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Spatial variation in long-term population change detection of *Acacia tortilis* subsp. *raddiana* in arid environment using RS and GIS

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ABSTRACT

Although Acacias are ecologically and culturally significant in arid environments, their mortality, recruitment and long-term change are poorly known. This study aims to quantify population change of the *Acacia tortilis* subsp. *raddiana* in South Sinai of Egypt in the period between 1968 and 2004. Remote sensing (RS) and geographic information systems (GIS) analyses of aerial photographs (1968) and high-resolution IKONOS images (2004) in combination with topographic maps (1987) and field data were used to estimate changes in abundance, density, and canopy area of *A. tortilis*. Changes were statistically significant and the overall trend in population size was negative. At some sites this negative trend is alarming because the reduction in mature trees was substantial (about 40-50%) and the recruitment was nearly absent. The continuity of this trend over time will endanger tree populations in the study area. Due to increasing the growth of Acacia trees, changes in canopy area of Acacia trees were positive in most of the study area. Absence of juveniles and clear reduction in small categories suggest that *A. tortilis* are suffering population decline. Aridity conditions may explain some of the observed pattern of mortality, however our results indicate that human disturbances, particularly over-cutting and over-grazing, are considered the main driving forces of these negative changes in South Sinai. Understanding trend of long-term changes, awareness and engagement of Bedouins are crucial to establish effective conservation and sustainable use strategy for *A. tortilis* in South Sinai.

Keywords: *Acacia tortilis*, population change, Remote sensing, GIS, Sinai.

INTRODUCTION

Despite the significance global focus on land degradation in arid environment (Thomas and Middleton, 1994; Millennium Ecosystem Assessment, 2005), the long-term consequences of vegetation change is poorly known (Chen, 2000; Andersen and Krzywinsk, 2007). Arid and hyper arid environments are characterized by sparsness of vegetation and paucity of trees (Abd El-Wahab, 1995). Acacia trees are a good indicator for long-term vegetation change detection due to their long age and drought enduring.

They play a major role as a key species in biodiversity and soil ecology of arid ecosystems by modifying solar radiation, soil moisture, and nutrients available to plants and animals (Milton and Dean, 1995; Greenberg *et al*., 1997). Most studies have concentrated on the distribution behavior of Acacia trees (Helmy *et al.*, 1996); however, very little studies have monitored changes in their population structure and demography (Zaghloul *et al*., 2008; Moustafa *et al*., 2015). Although Acacia trees are ecologically and economically important, high mortality combined with lack of recruitment in their populations have been reported from arid and hyper-arid regions (Kenneni, 1980; Andersen and Krzywinsk, 2007; Zaghloul *et al*., 2008).

Mortality of Acacia trees is mainly associated by charcoal production in eastern desert of Egypt (Andersen and Krzywinski, 2007), overgrazing and overcutting in Sinai, and aridity conditions and limited surface water availability in Sinai and Negev deserts (Shrestha *et al*., 2003; Abd El-Wahab *et al*., 2013). Recruitment of Acacia trees throughout arid lands seems to be an infrequent event (Midgley and Nond, 2001).

Acacia tortilis is recorded in several African countries (Ross, 1979). In Egypt, this species is recognized in Oases of the western deserts, Nile Valley, Eastern Deserts, Red Sea coastal area, Gebel Elba, and Sinai (Täckholm, 1974; Boulos, 1999). Change detection of A. tortilis populations requires frequent and spatially detailed assessments and monitoring. RS and GIS seem to be an ideal way to gather and analyze these crucial data. The new generation of fine spatial resolution satellite sensors provides an opportunity for detailed and accurate ecological studies, reducing the need for expensive ground survey (Kerr and Ostrovsky, 2003). In this study we aim to quantify long-term changes (1968-2004) in abundance, density and canopy area of A. tortilis populations in South Sinai using RS and GIS analyses.

MATERIALS AND METHODS

Site description

Wadi Feiran area, one of the important hydrographic basins of South Sinai, is bounded by longitudes 33º 30′ and 33º 44′ E, and latitudes 28º 38′ and 28º 48′ N (Fig.1). The term wadi refers to a dried river-bed and represents the main ecosystem in a desert area. Wadis may be transformed into a temporary water courses after heavy rain (Kassas and Imam, 1954). The study area is covered by basement rocks and traversed by several

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wadis most of which are concomitant with fault lines. These wadis include W. Agala, W. Sorief, W. Tar, W. Nefuz, and W. Qusier (Fig. 1). The fractured granite and granodiorite of W. Feiran are the most important basement water-bearing zones (El-Ghawaby and Kassem, 1982). South Sinai is characterized by an arid to extremely arid climate (Ayyad and Ghabour, 1985). Orographic precipitation falls on the summits, cliffs and gorges of the mountains then transports to the upstream tributaries of the wadi system (Kassas and Girgis, 1970). The annual rainfall varies between 30 and 60 mm, most of which falls during the winter and spring months. Rare and heavy showers cause floods, which contribute effective moisture for the vegetation in the main wadis. Relative humidity reaches 55% in winter and 48% in summer. Average temperature during summer reaches 34°C during the day time and 23°C during the night. In winter, it reaches 20°C during the day and 10°C during the night (Abd El-Wahab *et al*., 2006). In Wadi Feiran area, *A. tortilis* (Forssk.) Hayne subsp. *raddiana* (Savi) Brenan is mainly recorded within altitude range of 350-920 m above sea level (Helmy *et al*., 1996). The most frequent associated species with *Acacia* trees are *Artemisia judaica*, *Citrullus colocynthis*, *Fagonia mollis*, *Capparis spinosa*, *Aerva javanica*, and *Zilla spinosa*. Distribution of *Acacia* trees is more related to catchment area, physiographic features, and topographical irregularities, which all act through modifying the amount of soil moisture (El-Ghareeb and Shabana, 1990; Moustafa and Klopatek, 1995; Abd El-Ghani and Amer, 2003; Abd El-Wahab *et al*., 2013).

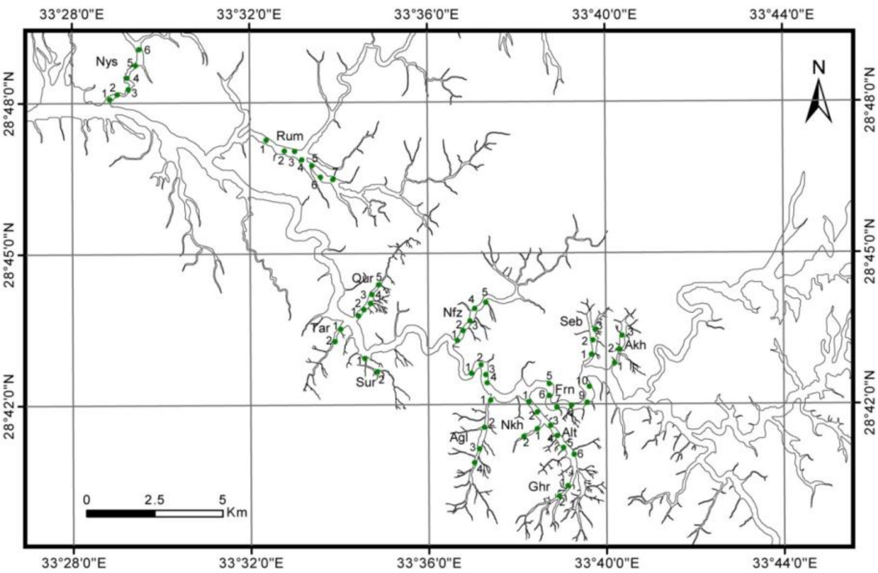


Figure (1): Location map of Wadi Feiran area showing 57 sites selected. Abbreviation letters refer to 13 study loclaities as follows: Nys = Nysrien, Rum = Rumana, Frn = Feiran, Qur = Qusier, Tar = El-Tar, Sur = Surief, Nfz = Nefuz, Agl = Agala, Alt = Alyat, Nkl = Nakhla, Ghr = Gohaier, Seb = Sebah, and Akb = Akhbar.

Field survey

Fifty-seven sites (100×100 m) were selected in thirteen localities representing the geographic distribution of *Acacia tortilis* in the study area. At each site, each individual of *A. tortilis* were labeled, described and mapped. Geographic position of each site was recorded using a handheld global positioning system (GPS, Magellan GPS 315, Magellan Corporation, USA). The GPS data were used for registration of ground control points (GCPs). Environmental variables, human impacts, and vegetation parameters were described and discussed in the previous literature (Abd El-Wahab *et al*., 2013).

Image acquisition and pre-processing

The data used in this study were: (1) aerial photographs taken on 16 August 1968 with a scale of 1: 20,000 and acquired from the archive of the Egyptian Military Survey, (2) high-resolution images (IKONOS) for the study area acquired on September 2004, (3) topographic maps for the study area with a scale of 1:50,000 and acquired from Egyptian Military Survey (1987), and (4) Field observations. The selected aerial photographs were scanned using L1945A *hp* scanner at a spatial resolution of 600 dpi. The resulting digital images were exported to ESRI ArcGIS 9.2 software for further processing. Permitted Google-Earth-Pro software was used for benefiting from the very high spatial resolution images of IKONOS in digitizing the canopy area of *Acacia* trees in the study localities (Gaber *et al*., 2009). The layers of *Acacia* trees canopy area were digitized and saved as KML files. These KML files were exported to ArcGIS software as shape-files using both KML 2.0.5, and XTools-Pro modules. The high resolution images were also used for surface feature mapping, and delineation of the main drainage courses at the study area. Digitized layers were saved as KML files and exported to ArcGIS software as shape-file for further analysis. Topographic data were obtained by the Shuttle Radar Topography Mission (SRTM), a joint project of NASA and the Department of Defense's National Imaging and Mapping Agency (NIMA). The data are available internationally at a 3-arc sec (w90 m) horizontal resolution and a 16 m vertical accuracy with a 90% confidence level (Gaber *et al*., 2009).

Geometric Correction

The intent of geometric correction of images is twofold: (1) to correct the image for any spatial distributions caused by earth surface or by sensor positioning, and (2) to provide the image with a spatial reference system using a coordinate system. These factors can be either systematic or random. A systematic factor can easily be modelled and thus corrected separately. One example is the error caused by the rotation of the earth, where de-skewing is the subsequent process of correction (Richards and Jia 2006). Random factors, for example those caused by instability in a platform, have to be corrected by analysing well distributed Ground Control Points (GCPs) in the image. The method of this correction overlaps with the practical part of correction in that both processes normally interpret GCPs in a well-known geographical framework. In practice a correction therefore puts the images into the same geographical framework as that of other data sources. Rectification is a regression process where GCPs are the link between images coordinates and coordinates of the selected framework. Residuals of the regression are reported as the Root Mean Square (RMS) error, interpreted as the distance between the input/correct position and the retransformed/actual output position. The distance is calculated in pixel size. In the present work, the scanned images were corrected geometrically for the images covering the study area. Geometric Correction is applied to raw images data to transform them to map projections. The rectified imagery was projected according to the Universal Transverse Mercator System (UTM), and geo-referenced to the Egyptian coordinates system (WGS 1984 UTM Zone 36N).

Detection and measurements of *Acacia* trees

In the images used for this study (1968 and 2004), *Acacia* trees appear as dark rounded to oval dots. The shadows of their canopies contribute to this appearance (Campbell, 2002). The size of the shadow on the image is given not only by the size of the canopy and its height above the ground but also by the sun-camera geometry (Strahler and Jupp, 1990). The brightness of the image structure is related to the density of the canopy (number of branches and leaves). The brightness of the background is influenced by the type of soil material and its texture. A successful recognition of trees requires good contrast between canopy and background. The spatial resolution of the total photographic system is influenced by several factors external to the system itself (*e.g*. camera vibrations) that cause the spatial resolution of the images to vary, *i.e.* that the spatial resolution becomes dynamic (Andersen, 2006). A visual image interpretation was adopted in this study for tree detection. Each tree-like structure was digitized manually and represented by a polygon. These polygons are referred to as 'interpreted trees'. The end product of this stage of analysis was vector maps delineate the spatial distribution of individual *Acacia* trees in (1968) and (2004) images within each study locality. These maps were used to calculate changes in abundance, density, and canopy area of *Acacia* trees in each locality. Tree density was calculated as number of *Acacia* trees per a grid cell of 100 × 100 m that provides a low fraction of empty cells in comparison to smaller cell sizes, and lower edge effects relatively to larger cell sizes.

Data Treatment

In order to integrate and manage the results of the large volume of different spatial features of the study area and vegetation parameters of *A. tortilis*, a geo-database for *Acacia* populations in the study area was structured. The distribution of the different parameters and associated changes between 1968 and 2004 are displayed and analysed using ESRI® ArcGIS 9.3 software. Statistical analyses of the abundance, density, canopy area of *Acacia* trees in 1968 and 2004 were carried out using SPSS software (Statistical Package for Social Sciences version 11.5).

Descriptive statistics are used to describe the average value and standard deviation (*SD*) of abundance, density, canopy area of *Acacia* trees, and change percentage of each of these variables between 1968 and 2004 at each locality and for the study area in general. One-way ANOVA and Duncan multiple range test were applied for different variables to assess for significant differences between different localities. Paired sample *t*-test was used to assess for significant differences in abundance, density, and canopy area of *Acacia* trees between 1968 and 2004. Relationships between change percentage in abundance, density and canopy area of *Acacia* trees at different localities were conducted using Pearson correlations (*r*). The data of canopy area were used to build frequency distribution of *Acacia* population size structure at each locality.

RESULTS

Change in *A. tortilis* abundance

A total of 3378 *Acacia* trees were identified in the study area in 1968. In 2004, the number of trees decreased to 2149 trees (Table 1). In 1968, W. Feiran showed the highest number of identified *Acacia* trees (884 trees), followed by W. Alyat (578 trees) and W. Rumana (431 trees). In the meantime W. Surief and W. El-Tar showed the lowest number of identified *Acacia* trees (38 and 20 trees, respectively). In 2004, the highest number of *Acacia* trees was recorded at W. Feiran (582 trees), followed by W. Alyat (330 trees), and W. Rumana (313 trees), and the lowest value was recorded at W. El-Tar (13 trees). The average abundance of *Acacia* trees was 259.9 (SD = 243.1) in 1968, and 165.3 (SD = 158.20) in 2004. The loss in abundance of *Acacia* trees between 1968 and 2004 ranged from 27.4% in W. Rumana to 56.6% in Wadi Akhbar (Fig. 2), with an average of 36.8 (SD = 8.29). The results of paired sample t test showed highly significant differences in abundance of *Acacia* trees between 1968 and 2004 ($t = 3.85$, $p < 0.002$) (Table 1).

Table 1 Changes in *A. tortilis* abundance (total number of trees), density (average number of trees per hectare ± *SD*, standard deviation) and canopy area (average value of tree canopy area ± *SD*) between 1968 and 2004 at different localities and for the study area as a whole.

Locality	Abundance			Density (tree ha^{-1})			Canopy area (m^2)		
	1968	2004	Loss %	1968	2004	Loss %	1968	2004	Change %
Nysrien	171	124	27.5	$2.3\pm1.3^{ab*}$	1.8 ± 1.0^{a}	23.3	37.9 ± 23.7^{b}	42.0 ± 25.8^{ab}	10.6
Rumana	431	313	27.4	2.9 ± 1.7^{ab}	2.1 ± 1.2^{a}	28.3	33.4 ± 21.7^{ab}	48.7 ± 27.6^{abc}	45.7
Feiran	884	582	34.2	2.4 ± 1.9^{ab}	1.7 ± 1.1^{a}	30.6	61.2 ± 50.3^{d}	82.6 ± 59.4^{d}	34.9
Qusier	178	127	28.7	2.7 ± 1.8^{ab}	2.1 ± 1.1^{a}	29.8	31.4 ± 16.7^{ab}	40.2 ± 21.8^{ab}	27.9
El-Tar	20	13	35.0	2.0 ± 1.3^{a}	1.6 ± 0.7^{a}	7.2	50.7 ± 30.0^{c}	60.7 ± 30.9^{c}	19.7
Surief	38	23	39.5	2.7 ± 1.7^{ab}	1.9 ± 0.7^{a}	29.4	32.2 ± 23.7^{ab}	46.1 ± 26.4^{abc}	3.1
Nefuz	180	112	37.8	3.0 ± 1.8^{ab}	2.1 ± 1.2^{a}	30.9	36.0 ± 23.4^{ab}	37.7 ± 23.7^{ab}	5.0
Agala	266	159	40.2	4.4 ± 3.3^{cd}	2.9 ± 2.0^{bc}	33.6	52.2 ± 27.3^{cd}	36.8 ± 29.4^{ab}	-29.6
Alyat	578	330	42.9	5.6 ± 3.6^{e}	3.3 ± 2.2^{c}	41.2	47.6 ± 26.6^{c}	60.5 ± 38.3^{c}	27.1
Nakhla	123	89	27.6	5.4 ± 3.3^{de}	4.2 ± 2.1^{d}	20.8	51.3 ± 33.8^{c}	52.7 ± 27.7^{bc}	2.7
Gohaier	96	60	37.5	3.4 ± 2.2^{bc}	2.9 ± 1.9^{bc}	16.7	71.2 ± 40.7^{e}	82.5 ± 46.7^{d}	15.8
Sebah	277	158	43.0	3.4 ± 2.2^{bc}	2.4 ± 1.4^{ab}	31.1	25.4 ± 17.1^{a}	34.9 ± 23.6^{a}	37.7
Akhbar	136	59	56.6	3.1 ± 2.1^{ab}	1.7 ± 0.9^{a}	43.9	31.0 ± 23.0^{ab}	32.8 ± 18.9^{a}	6.0
Study Area	259.9±243.1	165.3±158.2	36.8±8.3	3.4±1.1	2.4±0.8	28.2±9.7	43.2±13.7	50.6±16.8	15.9±19.7

*Similar letters for each variable indicate no significance differences based on Duncan multiple range test.

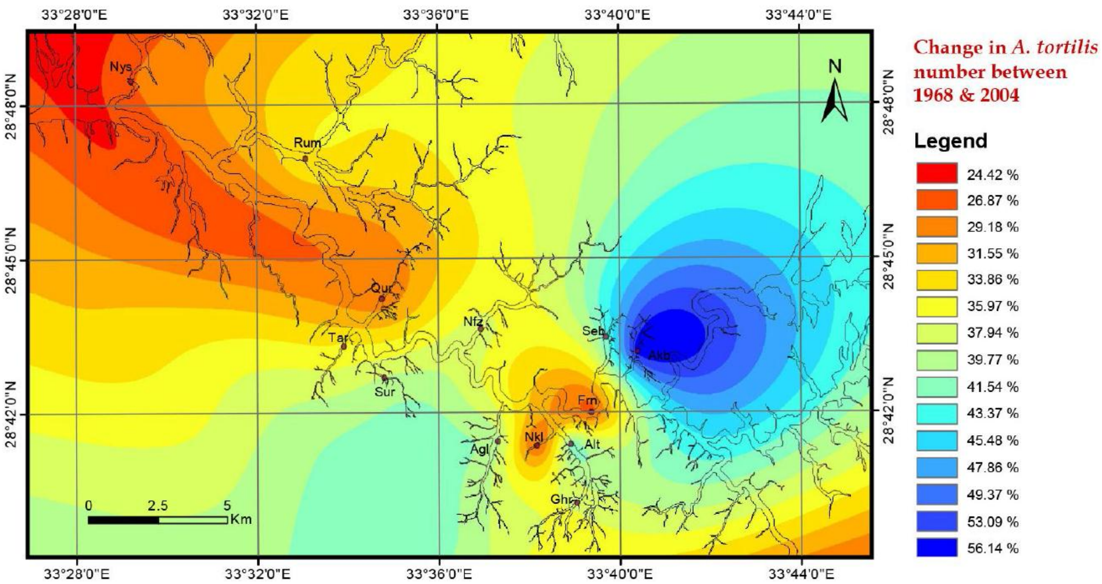


Figure (2): Change in *Acacia tortilis* abundance between 1968 and 2004 represented as loss percentage at different study localities. Nys = Nysrien, Rum = Rumana, Frn = Feiran, Qur = Qusier, Tar = El-Tar, Sur = Surief, Nfz = Nefuz, Agl = Agala, Alt = Alyat, Nkl = Nakhla, Ghr = Gohaier, Seb = Sebah, and Akb = Akhbar.

Change in *A. tortilis* Density

The average density of *Acacia* trees in the study area was 3.4 tree ha^{-1} in 1968 and 2.4 tree ha^{-1} in 2004, which means loss in density by 28.2%. In 1968, density of *Acacia* trees ranged from 2.3 tree ha^{-1} in W. Nysrien to 5.6 tree ha^{-1} in Wadi Alyat, with an average density of 3.4 tree ha^{-1} (SD = 1.1). In 2004, density of *Acacia* trees ranged from 1.7 tree ha^{-1} in W. Feiran to 4.2 tree ha^{-1} in W. Nakhla, with an average density of 2.4 tree ha^{-1} (SD = 0.8). Results of One-way ANOVA showed that differences in density of *Acacia* trees between different localities in 1968 and 2004 were highly significant (Table 1). The results of paired sample t test showed highly significant differences in *Acacia* trees density between 1968 and 2004 ($t = 6.706$, $P < 0.0001$) (Table 1). Wadi Akhbar showed the highest percentage of negative change in density of *Acacia* trees (43.9%), followed by W. Alyat (41.2%) and W. Agala (33.6%), on the other hand W. El-Tar showed the lowest percentage of change (7.2%), followed by W. Gohaier (16.7%) (Fig. 3). The average loss in density of *Acacia* trees between 1968 and 2004 was 28.2% (*SD* = 9.68). The loss in abundance was significantly positively correlated with the loss in density of *Acacia* trees (r = 0.58, p = 0.001).

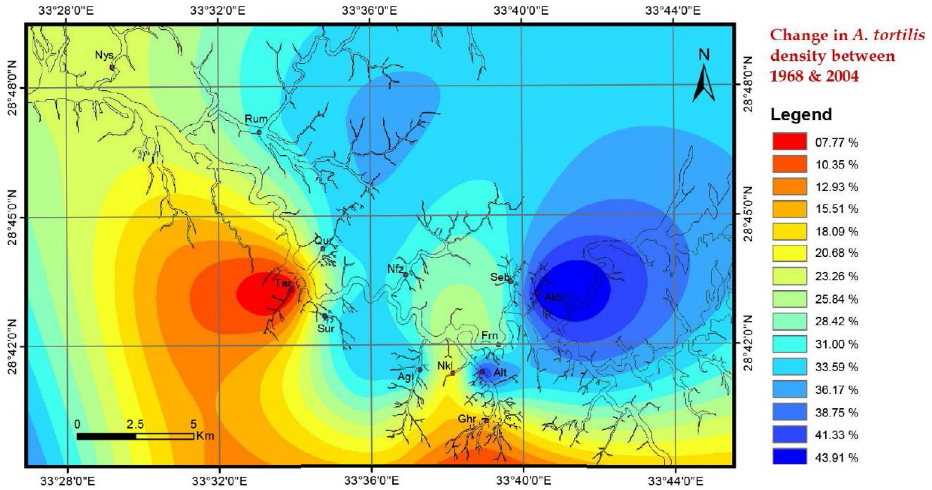


Figure (3): Change in *Acacia tortilis* density between 1968 and 2004 represented as loss percentage at different study localities. Nys = Nysrien, Rum = Rumana, Frn = Feiran, Qur = Qusier, Tar = El-Tar, Sur = Surief, Nfz = Nefuz, Agl = Agala, Alt = Alyat, Nkl = Nakhla, Ghr = Gohaier, Seb = Sebah, and Akb = Akhbar.

Change in *A. tortilis* canopy area

In spite of the intense decline in *Acacia* trees abundance and density, positive changes were recorded in canopy area of *Acacia* trees (about 18.7%) in the period between 1968 and 2004. In 1968, canopy area of *Acacia* trees ranged from 25.4 m^2 to 71.2 m^2, with an average canopy area of 43.2 m^2 (*SD* = 13.7). In 2004, canopy area ranged from 32.8 m^2 to 82.6 m^2, with an average canopy area of 50.6 m^2 (*SD* = 16.8). Differences in canopy area of *Acacia* trees between different localities were highly significant (F= 42.65, p<0.001 in 1968, and F=37.86, p<0.001 in 2004) (Table 1).

The results of paired sample t test indicate significant differences in canopy area of *Acacia* trees between 1968 and 2004 (t = 3.543, P < 0.004), (Table 1). Most of the localities showed an increase in *Acacia* trees canopy area between 1968 and 2004. The positive change in canopy area of *Acacia* trees ranged from 2. 7% in W. Nakhla to 45.7% in Wadi Rumana. Wadi Agala showed a decrease in canopy area by 29.6% from 52.2 m^2 to 36.9 m^2. (Fig. 4).

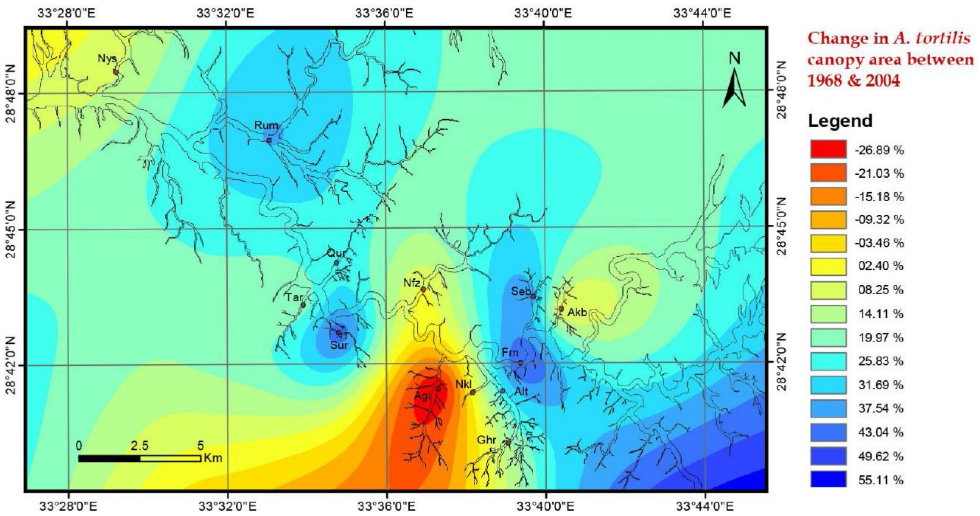


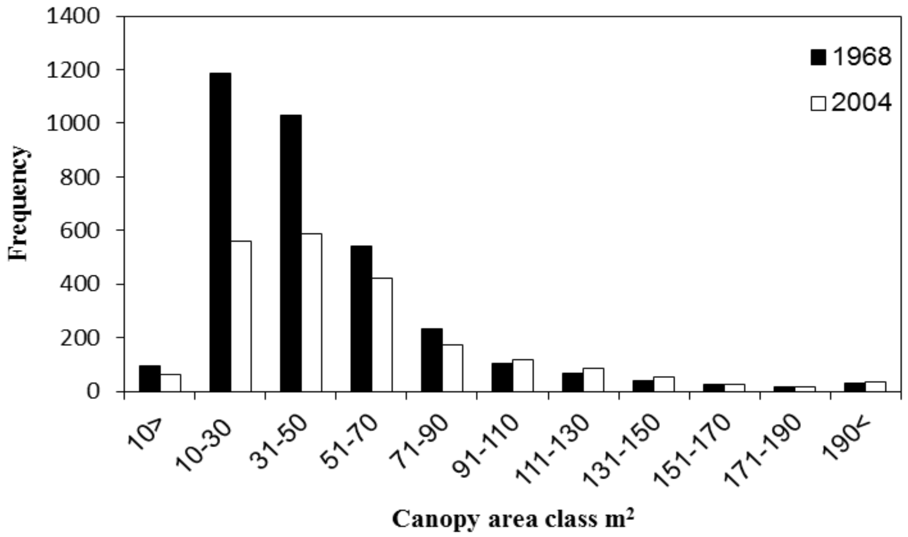
Figure (4): Change in *Acacia tortilis* canopy area between 1968 and 2004 at different study localities. Nys = Nysrien, Rum = Rumana, Frn = Feiran, Qur = Qusier, Tar = El-Tar, Sur = Surief, Nfz = Nefuz, Agl = Agala, Alt = Alyat, Nkl = Nakhla, Ghr = Gohaier, Seb = Sebah, and Akb = Akhbar.

Frequency distribution of *Acacia* trees canopy area

In general, the frequency of small-size categories (< 50 m^2) of *Acacia* trees canopy area decreased, while the frequency of large-size categories (> 90 m^2) increased in the study area, during the period between 1968 and 2004 (Fig. 5). In 1968, the second and third categories of *Acacia* trees canopy area (10-30 m^2 and 31-50 m^2) represent the highest frequency in the different localities of the study area. In 2004, there is a general increasing in the frequency of *Acacia* trees towards large size categories, and reduction in small size categories. In the first category (< 10 m^2), frequency of *Acacia* trees decreased at five localities (W. Rumana, W. Surief, W. Nefuz, W. Sebah, and W. Akhbar), and increased at four localities (W. Nysrien, W. Qusier, W. Agala, and W. Alyat).

In the second category (10-30 m^2), except W. Gohaier all localities showed reduction in frequency of *Acacia* trees. In the third category (31-50 m^2), all localities declined in frequency of *Acacia* trees canopy area. In the following two categories, certain localities showed increasing in frequency of *Acacia* trees. In the fourth category (51-70 m^2) frequency of *Acacia* trees canopy area increased in five localities (W. Nysrien, W. Ruman, W. Qusier, W. El- Tar, and W. Sebah), and in the fifth category (71-90 m^2) it increased in seven localities (W. Nysrien, W. Rumana, W. Qusier, W. El-Tar, W.Surief, W. Nefuz, and W. Sebah). Frequency distribution analysis of *Acacia* trees canopy area indicates that localities of W. Feiran, W. Alyat, W. Rumana, W. Gohaier, and W. Nakhla are higher in frequency of large trees than other localities, while localities of W. El-Tar, W. Akhbar, W. Surief. W. Sebah and W. Nefuz are higher in frequency of small trees than others.

Fig.ure (5): Frequency distribution of *Acacia* trees in W. Feiran Area in 1968 and 2004 based on their canopy area (m^2).



DISCUSSION

In the recent years, most of woody plant species in Sinai desert including *A. tortilis* have become threatened (Boulos and Gibali, 1993; Helmy *et al*., 1996; Moustafa *et al*., 2001). Changes in the abundance of *A. tortilis* populations may have significant impacts on ecosystem functioning and biodiversity (Dean *et al*., 1999). Therefore, long-term change detection is essential for conservation plans of such threatened species and for providing valid scenarios of the current status and anticipation of further changes.

The observed rarity of seedlings and small individuals in addition to the decrease in abundance and density of *A. tortilis* in South Sinai indicate a lack of recruitment and a decline in population structure of *A. tortilis*. These negative changes were observed all over the study area; however their magnitude varied among the different localities. Changes in abundance and density were alarming at W. Akhbar, W. Sebah and Wadi Alyat. Andersen and Krzywinski (2007) reported similar findings in the Eastern Desert of Egypt, where substantial reduction in the mature trees of *A. tortilis* reached (50%) occurred in the period between 1965 and 2003.

Most of localities in the study area showed positive change in the mean canopy area of *Acacia* trees. This finding is in agreement with Lahav-Ginott *et al*., (2001). They documented an increase in canopy area of *Acacia* trees in the Negev Desert between (1956 and 1996), and they mentioned that this increment take place as a result of increasing the growth of *Acacia* trees in the area. On the other hand, the decrease in the canopy area of *Acacia* trees in W. Agala is due to intensive human interference specifically pollarding, in which Bedouins cut branches of *Acacia* trees without cutting the main trunk (Andersen, 2006).

A basic demographic characteristic that is often used as a criterion for determining the health of tree populations is the shape of the size distribution (Harper, 1977; Condit *et al*., 1998). Assuming a general positive correlation between age and size, a relatively large number of small individuals is taken to indicate that a population is stable or growing, while a relatively low frequency of small individuals is interpreted as a warning that the population is in decline (Ward and Rohner, 1997). Frequency distribution analysis showed obvious negative change in most of small size categories of *Acacia* trees canopy area between 1968 and 2004.

Although W. Akhbar and W. Sebah have relatively favorable conditions for the growth of *Acacia* trees in the area (*e.g* low elevation, low slope degree, and large catchment's area), they are considered the most disturbed localities with a sharp decline in the abundance and distribution of *Acacia* trees particularly in the small categories. An explanation for this decline related to the fact that these localities are characterized by high density of local Bedouin communities (high degree of urbanization), high grazing intensity, and high degree of accessibility (located at the downstream of wadis, on or near the main road of St. Katherine). Grazing intensity has significant negative correlation with vegetation parameters of *Acacia* trees. Grazing intensity was reported to be high in W. Akhbar, W. Sebah, W. Nefuz, W. Feiran, and W. Alyat, medium in W. Qusier, W. Nysrien, W. Agala, and W. Surief, and low in W. Nakhla, W. Rumana, W. El-Tar and W. Gohaier. The negative changes were positively correlated with grazing, cutting and urbanization intensity (Abd El-Wahab *et al*., 2013). Overgrazing affects the vegetation structure in South Sinai desert (Moustafa, 2000) and may be responsible for reducing recruitment of *A. tortilis* to the point that it is difficult to find juveniles (Zaghloul *et al*., 2008). The aridity and sparseness of vegetation in South Sinai made the ecosystem fragile and sensitive to human impacts (Batanouny, 1983). Ward and Rohner (1997) estimated that up to 60% of the total mortality of *A. tortilis* is caused by anthropogenic disturbances. These effects are usually confined to densely populated settlement areas (Darkoh, 1998; Seleem *et al*., 2013). Ward and Rohner (1997) investigated aquifer depletion and road building as the major anthropogenic sources of *Acacia* trees mortality in the Negev desert.

CONCLUSION

In conclusion, this study provides the baseline information about change detection of *A. tortilis* in South Sinai, and its driving forces. Change trend in abundance and density of *A. tortilis* populations in W. Feiran area is negative. At certain localities this negative trend is alarming because the reduction in mature trees is substantial (about 40-50%). However, there are also a few sites where the trend in terms of canopy area is slightly positive. Aridity conditions may explain some of the observed pattern of mortality, but our results indicate that human disturbances, particularly over-cutting and over-grazing, are considered the main driving forces of tree mortality in South Sinai.

Understanding trend of long-term changes will help decision-makers and resources managers to establish a sustainable use strategy and effective conservation program to protect this important and endangered species. Awareness and engagement of Bedouins, the local inhabitants, are crucial for successful of any conservation plan and sustainable use strategy for *A. tortilis* in South Sinai.

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