1 **Consideration of NDVI Thematic Changes on Density Analysis and Floristic Composition**

2 **of Wadi Yalamlam, Saudi Arabia**

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13 **Abstract**

14 Wadi Yalamlam is known as one of the significant Wadies in the west of Saudi Arabia. It is a

15 very important water source for the western region of the country. Thus, it supplies the holy

16 places in Mecca and the surrounding areas with drinking water. Floristic composition of Wadi

17 Yalamlam has not been comprehensively studied. For that reason, this work aimed to assess the

18 Wadi vegetation cover, life-form, chorotype, diversity, and community structure. The Wadi was

19 divided into seven stands. Stands 7, 1 and 3 were the richest with the highest Shannon index

20 2.98, 2.69 and 2.64 respectively. On the other hand, stand 6 has the least plant biodiversity with

21 Shannon index of 1.8. The study also revealed the presence of 48 different plant species

22 belonging to 24 families. Fabaceae (17%) and Poaceae (13%) were the main families that form

23 most of the vegetation in the study area, while many families were represented only by 2% of the

24 vegetation of the Wadi.

25 **Keywords**: Floristic composition, Plant diversity, Species richness, Wadi Yalamlam, Saudi

26 Arabia.

27 1. Introduction

28 Kingdom of Saudi Arabia is a big desert with a land area of approximately 2,250,000 km2

29 comprising the basic area of the Arabian Peninsula. Based on that, xerophytic vegetation forms

30 the distinguished topographies of the plant life in the country (Khalik et al., 2013). According to

31 Abuzinadah *et al*. (Abuzinada et al., 2005), the natural areas and the biological diversity are very

32 large in the kingdom, and these factors are very important for dealing with ecosystems. The

33 vegetation structure in Saudi Arabia presents differences in the distributional manner and that's

34 rising from changes in different factors and resources such as weather and soil variables,

35 anthropogenic pressures and water (Hegazy et al., 2007).

36 The geographical location of Saudi Arabia between the surrounding continents indicates the

37 importance of the vegetation structure in the kingdom. Hence the flora contains different global

38 elements such as the Palaearctic (located in Asia and Europe) the Afrotropical (located in Africa)

39 and the Malayan-Indo worldly (Ghazanfar, 2006). Saudi Arabia has three categories of species

40 called: Sudano-Deccanian, Saharo Sindian, and Tropical Indian – African (Alfarhan, 1999,

41 Thomas et al., 2008). According to Collenette (Collenette, 1998), some areas in Saudi Arabia

42 like Asir, Alhejaz and western Mountains have high floristic diversity. These mountains chains

43 are near the Red Sea and it have the greatest level of rainfall. The height of these mountains

44 reaches up to 2850m. Some researchers prove that the topography and climate of the area are

45 affecting the level of speciation (Abulfatih, 1992, Kady et al., 1995, altout and Mady, 1996,

46 Shaltout et al., 1997). The flora of Saudi Arabia is reasonably well identified at the taxonomic

47 level. The species richness of the 15 Protected Areas controlled by the National Commission for

48 Wildlife Conservation and Development, as well as many of the zones protected by the

49 administration of the Ministry of Agriculture, is somehow well documented in the work of

50 Forbis (Forbis et al., 2006), but this is more than ten years ago. The number of the verified

51 species in Saudi Arabia is growing day by day based on the recent field trips and biodiversity

52 studies. An example is that over 1500 species was recorded by Migahid [17] between the years

53 1974-1988. Far ahead, this number was upraised to 2300 within a period of about three decades;

54 according to the accounts given in the Flora of Saudi Arabia (Chaudhary, 1999 Chaudhary,

55 2000 farhan et al., 2005 asrahi et al., 2012). Several scholarly works are available on the

56 flora of Saudi Arabia. Two of the most comprehensive works on the Flora of Saudi Arabia are:

57 Flora of Saudi Arabia by Migahid (Migahid, 1978) which have been published four times and the

58 three-volume book of Flora of the Kingdom of Saudi Arabia done by Chaudhary (Chaudhary,

59 1999 audhary, 2000). There are some studies on different areas of Saudi Arabia such as

60 Shultz and Whitney (Schulz and Whitney, 1986) have studied the vegetation and floras of the

61 sabkhas, hillocks and other prominent mountains of the Najd region "Twaik, Aja, and Salma".

62 Considerable efforts have also been made toward the elucidation of vegetation–environmental

63 relationships in the ecosystems "raudhas" or depressions (Shaltout and Mady, 1996 araf El

64 Din et al., 1999 farhan, 2001). The plant communities of Wadies have been recorded in some

65 studies like Wadi Al-Ammaria by Al-Yemeni (Al-Yemeni, 2001) and Wadi Hanifa by Taia and

66 El-Ghanem (Taia and El-Ghanem, 2001) and El-Ghenem (El-Ghanem, 2006). But no previous

67 study has been done on the flora of Wadi Yalmlam.

68 Therefore, the aim of the current research study is to study the vegetation cover in Wadi

69 Yalamlam from different aspects, such as species richness, life form, and biodiversity in relation

70 habitat change in the study area. Normalized Difference Vegetation Index has been conducted

71   from a temporal remote sensing data to assess the status of the vegetation cover within the

72   designated study area over the last four years. Moreover, species diversity indices have been

73   used to discriminate vegetation sets and to evaluate the relation between the vegetation aspects in

74   the study area.

75   **2. Materials and Methods**

76   *2.1 Study Area*

77   The location of Wadi Yalamlam is about 100 km south Mecca city between 20° 26′:21° 8′N; 39°

78   45′:40° 29′E (Figure 1). The Wadi basin covers a large area of about 180,000 hr. The border of

79   the basin located in downstream is expanded to comprise almost nearly all the flat area in the

80   lower part. Wadi Yalamlam initiate from the high altitude of Hijaz mountains near Taif exactly

81   from AlShafa area. Its average annual rainfall is c.140mm. The Wadi has different altitudes

82   greatly varying from 2850 m to 25 m (a.s.l.) in upstream and downstream areas, respectively..

83   The main route of Wadi Yalamlam is traversed by the greatly cracked granitoides, gabbroic and

84   metamorphic rocks until it reaches the Red Sea coastal plain and its about 120 km in length.

85   Incisive natural vegetation covers the higher and the central parts of the basin. On the other hand,

86   Quaternary deposits and sand dunes accompanied by tiny scattered vastly alter the granitoids and

87   metamorphosed basaltic hills which are the constitutes of the lower part of the Wadi. Several

88   basic ditches are observed in the lower part of the basin. Moreover, the depth of the Quaternary

89   deposits of the Wadi is larger in the lower part.

90

91

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

93   *2.2 Climate of the Study Area:*

94   The climate of the Red Sea coast is usually stable as the weather is cold in the winter season and

95   warm in the summer. Based on the weather recorded, the average maximum temperature is

96   between 37-39 ℃ and the minimum temperature is around 19 ℃. The highest temperature was

97   49℃ and the lowest was 12℃. The maximum average of evaporation value is between 450 to

98   550mm in summer, while in winter it's around 200mm (Subyani and Bayumi, 2003).

99   *2.3 Sample sites*

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

101   •   Upstream midstream

102   •   Downstream parts

103   •   And different Wadi streams

104   The study area was visited from the beginning of March 2015 to the end of February 2016.

105   Almost seven stands were randomly chosen in every area for the current investigation during

106   different growing seasons.

107   Locations and samples were selected as an example of a large range of physiographic and

108   environmental variability in every branch.

109   Sample plots were randomly selected using the relevé process in every site described by

110   Mueller- Dombois and Ehlenberg (Mueller-Dombois and Ellenberg, 1974).

111   The plots were 10-meter × 10 meters and samples were taken through the spring season when

112   taxa were expected to be growing and flowering. The vegetation sampling included recording

113   all plant taxa in the plots.

114   The plant cover of each taxa was estimated using the Zurich- Montpellier technique (Braun-

115   Blanquet et al., 1965). The collected sample specimens were recognized according to

116   Collenette (Collenette, 1999), Cope (Cope, 1985), Rahman *et al.* (Rahman et al., 2004), and

117   Chaudhary (Chaudhary, 1999, Chaudhary, 2000).

118   *2.4 Realization of Species Richness Equations*

119   Various indices have been developed for examining species richness in a region based on the

120   estimations of the relative abundance of the species derived from samples (Heip et al., 1998).

121   Among these indices are the Shannon-Wiener information function (Lloyd et al., 1968), the

122   Simpson's dominance index((Hunter and Gaston, 1988), the Margalef species richness index

123   (Meurant, 2012), and Pielou evenness index (Pielou, 1966). The first two were used in the

124   current study due to feasibility reasons.

125

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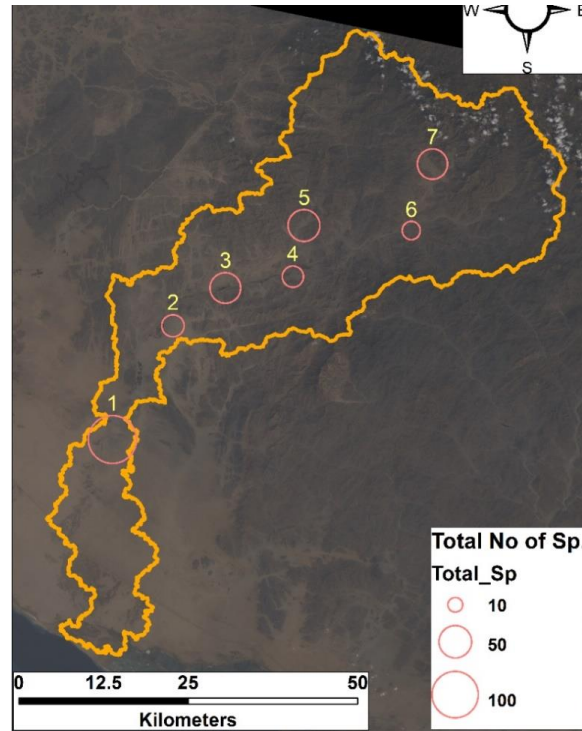
Figure 2. A total number of species in Wadi Yalamlam.

127

128   *2.4.1 The Shannon index*

129   The main principle of this index is that the diversity of a community is the amount of data in a

130   code. It is calculated as follows:

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

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

133   N is the total number of individuals

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

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

136   *2.4.2 Simpson's index*

137   Simpson's approach for assessing species diversity evaluates the dominance of a species relative

138   to the number of species in a sample or population (Hunter and Gaston, 1988). It is calculated as

139   follows:

140    $D = [\Sigma\, ni\,(ni - 1)] / N\,(N - 1)]$ Eq.2

141   D is the Simpson Diversity Index,

142   ni is the Number of individuals belonging to i species,

143   N is the Total number of individuals

144

145   **2.5. Density Analysis**

146   The new improvements in remote sensing and in GIS resulted in advanced alternative methods

147   for representing vegetation maps far from regular field surveys and photo analysis. Predictive

148   vegetation modeling is considered as one of the commonly used methods. It is described as

149   "predicting the distribution of vegetation across a landscape based on the relationship between

150   the spatial distribution of vegetation and certain environmental variables" (Franklin, 1995

151   Guisan and Zimmermann, 2000). Concepts of spatial variations are obtained according to the

152   following equations:

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

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

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

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

157
158   Where: $Z*(x_o)$ is the interpolated value of variable Z at location

159   x_o, $Z(x_i)$ is the values measured at location x_i,

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

161 $\sum_{i=1}^{n} \lambda_i = 1$

162 Consequently, it is possible to obtain non-biased interpolated values that is, the expected value:

163 $E[Z^*(x_o) - Z(x_o)] = 0$ and the estimated variance *Var. [Z*(x_o) - Z(x_o)]* = minimum (Elhag and

164 Bahrawi, 2016).

165

166 The relationship between environment and vegetation could be associated with the observed

167 connection or to the hypothetical or investigational physiological limitations of diverse plant

168 taxa. This relationship has been calculated using statistical methods. These statistical methods

169 have become gradually more flexible to show what is known as non-Gaussian species response

170 curves (Heath and Smith, 1989).

171

172 **2.6. NDVI Change Detection**

173 The multispectral remote sensing data image was obtained from the United States Geological

174 Survey (USGS). Landsat-8 images are consisting of nine spectral bands ranging from Visible to

175 Thermal Infrared with a spatial resolution of 30 meters for Bands from 1 to 7 and then 9. The

176 resolution for the panchromatic Band 8 is 15 meters. Spectral bands are selectable across the

177 range: 435 nm to 1251. The temporal data sets were acquired in April 2013 as an early data of

178 acquisition and in April 2017 as a late date of acquisition (Path, 169; Row, 46).

179 There are quite a few indices for defining vegetation behavior zones on a remote sensing

180 imagery. One of which is NDVI (Bhandari et al., 2012). It is a crucial and commonly used

181 vegetation index. In addition, it is widely applied to research works related to climatic and global

182 environmental changes (Bhandari et al., 2012). NDVI can be estimated as a ratio variance

183   between measured canopy reflectance in the red and near-infrared bands respectively (Elhag and

184   Bahrawi, 2017).

185   In other words, NDVI is a simple numerical indicator which by using a remote platform can

186   analyze the remote sensing measurements to decide whether the target or object being observed

187   comprehends live green vegetation or not. It can be calculated as follows (Jensen and Binford,

188   2004);

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

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

191   Where:

192   NIR band = (750-1300 nm),

193   Red band = (600-700 nm)

194

195   **3. Results and Discussion**

196   *3.1 Floristic analysis and plant diversity of the study area:*

197   Vegetation in the seven stands was represented by 48 species belonging to 24 families. The

198   families Fabaceae and Poaceae were the richest (17%), (13%) followed by Zygophyllaceae

199   (10%), Cucurbitaceae (10%) and Euphorbiaceae (6%), Asclepiadaceae, Molluginaceae,

200   Cleomaceae, Solanaceae and Caryophyllaceae (4%), and 14 families were represented by only

201   (2%) of the vegetation of the Wadi (Figures 3and 4).

202   Many studies and comparisons of families about the largest number of species were listed in

203   various regions of Saudi Arabia such as Asir Mountains in Hosni and Hegazi, (Hosni and

204   Hegazy, 1996), Mosallam (Mosallam, 2007) who studied Taif area, Alatar *et al*., (Alatar et al.,

205   2012) in Al-Jufair Wadi and Al-Turki and Al-Olayan (Al-Turki and Al-Olayan, 2003) in Hail

206   region. As well as similar to these studies and results were recorded outside the kingdom like

207   Egypt (El-Ghani and Abdel-Khalik, 2006; Ghani and El-Sawaf, 2004) and Jebel Marra in

208   Alsudan (Al-Sherif et al., 2013). The most famous plant species in Saudi Arabia belong to the

209   families Fabaceae and Asteraceae (Migahid, 1978; Chaudhary, 1999; Rhman et al., 2004). As

210   the Poaceae is the largest family listed in some researchers but there are also other large families

211   in the flora of Saudi Arabia (Collenette, 1999; Shafie, 2008).

212   Stand 1 was the most diverse with about 28 different taxa, followed by stand 7 about 22 different

213   taxa because it is surrounded and near the water dam. Whereas, stand 6 was least diverse with 7

214   taxa only.

215

216   *3.2 Plant growth form of the study area*:

217   It was observed that herbs dominated the vegetation of the study area (48%) followed by shrubs

218   (19%), grass (11%) shrubs to trees (10%) and subshrubs (6%) (Figure 5). The higher number of

219   species belonged to the herbs followed by grasses, shrubs, and trees. These observations of many

220   differences in vegetation cover composition and structure can be endorsed to inundation,

221   competition and the environmental factors that might affect vegetation communities on the wadi

222   (Lenssen et al., 1999; Yang et al., 2005). The difference in density, frequency, and abundance

223   between taxa might be referred to the variation in the habitat (Nardi et al., 2016).

224   *3.3 Plant life form of the study area*

225   The life form range of the study area showed predominance of therophytes and chamaephytes

226   which were constituted 31% and 29% of the total flora, respectively, followed by phanerophytes

227   19%, while hemicryptophytes are 17 %. Then both geophytes and epiphyte represent 2% of the

228   total flora as shown in Figure 6. Life-form spectrum in the study area is distinguished by an arid

229   desert region with the dominance of therophytes. This result supports the theory of Cain (Cain,

230   1950) and Deschenes (Deschenes, 1969) which states that "dry climate, overgrazing, and

231   trampling which is so prevalent on grasslands, tend to increase the percentage of therophytes

232   through the introduction and spread of weedy grasses and forbs of this life form". Furthermore,

233   the high percentage of therophytes could be also regarding human activities as claimed by

234   Barbero *et al*. (Barbero et al., 1990). Therophytes (annuals and biennials) are not unexpectedly

235   recorded for 60% of the overall taxa of the region. They generally bloom and form well-

236   developed growth in the wadis and at the base of steady dunes, where water gathers after

237   appropriate rain. Moreover, it is essential to specify that the dominance of both Fabaceae and

238   therophytes in a local flora can be an indicator of the relative index of disturbance for

239   Mediterranean ecosystems (El-Ghani and Abdel-Khalik, 2006). These results are in agreement

240   with the life form scales among desert habitats in further parts of Saudi Arabia (El-Demerdash et

241   al., 1994; Ollenette, 1999; audhary, 2000; Turki and Al-Olayan, 2003; Ghanim et al.,

242   2010; tar et al., 2012; ur, 2012).

243

244   ***3.4 Species richness of the study area***

245   The values of Shannon index in the study area are as follows: 1.8 (stand 6), 2.20 (stand 4) and

246   the highest values reach up to 2.69 (stand1), 2.64 (stand 3) and 2.98 (stand 7) (Figure 7).

247   Shannon index examination demonstrates a high species diversity. Typically, the Shannon index

248   in real ecosystems ranges between 1.5 and 3.5 (Macdonald and Macdonald, 2003). The value

249   rarely surpasses 4 (Margalef, 1972).

250   The value of Simpson's ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1,

251   no diversity. That is, the bigger the value the lower the diversity (Hunter and Gaston, 1988).

252   Simpson's results in the study area showed that the values of the index are 0.88 (stand 1, 5 and

253   6), 0.92 (stand 4), 0.94 (stand 3), 0,95 (stand 2) and 0.96 (stand 7) (Figure 7). Which means that

254   stands 1,5 and 6 have the highest in biodiversity while the lowest is stand 7.

255   *3.5 Plant density mapping of the study area*

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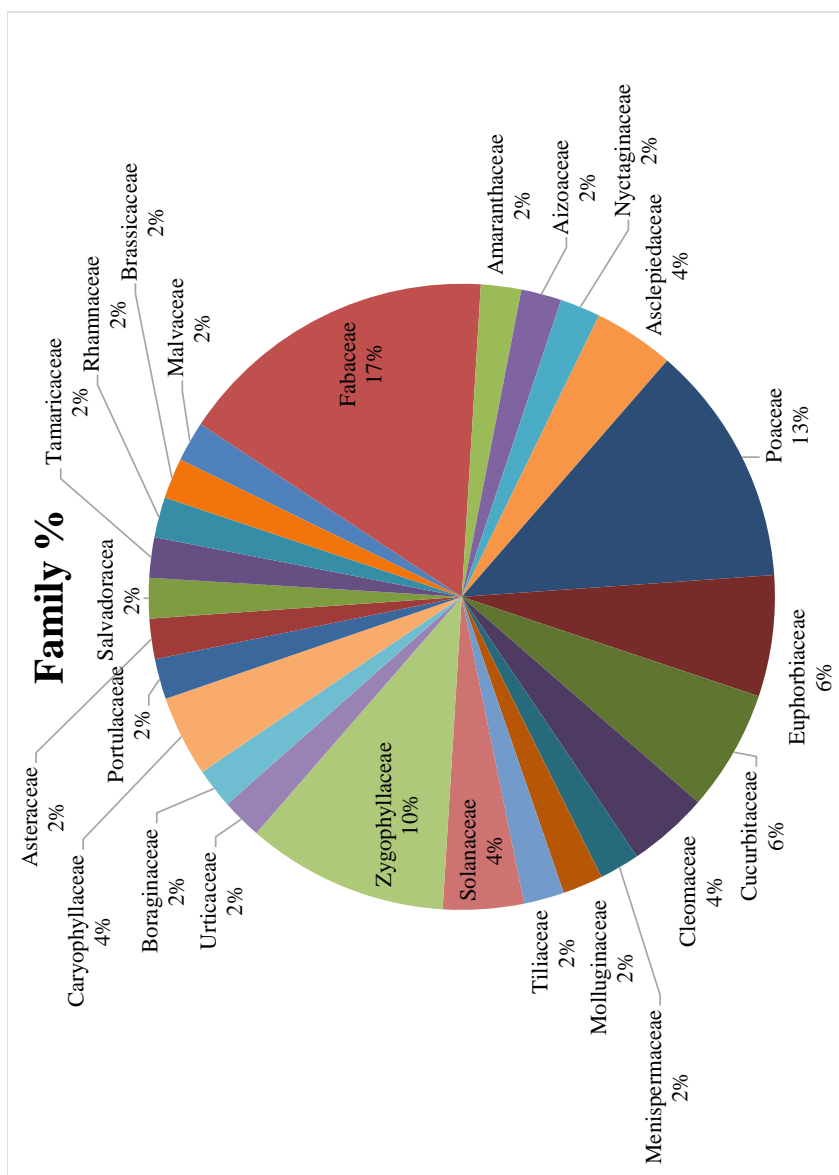


Figure 3. Floristic richness - diversity of the studied area.

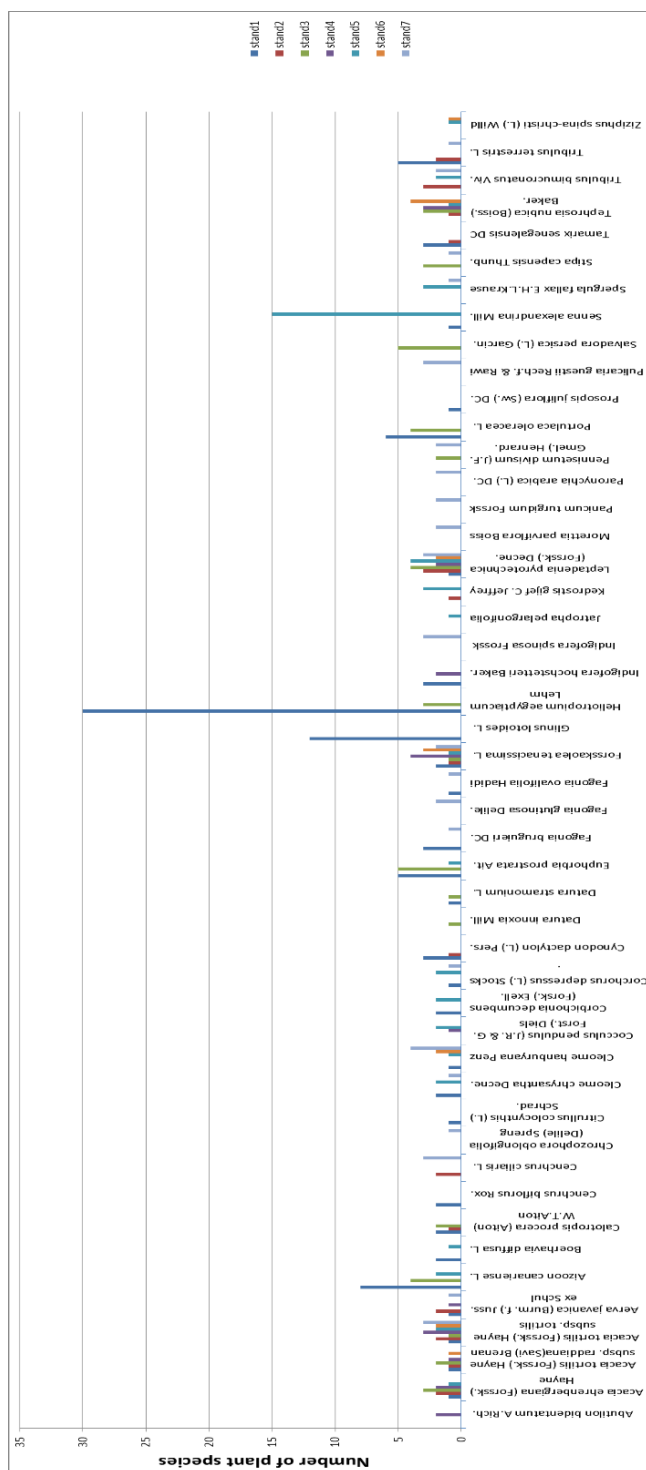
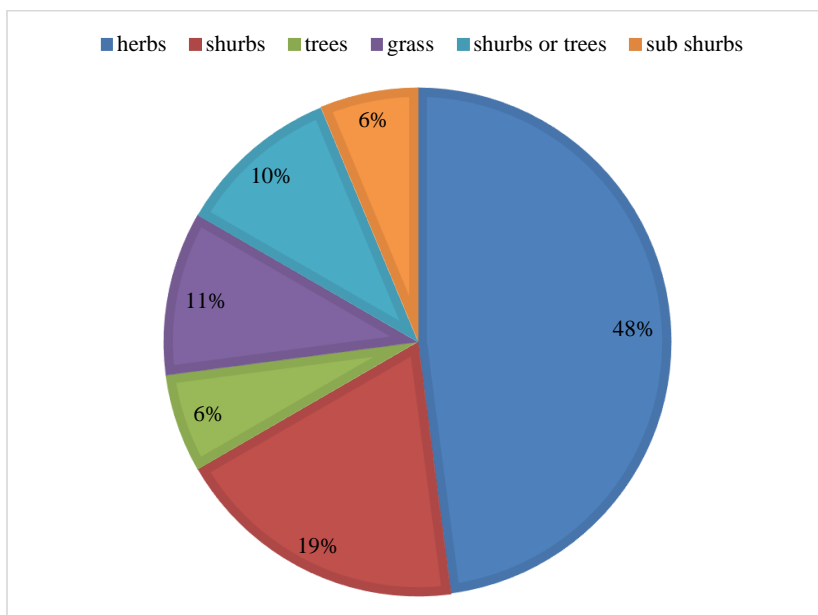
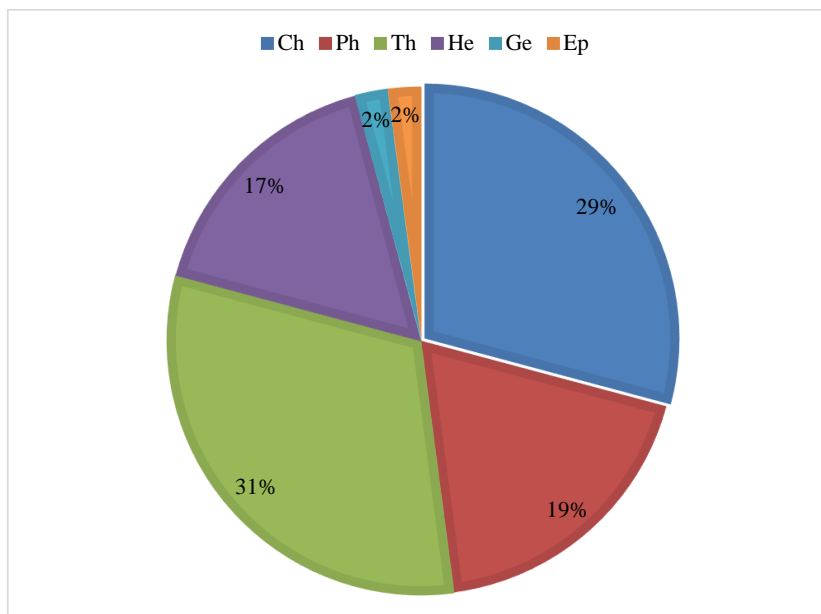
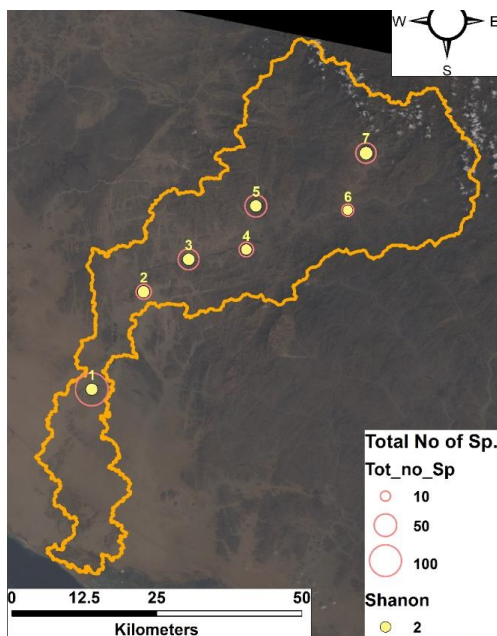
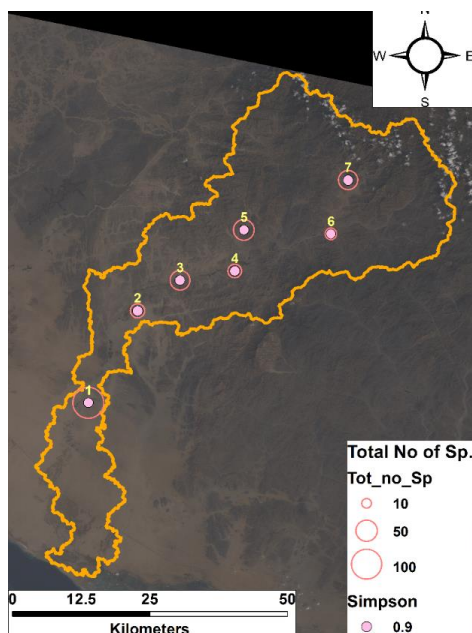



Figure 4. Floristic diversity at the studied sites.

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

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

6   **Figure 7. Species richness according to Shannon index.**

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

9   Normalized Difference Vegetation Index was practiced evaluating the status of Wadi Yalamlam

10   vegetation cover compared to data obtained four years ago (Figures 9 a & b). NDVI change

11   detection showed a decrease in vegetation cover. Upper-stream areas of Wadi Yalamlam were

12   the most fragile parts of the Wadi Basin due to anthropogenic activities (Bahrawi et al., 2016).

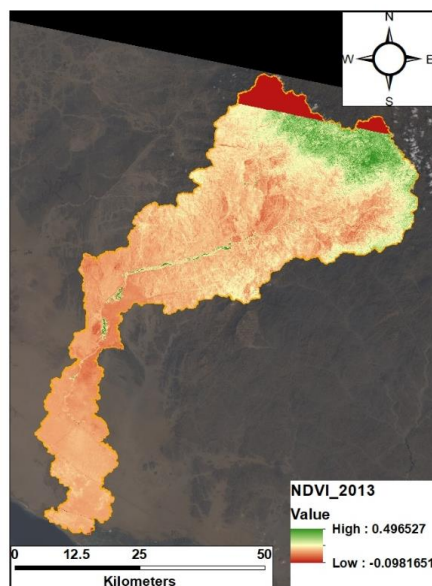
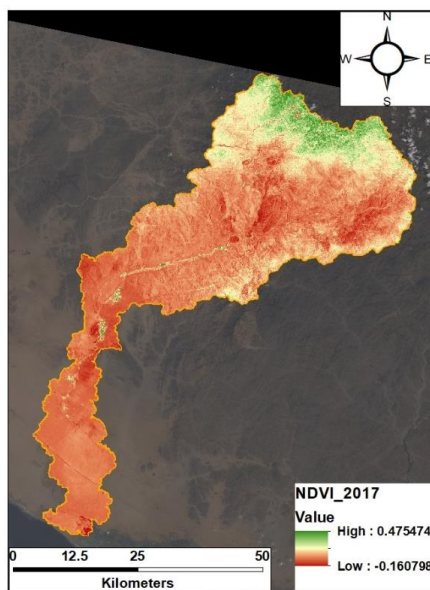
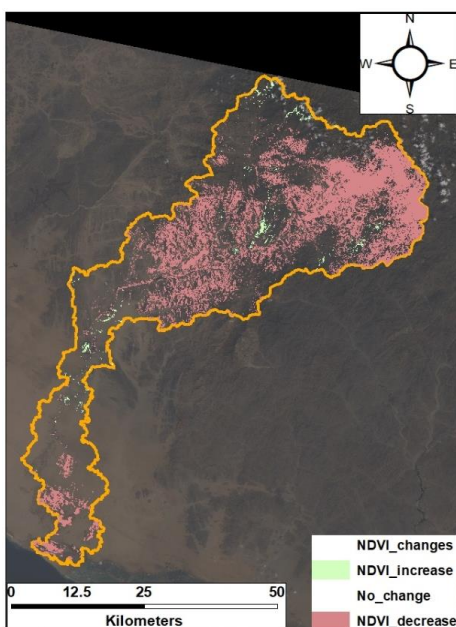
13   The mid-stream section of Wadi Yalamlam showed no significant difference in vegetation cover.

14   Such stability in vegetation cover is explained by the water availability in the mid-stream section

15   due to its morphometric features (Elhag et al., 2017). The vegetation cover of the lower section

16   of Wadi Yalamlam basin was not abundant in both temporal datasets. The lower section has

17   mainly alluvial deposits occurring frequently due to soil erosion (Elhag, 2016; Bahrawi et al.,

18   2016).

21   **Figure 9 a. NDVI thematic map acquired in 2013.**

23   **Figure 9 b. NDVI thematic map acquired in 2017.**

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

26

27 **4. Conclusion**

28 The current research focuses on the species richness and species diversity in the designated study

29 area. Field surveys in addition to Shannon index examination demonstrate a high species

30 diversity in different plant growth forms. More investigations shall be carried out to identify the

31 threatened plant species and to implement effective monitoring plans.   The spatial configuration

32 of the vegetation cover in Wadi Yalamlam shows a significant variation in term of Normalized

33 Difference Vegetation Index and the species richness indices. The upper-stream section of the

34 Wadi requires immediate regulation to stop losing the species diversity. Restoration and

35 rehabilitation schemes shall be adopted in the designated study area. Sediments transport shall be

36 regulated in the lower-stream section to allow the natural vegetation to success.

37

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42

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