Identify the Topographic Aspect Characteristics Preferred by Wild Olive Trees in Al-Baha Region, Saudi Arabia.

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Abstract :- The aim of this research is to identify the topographical Aspect characteristics preferred by wild olive trees in Al-Baha region, This study successfully identifies the aspect responsible for wild olive distribution. Results indicate that wild olive occurrence is more dominant in the aspect facing west, which comprises fog-affected seaward-facing mountain slopes. These landscapes support dense deciduous woodland dominated by juniper and acacia. Fog increases humidity, thereby favoring wild olive growth; the influence of fog decreases in the north-east. However, there are areas in Al-Qura, Al-Mandaq, Al-Baha, and part of Bajurashi that have high occurrences of wild olive on the slopes facing north. Moreover, there is no significant difference in the crown size and neighbouring species based on difference in the aspect of landform. Therefore, the findings of the study show theoretically potential landform suitable for olive plantation. Thus, these topographical characteristics are the prerequisites for suitability of olive plantation. However, it is obvious that site suitability is subject to the temporal dynamics of environmental variables.

Key words: -Wild olive tree, Mapping, Extent, Distribution, Al-Bahah region, Remote Sensing, Crown size, Aspect, Neighbouring Species

1. Introduction

1.1 Wild olive tree

Olea oleaster, the wild olive, has been considered by various botanists a valid species and a subspecies of the *Olea europea*, the cultivated olive, which is a tree of multiple origins [8] .It now appears that it was domesticated at various places during the fourth and third millennia BCE through selections drawn from varying local populations [7].

Today, as a result of natural hybridisation and the very ancient domestication and extensive cultivation of the olive throughout the Mediterranean Basin, wild-looking feral forms of olive, called "*oleasters*", constitute a complex range of varieties, potentially ranging from feral forms to the wild olive [24].

The wild olive is a tree of the maquis shrubland, which is 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 [9].

Meanwhile, wild olive is also reported to be native to North American evergreen tree, which reaches 20-feet height with a10-to-15-foot spread. This rarely found small tree is reportedly close to extinction. Its olive-like, white fruits have a sweet flesh, which is relished by birds and other wildlife; although edible to man, it should not be eaten in high quantities. However, at the United States of America, another olive tree species known as the Russian olive (Elaeagnus angustifolia L.) is considered as an exotic invasive weed. This thorny shrub or tree originated in South eastern Europe and Western Asia and was reported by *[18] as* the plant intentionally introduced in the United States for controlling windbreaks, erosion control, and wildlife habitat and for other horticultural purposes. This tree was observed to be well adapted to semiarid and saline environments. Early in the 20th century, Russian olive escaped cultivation and spread, particularly in the large moist riparian environments in arid or semiarid regions of the western United States [33].

1.2 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, since they are time consuming, date lagged, and often too expensive. Conversely, remote sensing offers a practical and economical means to study vegetation cover changes, especially over large areas [28].

Owing to its 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 enormous efforts have been made by researchers and application specialists to delineate vegetation cover from local scale to global scale by applying remote sensing imagery.

Numerous regional or national efforts have been made to map wild olives using remote sensing. For example, a pilot project was initiated to develop a cost-effective method to map 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 in a semiarid region of the Fishlake National Forest, located in central Utah. Two scales of natural-color aerial photographs (1:4000 and 1:12 000) were evaluated as part of the project. Feature Analyst, an extension of the ArcGIS software, and several image processing software packages were used to map the invasive trees. Overall, Feature Analyst successfully located the Russian olive 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 Russian olive was actually present. However, the smaller trees were sometimes missed, and the size and groups of the trees were frequently underestimated. The map derived from 1:4000-scale photographs was slightly more accurate than the map derived from 1:12 000-scale photographs, suggesting that the smaller scale photography may be adequate for mapping the Russian olive [15].

Another research, conducted in Australia, tested the ability of remote sensing imagery to map olive groves and their attributes. This reserch aimed to (a) discriminate olives varieties and (b) detect and interpret within-field spatial variability. Using high spatial resolution (2.8 m) acquired via QuickBird multispectral imagery over Yallamundi (southeast Queensland) on 24 December, 2003, both visual interpretation and statistical (divergence) measures were employed to discriminate olive varieties. Similarly, the detection and interpretation of within-field spatial variability was conducted on enhanced false-color composite imagery and confirmed by the use of statistical methods. The results showed 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 showed little difference in the mean spectral reflectance values, indicating that the two varieties have low spectral separability.

1.3 Distribution of Wild Olive Trees in Al-Bahah Region

Information extracted from the Pleaides satellite image reveals that from 1,991 km of the study area, only 817 km (41%) indicates the presence of wild olive trees. Al-Qura, covering 270 km^2, was found to be the sub-region with the most extensive wild olive distribution, followed by Baljurashi, covering 192 km^2, and Al-Mandaq, covering 150 km^2. Automatic enumeration conducted on the Pleaides satellite image estimated 717,894 trees (with a crown diameter bigger than 1.5 m), equalling an average of 360 trees per km^2. Regarding the density of wild olive tree, Al-Mandaq district has the densest wild olive population, with 613 trees per km^2, followed by Al-Baha 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 **(see Table 1 and Figure 1**; [3].

Table 1. District-Wise Distribution of Wild Olive Tree in Al-Bahah

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-Bahah	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 shown in **Figure 1,** it can be observed that the areas with the highest distribution of wild olive are located in the northeastern Al-Mandaq, southwestern Baljurashi, and the boundary edges of Al-Baha.

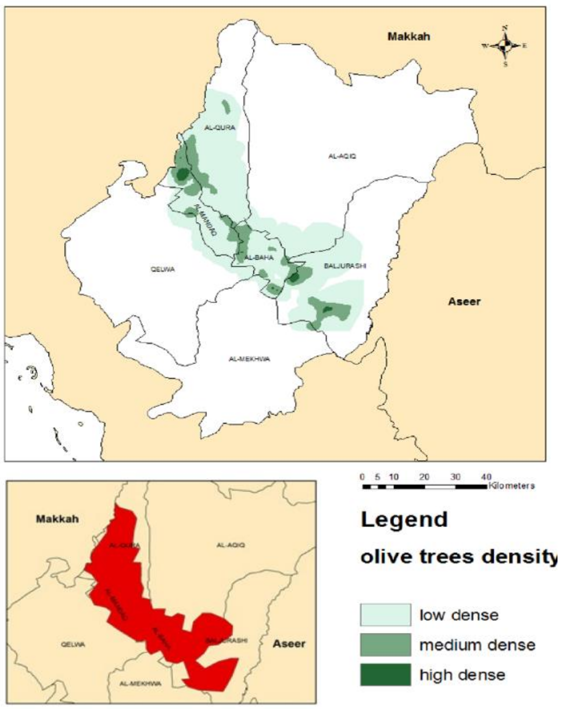


Figure 1: Density of Wild Olive Trees in Study Area

1.4 Distribution of Wild Olive Trees Based on Crown Diameter

The crown diameter of each tree was measured automatically from the Pleaides satellite imagery. Three diameter size categories were established: small (1.5–2.5 m), medium (2.5–3.5 m), and big (>3.5m). A crown diameter size smaller than 1.5 m could not be easily discriminated from the image; hence, it was not enumerated, rendering the tree counting underestimated in this project. The measurement indicated 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 big crown diameter. Moreover, it was observed that big and medium crown trees are mostly located at Al-Qura, Al-Mandaq, Al-Baha, and Baljurashi. However, Al-Mandaq, with the wildest olive trees, also has a high percentage of small crown trees (36.7% or 144,376 trees). Districts with low density of wild olive such as Al-Aqiq, Al-Mekhwa, and Al-Qelwa have more smaller crown trees **(see Table 2 and Figure 2;** [4].

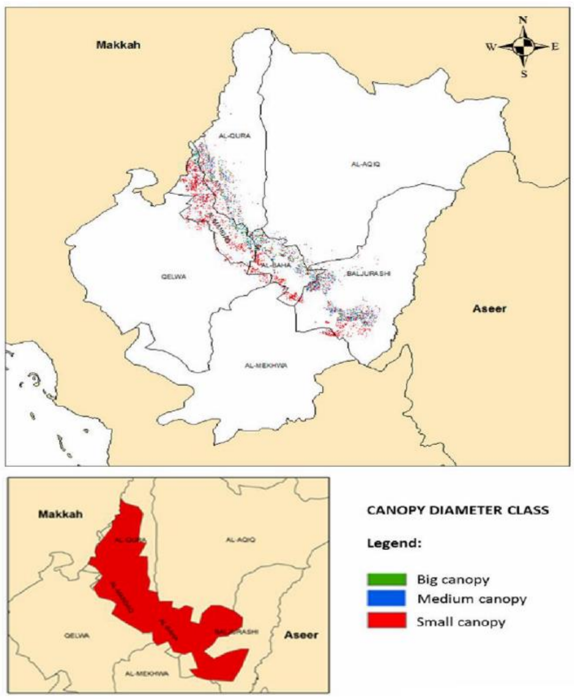


Figure 2: Distribution of Wild Olive Trees based on Crown Diameter

Table 2. District-Wise Distribution of Wild Olive Crown Diameter Size

District	Number of trees	Crown diameter size					
		Small crown (1.5–2.5m)		Medium crown (2.5–3.5m)		Big crown (> 3.5m)	
		No.	(%)	No.	(%)	No.	(%)
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-Bahah	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

1.5 Distribution of Neighbouring Species of Wild Olive Trees

In the second-phase of the project, neighbouring species were determined automatically by software ERDAS to classify and enumerate trees within 5 meters around wild olive trees by using ArcGIS software. The Pleaides satellite imagery was used to identify the wild olive trees, juniper, acacia, and other species. It was found that the main neighbouring species of the wild olive are juniper (40.2%) and acacia (36%), and other species constituted only 23.8%. juniper is the most common neighbouring species of wild olive in Al-Mandaq (32.2%) and Al-Baha (29.4%), while acacia is the main neighbouring species in Al-Baha (28.3%) and Baljurashi (29.6%). The abundance of juniper trees in Al-Mandaq and Al-Baha districts is probably attributed to its higher elevations and the rugged nature of its mountains (especially in the past before the introduction of modern roads), which has protected its forest from extensive exploitation and facilitated ease of access to the area. Meanwhile, the small size of the trees and irregular growth show that they have been cut in the past, and the branches growing from them as coppices are being considered the current trees **(Table 2 and Figure 3;** [5].

1.6 Topographical Preference of Vegetation

The study of plant communities is the best way to learn about habit, habitat, niche, and vegetation structure [20]., as well as the various interactions among the plants in an ecosystem. Variations in plant species composition along altitude and latitude is well establishment phenomenon [21]; [23]; and one of the important factors restricting plant species and community types in mountainous regions [19]. Furthermore, soil, an environmental factor, also determines plant growth, which is influenced by organisms, climate, topography, time, and parent material [16].

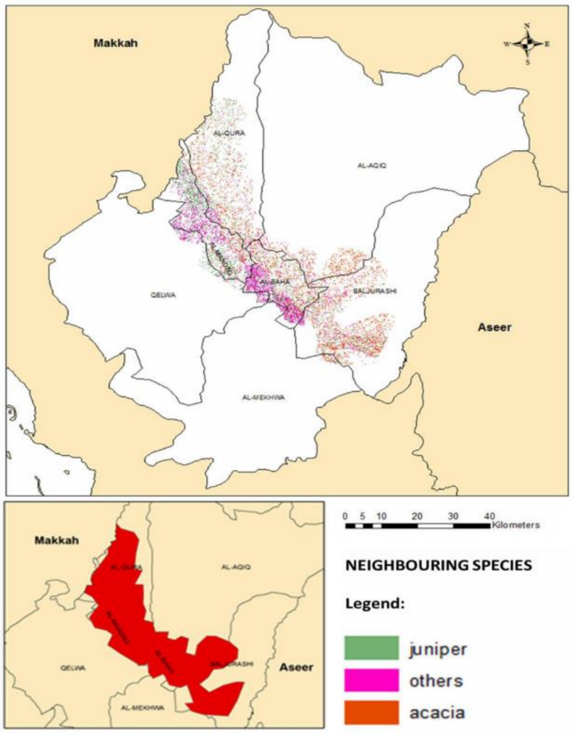


Figure 3: Distribution of Wild Olive Tree Based on Neighbouring

Table 3. District-Wise Distribution of Neighbouring Species of Wild Olive Trees

District	Number of neighbouring trees*	Number of neighbouring trees					
		Juniper		Acacia		Others	
		No.	%	No.	%	No.	%
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

* Trees surrounding wild olive within 5m radius.

Climate is affected by topography, such as slope, elevation, and aspect, and evapotranspiration and temperature; these result in rich vegetation in the northern regions as compared to southern ones [29]. Plant species are restricted to specific habitat based on origin, and they originate in a particular habitat due to the presence of optimum topographical factors (slope, elevation, aspect, and proximity to river) as well as biotic and abiotic factors; this clearly shows that plant communities and vegetation composition changes based on these factors. Topographic attributes provide significant information for the categorization of different vegetation classes.

Moreover, topographical heterogeneity strongly affects other types of landscape heterogeneity, e.g., variation in mesoclimate, natural disturbances, soil conditions, or intensity of human impact. The effect of landscape-scale topographical heterogeneity on richness of the local (microsite) species can be seen in the control of the spatial configuration of habitats surrounding the target site. In a topographically homogeneous landscape, neighbourhood usually contains the identical or similar habitats, while in a heterogeneous landscape, different habitats may be found close to the target site [37].

Observations reveal that species ranges are shifting, contracting, expanding, and fragmenting in response to global environmental changes [10]. The emergence of global-scale bioinformatic databases has provided new opportunities to analyse species occurrence data in support of conservation efforts [17]. This has paved the way for a more systematic and evidence-based conservation approach [26]; [34]. However, records of occurrence of observed species typically provide information on only a subset of sites occupied by a species [31]. Moreover, these do not provide information on sites that have not been surveyed or that may be colonised in the future following climate change [13]. or biological invasions [6]; [12]; [35].

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

1.7 Geographical and Topographical Ecology

Both geographical and topographical ecology help understand spatial patterns and process. They introduce fundamental questions on the concepts of scale, space, and place [36]. 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 system. Ultimately, geographical and topographical ecology are concerned with broad-scale environmental issues and help provide insights into the studies of the ecological systems, which operate over various scales.

For example, the ecosystem provided and maintained by bees is inherently related to geographical and topographical ecology, because of the importance of spatial scale and spatial pattern in the bees' habitat. Bee distribution is geographic in nature, since it is limited by climate, topography, soil, and vegetation type [29].

Thousands of bee species exist on our planet, and their distribution is limited by spatial variables, which creates great regional diversity in bee populations. Topographical ecology is important for understanding bee populations, since the discipline focuses on broad spatial scales and the ecological effects of the spatial patterning of ecosystems [36].

One theory that is common to topographical ecology and important to the conceptualisation of this research is the Percolation theory, which addresses the spatial pattern in random assembly. Applications of the Percolation theory have brought to light the questions regarding size, shape, and connectivity of habitats [36]. The Percolation theory has offered much insight into the nature of connectivity or the inverse fragmentation of topography [11].

Information on wild olive trees and suitable conditions for their growth in forests is 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 (GIS), local people can now trace the exact locations of wild olive trees and manage a planned future area to grow olive plantations with established topographical characteristics. It has been observed that wild olive trees are more disease resistant than normal olive trees. Once affected, diseases are more easily spread in a normal olive plantation 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.

1.8 The Study Area

According to Price, [36], the most effective way to map range of plant species in an area is by demarcating a general bioclimatic envelope in biogeographic regions where a species has been found. Hence, this study requires building a species database that includes data on the distribution of species by geographic region, major habitat type, and elevation range. Furthermore, in the first phase of the project, owing to the vastness of the area of study and to save time, cost, and energy, only areas with high potential of wild olive tree presence, indicated by high- (61.8 km^2) and medium-density vegetated areas (790.7 km^2), were included (**see Table 1 and Figure 4;** [2].

Table 4. District-Wise Distribution of Study Area

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**

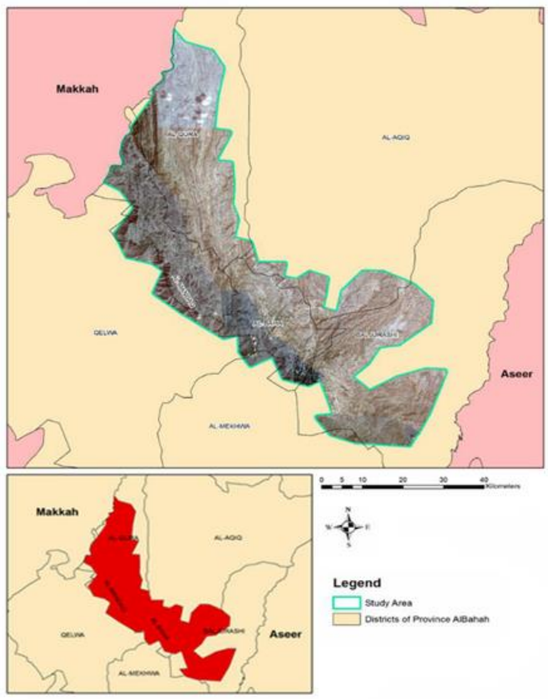


Figure 4: Satellite Image of Pleaides Showing Area of study.

Additional search areas included nearby lower–vegetation-density areas that had similar neighbourhood characteristics. This area expanded to the northern part but not to the southern part, since the southern part, i.e., Al-Mekhwa and Qelwa has a steep slope tending towards lower elevation. The overall study area, covering around 1,991 km^2 (**see Figure 4**), makes up only 18.0% of the Al-Baha region.

1.9 Objectives

This study aims to identify the topographical characteristics 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. Moreover, the study will establish knowledge about the location and preferred topographical characteristics of wild olive trees in Al Bahah region, Saudi Arabia.

2. Material and Method

The main data source for the location of wild olive trees in the study area were provided from study by Al-Ghamdi, [2]. The distribution coordinates obtained from the study were overlaid with topographical parametres derived from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data to identify the preferred topographical characteristics of wild olive trees in Al-Baha region. The following sections delineate the methods applied in this study.

2.1 Material and Data

In this study, the following geospatial software are used:

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

Following are the data used in this project:

- ASTER Global Digital Elevation Model (GDEM) – used to generate aspect map and
- Digital boundary of Al-Baha region and its districts

2.2 Method

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

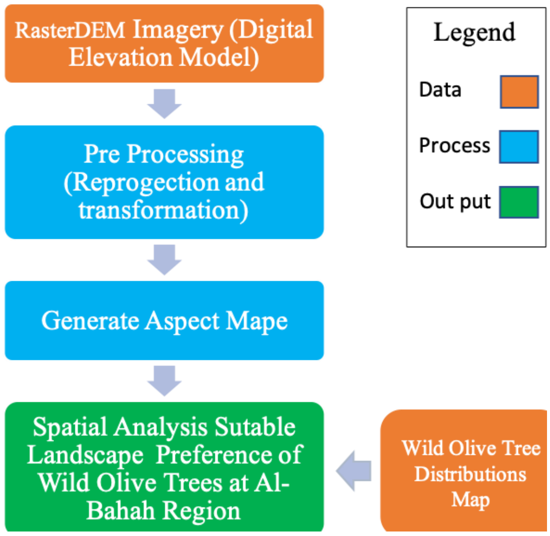


Figure 5. Activity Flowchart for Topographical Preference of Wild olive.

LANDSAT-8 Satellite images dated May 2016 were used as the primary source for extracting the data for this study and identifying the vegetated area in Al-Baha region. Upon downloading from the USGS website, the LANDSAT-8 Image was processed using Normalised Differential Vegetation Indices (NDVI) to demarcate areas with vegetation or chlorophyll. A workflow of the activities is shown in detail in the next section

2.3 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 only represent height information without any definition of the surface. Other definitions either consider the terms DEM and DTM as interchangeable or DEM as a subset of DTM, which also represents other morphological elements. Moreover, there are definitions that consider the terms DEM and DSM as interchangeable. On the Internet, definitions can be found that define DEM as a regularly spaced GRID and DTM as a three-dimensional model (TIN). All datasets 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 [22]. 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 ASTER images, which is a Japanese sensor on board the Terra satellite, which was 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 topographical isoline contours comprise 5-meter intervals that were generated in 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 DEM-generation process.

Aspect maps were also generated using ASTER data and ArcGIS tool. The aspect was generated in 9 class intervals. The resulting dataset was then used to produce a 3D aspect using ArcScene software with the 3D extension analyst. Both data were reclassified before being converted 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.

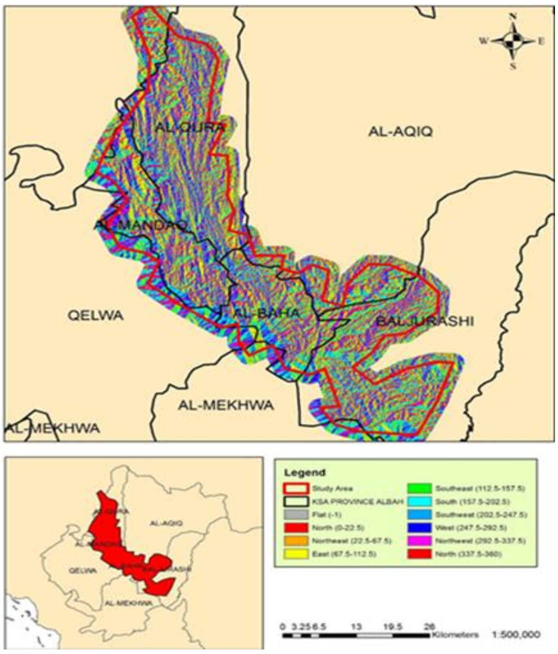
2.4 Topographic Characteristic Measurement

Many topographic components are considered to have an effect on the distribution of wild olive tree. In this study, we study aspect topographic component. The wild olive characteristics investigated to assess their association with the topographic/landform features are crown canopy size, neighbouring species, and distribution. These characteristics were overlaid with the aspect topographical components to identify their association. Details of this topographic categorization are outlined as follows: Aspect maps were generated from DEM by ArcGIS software and were divided into following nine direction classes:

1. Flat;
2. North;
3. North East;
4. East;
5. South East;
6. South;
7. South West;
8. West; and
9. North West.

3. Result

Aspect criteria contributed to the formulation of a habitat suitability index for wild olive trees. Topographical layers were categorised into several classes to quantify their variation. Subsequently, these layers were overlaid with the wild olive distribution layer to analyse the pattern. The aspect direction was generated using a Raster World DEM from the United States Geological Survey (USGS). Using ArcScene modules from ArcGIS, nine classes of elevation were categorised. These aspect classes were then displayed and overlaid with the wild olive tree-point layer to determine the intersection point (**see Figures 6 and 7**).



Figures 6: Aspect Map of Study Area

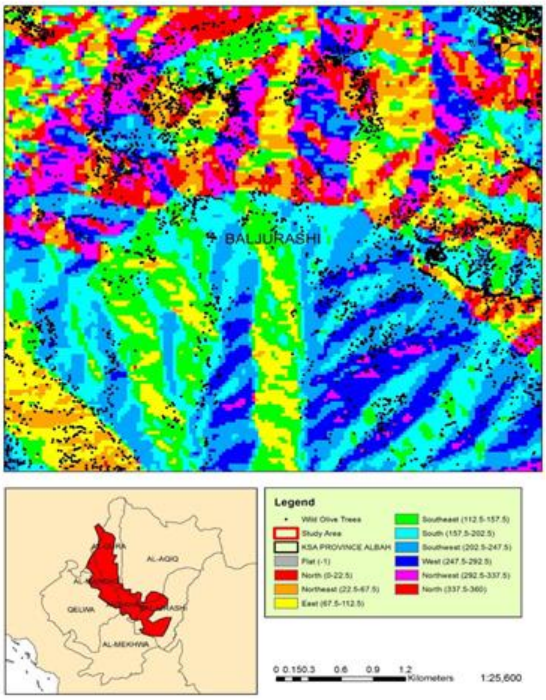


Figure 7: Close-up View of Wild Olive Distribution on Aspect Map

It was found that there are higher number of wild olive trees (47.2%) at the aspects facing West (including South West, West and North West) compared to those facing East (33.5%; including North East, East, and South East**; see Table 5**)

Aspect	Direction	Number of olive tree	%
1	Flat	113	0.0
2	North	78,893	11.0
3	North East	104,061	14.5
4	East	79,402	11.1
5	South East	57,012	7.9
6	South	59,694	8.3
7	South West	101,839	14.2
8	West	139,812	19.5
9	North West	97,068	13.5
	Total	**717,894**	100.0

Table 5. Number of Wild Olive Tree Against Aspect

3.1 District-Wise Distribution of Wild Olive Based on Aspect

The result shows that the aspect preference of wild olive trees varies with districts and seems to be related with topographic orientation. Al-Qura, Al-Mandaq, and Al-Baha, which neighbour each other, share almost the same pattern, where wild olive trees are found mostly at the aspects facing West (including South West, West, and North-West). Meanwhile, wild olives in Bajurashi are found mostly (88.6%) at North, East (including East, North East, and South East), and South (including South East, South, and South West) aspects. Unlike Al-Mandaq, Al-Qura, and Al-Baha, a smaller number of wild olives were observed in the West aspect of Bajurashi. This was probably due to the different district orientation. Meanwhile, Al-Mekhwa and its neighbouring district Qelwa have higher number of (83.6%) wild olive trees at aspects facing South (including South East and South) and West (including South West, West, and North West). Moreover, wild olive trees were found to be evenly distributed in Al-Aqiq at all the aspects **(see Table 6)**.

3.2 Distribution of Neighbouring Trees of Wild Olive Based on Aspect

The neighbouring species surrounding wild olive show no variation in the aspect pattern between small, medium, and big crown sizes. All the species are mostly found at the North (including North and North East) and West (including South West, West, and North West) aspects, except for acacia, which is also abundant at the East aspect (see **Table 8**

3.3 Distribution of Wild Olive Crown Diameter Size Based on Aspect

The result shows that there is no variation in the aspect pattern between small, medium, and big crown diameter sizes. Wild olive trees are evenly present at all the aspects, except at the South East and South aspects. This indicates that the aspect does not affect crown size of wild olive tree **(see Table 7).** The histogram pattern in **Figure 8** shows the uniformity of crown size at each aspect.

The histogram pattern in **Figure 9** shows the uniform distribution of wild olive's neighbouring species at each aspect.

Table 6. District-Wise Distribution of Wild olive Based on Aspect

Olive density											
distracts	No.	Aspect									total
		Flat	North	North East	East	South East	South	South West	West	North West	
Al-Qura	No.	22	12,142	14,913	14,006	7004	7714	19,277	34,726	20,099	**129903**
	%	0.02	9.35	11.48	10.78	5.39	5.94	14.84	26.73	15.47	100.00
Al-Mandaq	No.	20	27,271	38,447	18,196	6512	7592	25,551	50,282	34,163	**208034**
	%	0.01	13.11	18.48	8.75	3.13	3.65	12.28	24.17	16.42	100.00
Al-Baha	No.	5	18,101	20,904	18,039	13,285	13,349	24,711	30,202	23,206	**161802**
	%	0.00	11.19	12.92	11.15	8.21	8.25	15.27	18.67	14.34	100.00
Bajurashi	No.	64	19,244	27,167	26,602	26,586	26,195	23,586	15,602	13,755	**178801**
	%	0.04	10.76	15.19	14.88	14.87	14.65	13.19	8.73	7.69	100.00
Qelwa	No.	0	1149	1313	1253	1689	2560	6084	6272	3750	**24070**
	%	0.00	4.77	5.45	5.21	7.02	10.64	25.28	26.06	15.58	100.00
Al-Mekhwah	No.	0	547	801	891	1505	1820	2192	2379	1716	**11851**
	%	0.00	4.62	6.76	7.52	12.70	15.36	18.50	20.07	14.48	100.00
Al-Aqiq	No.	2	409	546	415	431	464	438	349	379	**3433**
	%	0.06	11.91	15.90	12.09	12.55	13.52	12.76	10.17	11.04	100.00
Total	No.	**113**	**78863**	**104091**	**79402**	**57012**	**59694**	**101839**	**139812**	**19.48**	**717894**
	%	**0.02**	**10.99**	**14.50**	**11.06**	**7.94**	**8.32**	**14.19**	**97068**	**13.52**	**100.00**

* Yellow-highlighted cells represent highest distribution of wild olive trees (> 10%)

Table 8. Distribution of Neighbouring Species of Wild Olive Based on Aspect

Aspect	No. of neighbouring trees						Total	
	Juniper		Acacia		Other			
	No.	%	No.	%	No.	%	No.	%
Flat	56	0.01	82	0.02	4	0.02	**142**	**0.02**
North	54,553	12.25	48,503	11.17	2587	11.55	**105643**	**11.71**
North East	65,945	14.80	59,493	13.70	2743	12.25	**128181**	**14.21**
East	38,641	8.67	44,329	10.21	1430	6.39	**84400**	**9.36**
South East	24,981	5.61	35,654	8.21	1037	4.63	**61672**	**6.84**
South	32,911	7.39	42,700	9.83	1390	6.21	**77001**	**8.54**
South West	66,391	14.90	65,198	15.02	3151	14.07	**134740**	**14.94**
West	92,645	20.80	78,700	18.13	5511	24.61	**176856**	**19.61**
North West	69,377	15.57	59,516	13.71	4542	20.28	**133435**	**14.79**
total	**445500**	100.00	**434175**	100.00	**22395**	100.00	**902070**	**100.00**

*Yellow-highlighted cells represent highest distribution of wild olive trees (> 10%)

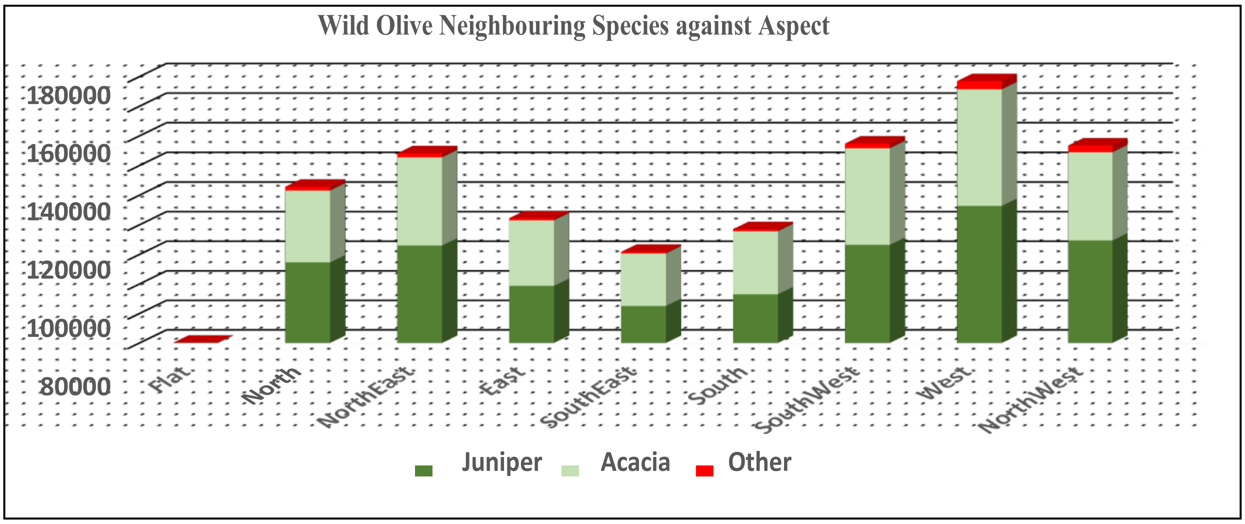


Figure9: Distribution of Neighbouring Species of Wild Olive Based on Aspect

4. Discussion

Species ranges are shifting, contracting, expanding, and fragmenting in response to global and local environmental changes and human interferences with natural topography or landscapes [10].

Understanding the natural topography where species are abundant indicates the preference or suitability of that species. This research and development of the wild olive geoinformatic database of local Al-Bahah region has provided new opportunities to analyse wild olive occurrence data in support of conservation efforts and allowed for a more systematic and evidence-based conservation approach. In this study, species occurrence, which typically provided information on areas previously demarcated as having medium–high vegetation density, was recorded during the first phase, while the number of trees and location were acquired during the second phase.

In this study, the topography and landform preference of wild olive trees was investigated to gain a better understanding of the occurrence and morphology of this tree species in the study area.

Results indicate that the wild olives occur more at the aspect facing West (including South West, West, and North West), which comprises the fog-affected seaward-facing mountain slopes, occurring in the mountains above Aqabat Hizna and around Baljurashi. These landscapes support dense deciduous woodland dominated by juniper and acacia. Fog increases humidity, favouring wild olive's growth. According to Al-Aklabi, [1] as the influence of fog decreases further North East, forest and woodland are replaced by sparse woodland or shrubland dominated by A. asak, A. tortilis, and A. ehrenbergi ana. Beyond this, the vegetation gets sparser and finally gives way to open semi-desert. However, there are areas in Al-Qura, Al-Mandaq, Al-Baha, and part of Bajurashi that have high occurrences of wild olive at the slopes facing north (including North East). However, no significant difference is observed in the crown size and neighbouring species with the difference in aspect.

Besides these topographical factors, olive trees 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 holding capacity. Sandier soils do not have good nutrient or water holding capacity. Heavier clays often do not have adequate aeration for root growth and do not drain well. Olive trees are shallow rooted and do not require very deep soils to produce well [32].

Furthermore, according to Sibbett [32] Soils having an unstratified structure of 4 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, therefore, should be ripped. Olives tolerate soils of varying chemical quality. They grow well on moderately acid (pH>5) or moderately basic (pH< 8.5) soils. However, 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.

5. Conclusion

This study successfully identified the preferred topographic and landform characteristics of wild olives. The findings depicted that wild olive trees prefer topography or landform that have aspect facing West and are in proximity of a river (< 600 m). Moreover, it was found that wild olive trees have bigger crown at more gentle slopes, ranging 0–25°. However, aspect does not exhibit any significant influence on crown size of wild olive. In addition, wild olive trees were observed to be associated with both juniper and acacia.

These findings show theoretically potential landform suitable for olive plantation. For a site to be suitable for olive plantation, these factors are the prerequisites. 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 to plan for future investment opportunities in wild olive.

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