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Identifying the Topographic Slope Characteristics Most Preferred By Wild Olive Trees in Al-Bahah Region, Saudi Arabia

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ABSTRACT

The aims of this research were to identify the topographical slope characteristics most preferred by wild olive trees in the Al-Bahah region. This study successfully identified the degree of the slope preferred for wild olive groves. The findings revealed that the majority (72.9%) of wild olive trees in Al-Bahah region occupy slopes of 5–30°. However, the patterns in Qelwa and Al-Mekhwah districts are a bit different where most of the wild olives were found on steeper slopes of 20–40°. This is probably because these sub-regions have a medium to steep slope, descending gradually toward the west, the altitudes ranging from 200 (400) to 2001 and 2200 m west of Al¬-Bahah city and Uwera, and between 2000 and 2100 m west of Baljurashi. The results further depicted that the wild olive with the medium-large crown diameter mostly occupied the gentler slopes of 0–25° compared to those with small crown diameters at steeper slopes of 5–35°. This indicates that the wild olive trees grow better on gentler slopes. These findings can be regarded as theoretically revealing the potential landform suitable for olive plantation. As a basis for olive plantation site suitability, these factors are the essential prerequisites to be considered. However. In addition, it is obvious that site suitability is subject to the temporal dynamics of environmental variables.

Keywords: Wild olive tree; Mapping; Extent; Distribution; Al-Bahah region; Remote sensing; Crown size; Slope; Neighboring Species

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INTRODUCTION

Wild Olive Tree

Olea oleaster, the wild-olive, has been considered a valid species by various botanists and a subspecies of the cultivated olive tree, *Olea europea*, which is a tree of multiple origins (Besnard, G., and André Berville 2000), which appears to have been domesticated at various places during the fourth and third millennia BCE in selections drawn from its varying local populations (Besnard, G. Baradat, 2001).

Today, as a result of natural hybridization and the very ancient domestication and extensive cultivation of the olive throughout the Mediterranean Basin, feral forms of olive, called "*oleasters*", constitute a complex of populations, potentially ranging from feral forms to the wild-olive (Lumaret, R., Ouazzani, et al. 2004).

The wild-olive is a tree of the maquis shrubland, itself in part the result of the long presence of mankind. The drought-tolerant sclerophyllous wild olive tree is believed to have originated in the Mediterranean Basin. It still provides the hardy and disease-resistant rootstock on which cultivated olive varieties are grafted (Breton Catherine Marie, *et al.*, 2006).

Meanwhile, wild olive is also reported to be native to North America. It is an evergreen tree which reaches 20-feet in height with a 10- to 15-feet spread. This small tree is very rarely found and is even reportedly close to extinction. The olive-like, white fruits that are produced have a sweet flesh relished by birds and other wildlife and, although edible by man, should not be consumed in quantities. However, in the United States of America, another olive tree species known as the Russian olive (*Elaeagnus angustifolia* L.) was considered an exotic invasive weed. This thorny shrub or tree originating in South-eastern Europe and Western Asia, was reported by Katz, Gabrielle. L., and Shafroth, Patrick B. (2003) as intentionally introduced and planted in the United States for windbreaks, erosion control, wildlife habitat, and other horticultural purposes. This tree was then observed to be very well adapted to semiarid and saline environments. Early in the 20th century, Russian olive escaped cultivation and spread, particularly into the large moist riparian environments in arid or semiarid regions of the western United States (Stannard, M., D., Ogle, *et al.* 2002).

Mapping Wild Olive Using Remote Sensing

Traditional methods (e.g., field surveys, literature reviews, map interpretation, and collateral and ancillary data analyses) have not been effective in acquiring mass vegetation covers because they are time consuming, data-lagged, and often too expensive. Meanwhile, remote sensing offers a practical and economical means to study vegetation cover changes, especially over vast areas (Nordberg Maj-Liz and Joakim Evertson, 2004). Because of the potential capacity for systematic observations at various scales, remote sensing technology extends possible data archives from the present time to over several decades back. Using this advantage and inventory, enormous efforts have been made by researchers and application specialists to delineate vegetation cover from a local to global scale by applying remote sensing imagery. Since then, there have been numerous efforts at the regional or national level to map wild olives using remote sensing. One example is a pilot project initiated to develop a cost-effective method for mapping the Russian olive (*Elaeagnus angustifolia* L.), an invasive tree species, from scanned large-scale aerial photographs. This study area was established along a riparian zone within a semiarid region of the Fishlake National Forest, located in central Utah. Two scales (1:4000 and 1:12,000) of natural color aerial photographs were evaluated as part of the project. Feature Analyst, an extension of the ArcGIS software, and several image processing software packages, were employed to map the invasive trees. Overall, Feature Analyst successfully located the Russian olive (RO) using the imagery with a relatively high degree of accuracy. For the map derived from 1:4000-scale photographs, the software correctly located the tree in 85

% of all 4-by-4 meter transect cells where the RO olive was actually present. However, smaller trees were sometimes missed and the size of trees and their trees were frequently underestimated. The map derived from 1:4000-scale photographs was only slightly more accurate than that derived from 1:12000-scale photographs, suggesting that the smaller scale photography may be adequate for mapping the RO. (Hamilton, R., K. Megown, et al. 2006).

Another attempt was conducted in Australia to test the ability of remote sensing imagery to map olive groves and their attributes. Specifically, this attempt aimed to do the following: (a) discriminate olive varieties; and (b) detect and interpret within-field spatial variability. Using high spatial resolution (2.8 m) via QuickBird multispectral imagery acquired over Yallamundi (southeast Queensland) on 24 December 2003, both visual interpretation and statistical (divergence) measures were employed to distinguish olive varieties. Similarly, the detection and interpretation of within-field spatial variability were conducted on enhanced false-color composite imagery and confirmed by statistical methods. The results indicated that the two olive varieties (i.e. Kalamata and Frantoio) can be visually differentiated and mapped on the enhanced image based on texture. The spectral signature plots demonstrated little difference in the mean spectral reflectance values, indicating that the two varieties have very low spectral separability.

Extent and Distribution of Wild Olive Trees in Al-Bahah Region

Information extracted from the Pleaides satellite image revealed that of 1,991 km of the study area, only 817 km (41%) indicate the presence of wild olive trees. The sub-region with the most extensive area of wild olive trees is Al-Qura, covering 270 km^2, followed by Baljurashi at 192 km^2, and Al-Mandaq at 150 km^2. Automatic enumeration was done on the Pleaides satellite image estimating 717,894 trees (with a crown diameter greater than 1.5 m) equaling an average of 360 trees per km^2.In terms of wild olive tree density, Al-Mandaq district has the densest population, with 613 trees per km^2, followed by Al-Bahah with 563 trees per km^2. Meanwhile, Al-Aqiq district has the lowest density, with only 22 trees per km^2, followed by Al-Qura with 222 trees per km^2 **(Table 1. and Figure 1**: (Al-Ghamdi, A. S. 2020 b).

Table 1. Wild olive tree Presence in Al-Bahah by Districts

District	Study area (km^2)	Area with Wild olive trees		Number of Wild olive trees	
		(km^2)	(%)	Tree	Tree/ km^2
Al-Qura	586	270	13.6	129 903	222
Al-Aqiq	165	69	3.5	3433	21
Al-Mandaq	339	150	7.5	208 034	613
Al-Mekhwa	27	10	0.5	11 851	444
Al-Baha	287	103	5.2	161 802	563
Baljurashi	506	192	9.6	178 801	353
Qelwa	81	24	1.2	24 070	297
TOTAL	**1991**	**817**	41.1	**717 894**	360

From the maps in **Figure 1)** it can be observed that most wild olive dense areas are located in north-eastern Al-Mandaq, in south-western Baljurashi, and at the edges of Al-Bahah.

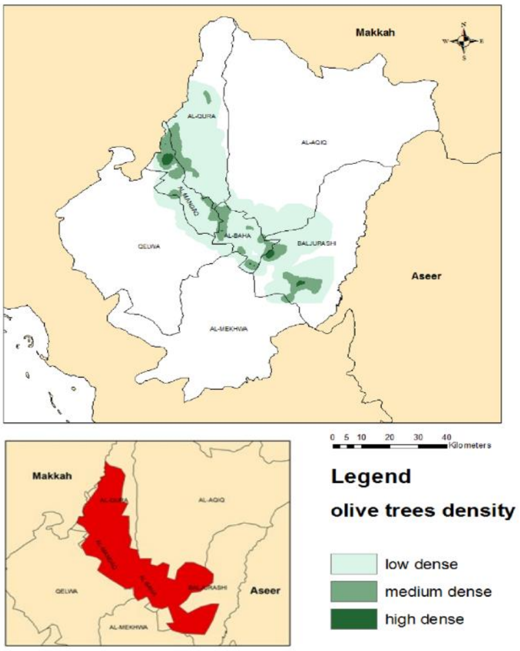


Figure 1. Density of wild olive trees in the Study Area

Extent of Wild olive tree Presence According to Crown Diameter Size

The crown diameter of each tree was directly measured automatically from the Pleaides satellite imagery. Three diameter size categories were established, i.e., small (1.5–2.5 m), medium (2.5–3.5 m), and large (>3.5 m). A crown diameter size smaller than 1.5 m could not be easily discriminated from the image, hence no enumerated rendering of underestimated tree counting in this project. The measurement indicates that most of the trees have a small crown diameter with 392,908 trees representing 54.7% of the total wild olive trees, and only 13.4% having a large crown diameter. It was also observed that large and medium crown trees are mostly located at Al-Qura, Al-Mandaq, Al-Bahah and Baljurashi. However, Al-Mandaq, with the wildest olive trees, has a high percentage of small crown trees at 36.7%, or 144,376 trees. Lower wild olive density districts such as Al-Aqiq, Al-Mekhwa, and Al-Qelwa have more smaller crown trees **(Table 2, Figure 2:** Al-Ghamdi, A. S. 2020 c).

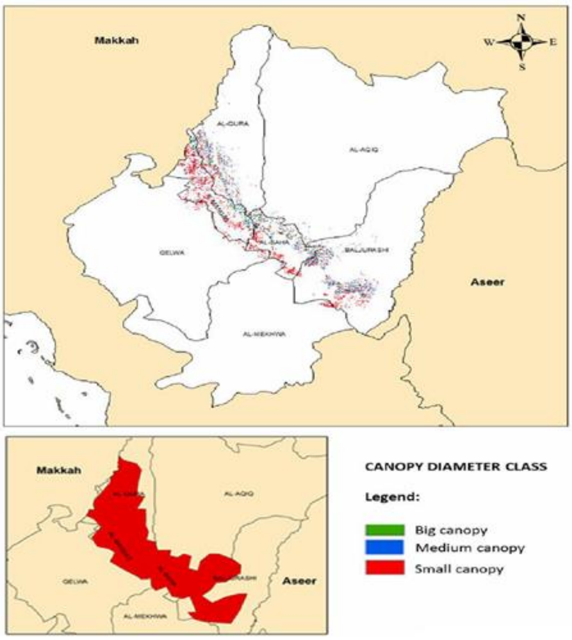


Figure 2. Distribution of Wild olive tree according to Crown Diameter

Table 2. Wild olive Crown Diameter Size by District

District	Total Number of Trees	Crown Diameter Size					
		Small Crown (1.5–2.5m)		Medium Crown (2.5–3.5m)		Large Crown (> 3.5m)	
		Tree	(%)	Tree	(%)	Tree	(%)
Al-Qura	129 903	49 645	12.6	57 913	25.3	22 345	23.3
Al-Aqiq	3433	1325	0.3	1713	0.7	395	0.4
Al-Mandaq	208 034	144 376	36.7	40 341	17.6	23 317	24.3
Al-Mekhwa	11 851	8835	2.2	2577	1.1	439	0.5
Al-Baha	161 802	89 433	22.8	50 126	21.9	22 243	23.2
Baljurashi	178 801	78 512	20.0	73 262	32.0	27027	28.2
Qelwa	24070	20 782	5.3	3064	1.3	224	0.2
TOTAL	**717 894**	**392 908**	100.0	**228 996**	100.0	**95 990**	100.0

Extent of Wild olive trees according to Neighboring Species

In the second-phase project, neighboring species were automatically determined by ERDAS software classification and enumeration of trees within 5 meters of wild olive trees by using ArcGIS software. The Pleaides satellite imagery was used to determine the wild olive trees, Juniper, Acacia, and other species. It was found that the main neighboring species of the wild olive are Juniper (40.2%) and Acacia (36%), and other species (23.8%). Juniper is the most common neighbor around wild olive in Al-Mandaq (32.2%) and Al-Bahah (29.4%), while Acacia is the main neighbor for the wild olives in Al-Bahah (28.3%) and Baljurashi (29.6%). The abundance of Juniper trees in Al-Mandaq and Al-Bahah districts is probably attributed to their higher elevation and the rugged nature of its mountains (especially in the past before the introduction of modern roads), which has protected their forest from extensive exploitation and prevented ease of access to the area. Meanwhile, the small sizes of the trees and irregular growth reveal that they have been cut in the past, and the branches growing from them as coppices are considered the current trees **(Table 2, and Figure 3:** Al-Ghamdi, A. S. 2020 d).

Table 3. Extent of Wild olive tree Neighboring Species by District

District	Number of Neighbor Trees*	Number of Neighbor Trees					
		Juniper		Acacia		Others	
		tree	%	Tree	%	tree	%
Al-Qura	79,521	29,525	12.2	46,250	21.3	3746	2.6
Al-Aqiq	2,296	1347	0.6	836	0.4	113	0.1
Mandaq	148,886	78,219	32.2	21,359	9.8	49,308	34.3
Mekhwa	41,875	20293	8.4	14592	6.7	6990	4.9
Al-Bahah	193,920	71,354	29.4	61,443	28.3	61,123	42.5
Baljurashi	102,297	30,522	12.6	64,271	29.6	7504	5.2
Qelwa	35,493	11743	4.8	8742	4.0	15008	10.4
TOTAL	**604,288**	**243,003**	100.0	**217,493**	100.0	**143,792**	100.0

* neighbor trees are trees surrounding wild olivetrees within 5m radius

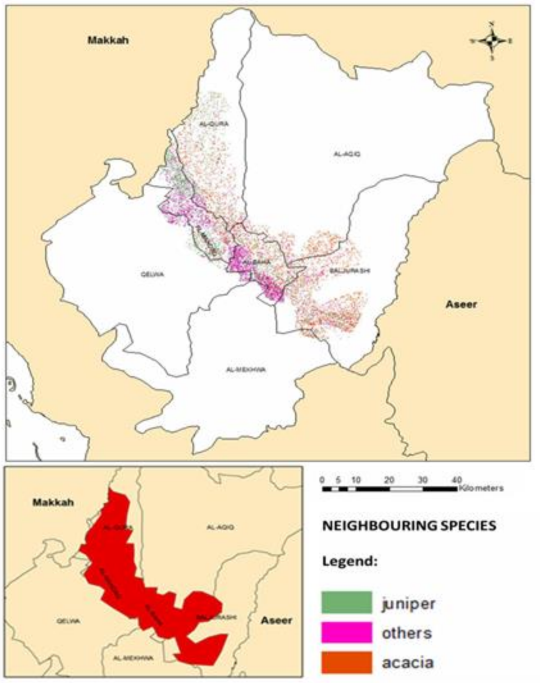


Figure 3. Distribution of Wild olive tree according to Neighboring

Vegetation Topographical Preference.

The study of plant communities is the best way to learn about habit, habitat, niche and vegetation structure (Khan, W., *et al*. 2016; Malik Z. 1986) as well as various interactions among the plants in an ecosystem. Variations in plant species composition along altitude and latitude is a well-established phenomenon (Kitayama, K. 1992; Lieberman, Milton et al. 1985; Shaheen Hamayun, *et al.* 2012), and one of the ultimate factors in restricting plant species and community types in mountainous regions (Khan S. M., *et al.* 2011). Furthermore, soil is an environmental factor that also determines plant growth, which is influenced by organisms, climate, topography, time, and parent material (Hoveizeh H. 1997).

Climate is affected by topography such as slope, elevation, and aspect in addition to effect of evapotranspiration and temperature that as a whole result in rich vegetation in the northern aspects compared to southern ones (Ordóñez Lisa D. *et al.* 2009). Plant species by origins are restricted to specific habitat and can be found in that particular habitat due to the presence of optimum topographical factors (Slope, elevation, aspect, and river proximity) as well as biotic and abiotic factors which clearly suggests that plant communities and vegetation composition change with these diverse factors from point to point. Topographic attributes provide significant information for the categorization of different vegetation classes.

Topographical heterogeneity strongly affects other types of landscape heterogeneity, e.g. variation in mesoclimate, natural disturbances, soil conditions, or intensity of human impact. The main effect of landscape-scale topographical heterogeneity on local (microsite) species richness can be observed in the control of the spatial configuration of habitats surrounding the target site. In a topographically homogeneous landscape, a site's neighborhood usually contains the same or similar habitat, while in a heterogeneous landscape very different habitats may be found close to the target site (Zelený David, *et al.* 2010).

Observations revealed that species ranges are shifting, contracting, expanding, and fragmenting in response to global environmental changes (Chen, I. C., *et al.* 2011).

The emergence of global-scale bioinformatic databases has provided new opportunities to analyze species occurrence data in support of conservation efforts (Jetz, W., McPherson, *et al.* 2012). This has paved the way for more systematic and evidence-based conservation approaches (Margules C. R. and R. L. Pressey 2000; Sutherland William J., *et al.* 2004.) However, records of observed species occurrence typically provide information on only a subset of sites occupied by a species (Rondinini, C., Stuart, S, and Boitani, L 2005). Moreover, these do not provide information on sites that have not been surveyed or that may be colonized in the future following climate change (Hoegh-Guldberg O., *et al,* 2008) or biological invasions (Thuiller, Wilfried, *et al.* 2005; Baxter Peter W. J. and Hugh P Possingham 2010; Giljohann, Katherine M., *et al.* 2011)

Nevertheless, this information is important for making robust conservation management decisions and can be provided via predictions of species occurrences derived from environmental suitability models combining biological records with spatial environmental data. Species distribution models (SDM), also commonly referred to as ecological niche models (ENM), are currently the main tools used to derive spatially explicit predictions of environmental suitability for a species.

Geographical and Topographical Pattern Concepts

Both geographical and topographical ecology are concerned with understanding spatial patterns to understand process, and process to understand pattern. Geographical and topographical ecology introduce fundamental questions on the concepts of scale, space, and place Turner M. G, *et al.* (2001). A major difference between the two disciplines is that topographical ecology focuses solely on ecological processes, whereas geographical ecology encompasses all systems including human, ecological, biological, and physical. Ultimately, geographical and topographical ecology are concerned with broad-scale environmental issues and help provide insights into studies of ecological systems operating over various scales.For example, the ecosystem provided and maintained by bees is inherently related to the geographical and topographical ecology because of the importance of spatial scale and pattern in the bees' habitat. Bee distribution is geographic in nature because it is limited by climate, topography, soils, and vegetation types (Michener, C. D. 2000).

Thousands of species of bees exist on our planet, and their distributions are limited by spatial variables, which create great regional diversity in bee populations.

Topographical ecology is also central to understanding bee populations because of the discipline's focus on broad spatial scales and the ecological effects of the spatial patterning of ecosystems (Turner M. G, *et al.* 2001).

One theory that is common to topographical ecology and important to the conceptualization of this research is the Percolation theory, which addresses the spatial pattern in random assembly. Applications of the Percolation theory have brought to light questions of size, shape, and connectivity of habitats (Turner M. G, *et al.* 2001).

The Percolation theory has offered much insight into the nature of connectivity or the inverse fragmentation of topographical (Gardner R. H., et al. 1992) information on wild olive trees, and suitable conditions for their growth in forests are still limited. Thus, a complete understanding of the topographical characteristics preferred by wild olive trees is yet to be achieved. Using Remote Sensing and Geographic Information System, local people can now trace the exact locations of wild olive trees and manage a planned future area to develop olive plantations with these established topographical characteristics as compared to other olive plantation topographical areas.

It has been observed that wild olive trees are more resistant to diseases compared to normal olive plantation trees. Once affected, diseases are more easily spread in a normal olive plantation rather than in wild olive trees. Hence, it is essential to determine factors that contribute to this variation in the wild olive trees, especially in a disease-prone situation. This can be due to weather conditions such as rainfall, temperature, humidity, etc., or topographical conditions such as elevation, slope, aspect, river proximity, etc.

The Study Area

According to Price, J. P. (2004), the most effective way to map plant-species ranges in an area is by demarcating a general bioclimatic envelope within biogeographic regions in which a species is known to have been found. Hence, this study requires *building a* database of species that includes data on the distribution of species by geographic region, major habitat type, and elevation range.

Furthermore, in this project, due to the large area of study and to save time, cost, and energy, only areas with high potential for wild olive tree presence, indicated by high (61.8 km^2) and medium (790.7 km^2) density vegetated areas, were included in the first-phase study **(Table 1, Figure 4).**

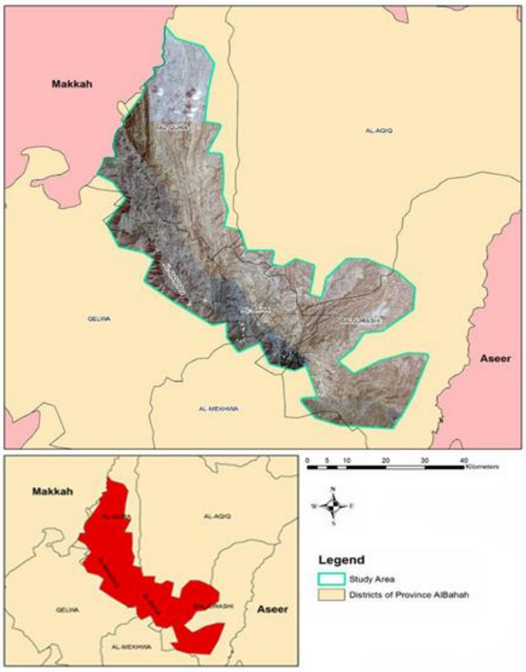


Figure 4. Satellite image Pleideas showing extent of study

Additional search areas were also expanded to nearby lower vegetation density areas based on similar neighborhood characteristics. This area expanded to the northern part but not to the southern because the southern part, i.e. Al-Mekhwa and Qelwa, of the entire Al-Bahah region (Al-Ghamdi, A. S., 2020 a),

Table.4: Study Area according to District.

District		Study Area	
Name	**km^2**	**km^2**	**(%)**
Al-Qura	1,049	586	55.9
Al-Aqiq	3,667	165	4.5
Al-Mandaq	361	339	94
Al-Mekhwa	1,949	27	1.4
Al-Bahah	298	287	96.4
Baljurashi	1,505	506	33.6
Qelwa	2,232	81	3.6
TOTAL	**11, 060**	**1,991**	**18**

consists of a steep slope tending towards lower elevation. The overall study area, which totaled around 1991 km^2 (Figure 4), makes up only 18.0%.

Objectives

This study aims to identify the topographical characteristics (slope) most preferred by wild olive trees in Al-Bahah region, which will act as a knowledge base for a better understanding of the occurrence and morphology of this olive species' activities in November 2016 and establish a knowledge base on the location and preferred topographical characteristics of wild olive trees in Al-Bahah region.

MATERIAL AND METHOD.

The main data source for the location of wild olive trees in the study area was provided from a pre-views study (Al-Ghamdi, A. S. 2020 a). These distribution coordinates were then overlaid with topographical parameters derived from ASTER data to identify the most preferred topographical characteristics of wild olive trees in the Al-Bahah region. The following sections delineate the methods applied in this project.

Material and Data

In this study, the geospatial software used are as follows:

- ERDAS Imagine 2014 - an image processing software
- ArcGIS ver 10.3 - a GIS software to conduct spatial analysis
- ArcScene -an extension of ArcGIS software to process and display 3D images

Meanwhile, the data used in this project are as follows:

- ASTER Global Digital Elevation Model (GDEM) - to generate elevation, slope, aspect, and rivers
- Digital boundary of Al-Bahah region and its districts

Method

In this study, three main activities were conducted: satellite data procurement, data collection, data analysis, and field work. The overall workflow of this study is shown in **Figure 5.**

May 2016 was used as the primary source for extracting the data for this study. Upon downloading from the USGS website, the LANDSAT-8 image was processed using Normalized Differential Vegetation Indices (NDVI) to demarcate areas with vegetation or chlorophyll.

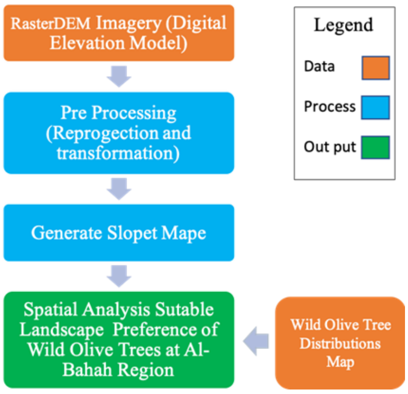


Figure 5. Activities flowchart for Wild olive Topographical Preference

Digital Elevation Model

Digital elevation model (DEM) is often used as a generic term for digital surface models (DSMs) and digital terrain models (DTMs) and represents only height information without any further definition of the surface. Other definitions consider the terms DEM and DTM equivalent or define the DEM as a subset of DTM, which also represents other morphological elements. There are also definitions, which consider the terms DEM and DSM interchangeable. On the web, definitions can be found of DEM as a regularly spaced GRID and DTM as a three-dimensional model (TIN). All datasets, which are captured with satellites, airplanes or other flying platforms are originally DSMs (such as SRTM or the ASTER GDEM). It is possible to compute a DTM from high-resolution DSM datasets with complex algorithms (Li, Z., *et al.* 2005). In the following paragraph, the term DEM is used as a generic term for DSMs and DTMs.

In this study, the topographical map was acquired from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) images, which is a Japanese sensor on board the Terra satellite launched into the Earth's orbit by NASA in 1999. The instrument has been collecting data since February 2000. ASTER provides high-resolution images of planet Earth in 14 different bands of the electromagnetic spectrum, ranging from visible to thermal infrared light. The resolution of images ranges between 15 and 90 meters. ASTER data are used to create detailed maps of the surface temperature of land, emissivity, reflectance, and elevation. ASTER's topographical isoline contours consist of

5-m intervals that were eventually generated into GIS. Prior to that, the contour lines were assigned an attribute value according to their height in meters above the sea level. The resulting dataset was then used to produce a DEM using ArcScene software with the 3D extension analyst. Height value was added to the existing contour line used previously in generating the DEM. Adding the height information to the contour lines is the most time-consuming stage of the process to generate a DEM.

Slope map was also generated using ASTER data using the ArcGIS tool. The aspect was divided in to 9 class intervals; the resulting dataset was then used to produce a 3D slope using ArcScene software with the 3D extension analyst. Both data were reclassified before converting into shapefile format.

The resulting dataset was then used to overlay the wild olive tree points. Subsequently, these layers were overlaid with a tree-point layer for spatial data analysis. The last output from the spatial analysis is the suitable topographical preference of wild olive trees.

Topographic Characteristic Measurement

Many topographic components are considered to highly affect wild olive tree presence. In this study, we study slope topographic component, Meanwhile, the wild olive characteristics investigated to associate with the topographic/landform features are crown canopy size, neighboring species, and distribution. These characteristics were overlaid with the slope topographical components to identify their association. Details of this topographical categorization are outlined as follows: Slope was generated using software ArcGIS and was divided into nine (9) degree (°) classes as below:

0.0–5.0° 5.1–10.0°
10.1–15.0° 15.1–20.0°
20.1–25.0° 25.1–30.0°
30.1–35.0° 35.1–40.0°
> 40.0°

RESULT

Slope criteria is deemed to contribute to the formulation of a habitat suitability index for Wild olive trees. Topographical layers were categorized into several classes to quantify its variation. Subsequently, these layers were overlaid with the wild olive distribution layer to analyze the pattern. The results of this exercise are presented in this study. The slope degree was generated using a Raster World DEM from the United States Geological Survey (USGS). Using the ArcScene module from ArcGIS, nine slope classes were divided as referred to before. The slope classes were then displayed and overlaid with the wild olive tree point layer (**Figures 6** and **7)** to determine the point of contact between the trees and the slope map.

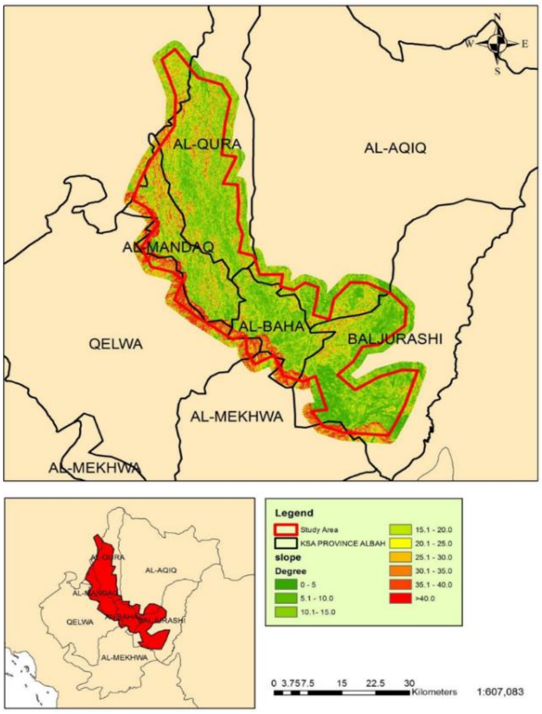


Figure.6. Slope Map of Study Area

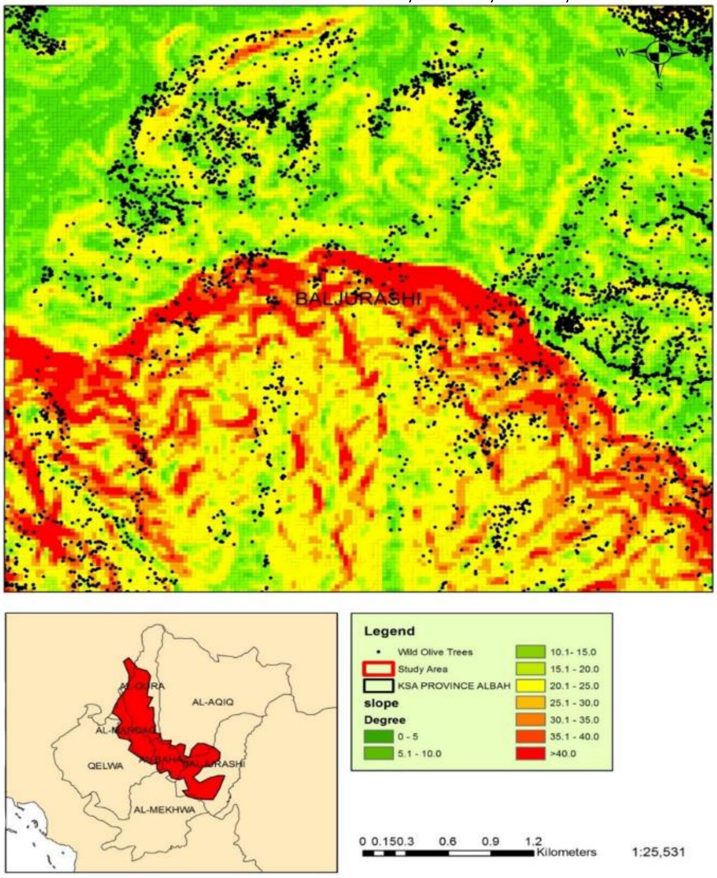


Figure.7. View Wild olive Distribution on Slope Map Close-up

Table 5 depicts that about 80% of wild olive trees were found on the slopes less than 30°, and about 60% of the wild olive trees were found on slopes less than 20°. In view of the slope classes, slopes of 10.1–15.0° (17.8%) have the presence of highest wild olive tree numbers, followed by slopes of 5.1–10.0° (17.2%) and 15.1–20.0° (15.0%), respectively.

Extent of Wild olive by Slope according to District

Table 6 shows the distribution pattern of preferred wild olive trees consisting of slopes of 5–30°. This is the same for all the districts except for Qelwa and Al-Mekhwah, where steeper slopes of 25° to more than 40° are preferred.

Table 5. Number of Wild olive trees by slope

Slope code	Degree (^{0})	Olive tree	(%)	
1	0.0–5.0	56,921		7.9
2	5.1–10	123,267	17.2	
3	10.1–15.0	127,755	17.8	
4	15.1–20.0	108,017	15.0	
5	20.1–25.0	90,079	12.5	
6	25.1–30.0	74,748	10.4	
7	30.1–35.0	57,839		8.1
8	35.1–40.0	39,837		5.5
9	>40.0	39,431		5.5
	Total	**717,894**	**100.0**	

* Highlighted in yellow are slopes where most wild olive trees are found (> 10%)

Extent of Wild olive Crown Diameter Size by Slope

Table 7 shows that 78% of the small crown trees are mostly found on slopes of 5–35°, while both medium and large crown trees are mostly found on slopes of from 0–25° (81%). This indicates that at gentler slopes, the wild olive grows better, while at steeper slopes, the olives have smaller crowns. It was further observed that Al-Bahah sub-region, being hilly and undulating, has smaller crown olive trees, as shown in **Table 7** with small crown trees making up 55% of the data, medium crowns at 32%, and large crowns at only 13%. The histogram

pattern in **figure 8** shows that most of the wild olive trees can be found in the slope class 10–15°, followed by 5–10°, 15–20°, and 20–25°. A lesser presence of wild olive can be seen in the slope classes 0–5° and > 35°. Meanwhile, medium- and large - crown wild olives are seen less from slope class 25–30° onwards and mostly in slope class 5–15°.

Extent of Wild Olive Neighboring Species by Slope

Table 8. shows that Acacia was mostly found on a slope of 0–25° (75%), while Juniper and others were found mostly on slopes of 5–35° (79% and 78%, respectively). **Table 8** also indicates that neighboring tree species surrounding wild olive within 5 meters are mostly Juniper (49%) and Acacia (48%), while others are very few (2%). More Acacia can be found on gentler slopes with Juniper on steeper slopes.

The histogram pattern in **figure 9** shows that there is more Acacia on gentler slops (< 25°) and more Juniper at steeper slopes (> 25°). This indicates that local people would likely use Juniper for fuel consumption compared to Acacia.

DISCUSION

Species ranges are shifting, contracting, expanding, and fragmenting in response to global and local environmental changes and human interferences with natural topography or landscapes (Chen, I. C., et *al.* 2011). Understanding the natural topography where a species is abundant indicates the preference of or suitability for that species. This research and development of the wild olive geoinformatic database of the local Al-Bahah region has provided new opportunities to analyze wild olive occurrence data in support of conservation efforts and allowed for a more systematic and evidence-based conservation approach. In this project, observed species occurrence that typically provided information on areas previously demarcated as having medium-high vegetation density was recorded during the first phase of the project, while the number of trees and location were acquired during the second phase of the project.

In this third phase of the project, the topography and landform preference of wild olive trees was investigated to gain a better understanding of the occurrence and morphology of this species in the study area. The main topographic characteristics studied are discussed in detail in the following sections.

Table. 6. Number of Wild Olive Trees Against Slope by District.

Slope (°)	olive Density																Total	
	Al Qura		Al Mandaq		Al Baha		Baljurashi		Qelwa		Al Mekhwah		Al Aqiq					
	Tree	%	Tree	%	Tree	%	Tree	%	Tree	%	Tree	%	Tree	%			Tree	%
0.0–5.0	10,668	8.21	7028	3.38	11,448	7.08	26,843	15.01	255	1.06	54	0.46	625	18.21			**56921**	**7.93**
5.1–10	25,372	19.53	19,569	9.41	28,278	17.48	47,974	26.83	842	3.50	143	1.21	1089	31.72			**123267**	**17.17**
10.1–15.0	27,911	21.49	28,264	13.59	30,185	18.66	39,133	21.89	1284	5.33	251	2.12	727	21.18			**127755**	**17.80**
15.1–20.0	22,550	17.36	32,462	15.60	23,946	14.80	26,246	14.68	1726	7.17	665	5.61	422	12.29			**108017**	**15.05**
20.1–25.0	17,603	13.55	34,925	16.79	18,276	11.30	15,236	8.52	2394	9.95	1399	11.80	246	7.17			**90079**	**12.55**
25.1–30.0	12,737	9.81	32,855	15.79	14,336	8.86	9518	5.32	3371	14.00	1776	14.99	155	4.52			**74748**	**10.41**
30.1–35.0	7346	5.65	25,756	12.38	12,556	7.76	5707	3.19	4077	16.94	2311	19.50	86	2.51			**57839**	**8.06**
35.1–40.0	3699	2.85	15,159	7.29	10,375	6.41	3823	2.14	4402	18.29	2336	19.71	43	1.25			**39837**	**5.55**
>40.0	2017	1.55	12016	5.78	12402	7.66	4321	2.42	5719	23.76	2916	24.61	40	1.17			**39431**	**5.49**
total	129,903	100	208,034	100	161,802	100	178,801	100	24,070	100	11,851	100	3,433	100			717,894	100

** Highlighted in yellow are where most wild olive trees are found (>10%)*

Table.7. *Wild olive Crown Diameter Size relation with slope*

Slope (Degree)	Crown Diameter Size						Total	
	Small		Medium		Large			
	Tree	%	Tree	%	Tree	%	Tree	%
0.0–5.0	23,816	6.1	23,708	10.3	9397	10.0	**56,921**	**7.9**
5.1–10	53,569	13.6	49,721	21.6	19,977	21.2	**123,267**	**17.2**
10.1–15.0	59,042	15.0	48,581	21.1	20,132	21.3	**127,755**	**17.8**
15.1–20.0	55,061	14.0	37,060	16.1	15,796	16.7	**107,917**	**15.0**
20.1–25.0	52,145	13.3	26,599	11.5	11,435	12.1	**90,179**	**12.6**
25.1–30.0	47,716	12.1	18,976	8.2	8056	8.5	**74,748**	**10.4**
30.1–35.0	40,423	10.3	12,394	5.4	5022	5.3	**57,839**	**8.1**
35.1–40.0	29,579	7.5	7493	3.3	2765	2.9	**39,837**	**5.5**
>40.0	31,555	8.0	6018	2.6	1858	2.0	**39,431**	**5.5**
total	**392,906**	**100**	**230,550**	**100**	**94,438**	**100**	**717,894**	**100.0**

** Highlighted in yellow are where most wild olive trees are found (> 10%)*

Figure. 8. Histogram showing pattern of Wild olive Crown Diameter Size against Slope.

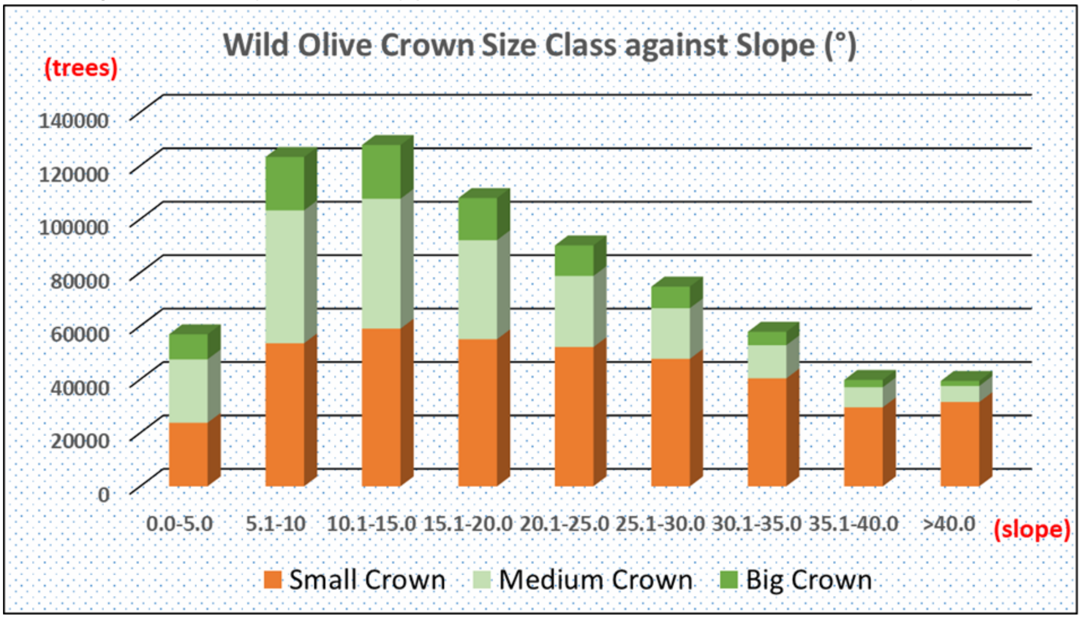
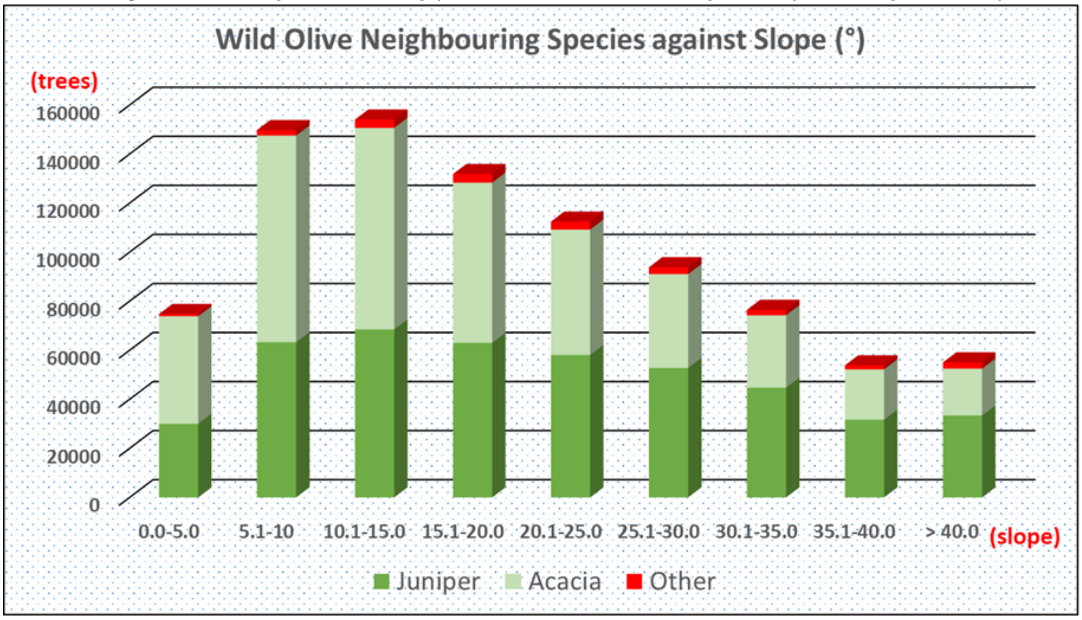


Table.8. *Wild olive Neighbor Species Relation with Slope*

Slope (Degree)	No of Neighbor Trees						Total	
	Juniper		Acacia		Other			
	Tree	%	Tree	%	Tree	%	Tree	%
0.0–5.0	30,003	6.7	43,893	10.1	865	3.9	**74,761**	**8.3**
5.1–10	63,279	14.2	84,257	19.4	2250	10.0	**149,786**	**16.6**
10.1–15.0	68,516	15.4	82,160	18.9	3397	15.2	**154,073**	**17.1**
15.1–20.0	63,015	14.1	65,335	15.0	3489	15.6	**131,839**	**14.6**
20.1–25.0	58,069	13.0	51,134	11.8	3244	14.5	**112,447**	**12.5**
25.1–30.0	52,773	11.8	38,303	8.8	2771	12.4	**93,847**	**10.7**
30.1–35.0	44,768	10.0	29,508	6.8	2311	10.3	**76,587**	**8.5**
35.1–40.0	31,696	7.1	20,528	4.7	1621	7.2	**53,845**	**6.0**
> 40.0	33,421	7.5	19,086	4.4	2449	10.9	**54,956**	**6.1**
total	**445,540**	**100**	**434,204**	**100**	**22,397**	**100**	**902,141**	**100.0**

** Highlighted in yellow are where most wild olive trees are found (> 10%)*

Figure.9. Histogram showing pattern of Wild olive Neighbor Species against Slope



Slope

Majority (72.9%) of wild olive trees in the Al-Bahah region occupied a slope of 5–30°. However, the occurrence pattern in Qelwa and Al-Mekhwah districts are a bit different where most of the wild olives were found at steeper slope of 20–40°. This is probably due to these sub-regions having a medium to steep slope intersected by valley gullies, descending gradually toward the west, the altitude ranging from 200 (400) to 2001 and 2200 m west of Al-Bahah city and Uwera, and between 2000 and 2100 m west of Baljurashi. The results further depicted that medium-large crown diameter wild olive mostly occupied gentler slope ranges of 0–25° compared to small crown diameter wild olive on steeper slopes of 5–35°. This indicates that the wild olive trees perform better on gentler slopes.

It was observed that most Acacia surrounding wild olive trees inhabited much gentler slopes of 0–25°. This is probably because steep slopes are less sandy and are rockier. Jeldes, I., *et al.* (2013) observed that Acacia trees preferred sandy soil. Despite having a high reproductive capacity, the Acacia population is threatened because of its narrow genetic diversity and geographical range, small population size and low density, extreme environmental conditions, and indiscriminate felling of these trees. (Wickneswari R, and Norwati M (1993).

Meanwhile, Juniper surrounding wild olive was observed to mostly populate slopes of 5–35°. This indicates that Juniper can thrive and grow even on steep slopes. Juniper was reported by Aref, I.M. and L.I. El-Juhany (2004) as the most abundant tree species in Al-Bahah region, but it has been much reduced. The causes of this deterioration may be attributed to extensive forest clearing for cultivation, over-grazing, and exploitation of forests for firewood and construction materials without re-planting. This has also reduced the forest cover of the region.

Slope is an important indicator of land suitability since it affects drainage, irrigation, and soil erosion (Yu, J. *et al.* 2009). Steep slopes reduce the infiltration efficiency of rainfall because they facilitate runoff.

Slopes of up to 15° are ideal for optimum growth and the yield of most crops, whereas slopes between 15° and 30° exhibit a linear decrease in suitability. Slopes greater than 30° are not suitable for most crop production.

Besides these topographical factors, olive trees are known to prefer non-stratified, moderately fine textured soils, including sandy loam, loam, silt loam, clay loam, and silty clay loam. Such soils provide aeration for root growth, are quite permeable, and have a high-water retention capacity. Sandier soils do not have good nutrient or water retention capacity. Heavier clays often do not have adequate aeration for root growth and will not drain well. Olive trees are shallow rooted and do not require very deep soils to grow well (Sibbett, G. S. and Louise,

F. 2004).

Furthermore, according to Sibbett G. S. and Louise F. (2004), soils having an unstratified structure of four feet are suitable for olives. Stratified soils, either cemented hardpan or varying soil textures within the described profile, impede water movement and may develop saturated layers that damage olive roots and should be ripped. Olives tolerate soils of varying chemical quality. They grow well on moderately acid (pH greater than 5) or moderately basic (pH less than 8.5) soils. Basic (alkaline) or sodic soils should be avoided since their poor structure prevents water penetration and drainage, creating saturated soil conditions that kill olive roots.

CONCLUSIONS

This study successfully identified the preferred topographic and landform characteristics favored by wild olive distribution. The findings revealed that wild olive trees prefer topography or landform with slopes of 5–30°, an elevation between 1,750–2,250 m, aspect facing west, and river proximity of less than 600 m. Wild olive trees have larger crown at more gentler slopes ranging 0–25° but smaller crown at a lower elevation of 1,500–1,750 m. Meanwhile, slope aspect and river proximity do not exhibit any significant influence on wild olive crown size. Wild olive trees were observed to be associated with both Juniper and Acacia but more associated with Juniper at steeper slopes and with Acacia at gentler slopes.

These findings can be regarded as an evidence of the theoretically potential landform suitable for olive plantation. As a basis for olive plantation site suitability, these factors are the essential prerequisites to be considered. However, further evaluation of social and economic factors is still important. In addition, it is obvious that site suitability is subject to the temporal dynamics of environmental variables. Therefore, effects of climate variability and changes in other environmental variables also need to be evaluated so as to plan for future wild olive investment opportunities.

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REFERENCE

[1] Al-Ghamdi Abdullah Saleh (2020 a) Classifying and Mapping of Vegetated Area in Al- Baha Region, Saudi Arabia Using Remote Sensing. I. Extent and Distribution of Ground Vegetated Cover Categories. *Indian Journal of Applied Research*, Vol. **10**, (12). 75-80.

[2] Al-Ghamdi Abdullah Saleh (2020 b) Wild Olive Tree Mapping Extent, Distribution and Basic Attributes of Wild Olive Trees in the Al-Baha Region, Saudi Arabia using Remote Sensing Technology. I. Enumerate, Extent, Distribution and Mapping. *International Journal of Science and Research,* Vol. **9**, (12), 605-614.

[3] Al-Ghamdi Abdullah Saleh (2020 c) Wild Olive Tree Mapping Extent, Distribution and Basic Attributes of Wild Olive Trees in the Al-Baha Region, Saudi Arabia using Remote Sensing Technology. II. Distribution and mapping of wild olive trees according to tree crown size *International Journal of Science and Research,* Vol. **9,** (12), 1381-1390.

[4] Al-Ghamdi Abdullah Saleh (2020 d) Wild Olive Tree Mapping Extent, Distribution and Basic Attributes of Wild Olive Trees in the Al-Baha Region, Saudi Arabia using, III. Distribution and mapping of wild olive tree according to neighbouring tree species. *International Journal of Science and Research,* Vol. **9,** (12), Pp 1531-1540

[5] Aref, I. M. and L. I. El-Juhany (2004). Planting Juniperus trees in the natural forest of Saudi Arabia: The first trial. The Second International Conference for Development and Environment. Asuit, 23–25.

[6] Baxter Peter W. J. and Hugh P Possingham (2010). Optimizing search strategies for invasive pests: Learn before you leap. *Journal of Applied Ecology*, Vol. **48** (1) 86 – 95.

[7] Besnard, G. Baradat, (2001). Genetic relationships in the olive (*Olea europaea* L. reflect multilocal selection of cultivars, *Theoretical and Applied Genetics*, Vol. **102** (2/3) 251–258.

[8] Besnard, G., and André Berville (2000) Multiple origins for Mediterranean olive (*Olea europaea* L. ssp. *europaea*) DNA polymorphisms *Comates Rendus de l'Académie des Sciences*, Vol. **323** (2) .173–181.

[9] Breton Catherine Marie, Michel Tersac and,

André Jean Bervillé (2006). Genetic diversity and gene flow between the wild olive (*oleaster, Olea europaea* L.) and the olive: Several Plio-Pleistocene refuge zones in the Mediterranean basin suggested by simple sequence repeats analysis. *Journal of Biogeography* Vol. **33**, (11). 1916–1928.

[10] Chen, I. C., Hill, J. K., Ohlemüller, R., Roy, D. B. and Thomas, C. D. (2011) Rapid Range Shifts of Species Associated with High Levels of Climate Warming. *Science,* Vol. **333**, 1024–1026.

[11] Gardner R. H., M. G. Turner, R. V. O'Neill, and S. Lavorel. (1992). Simulation of the Scale Dependent Effects of Landscape boundaries on species persistence and dispersal. The Role of Landscape Boundaries in the Management and Restoration of Changing Environments. Pp. 76–89. Chapman and Hall, New York, New York, USA.

[12] Giljohann, Katherine M., Cindy E Hauser, Nicholas S G Williams, and Joslin L Moore (2011). Optimizing invasive species control across space: Willow invasion management in the Australian Alps, *Journal of Applied Ecology,* Vol. **48,** (5) 1286–1294.

[13] Hamilton, R., K. Megown, H. Lachowski, and R. Campbell (2006). Mapping Russian olive: Using remote sensing to map an invasive tree. RSAC-0087-RPT1. U.S. Department of Agriculture Forest Service, Remote Sensing Application Center, Salt Lake City, Utah, USA.

[14] Hoegh-Guldberg O., L. Hughes., S. McIntyre, D. B. Lindenmayer, C. Parmesan H. P. Possingham, C. D. Thomas, (2008). Assisted Colonization and Rapid Climate Change, *Science* Vol. **321**, (5887), 345–346.

[15] Hoveizeh, H. (1997). Study of the vegetation cover and ecological characteristics in saline habitats of Hoor-e-Shadegan**,** *J. Res. Constr*., Vol. **34**,.27–31.

[16] Jeldes, I., Drumm, E., Schwartz, J. (2013). The low compaction grading technique on steep reclaimed slopes: Soil characterization and static slope stability. Geologic and Geotechnical Engineering, 31. 1261–1274.

[17] Jetz, W., McPherson, J. M. and Guralnick, R. P. (2012). Integrating biodiversity distribution knowledge: toward a global map of life. *Trends in Ecology and Evolution,* Vol. **27**, 151–159.

[18] Katz, Gabrielle. L., Shafroth, Patrick B. 2003. Biology, ecology and management of *Elaeagnus angustifolia* L. (Russian olive) in western North America. *Wetlands*, Vol. **23,** (4) .763–777.

[19] Khan S. M., Harper D., Page S., Ahmad H. (2011). Species and community diversity of vascular flora along environmental gradient in Naran Valley: A multivariate approach through indicator species analysis. *Pak. J. Bot.,* Vol. **43.** 2337–2346.

[20] Khan, W., Khan, S. M., Ahmad, H., Ahmad, Z., Page, S. (2016): Vegetation mapping and multivariate approach to indicator species of a forest ecosystem: A case study from the Thandiani sub Forests Division (TsFD) in the Western Himalayas. *Ecological Indicators,* Vol. **71.** 336–351.

[21] Kitayama, K. (1992). An altitudinal transect study of the vegetation on Mount Kinabalu, Borneo. *Vegetation* Vol. **102,** (2). 149–171.

[22] Li, Z., Zhu, Q. and Gold, C. (2005): Digital terrain modeling: principles and methodology. Pp. 7–9. CRC Press. Boca Raton.

[23] Lieberman, Milton Lieberman, Rodolfo Peralta and G. S. Hartshorn (1985) Mortality Patterns and Stand Turnover Rates in a Wet Tropical Forest in Costa Rica Diana. *Journal of Ecology* Vol. **73** (3). 915–924.

[24] Lumaret, R., Ouazzani, N., Michaud, H., Vivier, G., Deguilloux, M. F. and Di Giusto, F. (2004). Allozyme variation of oleaster populations (wild olive tree) (*Olea europaea* L.) in the Mediterranean Basin. *Heredity*, Vol. **92**, 343–351.

[25] Malik Z. (1986). Deptt of Bot University of Peshawar; Peshawar: Phytosociological Studies on the Vegetation of Kotli Hill, Azad Kashmir. M Phill Thesis.

[26] Margules C. R. and R. L. Pressey (2000). Systematic conservation planning. *Nature,* Vol. **405**, 243–253.

[27] Michener, C. D. (2000). The Bees of the World. The John Hopkins University Press, Baltimore and London: 1-913.

[28] Nordberg Maj-Liz and Joakim Evertson, (2004). Monitoring Change in Mountainous Dry - heath Vegetation at a Regional Scale Using Multitemporal Landsat TM Data, AMBIO A *Journal of the Human Environment,* Vol. **32** (8). 502–509.

[29] Ordóñez Lisa D. Maurice E Schweitzer, Adam D. Galinsky, and Max H. Bazerma. (2009). Goals gone wild: The systematic side effects of over-prescribing goal setting. *Academy of Management Perspectives,* Vol. **23** (1). 6–16.

[30] Price, J. P. 2004. Floristic biogeography of the Hawaiian Islands: Influences of area, environment and paleogeography. *Journal of Biogeography* Vol.*,* **31.** 487–500.

[31] Rondinini, C., Stuart, S, and Boitani, L (2005). Habitat suitability models reveal shortfall in conservation planning for African vertebrates. *Conserv. Biol.,***19.** 1488–1497.

[32] Shaheen Hamayun, Zahid Ullah, Shujaul Mulk Khan, and David M. Harper. (2012) Species

composition and community structure of western Himalayan moist temperate forests in Kashmir. *Forest Ecology and Management,* Vol. **278** (2012).138–145.

[33] Stannard, Mark, Ogle, Dan, Holzworth, Larry, Scianna, Joe, Sunleaf, Emmy. (2002). History, biology, ecology, suppression and revegetation of Russian-olive sites (*Elaeagnus angustifolia* L.). Technical Notes. Plant Materials No. 47. Boise, ID: U.S. Department of Agriculture, Natural Resources Conservation Service. 14 p. [53196]

[34] Sutherland William J, Andrew Pullin, Paul M Dolman, Teri M. Knight (2004.) The Need for Evidence-Based Conservation, Trends in *Ecology & Evolution,* Vol. **19,** (6). 305–308.

[35] Sibbett G. Steven and Louise Ferguson (2004), Olive Production Manual

[36] Thuiller, Wilfried, Sandra Lavorel, Miguel B. Araújo, Martin T. Sykes, and I. Colin Prentice (2005). Climate change threats to plant diversity in Europe. *Proceedings of the National Academy of Sciences (*PNAS), Vol. **102,** (23) . 8245– 8250.

[37] Turner M. G, R. H Gardner, and R. V O'Neill. 2001. Landscape Ecology in Theory and Practice: Pattern and Process. Springer, New York.

[38] Wickneswari R, Norwati M (1993) Genetic diversity of natural populations of *Acacia auriculiformis*. Aust J Bot 41:65–77.

[39] Yu, J., Yang, C., Liu, C., Song, X., Hu, S., Li, F., and Tang, C. (2009). Slope runoff study in situ using rainfall simulator in mountainous area of North China. *J. Geogr. Sci.,* 19, 461–470.

[40] Zelený David, Ching‐Feng Li, Milan Chytrý, (2010), Pattern of local plant species richness along a gradient of landscape topographical heterogeneity: Result of spatial mass effect or environmental shift? *Journal Ecography,* Vol. **33** (3). 578–589.