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# Integrate Terrain Variables and Rapid Eye Satellite in Vegetation Indices, for Identifying Forest Cover Area and Density: A Case Study in Mountainous Iraqi Kurdistan Region (IKR)

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## ABSTRACT

The Topographic Wetness Index (TWI) measures of the relative wetness or dryness of a given area of land based on its topography. This index is frequently used to evaluate hydrology and ecology studies. This study examined the association between TWI and vegetation distribution using a number of remote sensing techniques. The study was identified patterns in the data and based statistical analyses to assess the strength and significance of the relationship between TWI and vegetation statues. The result is shown this forest cover patterns are influenced by various environmental factors, including topography, and moisture levels. It is also involved comparing vegetation cover in areas with different TWI values or analyzing the relationship between TWI and other topographical variables such as slope, aspect, and elevation. A significant vegetation variation was found between slope aspects in vegetation distribution. It was revealed that (78%) of a Normalized Difference Vegetation Index (NDVI) was affected by together aspects and TWI, which may be due to a significant association between (NDVI), but this parameter was also highly influenced by slope and DEM because (17%) of the vegetation cover was obtained within these two factors.



*Keywords: Density, Forest cover, Vegetation distribution, Vegetation indices, Remote sensing (RS)*

## 1. Introduction

Landscape ecosystem is defined in several works of literature as the study of the relationships between progression and phenomena in the landscape consisting of plant communities, animals, and humans[1], whereas other researchers defined it as the study of the composition, function and change in a diverse land spot collected of an interconnected ecological system[2]. For the present generation, primarily those living in developed countries, interaction with the landscape may be fluffier, but they are just as important economically and culturally[3]. Topographic features, including aspect, elevation, slope, and site, considerably effect vegetation distribution and characteristics as they adapt to the local climate[4]. Because of the different solar radiation obtained[5], the distinctive vegetation cover and associated with environments between slopes, aspects such as north or south aspects, and pole-facing slopes, which is a worldwide occurrence at the middle of the angular distance of a place north or south of the Earth's equator [6,7]. In general, south-facing slopes are described as dry and hot, with low soil nutrients and harsh eroded soil, and are inhabited by xeric vegetation[8], whereas north-facing slopes are cold and wet, with rich organic matter soil, and are linked with mesic vegetation.

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Another study stated that based on the data region, an abundance of the valuable assets of spatial data from the Internet has materialized as a method for its rapid dissemination in conjunction with global positioning systems (GPS) tools, and satellite pictures[9]. However, in the analysis section, computer processing speeds have increased [10]. and a significant range of software tools for operating and analyzing geographical data is recognized. Geographic Information Systems (GIS) have developed to benefit from substantially quicker processing speeds[9]. There are increasingly difficult questions in the landscape ecosystem that need to be dealt with, but the outcome is a cooperation between additional data and quicker computers for processing it, thus bringing difficulty into existence this chance. Additionally, there are an observation that with advanced technologies, environmental problems become more pervasive[11]. This identifies the fact that conservation processes must be applied over wide spatial scales rather than being undertaken in a small number of areas.

Vegetation indices (VI) are defined as the calculation of two or more bands linked to the spectral features typically belonging to vegetation and that is extensively used for the classification and

distribution of vegetation, radiometric biophysical derivation and parameters of vegetation composition[12]. It was believed that when (VI) are stated as band ratios, such as in normalized difference vegetation index (NDVI) and ratio-vegetation-index (RVI), the topographic variables impacts can be removed[13]. Surface vegetation is an important part of terrestrial ecosystems which can supply an association linking of the material cycles and energy flow of the soil and hydrosphere. It takes part a significant function in the terrestrial carbon balance and climate change regulation [14]. The influence of the strengthening of global climate change owing to human being behaviors on terrestrial ecosystem in current years cannot be underestimating[15]. for that reason, it is of enormous scientific importance and practical significance to conduct monitoring dynamic, of continuing and analysis of the normalized vegetation index (NDVI) to find out the factors controlling the changes in vegetation manners [15]. One preference to monitor vegetation changes for a long period of time and with a large spatial exposure is made available by remote sensing[16]. In addition, NDVI has been applied to monitor diverse aspects such as global warming and changes in land cover and land use, condition and health of crops and the degree of desertification[17].

In many studies applying remote sensing data are given attention to horizontal style, with a few studies focused on the impact of elevation, slope, and aspects on the vertical vegetation distribution and pattern in Erbil city's mountain regions. Therefore, the present study aims to investigate the relationship between the using of Topographic Wetness Index (TWI) and biological procedures together with forest site quality, and vegetation distribution in the Galala sub-district. The Likelihood Classification (MLC) in analyzing Landsat images is a good indicator that can be used in order to find a support and extraction important information as regards lime-rich areas in Garmian District[18]. In addition, Remote Sensing with GIS for Mapping Urban Change guide is a great technique with different resolutions[19]. The finding of the present study may help in the monitoring and management of forest resources in the region, which is an important for preserving biodiversity, mitigating climate change, and supporting local communities. This study investigates the influence of topographic factors such as aspect, elevation, slope, and the Topographic Wetness Index (TWI) on vegetation distribution in the Galala sub-district of Kurdistan region-Iraqi. While previous studies examined vegetation distribution, this research specifically focuses' on the role of these topographic variables in shaping the distribution of forests and vegetation. This integration of technology and data sources enhances the precision and comprehensiveness of the analysis. The research identifies that both aspect and TWI significantly influence NDVI, which is an important indicator of vegetation health. Furthermore, it highlights the significant impact of slope and DEM on vegetation cover. This insight into the relative importance of these factors contributes to a better understanding of the mechanisms driving vegetation distribution.

## 2. Materials and methods

### 2.1. Experimental site

Galala is a sub-district in Kurdistan Region in Iraq, it is nearly 9 km far from west of Choman and it is also located in the central Balkayate region. Precipitation begins in October and lasts until the end of April. As indicated in (Figure 1), the most precipitation was recorded in March (138 mm), while the least precipitation was recorded in October (64 mm). The maximum and minimum temperature ranged from 4°C to 32 °C, respectively. The height above sea level of the study location ranges from the highest of 3000 m to the lowest of 700 m (Figure 2).

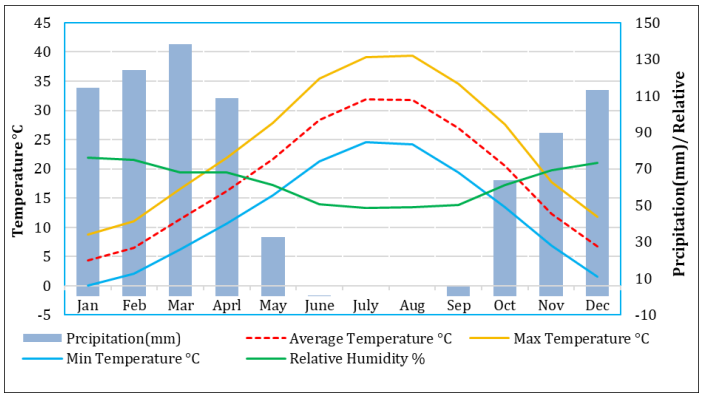


**Figure 1:** Meteorological data of the study location.

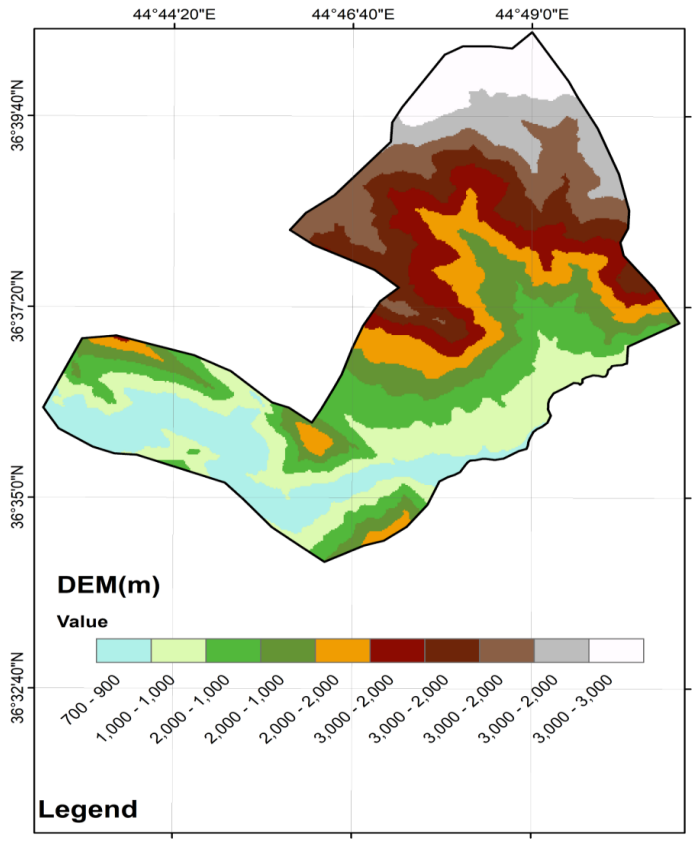


**Figure 2:** Study location digital elevation model (DEM).

### 2.2. Vegetation Index (VI)

Using the ERDAS ER-Mapper program, the ETM+ images were utilized to obtain vegetation spectral indices from the ETM+ images to emphasize the vegetated distribution position in the study area. The (NDVI) was used as a spectral vegetation index in this study as recognized [20].

## 2.3. Normalized Difference Vegetation Index (NDVI)

The NDVI was calculated using a Landsat ETM+ image with two bands, Red (R) and the near-infrared band (NIR). The first reorganization of this[21], as well as the NDVI calculated[20], which is stated below.

$$\textbf{NDVI} = (NIR - R) / (NIR+R) \quad (1)$$

Whereas; NIR= the reflectance of Near-Infrared band (760-900) nm. Red= the reflectance of Red band (630-690) nm.

## 2.4. Digital Elevation Model (DEM)

The Digital Elevation Model (DEM) is defined as the digital representation of the land surface elevation regarding any reference data [22]. The elevation values of the sites were extracted using the DEM raster dataset of the research area and the ERDAS Imagine platform. Furthermore, ArcGIS 10.8.1 was used to process and analyze the DEM datum to construct the maps of the aspect ratio, slope, and elevation contour[20].

## 2.5. Topographic Wetness Index (TWI) calculation

Topographic Wetness Index (TWI) is calculated by using a digital elevation model raster layer in Geographical Information System (GIS) software such as ArcGIS or QGIS, followed by several tools that were used within the program to calculate NDVI, DEM, forest classification, the slope, flow direction and accumulation and finally TWI using simple equations. The above parameters are computed in different ways depending on the TWI modification. The number of samples was equivalent for distinct classes of TWI values; for example, greater TWI values were sampled more frequently than their rate in the landscape. A GPS tool was used to locate the plots in the field. This study did not include marshland distribution exclusive of trees, lakes, and streams.

$$\textbf{TWI}= \ln \frac{\alpha}{Tan ß+C} \quad (2)$$

$$\textbf{SPI}= \alpha * tan ß \quad (3)$$

Where, TWI= Topographic Wetness Index, SPI= Stream Power Index, α= Flow accumulation, ß=Slope, and C= 0.001

## 2.6. Statistical analysis

The contradictory TWI datum and the observed variables forest classification, aspect, slope, elevation) in the study site were examined using Spearman's rank correlation. The results were calculated in two ways: first, the highest correlation coefficient between each measured variable and the parameter values was identified. After that, the variability of the highest correlation coefficient within each parameter was examined.

## 3. Results and Discussion

Figure 3 illustrates the effect of the factors calculated on (NDVI). It was discovered that (78%) of (NDVI) was strongly influenced by both aspect and TWI, which may be due to a significant association between (NDVI), but this parameter was also highly influenced by slope, and DEM, because (17%) of the vegetation cover was obtained with in these two factors. In the research area, a limited number of waypoints were collected.The relationship between (NDVI) readings and TWI, Slope, SPI, and DEM is described by a correlation matrix. It was discovered that parameters such as TWI and aspect have a 48% effect on NDVI and the distribution of forest density. Table 1 clearly shows that (17,38%) will be affected by DEM and slope, and 31,03% will be affected by SPI, DEM, and slope. The data revealed a positive correlation between NDVI and TWI (r = 0.27) alongside a significant negative correlation between NDVI and slope (r = -0.15). This recommends that as slope steepens, there's a decline in forest distribution and density, even though the relationship in climatic conditions.

**Table 1:** Pearson correlation between TWI and measured parameters. Values in bold are different from 0 with a significance level alpha=0.05.

| | TWI | SPI | Slope | Aspect | DEM | NDVI |
|---|---|---|---|---|---|---|
| TWI | | 0.217 | -0.634 | 0.067 | -0.182 | 0.267 |
| SPI | 0.217 | | -0.111 | -0.013 | -0.027 | 0.060 |
| Slope | -0.634 | -0.111 | | -0.067 | 0.170 | -0.105 |
| Aspect | 0.067 | -0.013 | -0.067 | | -0.011 | -0.040 |
| DEM | -0.182 | -0.027 | 0.170 | -0.011 | | -0.072 |
| NDVI | 0.267 | 0.060 | -0.105 | -0.040 | -0.072 | |

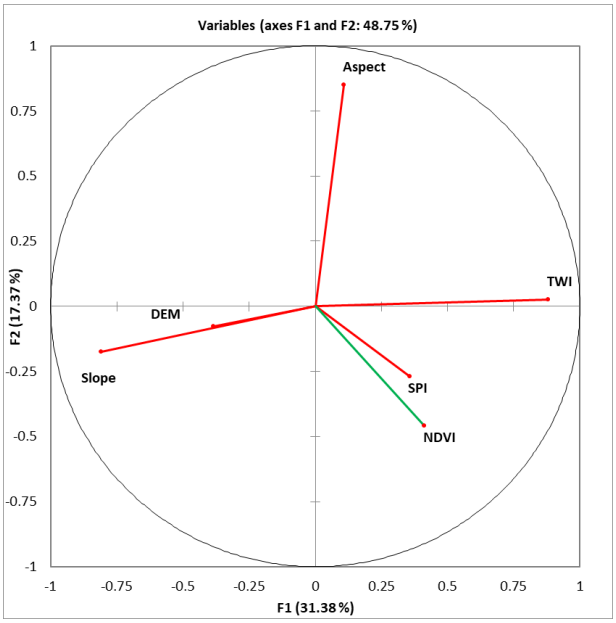


**Figure 3:** Biplots showing associations between TWI and SPI, Slope, Aspect, DEM, and NDVI in the experiment based on the mean of which year for how many data points.

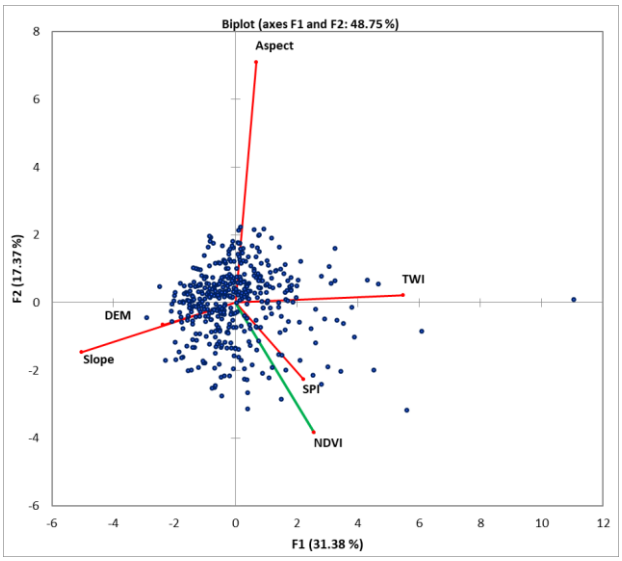


**Figure 4:** Biplots showing associations between TWI and SPI, Slope, Aspect, DEM, and NDVI in the experiment based on the mean of which year for how many data points (Number of points = 400).

## 3.1. Influence of Topographic Factors on NDVI

Figure 3 is illustrated that 78% of NDVI is strongly influenced by both aspects and TWI. It is suggested that a significant association between above measured factors and the health and density of vegetation in the study area. This finding highlights the importance of considering both aspects and TWI when analyzing vegetation distribution. The study also identifies that 17% of the variation in vegetation cover is attributed to slope and DEM. This implies that the local topography, as represented by slope and DEM, plays a substantial role in shaping vegetation patterns. These results emphasize the need to integrate topographic variables into vegetation distribution models.

## 3.2. Correlation Matrix Insights

The correlation matrix (Table 1) provides additional insights into the relationship between NDVI and various topographic factors. Notably, TWI and aspect are shown to have a 48% combined effect on NDVI and forest density. This underscores the significance of considering both of these factors in vegetation studies.

A significant positive correlation (r = 0.27) between NDVI and TWI suggests that areas with higher topographic wetness tend to exhibit healthier vegetation. This information can be crucial for identifying regions with optimal conditions for vegetation growth and potential for biodiversity conservation.

Conversely, a significant negative correlation was observed (r = -0.15) between NDVI and slope indicates that as slope steepness increases, thus forest distribution and density decrease. The finding results implies that the terrain's inclination plays a critical role in shaping vegetation patterns.

In terms of the effect of aspects, there was non significant correlation with forest density in the southern-east aspects, which means that no significant data showing a major change in forest area and tree density in the studied area. Furthermore, a negative datum (r = -0.18) was observed between (TWI) and (DEM), implying that as elevation above sea level increased, soil moisture content (SMC) decreased significantly as compared to forests in riparian areas and valleys (Figure 5). The two key parameters determining forest density in a research location, according to the data collected, are designated slope and TWI. It was observed that a significant negative correlation (r=-0.63) was obatined from above parameters, involving that 63% of the soil moisture content decreased in topography will return to both slope and (TWI) (Table 1).

To determine the best location for developing a protected area with a higher level of biodiversity, factors such as (TWI, DEM, and slope) must be calculated. As a result, places with limited diversity can be identified using investigated characteristics with studied factors. The vegetation attribute in the study area ranged between the elevations of 700 and above 2700 m the above sea level, as shown in (Figure 4,5 and 6). Various observations can be made regarding how altitude influences the growth of trees in a mountain area. First and foremost, it is obvious that altitude is the main determinant of vegetation development. Another study stated that, after classifying the slopes, NDVI zonal statistics were calculated, estimating the mean and standard deviation for both slope orientations [23]. Regardless of the seasonality, the study found that south-facing slopes had lower NDVI values than north-facing slopes, and the dry season had lower vegetation index values than the rainy season. For the timeframe under consideration, they were able to identified the 2007 exceptional dry year signal.

## 3.3. Effect of Aspect and Elevation

The research give emphasis to that specific aspects, for the most part those facing south and east, be deficient in significant correlations with forest density. This suggests that vegetation in these areas may be less influenced by aspects and exhibit more consistent forest cover.A negative correlation (r = -0.18) between

TWI and DEM means that as elevation above sea level increases, soil moisture content decreases significantly. It is indicates that areas at higher elevations, such as ridges and slopes, may have drier soil than compared to riparian areas and valleys. This finding has implications for vegetation management ,and conservation in mountainous regions.

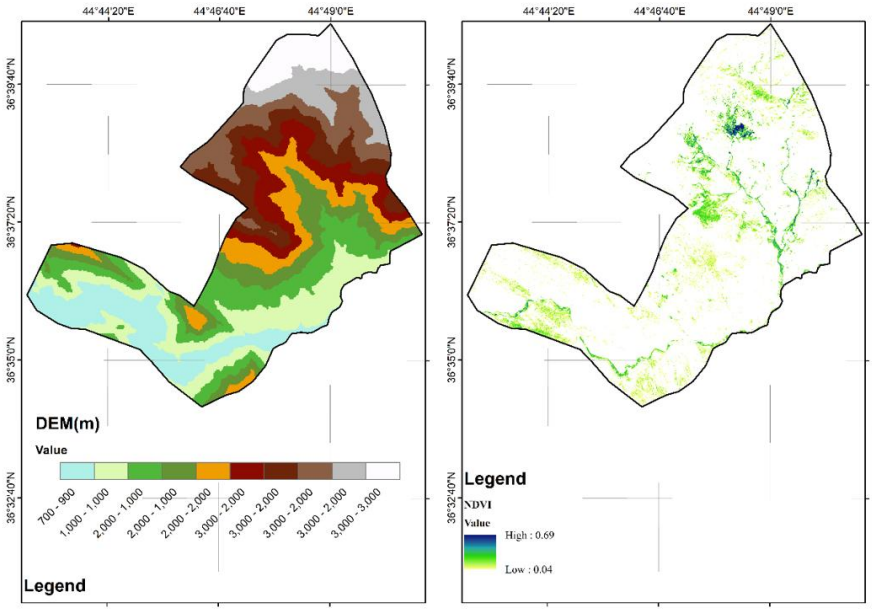


**Figure 5:** Effect of DEM on NDVI distribution.

An application of Nonmetric multidimensional scaling function for vegetation distribution was conducted in the Min River in China and thoroughly studied how the slope aspect affects vegetation characteristics [24]. In general, south-facing slopes had lower tree height, above-ground tree biomass (AGB) and a lower variety of species than north-facing slopes. Accordingly, another study stated that the throughout providing the opportunity for barrier slopes in opposition to the potential of climate change large differences in water systems over small spatial sizes may play a significant role in maintaining high species richness [4].

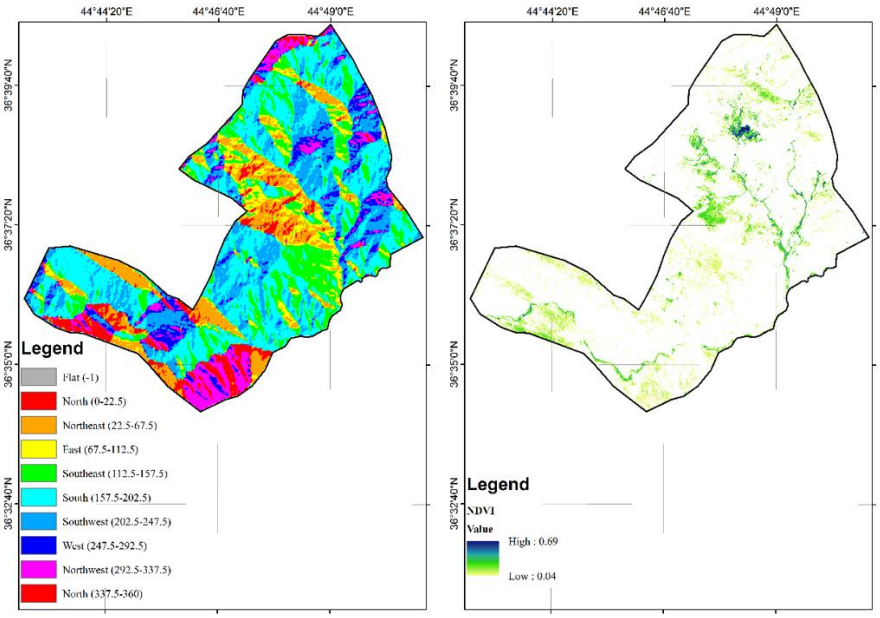


**Figure 6:** Effect of aspect on NDVI distribution.

Remote sensing data was used to investigate the relationship between elevation, aspect and vegetation attributes in Darab Mountain, Iran and found a positive correlation between increases in elevation, and aspect with both vegetation growth and vegetation indices. [25]. It was discovered that the most significant increase in vegetation distribution was observed in sites towards the Northwest aspect and that elevations ranged between 1500 and 3000 above sea level showed a significant

increase in vegetation growth because the NDVI was higher in the study. The current study's finding was consistent with the previous studies. With the distribution of small trees, forest density diminishes in areas above (2700 m). A transition zone between two distinct ecological systems, in this case, an alpine forest and open mountain areas, is defined as the borders of each forest margin [26]. Several ecologists identified the struggle region as the area above the forest borders when trees extend to a mature height of at least 3 meters.

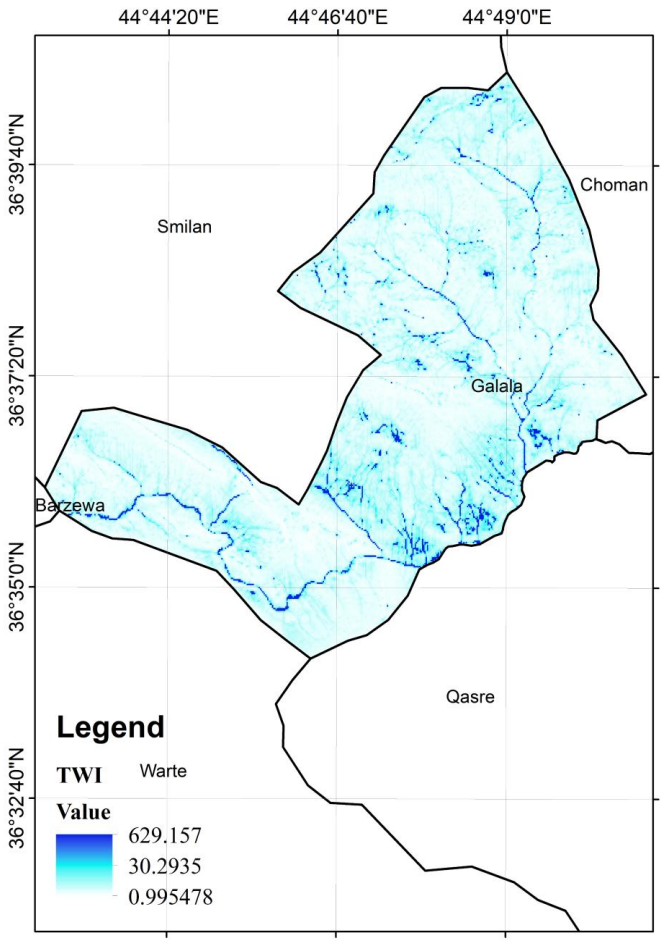


**Figure 7:** Effect of TWI on NDVI distribution.

In a region like Northern America, this area is normally the point where closed canopy forest stops. Under timber lines or forest boundaries, the natural growth of trees is typically sudden; above these boundaries, the growth of isolated trees may occur until the edge of the tree ranges. These trees offer shelter to newly sprouted seedlings, often in elongated ovals that shield them from the widespread winds. In addition, The temperature drop quickly in this region which is more than (2700 m) ,when trees on the windward side may be gradually killed through cold winter winds. New trees establish root on the sheltered side or as krummholz, stunted trees would be shaped by winds near mountain tree lines [26].

## 3.4. Influence of Topographic Factors on NDVI

It is shown from Figure 3 that 78% of NDVI is strongly influenced by both aspects and TWI. This suggests a significant association between these factors and the health and density of vegetation in the study area. This finding highlights the importance of considering both aspects and TWI when analyzing vegetation distribution.The study also identifies that 17% of the variation in vegetation cover is attributed to slope and DEM. It is found that the local topography, as represented by slope and DEM, plays a substantial role in shaping vegetation patterns. These results emphasize the need to integrate topographic variables into vegetation distribution models.

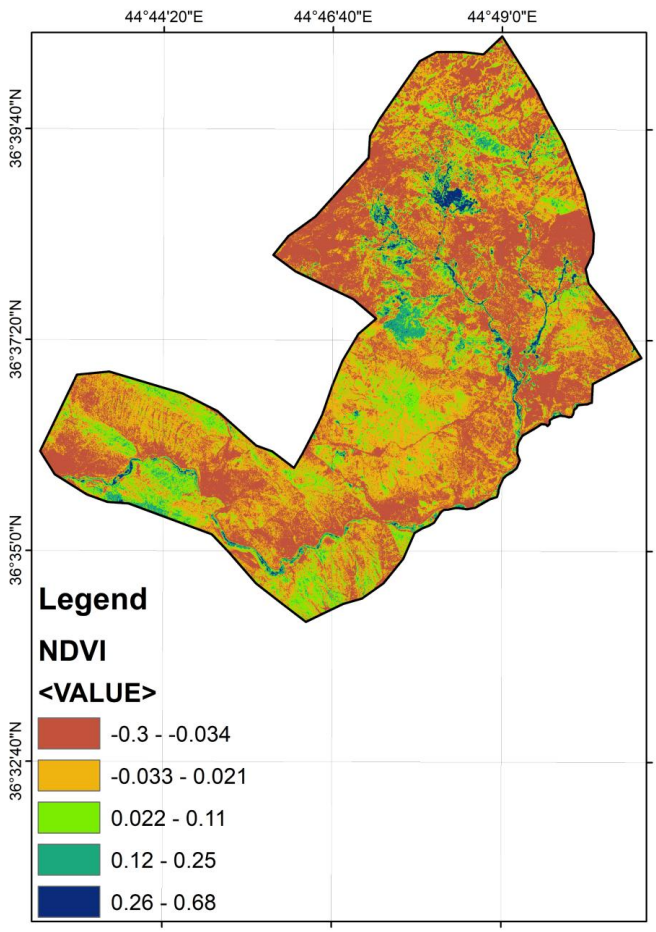


**Figure 8:** NDVI distribution of the study area.

## 3.5. Altitude and Vegetation Growth

The study underscores the strong influence of altitude on vegetation development. Altitude is a primary determinant of vegetation distribution in the mountainous area under study. The findings align with previous research that indicates south-facing slopes tend to have lower vegetation indices, especially during dry seasons. The measured observation highlights the importance of slope aspects in understanding vegetation characteristics. The study's consistency with prior research on the relationship between elevation, aspect, and vegetation growth reinforces the validity of its findings.

## 3.6. Transition Zone and Tree Growth

The identification of a transition zone between alpine forests and open mountain areas is a significant contribution. This zone is

where the natural growth of trees abruptly stops due to harsh environmental conditions, particularly cold winter winds and temperature drops at higher elevations. The ecological implication of single trees, attributed to as krummholz, in offering protection to newly regenerated tree seedlings within these transitional areas is a captivating observation. This phenomenon is important for understanding the dynamics of high-altitude ecosystems.

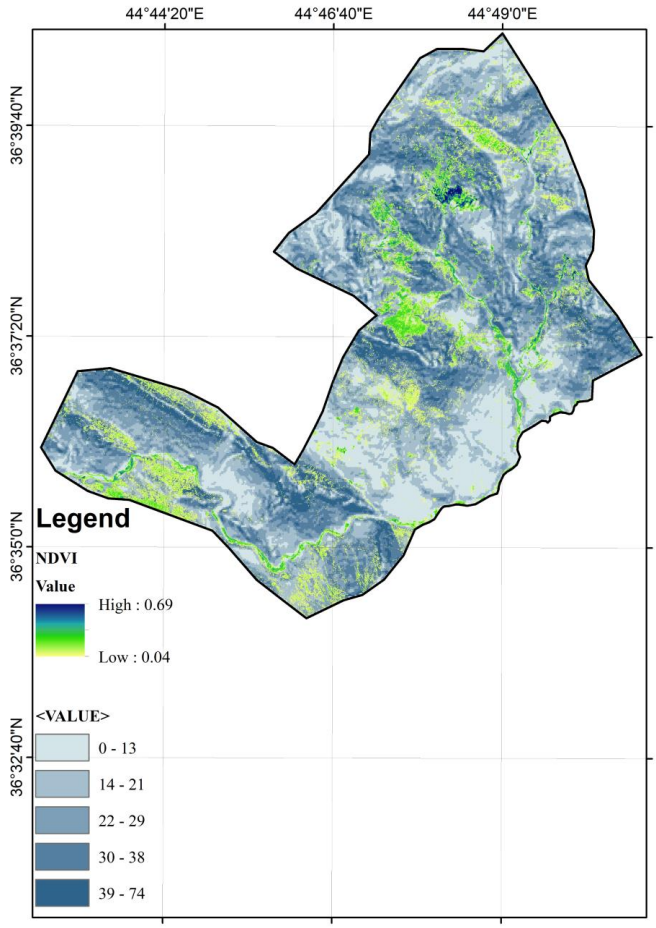


**Figure 9:** Effect of Slop on NDVI distribution.

## Conclusion

The local climate's adaptations are greatly controlled vegetation distribution throughout topographic factor such as aspect, elevation, slope, and site. The current study examined the relationship between the Topographic Wetness Index (TWI) and biological procedures, as well as forest site quality and vegetation distribution in the Galala sub-district. It was discovered that (78%) of the NDVI was influenced by both aspects, and TWI, which could be due to a significant correlation between (NDVI). Nevertheless, this parameter was also significantly influenced by both slope and DEM because (17%) of the vegetation cover was gained within these two measured parameters. Since there was less evapo-transpiration on the shaded face as opposed to the sunny face, vegetation distribution was better than all over a wider elevation range.

In conclusion, the study provides a comprehensive analysis of the influence of topographic factors on vegetation distribution in the Galala sub-district. The findings emphasize the importance of considering aspects, TWI, slope, and elevation in vegetation studies. This knowledge can inform conservation efforts, biodiversity management, and climate change adaptation strategies in mountainous regions. Additionally, the identifying of transition zones and the role of trees adds to our understanding of high-altitude ecosystems and their resilience to environmental challenges.

## Conflict of interests

None

## Author Contributions

Conceptualization, H.A.A.G. and H.A.S.; Data curation, H.A.A.G., and H.A.S.; Formal analysis, H.A.A.G., R.K., and H.A.S; Investigation, H.A.S., A.M.G., SH.H.S., SH.B., SH.H.S., F.O.O., and H.A.A.G.; Methodology, H.A.A.G., H.A.S., and; Resources,. and H.A.A.G.; Supervision, H.A.A.; Validation, H.A.A.G., R.K., SH.H.A., F.O.O and.; Visualization, A.M.G., SH.B., and H.A.A.G.; Writing—original draft, H.A.A.G., H.A.O., SH.H.S; Review, editing, improving, and. All authors have read and agreed to the published version of the manuscript.

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