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Consideration of NDVI Thematic Changes on Density Analysis and Floristic Composition of Wadi Yalamlam, Saudi Arabia

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Abstract

Wadi Yalamlam is known as one of the significant Wadies in the west of Saudi Arabia. It is a very important water source for the western region of the country. Thus, it supplies the holy places in Mecca and the surrounding areas with drinking water. Floristic composition of Wadi Yalamlam has not been comprehensively studied. For that reason, this work aimed to assess the Wadi vegetation cover, life-form, chorotype, diversity, and community structure. The Wadi was divided into seven stands. Stands 7, 1 and 3 were the richest with the highest Shannon index 2.98, 2.69 and 2.64 respectively. On the other hand, stand 6 has the least plant biodiversity with Shannon index of 1.8. The study also revealed the presence of 48 different plant species belonging to 24 families. Fabaceae (17%) and Poaceae (13%) were the main families that form most of the vegetation in the study area, while many families were represented only by 2% of the vegetation of the Wadi.

Keywords: Floristic composition, Plant diversity, Species richness, Wadi Yalamlam, Saudi Arabia.

1. Introduction

Kingdom of Saudi Arabia is a big desert with a land area of approximately 2,250,000 km2 comprising the basic area of the Arabian Peninsula. Based on that, xerophytic vegetation forms the distinguished topographies of the plant life in the country (Khalik et al., 2013). According to Abuzinadah *et al*. (Abuzinada et al., 2005), the natural areas and the biological diversity are very large in the kingdom, and these factors are very important for dealing with ecosystems. The vegetation structure in Saudi Arabia presents differences in the distributional manner and that's rising from changes in different factors and resources such as weather and soil variables, anthropogenic pressures and water (Hegazy et al., 2007).

The geographical location of Saudi Arabia between the surrounding continents indicates the importance of the vegetation structure in the kingdom. Hence the flora contains different global elements such as the Palaearctic (located in Asia and Europe) the Afrotropical (located in Africa) and the Malayan-Indo worldly (Ghazanfar, 2006). Saudi Arabia has three categories of species called: Sudano-Deccanian, Saharo Sindian, and Tropical Indian – African (Alfarhan, 1999, Thomas et al., 2008). According to Collenette (Collenette, 1998), some areas in Saudi Arabia like Asir, Alhejaz and western Mountains have high floristic diversity. These mountains chains are near the Red Sea and it have the greatest level of rainfall. The height of these mountains reaches up to 2850m. Some researchers prove that the topography and climate of the area are affecting the level of speciation (Abulfatih, 1992, El-Kady et al., 1995, Shaltout and Mady, 1996, Shaltout et al., 1997). The flora of Saudi Arabia is reasonably well identified at the taxonomic level. The species richness of the 15 Protected Areas controlled by the National Commission for

Wildlife Conservation and Development, as well as many of the zones protected by the administration of the Ministry of Agriculture, is somehow well documented in the work of Forbis (Forbis et al., 2006), but this is more than ten years ago. The number of the verified species in Saudi Arabia is growing day by day based on the recent field trips and biodiversity studies. An example is that over 1500 species was recorded by Migahid [17] between the years 1974-1988. Far ahead, this number was upraised to 2300 within a period of about three decades; according to the accounts given in the Flora of Saudi Arabia (Chaudhary, 1999, Chaudhary, 2000, Alfarhan et al., 2005, Masrahi et al., 2012). Several scholarly works are available on the flora of Saudi Arabia. Two of the most comprehensive works on the Flora of Saudi Arabia are: Flora of Saudi Arabia by Migahid (Migahid, 1978) which have been published four times and the three-volume book of Flora of the Kingdom of Saudi Arabia done by Chaudhary (Chaudhary, 1999, Chaudhary, 2000). There are some studies on different areas of Saudi Arabia such as Shultz and Whitney (Schulz and Whitney, 1986) have studied the vegetation and floras of the sabkhas, hillocks and other prominent mountains of the Najd region "Twaik, Aja, and Salma". Considerable efforts have also been made toward the elucidation of vegetation–environmental relationships in the ecosystems "raudhas" or depressions (Shaltout and Mady, 1996, Sharaf El Din et al., 1999, Alfarhan, 2001). The plant communities of Wadies have been recorded in some studies like Wadi Al-Ammaria by Al-Yemeni (Al-Yemeni, 2001) and Wadi Hanifa by Taia and El-Ghanem (Taia and El-Ghanem, 2001) and El-Ghenem (El-Ghanem, 2006). But no previous study has been done on the flora of Wadi Yalmlam.

Therefore, the aim of the current research study is to study the vegetation cover in Wadi Yalamlam from different aspects, such as species richness, life form, and biodiversity in relation habitat change in the study area. Normalized Difference Vegetation Index has been conducted from a temporal remote sensing data to assess the status of the vegetation cover within the designated study area over the last four years. Moreover, species diversity indices have been used to discriminate vegetation sets and to evaluate the relation between the vegetation aspects in the study area.

2. Materials and Methods

2.1 Study Area

The location of Wadi Yalamlam is about 100 km south Mecca city between 20° 26′:21° 8′N; 39° 45′:40° 29′E (Figure 1). The Wadi basin covers a large area of about 180,000 hr. The border of the basin located in downstream is expanded to comprise almost nearly all the flat area in the lower part. Wadi Yalamlam initiats from the high altitude of Hijaz mountains near Taif exactly from AlShafa area. Its average annual rainfall is c.140mm. The Wadi has different altitudes greatly varying from 2850 m to 25 m (a.s.l.) in upstream and downstream areas, respectively.. The main route of Wadi Yalamlam is traversed by the greatly cracked granitoides, gabbroic and metamorphic rocks until it reaches the Red Sea coastal plain and its about 120 km in length. Incisive natural vegetation covers the higher and the central parts of the basin. On the other hand, Quaternary deposits and sand dunes accompanied by tiny scattered vastly alter the granitoids and metamorphosed basaltic hills which are the constitutes of the lower part of the Wadi. Several basic ditches are observed in the lower part of the basin. Moreover, the depth of the Quaternary deposits of the Wadi is larger in the lower part.

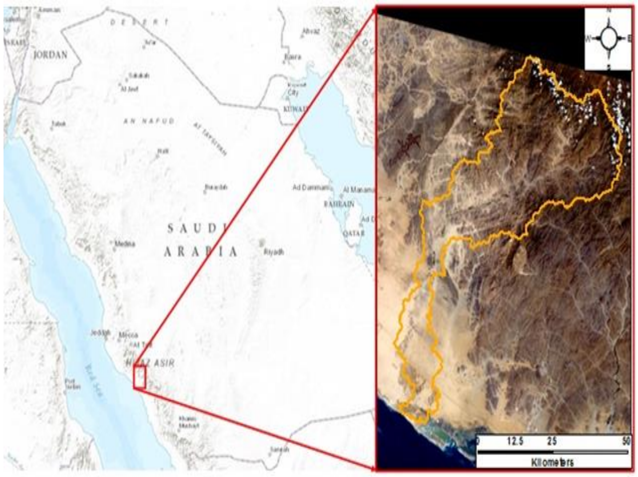

Figure 1. Location of the study area (Bahrawi et al., 2016).

2.2 Climate of the Study Area:

The climate of the Red Sea coast is usually stable as the weather is cold in the winter season and warm in the summer. Based on the weather recorded, the average maximum temperature is between 37-39 ºC and the minimum temperature is around 19 ºC. The highest temperature was 49ºC and the lowest was 12ºC. The maximum average of evaporation value is between 450 to 550mm in summer, while in winter it's around 200mm (Subyani and Bayumi, 2003).

2.3 Sample sites

Samples were chosen along Wadi Yalamlam areas such as (Figure 2):

- Upstream midstream
- Downstream parts
- And different Wadi streams

The study area was visited from the beginning of March 2015 to the end of February 2016. Almost seven stands were randomly chosen in every area for the current investigation during different growing seasons.

Locations and samples were selected as an example of a large range of physiographic and environmental variability in every branch.

Sample plots were randomly selected using the relevé process in every site described by Mueller- Dombois and Ehlenberg (Mueller-Dombois and Ellenberg, 1974).

The plots were 10-meter × 10 meters and samples were taken through the spring season when taxa were expected to be growing and flowering. The vegetation sampling included recording all plant taxa in the plots.

The plant cover of each taxa was estimated using the Zurich- Montpellier technique (Braun-Blanquet et al., 1965). The collected sample specimens were recognized according to Collenette (Collenette, 1999), Cope (Cope, 1985), Rahman *et al.* (Rahman et al., 2004), and Chaudhary (Chaudhary, 1999, Chaudhary, 2000).

2.4 Realization of Species Richness Equations

Various indices have been developed for examining species richness in a region based on the estimations of the relative abundance of the species derived from samples (Heip et al., 1998). Among these indices are the Shannon-Wiener information function (Lloyd et al., 1968), the Simpson's dominance index((Hunter and Gaston, 1988), the Margalef species richness index (Meurant, 2012), and Pielou evenness index (Pielou, 1966). The first two were used in the current study due to feasibility reasons.

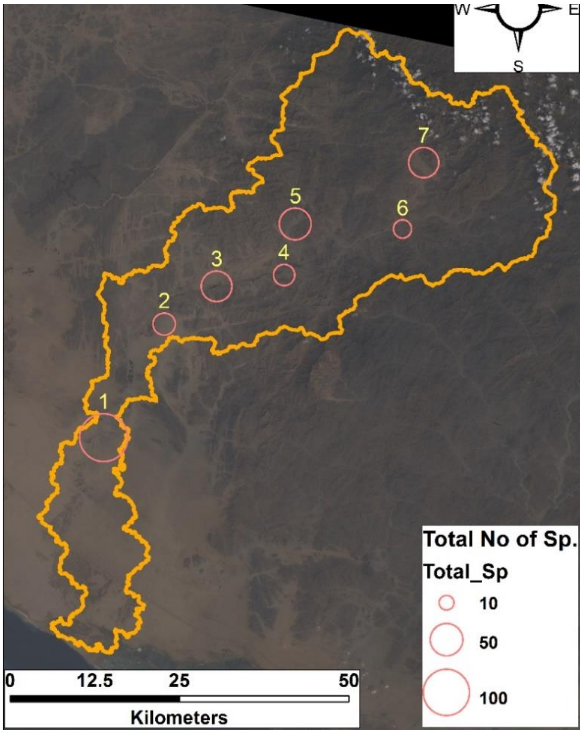

Figure 2. A total number of species in Wadi Yalamlam.

2.4.1 The Shannon index

The main principle of this index is that the diversity of a community is the amount of data in a code. It is calculated as follows:

$$H = -\sum_{i=1}^{S}(p_i \times \ln p_i) = -\sum_{i=1}^{S}(\frac{n_i}{N} \times \ln \frac{n_i}{N}) \quad \text{Eq.1}$$

In this formula, *S* is the total number of species

N is the total number of individuals

n_i is the number of individuals of the i-th species.

$\frac{n_i}{N}$ is equivalent to p_i, the probability of finding the i-th species.

2.4.2 Simpson's index

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Simpson's approach for assessing species diversity evaluates the dominance of a species relative to the number of species in a sample or population (Hunter and Gaston, 1988). It is calculated as follows:

$$D = [\Sigma\, ni\,(ni - 1)] \,/\, N\,(N - 1)\,] \qquad \text{Eq.2}$$

D is the Simpson Diversity Index,

ni is the Number of individuals belonging to i species,

N is the Total number of individuals

2.5. Density Analysis

The new improvements in remote sensing and in GIS resulted in advanced alternative methods for representing vegetation maps far from regular field surveys and photo analysis. Predictive vegetation modeling is considered as one of the commonly used methods. It is described as "predicting the distribution of vegetation across a landscape based on the relationship between the spatial distribution of vegetation and certain environmental variables" (Franklin, 1995, Guisan and Zimmermann, 2000). Concepts of spatial variations are obtained according to the following equations:

$$\gamma_{(k)} = \frac{1}{2n(k)} * \sum_{i=1}^{2(k)} \left[z_{(x_i)} - z_{(x_i+k)}\right]^2 \qquad \text{Eq.3}$$

Where: $n_{(k)}$ is the number of pairs of observation;

$Z(x_i)$ is the feature property measured in point x, and in point $x + k$.

$$Z * (x_0) = \sum_{i=1}^{n} \lambda_i * z(x_i) \qquad \text{Eq.4}$$

Where: $Z^*(x_o)$ is the interpolated value of variable Z at location x_o, $Z(x_i)$ is the values measured at location x_i,

λ_i is the weighed coefficients calculated based on the semivariogram when:

$$\sum_{i=1}^{n} \lambda_i = 1$$

Consequently, it is possible to obtain non-biased interpolated values that is, the expected value: $E[Z^*(x_o) - Z(x_o)] = 0$ and the estimated variance $Var. [Z^*(x_o) - Z(x_o)]$ = minimum (Elhag and Bahrawi, 2016).

The relationship between environment and vegetation could be associated with the observed connection or to the hypothetical or investigational physiological limitations of diverse plant taxa. This relationship has been calculated using statistical methods. These statistical methods have become gradually more flexible to show what is known as non-Gaussian species response curves (Heath and Smith, 1989).

2.6. NDVI Change Detection

The multispectral remote sensing data image was obtained from the United States Geological Survey (USGS). Landsat-8 images are consisting of nine spectral bands ranging from Visible to Thermal Infrared with a spatial resolution of 30 meters for Bands from 1 to 7 and then 9. The resolution for the panchromatic Band 8 is 15 meters. Spectral bands are selectable across the range: 435 nm to 1251. The temporal data sets were acquired in April 2013 as an early data of acquisition and in April 2017 as a late date of acquisition (Path, 169; Row, 46).
There are quite a few indices for defining vegetation behavior zones on a remote sensing imagery. One of which is NDVI (Bhandari et al., 2012). It is a crucial and commonly used vegetation index. In addition, it is widely applied to research works related to climatic and global environmental changes (Bhandari et al., 2012). NDVI can be estimated as a ratio variance

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between measured canopy reflectance in the red and near-infrared bands respectively (Elhag and Bahrawi, 2017).

In other words, NDVI is a simple numerical indicator which by using a remote platform can analyze the remote sensing measurements to decide whether the target or object being observed comprehends live green vegetation or not. It can be calculated as follows (Jensen and Binford, 2004);

$$NDVI = \frac{NIR-RED}{NIR+RED}$$

$$taking\ into\ consideration\ (-1 < NDVI > 1)$$

Where:

NIR band = (750-1300 nm),

Red band = (600-700 nm)

3. Results and Discussion

3.1 Floristic analysis and plant diversity of the study area:

Vegetation in the seven stands was represented by 48 species belonging to 24 families. The families Fabaceae and Poaceae were the richest (17%), (13%) followed by Zygophyllaceae (10%), Cucurbitaceae (10%) and Euphorbiaceae (6%), Asclepiadaceae, Molluginaceae, Cleomaceae, Solanaceae and Caryophyllaceae (4%), and 14 families were represented by only (2%) of the vegetation of the Wadi (Figures 3and 4).

Many studies and comparisons of families about the largest number of species were listed in various regions of Saudi Arabia such as Asir Mountains in Hosni and Hegazi, (Hosni and Hegazy, 1996), Mosallam (Mosallam, 2007) who studied Taif area, Alatar *et al*., (Alatar et al., 2012) in Al-Jufair Wadi and Al-Turki and Al-Olayan (Al-Turki and Al-Olayan, 2003) in Hail

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region. As well as similar to these studies and results were recorded outside the kingdom like Egypt (El-Ghani and Abdel-Khalik, 2006, El-Ghani and El-Sawaf, 2004) and Jebel Marra in Alsudan (Al-Sherif et al., 2013). The most famous plant species in Saudi Arabia belong to the families Fabaceae and Asteraceae (Migahid, 1978, Chaudhary, 1999, Rahman et al., 2004). As the Poaceae is the largest family listed in some researchers but there are also other large families in the flora of Saudi Arabia (Collenette, 1999, Alnafie, 2008).

Stand 1 was the most diverse with about 28 different taxa, followed by stand 7 about 22 different taxa because it is surrounded and near the water dam. Whereas, stand 6 was least diverse with 7 taxa only.

3.2 Plant growth form of the study area:

It was observed that herbs dominated the vegetation of the study area (48%) followed by shrubs (19%), grass (11%) shrubs to trees (10%) and subshrubs (6%) (Figure 5). The higher number of species belonged to the herbs followed by grasses, shrubs, and trees. These observations of many differences in vegetation cover composition and structure can be endorsed to inundation, competition and the environmental factors that might affect vegetation communities on the wadi (Lenssen et al., 1999, Zhang et al., 2005). The difference in density, frequency, and abundance between taxa might be referred to the variation in the habitat (Nardi et al., 2016).

3.3 Plant life form of the study area

The life form range of the study area showed predominance of therophytes and chamaephytes which were constituted 31% and 29% of the total flora, respectively, followed by phanerophytes 19%, while hemicryptophytes are 17 %. Then both geophytes and epiphyte represent 2% of the total flora as shown in Figure 6. Life-form spectrum in the study area is distinguished by an arid desert region with the dominance of therophytes. This result supports the theory of Cain (Cain, 1950) and Deschenes (Deschenes, 1969) which states that "dry climate, overgrazing, and trampling which is so prevalent on grasslands, tend to increase the percentage of therophytes through the introduction and spread of weedy grasses and forbs of this life form". Furthermore, the high percentage of therophytes could be also regarding human activities as claimed by Barbero *et al*. (Barbero et al., 1990). Therophytes (annuals and biennials) are not unexpectedly recorded for 60% of the overall taxa of the region. They generally bloom and form well-developed growth in the wadis and at the base of steady dunes, where water gathers after appropriate rain. Moreover, it is essential to specify that the dominance of both Fabaceae and therophytes in a local flora can be an indicator of the relative index of disturbance for Mediterranean ecosystems (El-Ghani and Abdel-Khalik, 2006). These results are in agreement with the life form scales among desert habitats in further parts of Saudi Arabia (El-Demerdash et al., 1994, Collenette, 1999, Chaudhary, 2000, Al-Turki and Al-Olayan, 2003, El-Ghanim et al., 2010, Alatar et al., 2012, Daur, 2012).

3.4 Species richness of the study area

The values of Shannon index in the study area are as follows: 1.8 (stand 6), 2.20 (stand 4) and the highest values reach up to 2.69 (stand1), 2.64 (stand 3) and 2.98 (stand 7) (Figure 7). Shannon index examination demonstrates a high species diversity. Typically, the Shannon index in real ecosystems ranges between 1.5 and 3.5 (Macdonald and Macdonald, 2003). The value rarely surpasses 4 (Margalef, 1972).

The value of Simpson's ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. That is, the bigger the value the lower the diversity (Hunter and Gaston, 1988).

Simpson's results in the study area showed that the values of the index are 0.88 (stand 1, 5 and 6), 0.92 (stand 4), 0.94 (stand 3), 0,95 (stand 2) and 0.96 (stand 7) (Figure 7). Which means that stands 1,5 and 6 have the highest in biodiversity while the lowest is stand 7.

3.5 Plant density mapping of the study area

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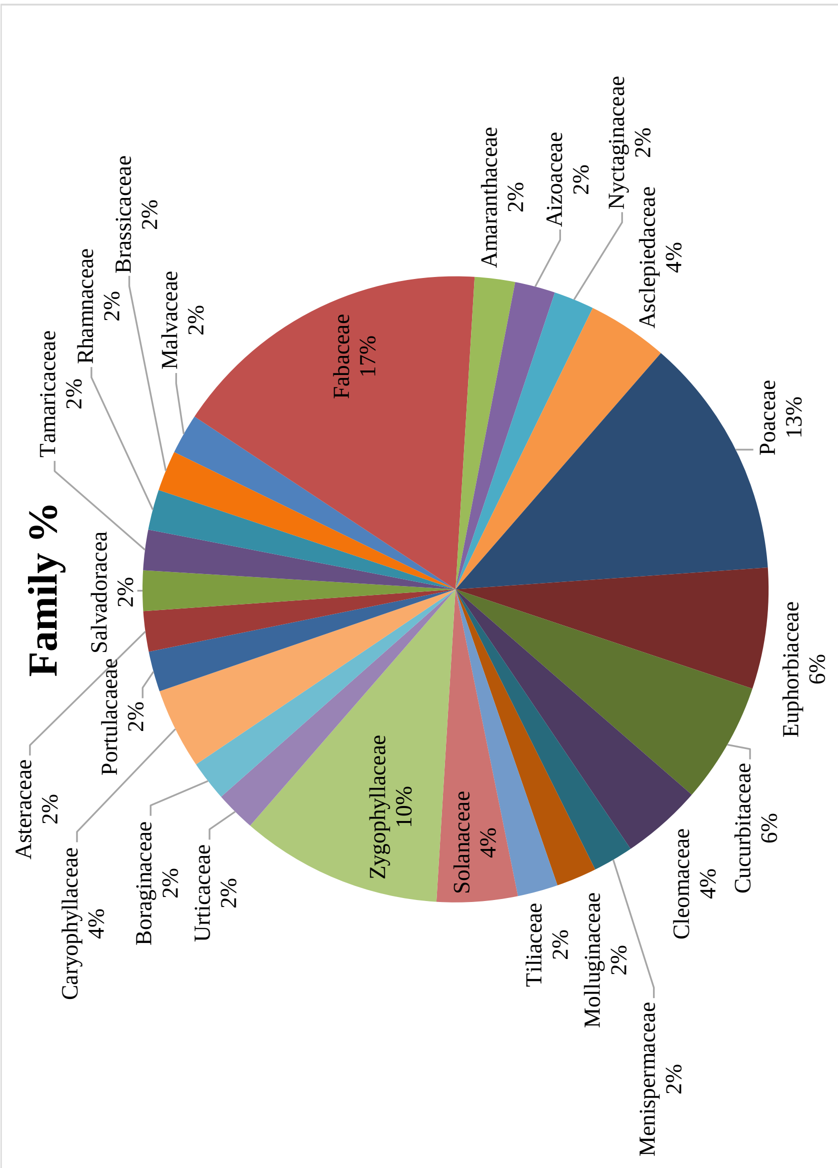

Figure 3. Floristic richness - diversity of the studied area.

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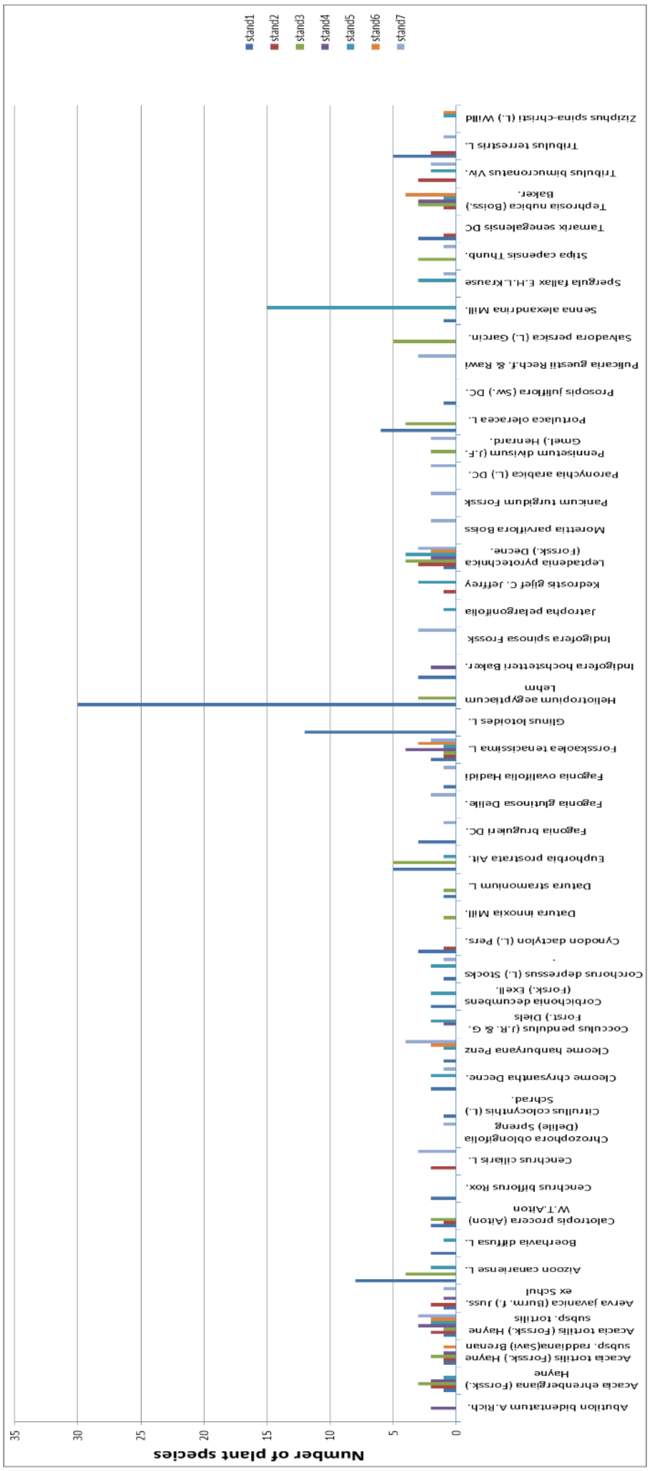
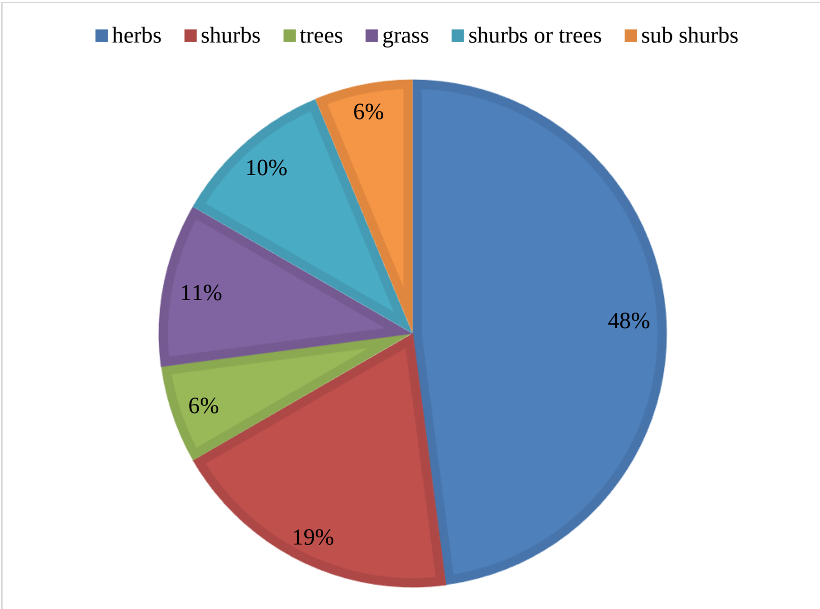
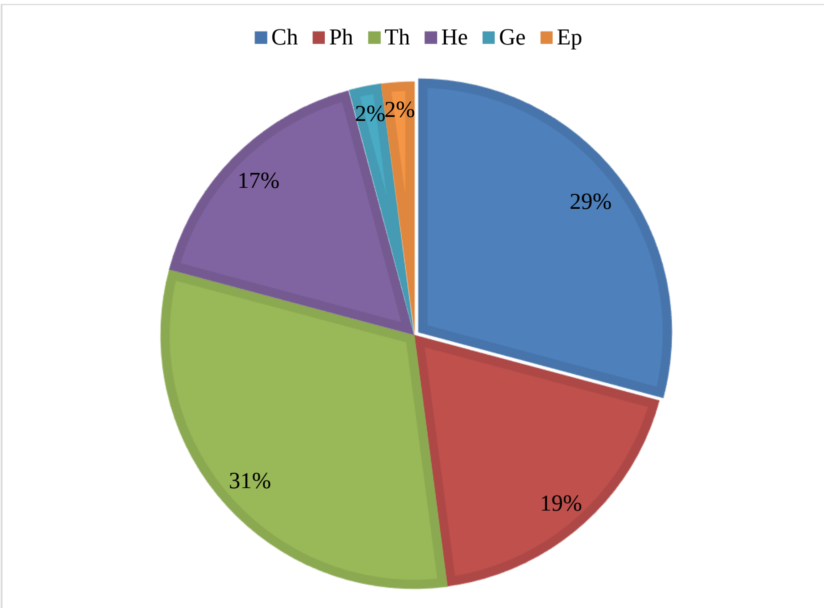


Figure 4. Floristic diversity at the studied sites.

1 

2 **Figure 5. Plant growth form of the study area.**

3 

4 **Figure 6. Plant life form of the study area.**

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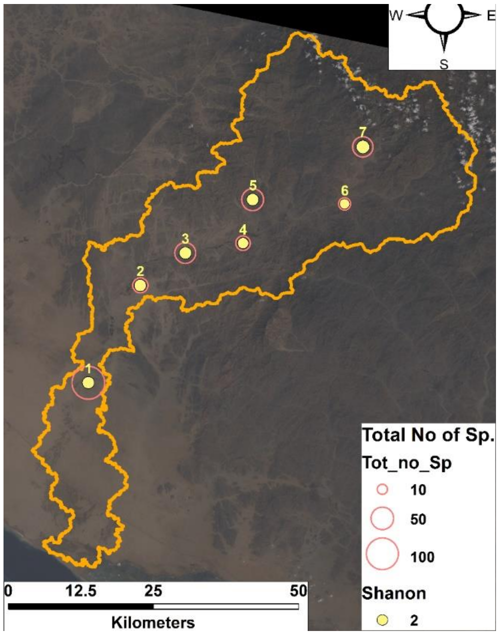

Figure 7. Species richness according to Shannon index.

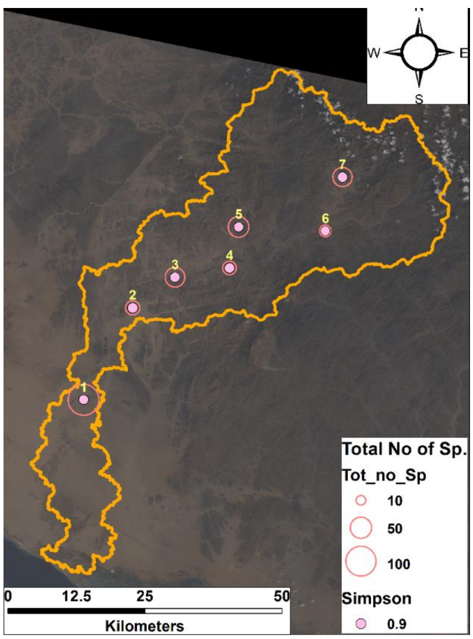

Figure 8. Species richness according to Simpson's index.

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Normalized Difference Vegetation Index was practiced evaluating the status of Wadi Yalamlam vegetation cover compared to data obtained four years ago (Figures 9 a & b). NDVI change detection showed a decrease in vegetation cover. Upper-stream areas of Wadi Yalamlam were the most fragile parts of the Wadi Basin due to anthropogenic activities (Bahrawi et al., 2016). The mid-stream section of Wadi Yalamlam showed no significant difference in vegetation cover. Such stability in vegetation cover is explained by the water availability in the mid-stream section due to its morphometric features (Elhag et al., 2017). The vegetation cover of the lower section of Wadi Yalamlam basin was not abundant in both temporal datasets. The lower section has mainly alluvial deposits occurring frequently due to soil erosion (Elhag, 2016, Bahrawi et al., 2016).

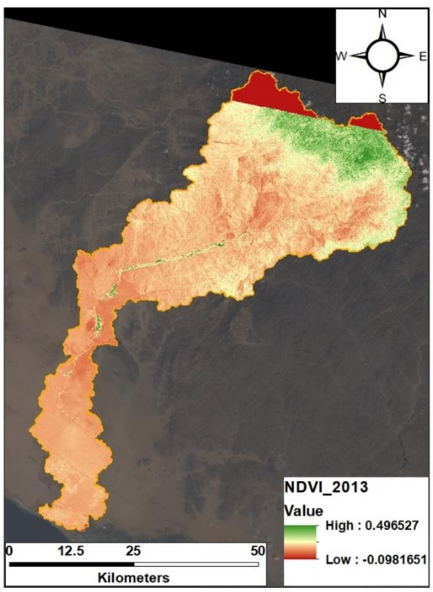

Figure 9 a. NDVI thematic map acquired in 2013.

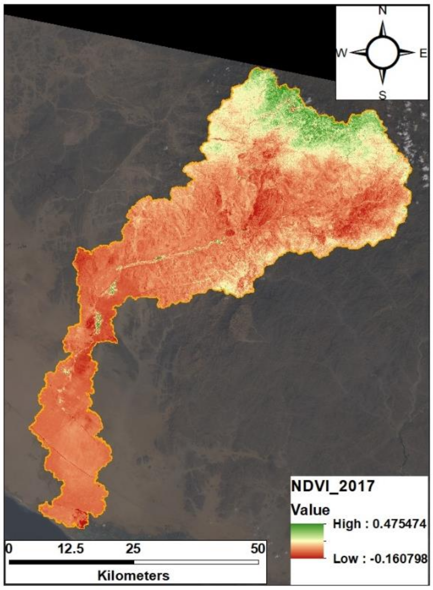

Figure 9 b. NDVI thematic map acquired in 2017.

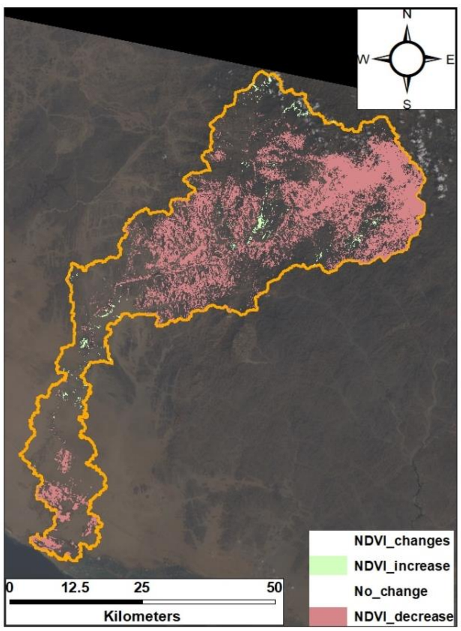

Figure 10. NDVI thematic change detection map within the study area.

4. Conclusion

The current research focuses on the species richness and species diversity in the designated study area. Field surveys in addition to Shannon index examination demonstrate a high species diversity in different plant growth forms. More investigations shall be carried out to identify the threatened plant species and to implement effective monitoring plans. The spatial configuration of the vegetation cover in Wadi Yalamlam shows a significant variation in term of Normalized Difference Vegetation Index and the species richness indices. The upper-stream section of the Wadi requires immediate regulation to stop losing the species diversity. Restoration and rehabilitation schemes shall be adopted in the designated study area. Sediments transport shall be regulated in the lower-stream section to allow the natural vegetation to success.

Acknowledgment

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