana* growing in South Sinai, Egypt, using integrated field survey, remote sensing and GIS

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ABSTRACT

Keywords

Acacia;
Anthropogenic threats;
conservation;
Wadi Feiran;
GIS;
Remote sensing.

The main objective of the present study is to assess the ecological risk at *Acacia tortilis* sup. *raddiana* populations in Wadi Feiran hydrographic basin in South Sinai. To achieve such aim, multiple data sets were collected, analyzed and integrated by means of Geographical Information System (GIS). The datasets used in the analyses included environmental factors of both human and geological factors derived from satellite images and field observations. Fifty-seven sites were selected in thirteen localities representing the geographic distribution of *A. tortilis* in the study area. SRTM-DEM was used for the detection of both drainage gradient (slope) and parameters of fracture density and intersection. According to the integration process of the different parameters through GIS, the populations at high risk lies within the central part of the study area with two distinctive clusters, the first one is assigned to Wadi Akhbar and W. Sebah and the second include W. Qusier, W. El-Tar, and W. Surief. The study recommended to manage the different human activities at high risk areas, and to propagate *Acacia* trees *in situ* to overcome the present decline in populations' sizes.

Introduction

Acacia is a large genus with about 1350 woody species (Maslin *et al.*, 2003). Most are shrubs or small trees of dry savannas and arid regions of Australia, Africa, India, and the Americas. There are about twenty five species of *Acacia* growing in dry areas of the Middle East - ten occur in Egypt - of which *Acacia tortilis* is the most widespread, drought-resistant, and heat-tolerant (Halevy and Orshan, 1972; Zohary, 1973; and Boulos, 1999). Four subspecies of *Acacia tortilis* are recognized in the

arid and semi-arid lands of Africa and the Near East (Wickens *et al.*, 1995). Two of the four *A. tortilis* subspecies are found in Egypt; *A. tortilis* subspecies *tortilis* extends south to Somalia and east to Arabia, and *A. tortilis* subspecies *raddiana* extends south to Sudan, Senegal, Somalia, and Kenya, and north and east to Israel, Jordan, and Saudi Arabia. Both subspecies are known from the Sinai but *raddiana* is the only subspecies in the study area, Halevy and Orshan (1972).

In South Sinai, despite its importance to human welfare, economy, and ecosystem as a multipurpose tree, *A. tortilis* subspecies *raddiana* became threatened due to aridity conditions and unmanaged human activities including over-grazing, over-cutting, over-collecting, and habitat destruction, in addition to seed predation by *bruchid* beetle, which increases the mortality of mature trees and reduces natural recruitment, Rohner and Ward (1999; Moustafa *et al.*, 2000). Previous results on age structure showed that populations of *Acacia tortilis* subsp. *raddiana* trees growing in South Sinai are unhealthy and shrinking with sharp decline in the last 25-50 years (Zaghloul *et al.*, 2008). It has therefore been suggested that changes in the abundance of *A. tortilis* subspecies *raddiana* populations may have significant impacts on ecosystem functioning and biodiversity (Dean *et al.*, 1999).

In order to study the different effects of environmental factors, the number and size of *Acacia* populations and their vegetative parameters (e.g. cover) need to be accurately estimated. Remote sensing and GIS have been tested extensively as a means in such ecological investigations, providing the most realistic, cost-effective means of acquiring and analysis of the different types of data (Nagendra, 2001, Kerr and Ostrovsky, 2003). The new generation of high spatial resolution satellite sensors provides an opportunity for detailed and accurate measurements, reducing the need for expensive ground survey. So, the new era of image analysis and GIS software are helpful for the decision makers in the different environmental issues.

The main objective of the present study is to assess the ecological risk at *Acacia*

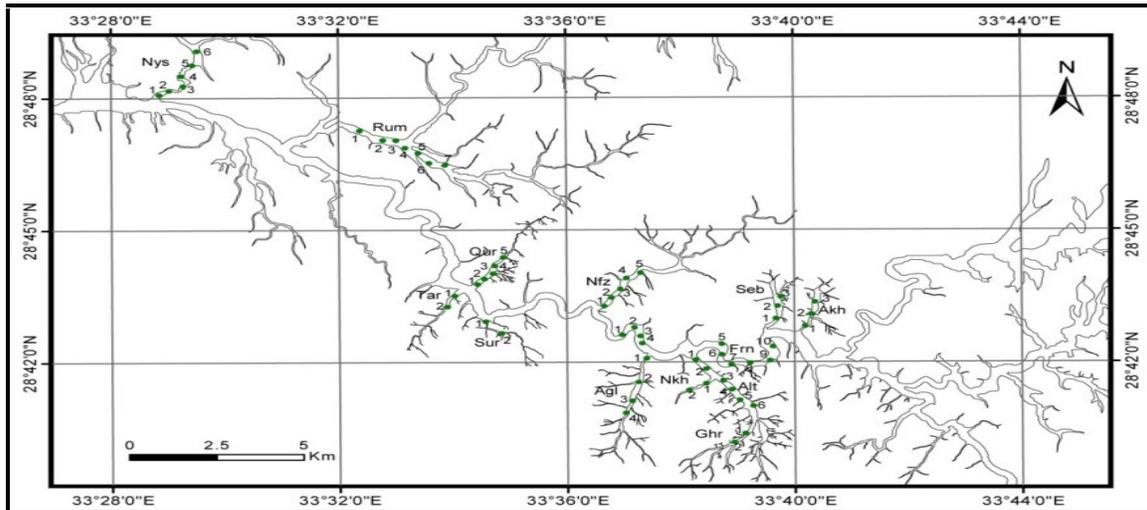
tortilis sup. *raddiana* populations in Wadi Feiran hydrographic basin in South Sinai through integrating collected and analyzed data by means of a Geographical Information System (GIS), to construct a risk assessment map for *A. tortilis* divided into suitability grades and to determine the conservation implications of the studied *A. tortilis* populations.

Study area

The present study is carried out in Wadi Feiran hydrographic basin which lies at the southwestern part of Sinai Peninsula. It is bounded by longitudes 33° 27' and 33° 46' E, and latitudes 28° 39' and 28° 50' N, (Figure1). The study area is traversed by many wadis, most of which are structurally controlled; where they are more or less concomitant with the observed fault lines. The major part of wadis strikes NNE–SSW to NE–SW. There are only three wadis that have NNW-SSE to NW–SE direction, represented by W. Feiran and W. Aliyat. The area under investigation is a conspicuous rugged terrain, especially at the northern and southern parts. Gabal Serbal; the highest peak (2097 m), followed in height by G. Sarabil (1719 m), G. Banat (1538 m), G. Abura (1298 m), G. Goza (1280 m), and G. Tar (1060 m) (Figure 1)

Wadi Feiran basin consists of igneous and metamorphic rocks, forming high patches. It is deeply dissected with numerous narrow and long wadis bounded by steep cliffs. The wadis act as water collectors, some of which have reasonable groundwater potentials (El-Rayes, 1992). These rocks are invaded by a few numbers of dykes. The granites, with the overlying thick volcanic sheets, form high mountains

Figure.1 Location map of the 57 sites at the 13 study localities, South Sinai.



Nys = Nysrine, **Rum** = Rummana, **Frn** = Feiran, **Qur** = Qusier, **Tar** = El-Tar, **Sur** = Surief, **Nfz** = Nefuz, **Agl** = Agala, **Alt** = Aliyat, **Nkl** = Nakhla, **Ghr** = Gohaier, **Seb** = Sebah, and **Akh** = Akhbar.

with extended flat-topped plateaus and steep slopes. The different rock units are highly affected by several faults and joints with different trends and densities (El-Shamy and El-Rayes, 1992). Such structures govern a widely distributed hydrographic system.

The hydrographic system of Wadi Feiran is the largest one of those systems draining westwards to the Gulf of Suez. The length of its total tributaries is about 512 km (Saad *et al.*, 1980). Feiran hydrographic system consists of a number of wadis dissecting the high lands and collects the surface runoff. Moreover, a number of such wadis with some of their tributaries are filled with alluvium deposits forming reasonable reservoirs for groundwater accumulation (Kassem, 1981). Wadi Feiran basin is covered by basement rocks. The basement rocks are represented by the prominent Feiran gneiss belt extending along the western side of South Sinai, quartz syenite of Gabal Banat, G. Goza, and the younger granite of G. Serbal and G. Sarabil. Feiran metamorphic belt,

which is a part of Feiran-Solaf metamorphic belt, extends NW-SE and forms a conspicuous rugged terrain that is intruded by different granitic bodies and invaded by dyke swarms of different compositions. Accordingly, the exposed basement rocks can be categorized chronologically into three major rock units, the metamorphic rocks, syntectonic granitoid, and the outcrops of the late- and post-tectonic.

The metamorphic rocks are composed of amphibolite, hornblende biotite gneisses, biotite gneisses, and quartzofeldspathic gneisses. Feiran metamorphic gneisses are bordered to the NE by synkinematic granitoids and to the SW by post-kinematic granites and Phanerozoic sedimentary cover. The main lithological units are quartzofeldspathic paragneiss and biotite-hornblende paragneiss with generally minor but locally abundant intercalations of amphibolite, calc-silicate gneiss and biotite schist (Fowler and Hassan, 2008).

The syntectonic granitoid rocks include grey granodiorite-tonalite-quartz diorite association that belongs to the grey granite of (Hume, 1934). Older granitoids of (El-Ramly and Akaad, 1960), syn-orogenic plutonites of (El-Shazly, 1964), syntectonic tonalite-granodiorite-adamellite group of (Sabet, 1972) and syn-orogenic granitoids of (El-Gaby, 1975). The granodiorite encompasses two types; white and gray granodiorite. The white granodiorite is medium to coarse-grained, where small outcrops are recorded through gneisses of Wadi Aliyat, W. Agala, and north of W. Nefuz.

The grey granodiorite is of pale pinkish grey color on fresh surfaces having coarse-grained, equigranular hypidiomorphic texture. This type of rock takes the form of an elongated tongue pluton covering the areas of Wadi Nefuz and W. Qusier, (Figure 1). The outcrops of the late- and post-tectonic are in contact with the gneisses and syntectonic granitoids in some places in the northern and southern parts of Feiran metamorphic belt. The late- and post- tectonic granitoids are of three phases; granodiorite, quartz syenite, and alkali granite.

Following the intrusion of tonalite-granodiorite batholiths and younger granites, faults formed including NE to NNE trending steep dextral faults (e.g. along Wadi Agala) and a NW-trending steep sinistral fault along Wadi Aleiyat. Cross-cutting the faults are late dykes especially a NE-trending swarm of thin basaltic and red felsite dykes and a massive porphyritic hornblende meladiorite dykes (Fowler and Hassan, 2008).

Climate

South Sinai is characterized by an arid to

extremely arid climate (Issar and Gild, 1982, Danin, 1986, Abd El-Wahab, 2003). The mean temperature of the hottest month ranges between 20 to 30 °C and 10 to 20°C in the coldest month. Precipitation occurs mostly in winter. The climate in south Sinai is affected by the Mediterranean and the impact of the high elevation of the mountains and the tropical effect of the Gulf of Suez and the Gulf of Aqaba. Rainfall in south Sinai is characterized by extreme variability in both time and space. The rainfall data revealed the occurrence of many periods of rainy years alternating with droughty ones, with a general trend toward more aridity (Abd El-Wahab, 2003).

Considerable precipitation occurs as a result of cyclonic cloudbursts which are very local in extent and irregular in occurrence. The rainfall gradient shows that the central and southwestern Sinai including the present study area are the areas of the lowest annual rainfall, which varies between 30 and 60 mm.

The main water bearing formations in south Sinai include both the basement complex occupying the southern Sinai, in particular, the highly fissured igneous rocks and the alluvial deposits occupying the alluvial plains which are parallel to the Gulf of Suez and the Gulf of Aqaba (Hammad, 1980). El-Ghawaby and Kassem (1982) concluded that the fractured granite and granodiorite of Wadi Feiran are the most important basement water-bearing zones. El-Rayes, (1992) classified the basement rocks of Saint Catherine area into three units; major aquifer, leaky aquitard, and local aquifer units. The depths to water table ranged from 4 to 8m in the basement rocks and up to 40 m in alluvial deposits.

Materials and Methods

Satellite imagery and field data collection

Two types of satellite images were used, the first one is a high resolution free Google imagery acquired in 2004 through the permitted free Google-Earth software (<http://earth.google.com/>) in the purpose of the detection and mapping of *A. tortilis* populations. The other type of satellite images is represented by SRTM –DEM of 90 m spatial resolution is used for the detection of geomorphic and fracture properties of both density and intersection. The topographic maps of the study area with scale of 1:50,000 (from Egyptian Military Survey, 1987) were used for the rectification process. The rectified images

were projected according to the Universal Transverse Mercator System (UTM) and geo-referenced to the Egyptian coordinates system (WGS 1984 UTM Zone 36N).

Fifty-seven sites (100m x 100m) distributed in thirteen localities representing the geographic distribution of *A. tortilis* subsp. *raddiana* in the study area were sampled (Figure 1). The population size in each site (number of trees) (Table 1) and basic information including geographic position, altitude, slope, grazing intensity, and soil characteristics were recorded.

All the collected data were introduced into GIS environment for further analysis and integration.

Table.1 The different localities, sites, and the number of observed trees in the study area.

ID	Localities	No. of sites	No. of trees	Slope (m/km)	Catchment area (Km ²)
1	Nysrine	6	26	5.48	35.25
2	Rummana	7	36	3.53	29.7
3	Feiran	10	38	5.01	27.31
4	Qusier	5	25	9.78	7.26
5	El-Tar	2	8	11.25	4.89
6	Surief	2	9	16.05	2.99
7	Nefuz	5	23	7.40	10.71
8	Agala	4	23	17.38	14.66
9	Aliyat	6	42	8.28	16.02
10	Nakhla	2	17	24.55	2.94
11	Gohaier	2	12	20.00	3.55
12	Sebah	3	18	5.80	5.92
13	Akhbar	3	11	3.17	5.75
		57	289		

GIS Analysis

In order to integrate and manage the large volume of different spatial features represented by maps, a geo-database of the different parameters controlling the distribution of *A. tortilis* populations in the study area was constructed. The distribution of the different parameters all over the study area was displayed as contour maps through GIS environment carried out by Arc GIS 10 software. All the collected data were implemented in a GIS environment to allow superposition and integration of the different thematic layers into potential classes' image. Figure 2 shows the methodology adopted for the present study.

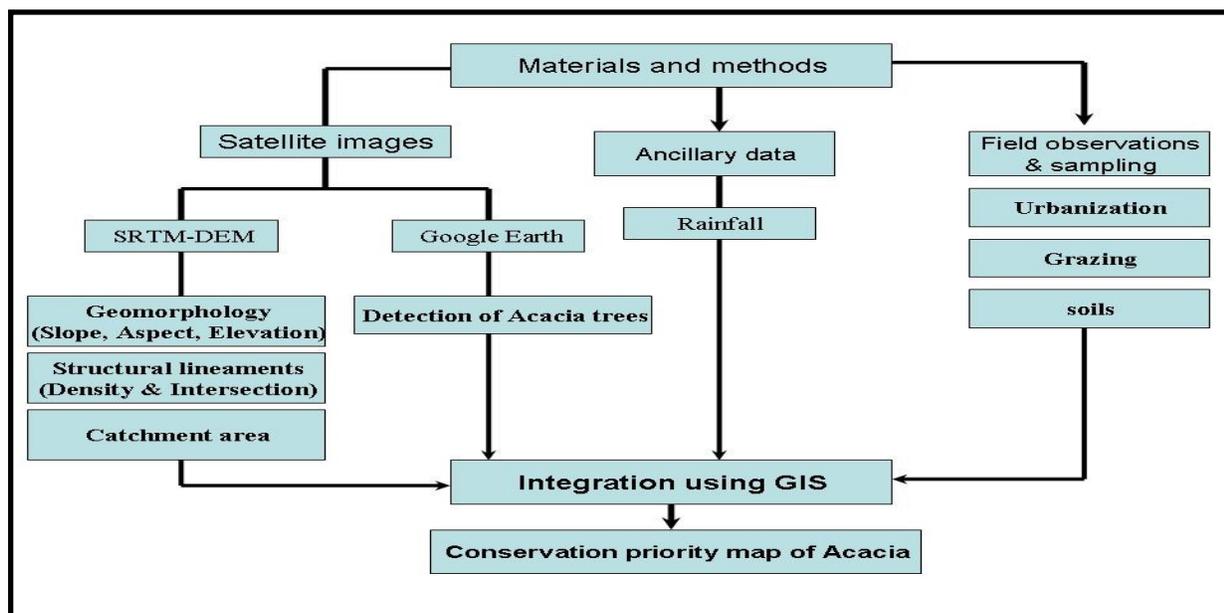
Before the integration process, different environmental factors and threats that affect distribution and abundance of *A. tortilis* in the studied area were determined. Subsequently, rating of the different parameters was carried out and

finally all factors were integrated and the final risk assessment map was produced.

Grazing intensity and Urbanization

The grazing intensity was recorded in each locality through subjective estimation based on human interface signs including cutting and browsing. Grazing was expressed as grazing intensity index ranging from 1 to 5 as follows: 1= no interface or grazing, 2= low, 3= medium, 4= high, and 5= severe impact (Moustafa, 2000, Abd El-Wahab, 2003). The basis of the grazing intensity index depends on the data collected from each locality including (1) number of grazing animals and their types (goats, sheep, donkeys, and camels), (2) percentage of browsed branches, (3) Number of visits by animals, and (4) Rate of cutting and uprooting (number of individual uproots and cut due to human activities). Grazing intensity of different localities is shown in figure 3A.

Figure.2 The different steps carried out through the present study.



To figure out the effect of urbanization on the distribution of *A. tortilis* populations, urbanization was estimated using number of indicator parameters including (1) number of dwellings (houses) at each nearby community, (2) average number of persons in each dwelling, and (3) distance between the study localities and the nearest Bedouin's community. The urbanization density of the different localities is shown in figure 3B.

The catchment area and drainage gradient (slope)

The catchment's areas of the study localities were outlined, measured, and classified according to (Yehia, 1973), (Figure 3C). Digital Elevation Model (SRTM-DEM) data of spatial resolution of 90m are used to calculate the slope in each of the cells of a raster map through a GIS environment. It represents the maximum

rate in elevation change over each cell and its eight neighboring cells. The slope map of the study area was created from DEM data using the Spatial Analyst of ArcMap; the output raster map was generated in percent of slope (Figure 3D).

Nature of soil surface

The nature of the soil surface was described subjectively according to the following scale of Hausenbuiller (1985) into five categories: fine earth (< 2mm), gravel (2-75 mm), cobbles (75-250 mm), stones (250-600 mm) and boulders (> 600 mm).

Faults and fractures (structural lineaments)

The expression of fractures is represented

as structural lineaments on satellite images. In the present study, shaded relief technique is applied on SRTM-DEM for the detection and extraction of such structural lineaments (Figure 4B). The structural factors that threat *A. tortilis* encompass both lineaments density and intersection counted in a definite cell dimension which are displayed as contour maps classified into four grades very low (0-2), low (2-6), moderate (6-10), and high (> 10).

Data integration and risk assessment map of *Acacia tortilis*

In the present study, the available environmental factors that are assumed to control the distribution and abundance of *Acacia tortilis* in the study area were measured. Each thematic map gives a clue for one factor of these factors that affecting distribution and abundance of *Acacia* trees in the study area. In order to obtain a final risk assessment map for *Acacia tortilis*, it is essential to integrate these layers in GIS model. Each item of evidence needs to be weighted according to its relative significance. This process is most commonly known as Multi Criteria Evaluation (MCE), (Voogd, 1983). In this model each thematic map has been given a weight value depending on its strength of contribution in distribution and abundance of *A. tortilis* (Table 2). The rank of each layer has been converted into layer weight by dividing each map rank by the total summations of the layers ranks. Similarly, the map classes were assigned different categories, which have been ranked in a numeric scale ranging from (1-5) where 5 is the most effective in threat to *A. tortilis* and 1 is the least. The rank of each class was divided by the total summation values of the layer classes to calculate the

Figure. 3 Distribution contour maps of (A) Grazing intensity, (B) Urbanization density, (C) Catchment area density, and (D) Slope percentage categories.

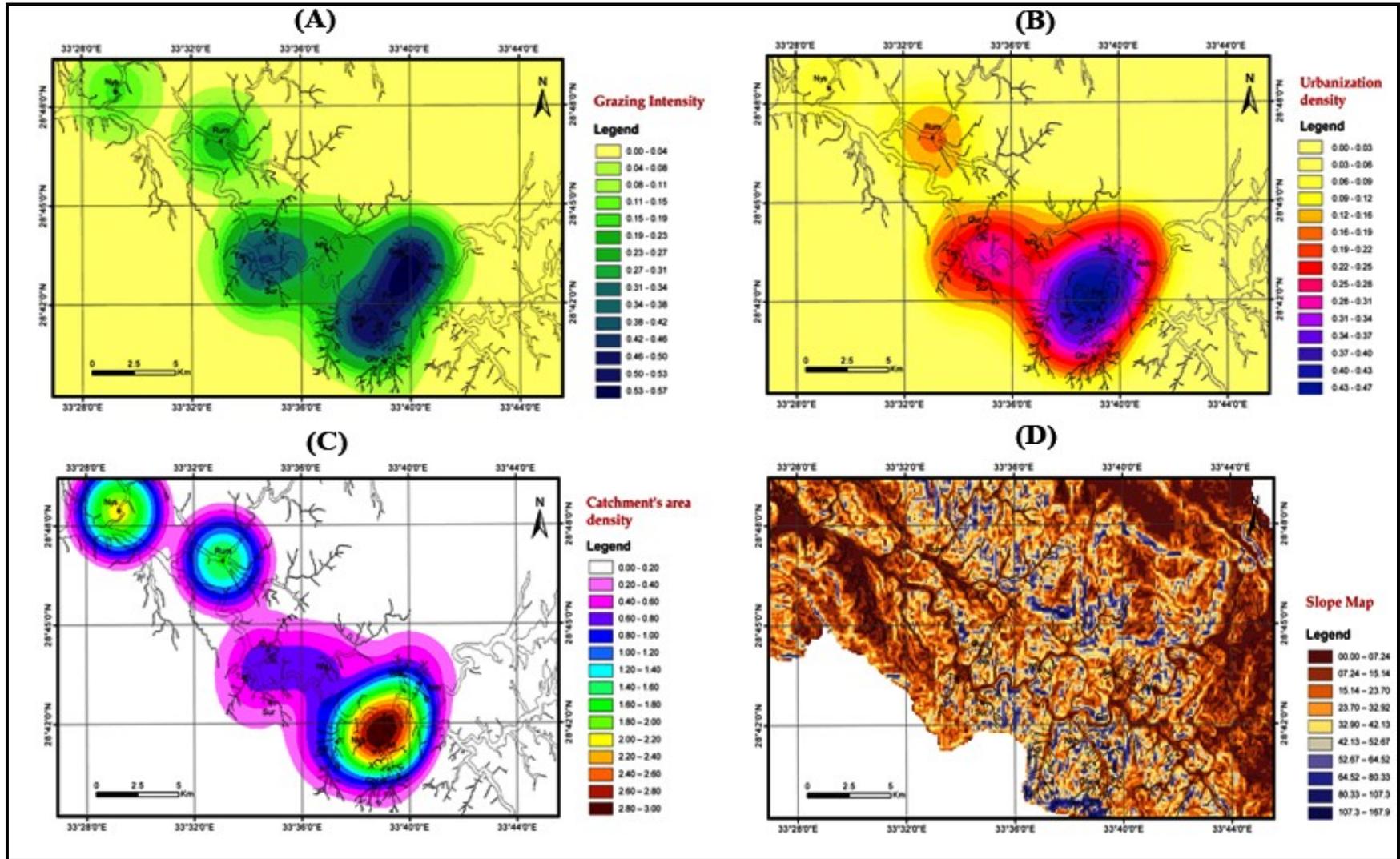


Figure.4 Distribution contour map of (A) Soil types, (B) the structural lineaments map derived from shaded relief of SRTM-DEM image (C) Structural lineaments density, and (D) Structural lineaments intersection.

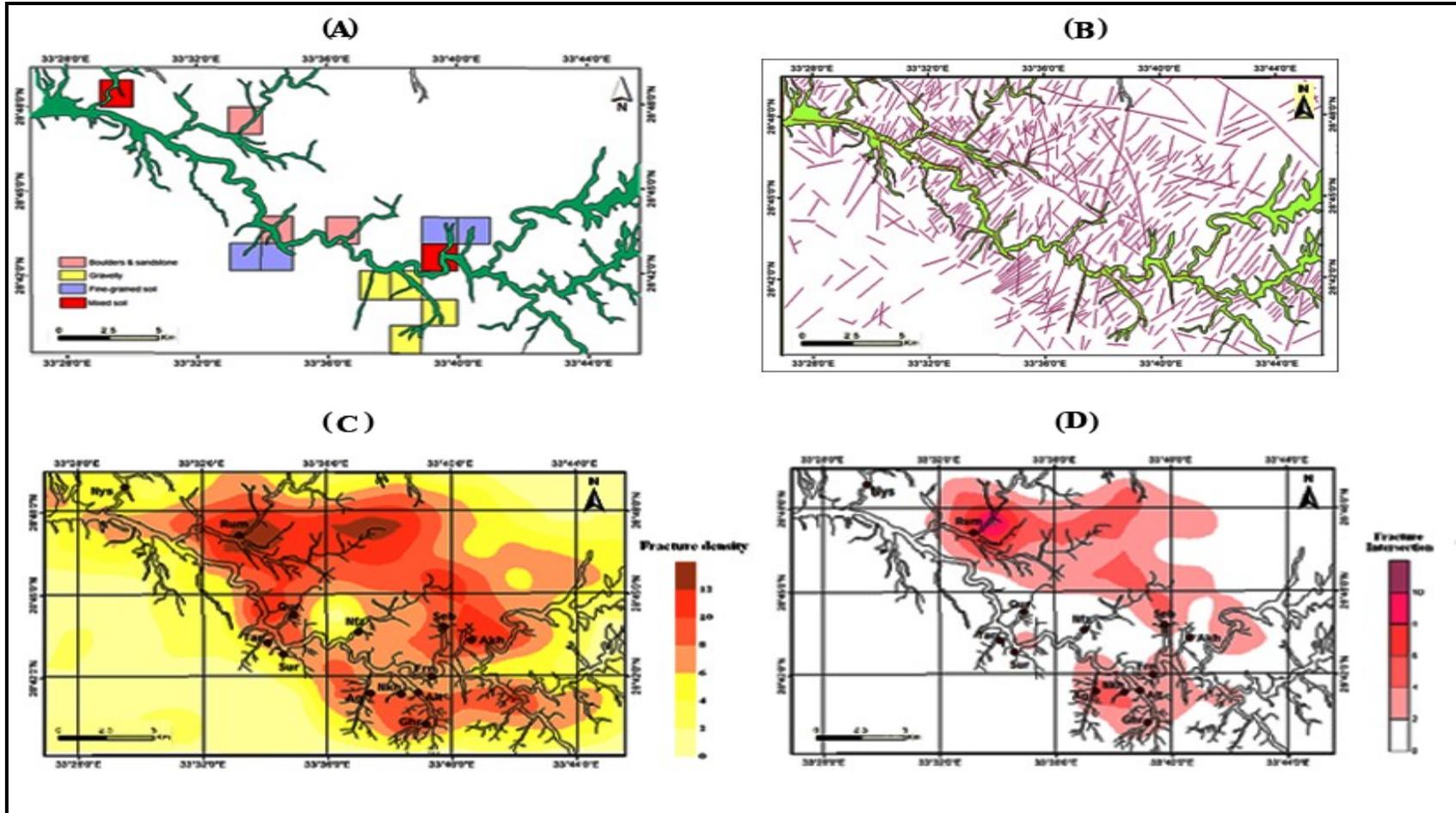


Table.2 Environmental factors controlling the distribution and abundance of *Acacia tortilis* and their weighting factors

Layer	Map rank	Map Weight	Class ranges	Degree	Rank	Capability value
Urbanization index	3	3/ 17 = 0.18	4-5	Very high	4	0.4
			3-4	High	3	0.3
			2-3	Moderate	2	0.2
			1-2	low	1	0.1
Grazing index	3	3/17 = 0.18	4-5	Very high	4	0.4
			3-4	High	3	0.3
			2-3	Moderate	2	0.2
			1-2	low	1	0.1
Lineament density	2	2/17= 0.12	0-2	Very high	5	0.33
			2-4	High	4	0.26
			4-6	Moderate	3	0.20
			6-8	Low	2	0.13
			≥ 8	Very low	1	0.06
Lineament intersection	2	2/17 = 0.12	0-2	Very high	5	0.33
			2-4	High	4	0.26
			4-6	Moderate	3	0.20
			6-8	Low	2	0.13
			≥ 8	Very low	1	0.06
Catchment area	3	3/17 = 0.18	≤ 1km	High	3	0.50
			1.1-2km	Moderate	2	0.33
			2.1-3km	Low	1	0.17
Soil types	2	2/17 = 0.12	Rock fragment	High	3	0.50
			Gravelly	Moderate	2	0.33
			Fine-grained	Low	1	0.17
Slope	2	2/17 = 0.18	Steep	High	3	0.50
			Moderate	Moderate	2	0.33
			gentle	low	1	0.17

capability values (CV) as shown in Table 2. These capability values (CV) were multiplied by the respective probability layer weight in each thematic layer to produce risk assessment map of *A. tortilis* (Figure 5).

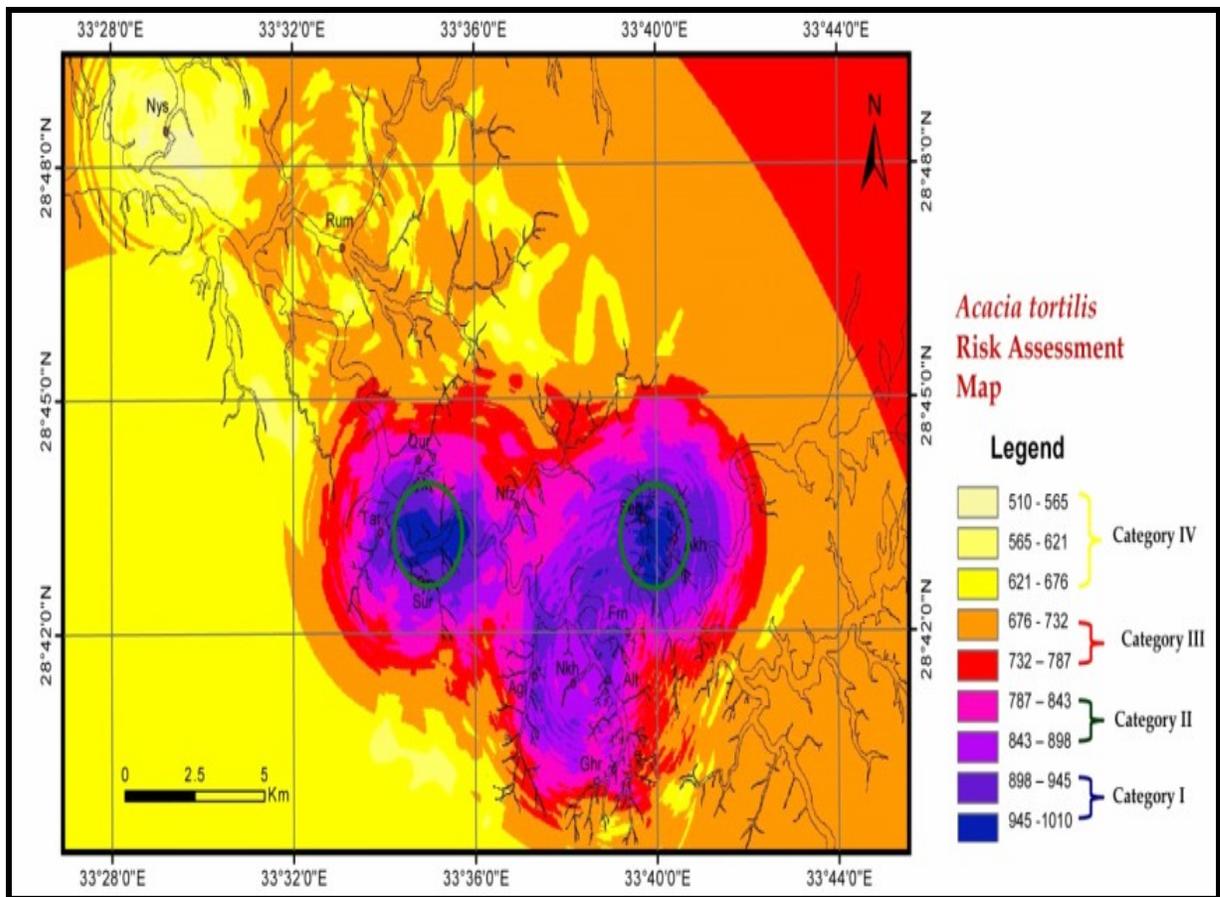
Result and Discussion

Grazing intensity and Urbanization

According to the distribution contour map of grazing intensity shown in figure 3A, it is clear that most of the study localities

show massive signs of human interference. Twelve localities (92.3%) have medium to high degree of grazing intensity including W. Nakhla, W. Rummana, W. El-Tar, W. Qusier, W. Agala, W. Gohaier, W. Surief, W. Akhbar, W. Sebah, W. Nefuz, W. Feiran, and W. Aliyat. On the other hand W. Nysrine and upstream of W. Gohaier shows low degree of grazing intensity due to its rugged and high elevation nature, the low number of herds, and long distance to the nearest Bedouin's community.

Figure.5 Risk assessment map of *Acacia tortilis* of Wadi Feiran hydrographic basin, South Sinai.



The urbanization, including construction new settlement, roads, tracks, and/or dams, has indirect effect on *Acacia tortilis* populations and their communities in the study area. The distribution contour map of urbanization elucidated that the major part of the study area has medium to high degree of urbanization density (Figure 3B) where there are five localities out of the thirteen studied localities (38.5%) have high degree of urbanization (W. Akhbar, W. Feiran, W. Nefuz, W. Aliyat, and W. Sebah) and other seven localities (53.3%) with medium degree of urbanization density including W. Gohaier, W. Rummana, W. Qusier, W. El-Tar, W. Surief, W. Nakhla, and W. Agala). On the other hand W. Nysrine is the only locality within the study area that has low urbanization density (Figure 3B).

The catchment area and drainage gradient (slope)

Acacia tortilis grows in desert wadis and sandy plains, usually in water catchment areas. According to (Yehia, 1973), the catchment's areas of the study localities could be classified as small basins (<50 km²). The highest catchment area was found at W. Nysrine (35.25 km²), W. Rummana (29.70 km²), W. Feiran (27.31 km²) and W. Aliyat (16.02 km²), while the lowest area was recorded at W. Surief (2.99 km²) (Table 1).

Both of W. Nysrine and W. El-Ager hydrographic major basins are characterized by gentle slope and high catchment area, while localities of W. Feiran downstream major basin showed variation in these two variables. Altitude and drainage gradient have negative significant correlation with catchment area ($r = - 0.627$ and $- 0.632$, respectively, $P < 0.05$), where the catchment area increased in localities with low altitude and low

drainage gradient or gentle slope and decreased at localities with high altitude and high drainage gradient or steep slope. The density contour map of the catchment area of the study area is shown in figure 3C.

Surface runoff is typically slow in areas of gentle slope, allowing more time for rain water percolation and promotes appreciable groundwater recharge required for *A. tortilis* populations. On the contrary, areas of steep slope promote fast surface runoff thus allowing less residence time for rain. South Sinai has a wide range of altitudinal gradient that decreases from the central part toward the east till Gulf of Aqaba, and west till the Gulf of Suez. The altitude directly affects the micro-climatic conditions, mainly temperature, and indirectly leads to greater probability of local accidental rainfall in the highlands than in the low lands.

Most of the localities in the study area correspond to steep terrains unsuited for sitting wells. Due to the great extension and varying topography of the study area, the drainage gradient showed a high significant variation between different localities ($P < .0001$). Four localities showed high degree of drainage gradient and described as steep slope (W. Nakhla, W. Gohaier, W. Agala, and W. Surief), whereas the remainder of wadis show medium to gentle slope tendency (Figure. 3D).

Soil conditions

Soil samples from studied different localities showed different soil types (Figure 4A). The nature of soil surface of W. Gohaier, W. Agala, W. Nakhla, and Wadi Aliyat have high percentage of rocky fragments (stones and boulders), that reach 68, 62, 54, and 46%

respectively). However, W. Qusier, W. Rummana, and W. Nefuz are characterized by gravely surface, (33 - 47%). On the other hand, W. Surief, W. Akhbar, W. Sebah, and W. El-Tar have higher values of fine soil on surface (36 -49%).

Faults and fractures (structural lineaments)

The field investigation revealed that the study area is dissected by different sets of fractures including faults and joints of variable attitudes, some of which are geomorphologically expressed by the major wadis such as Wadi Aliyat, W. Agala, W. Tar, W. Qusier, and W. Nefuz. Faults range in length and apparent displacement from small breaks in the outcrop scale to a large scale offset extending for several kilometers. It is observed that the distribution of *Acacia* trees is controlled by the attitudes of the major faults in many wadis in various localities of the study area.

According to the fracture density and intersection contour maps shown in figures 4C and 4D, the major part of the study is displaying very low to moderate grades, in particular, in the northeastern and southwestern parts. The higher grades of fracture density recorded in both W. Gohaier and W. Akhbar. The fracture density and intersection attain its maximum value (>10) at W. Rummana and its branching tributaries (Figure 4C and 4D).

Risk assessment map of *Acacia tortilis*

According to the resulted risk assessment map of *Acacia tortilis*, the study area could be classified into four categories; very high, high, moderate, and low risk

areas (Figure 5). Generally, most of areas classified under very high or high risk categories lie within the central parts of the study area, in particular, around W. Akhbar and W. Sebah. In these areas, the human interface levels are the highest and have the greatest effect on *A. tortilis* populations. This was reflected in sharp decline in the abundance and distribution of *Acacia* trees.

The localities encompassed under these categories are characterized by high density of urbanization and grazing intensity. Meanwhile, in these localities, the geological factors are rather somewhat favorable for *A. tortilis* growing. For example, soils are almost of fine-grained type which provides a suitable environment for growing *A. tortilis*. The catchment area is relatively large which could be used as indicator to the quantity of water received and stored. However, the structural lineaments are characterized by relatively high density but with low intersection tendency. Some high-risk localities of these categories harbor small-sized populations of *A. tortilis* (e.g. W. Surief and W. El-Tar).

Localities of low to moderate risk occupy the major part of the study area. These regions are characterized by more favorable geologic conditions. Nevertheless, the human impact on populations of *A. tortilis* due to urbanization and grazing is still effective. These areas are represented by W. Feiran, W. Aliyat, W. Nefuz, and W. Qusier. The localities away from high urbanization and grazing intensities have bigger populations of *A. tortilis* in both number and size. These areas are represented by W. Gohaier and W. Agala, W. Nakhla, W. Nysrine, and W. Rummana.

In Egypt, *Acacia tortilis* subspecies *raddiana* grows in desert wadis and sandy plains, usually in water catchments areas in the Sinai, Red Sea coast, Eastern Desert, and Gebel Elba (Boulos, 1999). In recent decades, drought and human interference including overgrazing, over-cutting, over-collecting, and habitat destruction have threatened this species by increasing the mortality of mature trees and reducing natural recruitment. Ward and Rohner (1997) estimated that up to 60% of the total mortality of *A. tortilis* in the Negev desert is caused by anthropogenic disturbances. As a multipurpose tree, *A. tortilis* has been cut and used as firewood, structural support, and charcoal. Branches are occasionally pruned, especially during the dry summer, for green fodder for goats and sheep.

Camels browse the lower branches of even relatively tall trees. (Darkoh, 1998) has shown that these effects are usually confined to densely populated settlement areas. As a result, it has undergone severe fragmentation and reduction in population number and sizes (Moustafa *et al.*, 2000; Zaghoul *et al.*, 2007). Such populations are prone to extinction due to stochastic demographic, environmental, and genetic factors as well as the deterministic processes which caused lowered numbers in the first place (Primack, 1998).

The present study is carried out in Wadi Feiran hydrographic basin; it is mainly a part of the rugged mountainous belt of South Sinai, and dissected with numerous wadis. In this area, *Acacia tortilis* populations were recorded between 353m a.s.l and 918m a.s.l. These results are in agreement with previous studies such as Ramadan (1988) and Salman (2004) who reported that the altitudinal range of *Acacia* trees ranges between 300m a.s.l and 900m a.s.l, and Batanouny and

Baeshin (1983) described *A. tortilis* communities at altitudinal range from 380m a.s.l to 820m a.s.l in wadis between Al-Masjed and Medina in Saudi Arabia. A wider altitudinal range (200m a.s.l to 1350m a.s.l) was outlined by Halevy and Orshan (1972) for *A. tortilis* populations growing near the Dead Sea in the Negev desert.

In present study, fifty-seven sites in thirteen localities were selected to cover the different factors affecting *Acacia tortilis* distribution and abundance whether human or geological factors. These parameters were prepared as potential GIS-layers. The different parameters were subsequently categorized into major factor groups. Through the integration of the different parameters according to their weighting factors in GIS environment, a risk assessment map for *A. tortilis* was created. The resulted risk assessment map confirmed the results of (Zaghoul *et al.*, 2007) that the human interface including over-cutting, over-collecting, removal of trees, and habitat destruction compose a severe stress on *A. tortilis* and threaten its populations in South Sinai. Population age structure data collected from the study area showed populations of *A. tortilis* populations growing in South Sinai are unhealthy shrinking populations (Zaghoul *et al.*, 2007).

The effect of grazing is among important factors in the desert habitats, ranking perhaps second to the water factor. Many studies showed that over-grazing has caused vegetation and soil deterioration (Moustafa, 2000). The present study showed a significant positive correlation between grazing intensity and urbanization ($r = 0.672$, $P < 0.01$), where grazing intensity increases in localities with increasing urbanization densities. Grazing intensity also has significant positive

correlation with the decline in *Acacia* trees density ($r = 0.589$, $P < 0.05$), and number ($r = 0.477$, $P < 0.05$). As a logic result, the correlation between grazing intensity and the change in number of grid cells occupied by *Acacia* trees was negative ($r = -0.060$, $P < 0.05$), which indicates that the change in grid cells number decreased in localities with high grazing intensity (Abd El-Hamid, 2009). Moustafa (2000) clarified that severe grazing is one of the main threats affecting the vegetation and changing its structure. Zaghoul *et al.*, (2007) mentioned that over-grazing may be responsible for reducing recruitment of *Acacia tortilis* to the point that it is difficult to find juveniles.

Urbanization has indirect effect on *A. tortilis* in many localities of the study area, it has significant positive correlation with the decline in *A. tortilis* number ($r = 0.725$, $P < 0.05$), and positive correlation with the change in density ($r = 0.466$), and number of grid cells occupied by *A. tortilis* trees ($r = 0.312$, $P < 0.05$), in which the change in *Acacia* trees number, density, and number of grid cells (negative change) increased in localities with high urbanization (Abd El-Hamid, 2009). Ward and Rohner (1997) investigated aquifer depletion and road building as the major anthropogenic sources of *Acacia* trees mortality in the Negev desert that prevent floodwater during winter storms from reaching the lower parts of the wadis.

The present study elucidated that altitude and drainage gradient have negative significant correlation with catchment area ($r = -0.627$ and -0.632 , respectively, $P < 0.05$), where the catchment area increased in localities with low altitude and low drainage gradient or gentle slope and decreased at localities with high altitude and high drainage gradient or steep slope.

Slope degree and catchment area are the main indicators of the magnitude of available water resources. Soil moisture availability which is a function of slope degree, nature of soil surface and soil texture is one of the most affecting factors in the distribution of plant communities in South Sinai (Moustafa and Zaghoul, 1993, Moustafa and Zayed, 1996). The frequency of *A. tortilis* within its natural range is distinctly affected by its relatively high demand for water and the indifference to soil type and lithology when growing in Wadi beds. It depends mostly on the size of the Wadi and its catchment area affecting the amount of water runoff (Halevy and Orshan, 1972).

Structural lineaments represent fracture zones that provide permeability required for the passage of either surface or ground water which is of vital importance for the conservation and growing of the *Acacia* trees. Since faults and associated fractures in the earth's crust are paths for the flow of both surface and underground water providing higher permeability, they have always been considered of great importance for the growing, distribution, and conservation of *A. tortilis* in the area under investigation. In general, the fracture zones in the present study area are presented as faults and joints. It is of vital importance to mention that the distribution of *A. tortilis* is more or less controlled by the general strike of the major fractures, in particular, in the main tributaries of wadis. This is clear in Wadi Nefuz, Surief, and W. Qusier, where the distribution of *A. tortilis* is linear with NE-SW direction (the same trend of wadis). On the contrary, the linear distribution of *A. tortilis* is trending NW-SE in Wadi Agala, Nakhla, and Aliyat (the same direction of the Wadi and associated fracture zones).

The field measurements of fractures constituting joints and faults indicated that

the main trend of joints is assigned to N20° - 30°W direction, followed by N70°-80°W, and N20°-30°E; the other directions are considered as minor trends. However, the fault planes measured in the field, shows that the most dominant fault trend is assigned mainly to N30°-40°E followed by N40°-50°E and N20°-30°E. The fracture planes appear on satellite images as linear features; structural lineaments. In the present study two parameters are selected of such lineaments to be of the controlling factors for *A. tortilis* distribution and abundance; lineaments density and lineaments intersection.

The major part of the deteriorated areas for *A. tortilis* is represented by moderate to high grades of lineament density and locates within very low to low lineaments intersection category. It is obvious that the more effective structural factor is the fracture intersection, where these areas are characterized by the parallelism of structural lineaments rather than intersection, which reduces the chance for the capturing and sufficient storage of either underground water or surface water.

Based on GIS analysis and integration of the different characteristic parameters controlling the distribution and abundance of *A. tortilis* in the study area, the output risk assessment map was constructed. The central part of the study area is the most deteriorated localities, in particular, Wadi Qusier, W. Tar, W. Surief, W. Akhbar and W. Sebah, although these areas are characterized by relatively favorable conditions for the growth of *A. tortilis* trees in the area (e.g. low elevation, low slope degree, moderate to high lineament density and relatively large catchment's area). They revealed a sharp decline in the abundance and distribution of *A. tortilis* populations. The decline was more pronounced among young trees. An

explanation for this decline related to the fact that these localities are characterized by high density of local communities (high degree of both urbanization and grazing intensity). Moreover, there is a high degree of accessibility where these areas are located at the downstream of wadis, or near the main road crossing the study area to St. Catherine town.

It is of worth mention that the capability of GIS to manage and integrate multiple data sets is helpful for the conservation planning of *A. tortilis* in the study area through detecting areas with high degree of deterioration and stress, identifying the main causes of deterioration of *A. tortilis* populations, and establishing a sustainable use strategy and effective conservation program.

Moustafa *et al.*, (2000) demonstrated a positive response to *in situ* conservation through temporary eliminating grazing by fencing selected populations in Wadi Mandar and W. Lithi. Temporary fencing helps in soil seed bank accumulation.

In a conclusion, this study suggests that the current unmanaged anthropogenic practices compose a drastically stress on *A. tortilis* subsp. *raddiana* populations growing in South Sinai. Remote sensing, GIS, and field survey were used as powerful tools for the collection, analysis, and integration of the different data sets that play an important role in planning for the conservation of *A. tortilis* populations. The resulted risk assessment map could be helpful for the establishing a sustainable use strategy and effective conservation program. This can be obtained through the following steps: The formulation of management strategy to manage different activities of local Bedouins.

In situ propagation of *A. tortilis* to overcome the high demand for its wood,

and keep the present populations of *A. tortilis* within safe limit out of extinction, Emphasizing the importance of the Environmental Impact Assessment (EIA) before construction of any projects (even developmental projects), construction of roads and dams, quarrying, and tourism, all these activities threatened the natural vegetation in the area in particularly *A. tortilis* populations.

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