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HYPERSPECTRAL INDICES FOR DISCRIMINATING PLANT DIVERSITY IN WADI AL-AFREET, EGYPT

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Abstract

Wadi Al-Afreet, North Western Coast of Egypt, contains many wild plant species especially endangered ones. Hyperspectral technology is considered a suitable tool for studying plant diversity in Wadis. The present work is the first attempt to monitoring the spectroscopic characteristics of the natural vegetation cover of Wadi Al-Afreet. The key target of the current research is determining the best spectral zone and the optimal waveband for plant species. Spectral signatures for 33 plants in Wadi have been measured by ASD spectroradiometer to assess the status of plants along Wadi Al-Afreet. Various hyperspectral indices of soil and Plant were calculated to evaluate the status of sixteen soil samples representing the studied stands and thirty-three plant species. As a result a unique spectral library has been established of wild plants in Wadi Al-Afreet contains soil analysis and vegetation indices. Results of Tukey's have shown that red and NIR region were the best spectral regions for discrimination among the studied species, while SWIRII was not enough to distinguish between different plants. Also, results showed that broadband vegetation indices indicated the overall health of the plant. Results also, showed that positive correlation has been found between chlorophyll content and Red Edge Normalized Difference Vegetation Index (RENDVI) and Modified Red Edge Normalized Difference Vegetation Index (MRENDVI). The study showed a negative correlation between electrical conductivity (E.C.) and Soil Adjusted Vegetation Index (SAVI) (low values of SAVI indicate low vegetation). Also, there is a significant positive correlation has been found between electrical conductivity (E.C.) and Desertification Soil Index (DSI).

Keywords: Wadi Al-Afreet, Hyperspectral Indices, Remote Sensing, Plant Diversity.

Introduction

Nowadays biodiversity in Egypt is deteriorating at the level of ecosystems, species and populations. The posses are due to a range of threats, including fragmentation, loss of habitat and unsustainable use of natural resources and invasive species. The flora in the North West coast (NWC) is characterized by high diversity and is one of the richest phytogeographical zones in Egypt for its relatively high rainfall. It comprises 50% of the total Egyptian flora (UNESCO, 2003) and considered as one of the highest grazing areas in the Egyptian coastal region (Heneidy, 2002). Wadi Al-Afreet contains many endangered wild plants. The study area of research lies at the Egyptian-Libyan border between Buqbuq and Sidi Barrani. It is included in the vegetation zone of the semi-desert, with a mitigated desert climate. The chosen study area is one of the unique Wadis in the North Western Coast, not only due to its location and varied vegetation, but also due to having two of the endangered species in Egypt (*Periploca angustifolia* Labill and *Ebenus armitagei* Schweinf. & Taub, Gamal *et al.*, 2018).

Hyperspectral approach provides a variety of absorption based on spectral narrow bands to discriminate among plants by their spectral signature (Nagendra, 2002). Plant's reflectance characteristic is correlated to biochemical compounds found in the leaves, and the leaves' physical characteristics such as the fraction of air spaces and air-water interfaces. The biochemical leaf compounds consist mainly of four elements: oxygen, hydrogen, carbon and nitrogen The interaction of light with C-O, O-H, C-H, and N-H bonds resulting in reflectance leads to vibrations, overtones, and combinations of variations (Kokaly and Clark, 1999). When there are differences in the canopy of the plant, structure of leaves, in addition to the content of water, there is a change in the properties of reflection (even among the closely related species) and thus it is possible to identify the separation and identify these species by their spectral properties (Thenkabail *et al.*, 2000). The spectral properties of plant species being based on plant physiology, morphology or anatomy (Jarocinska *et al.*, 2016; Kycko *et al.*, 2014). Even minor reflectance changes can be calculated, registered, and allocated to specified plants, allowing species to be classified based on spectral characters. That way, contrasting spectral reflectance pattern were used to identify spectral properties specific to the species (Kupková *et al.*, 2017; Marcinkowska *et al.*, 2017). There are multiple applications of multispectral and hyperspectral data in Egypt including for instance discrimination of vegetation cover, assessment of environmental components such as wild plants and cultivated crop as well as vulnerability studies such as (Khdery *et al* 2014; Kamal *et al* 2015; Aboelghar & Khdery, 2017; Effat, and El-Zeiny, 2017; El-Zeiny, 2017; El-Zeiny, 2019 a &b; Khdery *et al.*, 2019; Yones 2019 a and Gamal *et al.*, 2020).

Analysis and assessment of soil salinity intensity in arid and semi-arid regions worldwide relies on many calculated hyperspectral indices, such as the Soil Adjusted Vegetation Index (SAVI), Desertification Soil Index (DSI), Salinity Index (SI) and Normalized Difference Water Index (NDWI) for characterizing the severity salinity of soil. Hyperspectral indices have helped classify various features, for example; vegetation, soil regions below various levels of soil salinity (George and Kumar, 2015 and Khdery *et al.*, 2014).

The study aims to identify spectral characteristics and plant diversity of wild plants in Wadi Al- Afreet. Furthermore, the study calculated numbers of soil and vegetation indices from spectroscopic measurements to assess the vigor of wild species and soil. The study also aimed to establish a spectral library including spectral signature and hyperspectral indices for plants and soils in Wadi Al- Afreet.

Materials and Methods

Study Area

Wadi Al-Afreet is a part of the North Western Mediterranean Coast of Egypt. The area selected for the study lies between 25 ° 39’ 41.4’’ E 31 ° 13’ 1.8’’ N and 25 ° 37’ 24.8’’ E 31 ° 16’ 46.8’’ N, extends for about 8.7 km (Length) and 3.9 km between Sidi Barrani and Buqbuq on the Egyptian-Libyan frontier with a total area of about 25 km2 and its Perimeter about 21.9 km (Fig. 1).

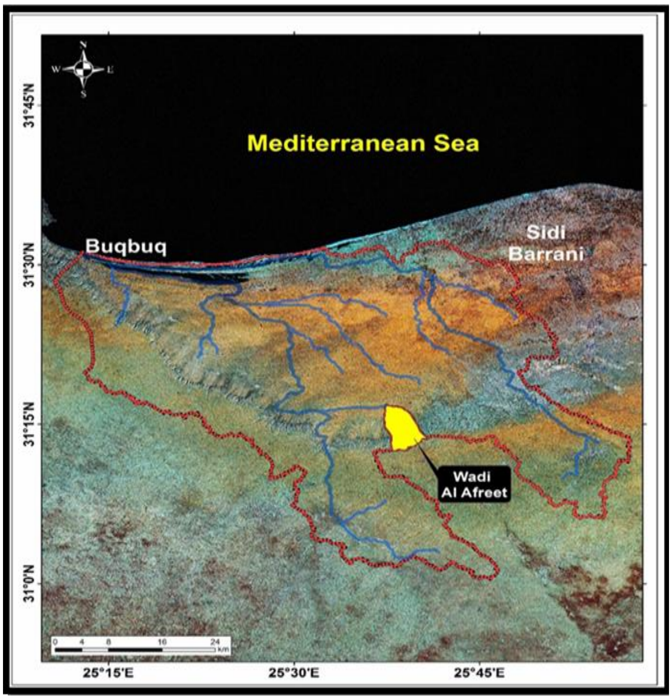

Fig. 1: Location map of Study Area.

Plant sampling

A comprehensive survey of the vegetation was conducted throughout the period July 2016 to May 2017. The selection of stands depended on structure and composition changes of the vegetation along Wadi Al-Afreet. Voucher species of each plant species have been collected and identified according to (Tackholm, 1974; Boulos, 1995, 1999, 2000, 2002 & 2009)

Soil Sampling

Samples of soil from sixteen stands at Wadi Al-Afreet was collected from the surface layer (0-20 cm), air-dried, then removed large gravels and fragments of plants and prepared for mechanical and chemical analysis. The analyses include (PH) soil reaction, Total Dissolved Salts (TDS) and the and the anions and cations of the soil extract (Cl−, HCO3, -2, Na+, Ca+2 and Mg+2).

Spectroscopic measurements

The work methodology concentrates on spectral measurements and statistical analysis of spectroscopic performance measurements to determine the optimal spectral area for differentiating among plants and to choose the optimal wavelength in each spectral zone that can use to differentiate every plant.

ASD Field Spec has been used to measure reflectance of 33 plant leaves under field conditions. The data acquired were exported to an ASCII file using the ASD View Pro statistical analysis program, with the vegetation spectral reflectance properties visually checked using spectral reflectance curves. A statistical study was carried out to determine the spectral bands that better discriminate between the plants being studied. This step was done by means of linear discriminant analysis (LDA) for band selection (Clark *et al.*, 2005) and (ANOVA) analysis to check the capacity of selected wavelengths and bands to differentiate plant species effectively (Anderson, 2001).

Table 1: Specifications of ASD Field Spec

Full Range	From 350 : 2500 nm
Spectral Resolution	700 nm is 3 nm 1400 nm is 8.5 nm 2100 nm is 6.5 nm
Sampling Interval	From 350 : 1050 nm is 1.4 nm From 1000 : 2500 nm is 2 nm

Vegetation and Soil Indices

The soil and vegetation indices values have been determined from spectroscopy measurements for each field plant are based on the contrast between maximum chlorophyll absorption of the red spectrum and pigments followed by the maximum reflectance of the cell structure of the leaf in the near infrared spectrum (Table 2 and 3). The correlation between different soil and vegetation indices were observed and represented by mathematical correlations (Bjerke, 2017).

Table 2: Summary of vegetation indices, algorithms and sources for vegetation indices, R_X is the reflectance at the given wavelength (nm).

Category	Index	Equation	Explanation	Source
Canopy water content	Moisture Stress Index	MSI = R1599 /R819	Water content	(Hunt and Rock 1989)
Dry or senescent carbon	Plant SenescenceReflectance Index	PSRI = R680−R500/ R750	Chlorophyll carotenoids ratio	(Merzlyak *et al.*, 1999)
Broadband greenness	Normalized Difference Vegetation Index	NDVI= R800-R680/ R800+ R680	Biomass content	(Xu *et al.*, 2013, Rouse *et al.*, 1974)
	Simple Ratio	SR = R800/ R680	General plant condition	(Mascarini *et al.*, 2006)
	Enhanced Vegetation Index	EVI=2.5 * (R800−R6801+R800+6 * R680−7.5 * R450)	NDVI with a correction of soil reflectance	(Peng *et al.*, 2017)
Leaf pigments	Anthocyanin reflectance index	ARI1 = 1 /R550 − 1 /R700	Anthocyanin amount	(Gitelson *et al.*, 2001)
Leaf pigments	Anthocyanin reflectance index	ARI2 = R800* (1/ R550 − 1/ R700)	Anthocyanin amount	(Gitelson *et al.*, 2001)
	Carotenoids Reflection index	CRI1 = 1 /R510 − 1/ R550	Carotenoids/ chlorophyll ratio	(Gitelson *et al.*, 2002)
	Carotenoids Reflection index	CRI2 = 1/ R510 − 1 /R700	Carotenoids/ chlorophyll ratio	(Gitelson *et al.*, 2002)
	Cab	R750-R705/R750+R705	Leaf Cab concentrations	(Gitelson *et al.*, 2005)
Red edge vegetation indices	Red Edge Normalized Difference Vegetation Index	RENDVI= R750-R705/R750+R705	NDVI based on red edge spectral range	(Gitelson *et al.*, 1994, Sims& Gamon, 2002)
	Modified Red Edge Normalized Difference Vegetation Index	MRENDVI = R750−R705/ R750+R705−2 * R445	Modification of RENDVI taking into account leaf specular reflection	(Sims& Gamon 2002)
	Modified Red Edge Simple Ratio (mSR705)	MRESR = R750−R445/ R705−R445	Red edge modification of SR.	(Olofsson *et al.*, 2013; Sims& Gamon 2002)
	Red Edge Position Index	REPI = (R670 + R780)/2 REPI = 700 + 40((R670 −R700)/(R740 −R700))	Chlorophyll shifts of red edge	(Curran *et al.*, 1995 ; Guyot& Baret, 1988)

Table 3: Summary of soil indices, equations and references.

Spectral Indices	Equation	Reference
Soil Adjusted Vegetation Index (SAVI)	(1+L) (R864-R660) / (R864+R660 + L)	(Huete, 1988)
Normalized Difference Water Index (NDWI)	(R864nm - R1245nm) / (R864nm + R1245nm)	(Gao, 1996)
Desertification Soil Index (DSI)	(R1648nm – R498nm) / (R1648nm - R2203nm +0.2)	(Wu *et al.*, 2010)
Salinity Index (SI)	√R436.99nm* R630.32nm	(Kumar *et al.*, 2015)

Results and Discussion

Spectral reflectance pattern and ANOVA and Tukey's HSD analysis

The Tukey's test results explained the importance of the spectral disparity between plant species in the six spectral zones related to the general mean of reflection for all plants, the maximum and minimum reflection values for plant species. The significance of the difference among the plant species also appears in each figure.

Tukey's Results showed that red and NIR regions were the best spectral regions for differentiate among most studied species. SWIRII was also found not to be sufficient to differentiate the various plants, such result agreed with (James *et al.*, 2011; Kamal *et al.*, 2015; Aboelghar and Khdery 2017; Yones, 2019 b and Khdery 2019). Blue, Green and SWIRI spectral regions showed convenient results to discriminate species. (Fig 2 and 3).

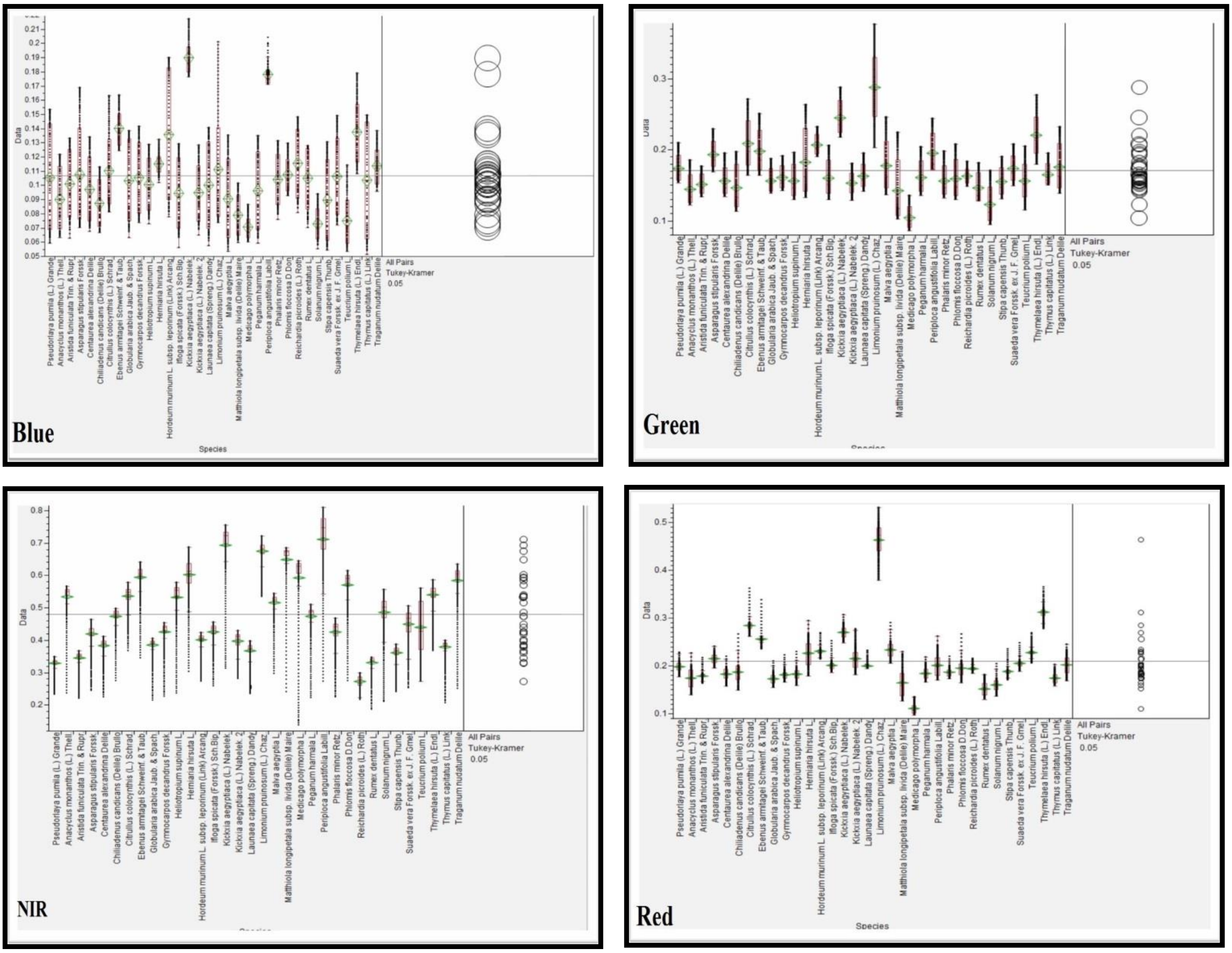

Fig. 2 Analysis of ANOVA and Tukey's for discrimination between plants (Blue, Green, NIR and Red zones).

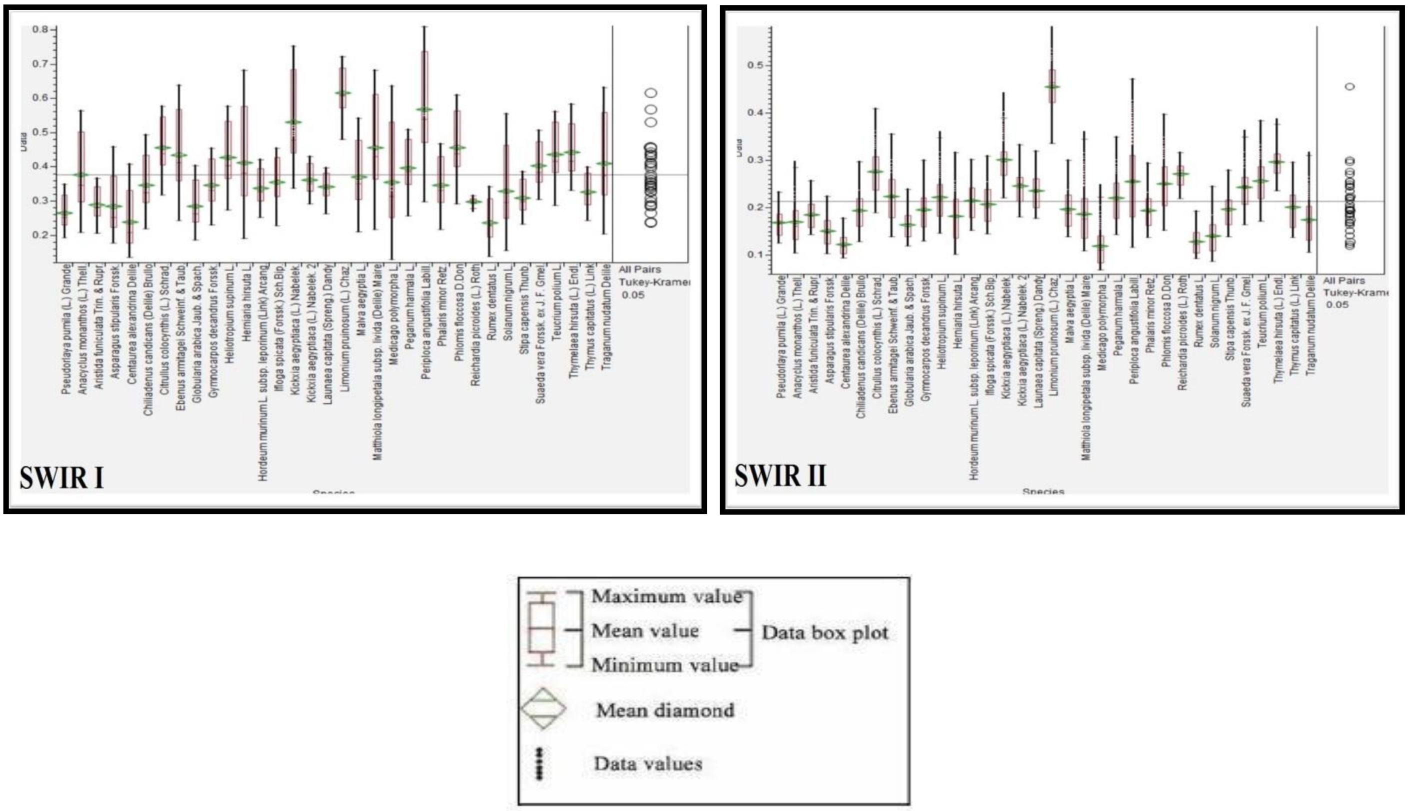

Fig. 3 : Analysis of ANOVA and Tukey's for discrimination between plants (SWIRI and SWIRII zones).

Linear discrimination analysis

Results indicated that Linear Discriminate Analysis determine the optimal wavebands and wavelengths for classifying various genera of plants. It was found that four plant species (*Ebenus armitagei, Kickxiaa egyptiaca, Medicago polymorpha and Periploca angustifolia*) have relatively wide unique spectral zones, and eight ones (*Aristida funiculate, Centaurea alexandrina, Citrullus colocynthis, Ifloga spicata, Launaea capitate, Phalaris minor, Stipa capensis* and *Traganum nudatum*) have only unique spectral zone. Studying the spectral signature of taxa, four plants (*Ebenus armitagei, Kickxia aegyptiaca, Medicago polymorpha and Periploca angustifolia*) were found to the most susceptible to discrimination and segregation through specific devices (Table 4). These species are distinguished by distinct wavelengths and high reflection values which are very separable.

Table 4: The optimal waveband to differentiate between studied species.

Species	**Optimal Wavelength Zones (nm)**
Aristida funiculata Trin. & Rupr.	1759
Centaurea alexandrina Delile	1904
Chiliadenus candicans (Delile) Brullo	1781,1815,1849,1883,
Citrullus colocynthis (L.) Schrad.	1983
Ebenus armitagei Schweinf. & Taub.	1982, 2016, 2050, 2084, 2118, 2152, 2186, 2220, 2254, 2288, 2322, 2356, 2390, 2424, 2458, 2492
Herniaria hirsuta L.	1498, 1532, 1634, 1668, 1770
Hordeum murinum L. subsp. leporinum (Link) Arcang.	1629, 1663, 1697, 1731
Ifloga spicata (Forssk.) Sch.Bip.	1764
Kickxia aegyptiaca (L.) Nabelek.	411, 445, 1975, 2009, 2043, 2077, 2111, 2145, 2179, 2213, 2247, 2281, 2315, 2349, 2383, 2417, 2451, 2485
Launaea capitata (Spreng.) Dandy	1717
Malva aegyptia L.	1831, 1865.
Matthiola longipetala subsp. livida (Delile) Maire	1786, 1820, 1854, 1888, 1922, 1956, 1990, 2024.
Medicago polymorpha L.	470, 504, 538, 572, 606, 640, 674,708, 742, 776, 810, 844, 878, 912, 946, 980, 1014, 1048, 1082, 1116, 1150, 1184, 1218, 1252, 1286, 1320, 1354, 1388, 1422, 1456, 1490, 1524, 1552, 1598, 1626, 1660, 1694, 1728, 1762, 1796, 1830, 1864, 1898, 1932, 1966, 2000, 2034, 2086, 2102, 2136, 2170, 2238, 2272, 2306.
Periploca angustifolia Labill.	681, 715, 749, 783, 817,851, 885, 919, 953, 987, 1021, 1055, 1089, 1123, 1157, 1191, 1225, 1259, 1293, 1327, 1361, 1395, 1429, 1463, 1497, 1531, 1565, 1599, 1633, 1667, 1701, 1735, 1769, 1803, 1837, 1871, 1905, 1939, 1973, 2007, 2041, 2075, 2109, 2143, 2177, 2211, 2245, 2279, 2313, 2347, 2381, 2415, 2449, 3483.
Phalaris minor Retz.	1787
Phlomis floccosa D.Don	1984, 2018
Reichardia picroides (L.) Roth	1767, 1801, 1835, 1869, 1903, 1937,
Solanum nigrum L.	1931, 1965, 1999, 2033.
Stipa capensis Thunb.	1789
Teucrium polium L.	2012, 2046, 2080, 2114.
Thymelaea hirsuta (L.) Endl.	1824, 1858, 1892.
Traganum nudatum Delile	1942

Extraction of some biophysical parameters from remote sensing data

A series of hyperspectral indices extracted from the spectrometric measurments have been used to evaluate the vitality of wild plants as shown in tables (5, 6 and 7).

The vegetation indices indicate the overall health of plants (Table 5), e.g.; low NDVI values (<0.6) indicate a reduced vegetation health. All species of plants under investigation exhibited low NDVI values. EVI index values showed a good condition for all plant species in Wadi (healthy vegetation usually ranges between the values of 0.20 to 0.80). The Moisture Stress Index (MSI) is an index for vegetation with water content that provides a measure of the water mount present in the canopy i.e., leaf water content, this index increases in water stress. Results of MSI refereed that water stress was not present, and the high values were in *Launaea capitata*, *Reichardia picroides* and *Teucrium polium.* As the simple ratio is an indication of plant condition the higher SR consider the better plant health. All plant species showed high values indicating the health of these plants. The values of the plant Senescence Reflectance Index (PSRI) indicated that all species were in borderline for good condition (Good condition range is -0.1–0.2) for *Limonium pruinosum* and *Thymelaea hirsute.* PSRI had an increased value, suggestion that these plant species was not in the stage of senescence. In table (6), Carotenoids Reflection index indicates the ratio between carotenoids and chlorophyll. For CRI1 all plant species lies in the good condition except *Hordeum murinum, Kickxia aegyptiaca, Limonium pruinosum* and *Reichardia picroides*. (CRI1: Good condition 1–12). For CRI2 all plants in good condition (CRI2: Good condition1-11).

The ARI1 and the ARI2 showed that all plants were in good condition (the values of this index range from 0 to more than 0.2). Increases in ARI2 indicate changes in the canopy through new growth or death in the foliage. Red Edge Normalized Difference Vegetation Index (RENDVI) showing that among the 33 species there was a majority for healthy species which lies in the range of healthy condition (0.2-0.9) the same was true for the Modified Red Edge Normalized Difference Vegetation Index (MRENDVI) (the range of health condition is 0.2-0.7) (table 7). Modified red edge simple ratio (mSR705 or MRESR) showed high values in most plant species within the range of health conditions (2-8).

From Pearson correlation, a strong significant positive correlation has been found between chlorophyll content and RENDVI, MRENDVI, REPI and MRESR (Table 8).

Chlorophyll content being related to NDVI values the same has been mentioned by (Haboudane, *et al.*, 2004; Aboelghar & Khdery, 2017) that Normalized Difference Vegetation Index (NDVI) being a widely used VI to estimate vegetation biophysical variables, relying on chlorophyll absorption in the red spectral region. The red-edge region is defined as the spectral region between (680 and 750 nm) where there is a sharp change in the vegetation reflectance. This happens because of the transition from chlorophyll absorption in the red zone to cell dispersion in the NIR (Clevers *et al*., 2002). The accumulation of nitrogen in leaves is generally associated with the photosynthetic potential and yield (Evans, 1989). Therefore, the leaves' chlorophyll and nitrogen status can be used to assess the overall photosynthetic ability of the canopy and the plant's productivity which correlated with the results obtained from the present study. Therefore, it can indicate that almost all plant species under investigation showed a healthy non-stressed performance.

Table 5: Values of vegetation indices: Normalized Difference Vegetation Index (NDVI), Plant Senescence Reflectance Index (PSRI), Moisture Stress Index (MSI) and Simple ratio (SR).

Plant Species	**ASD Vegetation Index**				
	Canopy water content	**Biomass content**	**General plant condition**	**Enhanced Vegetation Index**	**Senescent carbon**
	MSI	**NDVI**	**SR**	**EVI**	**PSRI**
Anacyclus monanthos (L.) Thell.	0.61	0.11	1.65	0.89	0.01
*Aristida funiculata*Trin. &Rupr.	0.79	0.11	1.31	0.93	0.06
*Asparagus stipularis*Forssk.	0.58	0.13	1.42	0.66	0.03
*Centaurea alexandrina*Delile	0.51	0.11	1.38	0.72	0.03
Chiliadenus candicans (Delile) Brullo	0.64	0.12	1.37	0.48	0.04
Citrullus colocynthis (L.) Schrad.	0.80	0.20	1.20	0.53	0.14
Ebenus armitagei Schweinf. & Taub.	0.66	0.21	1.36	0.63	0.09
*Globularia arabica*Jaub. &Spach.	0.65	0.11	1.45	0.8	0.02
Gymnocarpos decandrus Forssk.	0.75	0.12	1.49	0.92	0.04
Heliotropium supinum L.	0.73	0.12	1.67	0.78	0.03
Herniaria hirsuta L.	0.60	0.14	1.44	0.65	0.04
Hordeum murinum L. subsp. *leporinum* (Link) Arcang.	0.80	0.14	1.26	0.43	0.04
Ifloga spicata (Forssk.) Sch.Bip.	0.81	0.13	1.31	0.54	0.10
Kickxia aegyptiaca (L.) Nabelek.	0.65	0.18	1.72	0.43	0.02
Launaea capitata (Spreng.) Dandy	0.91	0.13	1.32	0.32	0.11
Limonium pruinosum (L.) Chaz.	0.84	0.28	1.15	0.98	0.33
Malva aegyptia L.	0.64	0.15	1.40	0.97	0.09
Matthiola longipetala subsp. *livida* (Delile) Maire	0.61	0.11	1.83	0.70	0.02
Medicago polymorpha L.	0.46	0.09	2.90	0.75	0.01
Peganum harmala L.	0.78	0.12	1.64	0.54	0.04
Periploca angustifolia Labill.	0.74	0.14	1.71	0.85	-0.01
Phalaris minor Retz.	0.77	0.12	1.44	0.65	0.07
Phlomis floccose D. Don	0.73	0.13	1.52	0.34	0.04
Pseudorlaya pumila (L.) Grande	0.75	0.12	1.22	0.25	0.04
Reichardia picroides (L.) Roth	1.15	0.11	1.11	0.95	0.15
Rumex dentatus L.	0.66	0.09	1.40	0.42	-0.01
Solanum nigrum L.	0.58	0.11	1.65	0.33	0.06
*Stipacapensis*Thunb.	0.81	0.12	1.25	0.22	0.08
Suaeda vera Forssk. ex J. F. Gmel.	0.87	0.13	1.34	0.35	0.06
Teucrium polium L.	1.08	0.14	1.17	7.99	0.22
Thymelaea hirsuta (L.) Endl.	0.75	0.20	1.25	0.46	0.20
Thymus capitatus (L.) Link	0.81	0.11	1.47	0.67	0.01
*Traganum nudatum*Delile	0.61	0.15	1.73	0.97	0.02

Table 6: Calculated Leaf pigment Index: Carotenoid Reflectance Index (CRI 1 and 2), Anthocyanin Reflectance Index (ARI 1and 2) and chlorophyll a and b Concentration.

Plant Species	**Biomass content**	**Anthocyanin Reflectance Index**		**Carotenoids Reflection index**		**Leaf Chl ab Concentration**
	NDVI	**ARI1**	**ARI2**	**CRI1**	**CRI2**	
Anacyclus monanthos (L.) Thell.	0.11	0.99	0.51	1.63	2.62	0.31
Aristida funiculate Trin. &Rupr.	0.11	1.04	0.36	0.89	1.93	0.17
Asparagus stipularis Forssk.	0.13	0.20	0.08	0.84	1.04	0.21
*Centaurea alexandrina*Delile	0.11	0.57	0.20	1.37	1.94	0.21
Chiliadenus candicans (Delile) Brullo	0.12	1.33	0.60	1.67	2.99	0.21
Citrullus colocynthis (L.) Schrad.	0.20	0.92	0.51	1.04	1.96	0.12
Ebenus armitagei Schweinf. & Taub.	0.21	1.1	1.40	4.28	2.07	0.20
Globularia arabica Jaub. &Spach.	0.11	0.59	0.22	1.12	1.70	0.23
Gymnocarpos decandrus Forssk.	0.12	0.73	0.32	0.98	1.71	0.24
Heliotropium supinum L.	0.12	0.76	0.42	1.26	2.02	0.31
Herniaria hirsuta L.	0.14	0.40	0.24	1.68	2.08	0.24
Hordeum murinum L. subsp. *leporinum* (Link) Arcang.	0.14	0.59	0.24	0.51	1.10	0.14
Ifloga spicata (Forssk.) Sch.Bip.	0.13	0.89	0.39	1.34	2.23	0.18
Kickxia egyptiaca (L.) Nabelek.	0.18	0.22	0.15	0.60	0.82	0.31
Launaea capitata (Spreng.) Dandy	0.13	0.82	0.32	0.97	1.79	0.17
Limonium pruinosum (L.) Chaz.	0.28	0.77	0.54	0.67	1.44	0.08
Malva aegyptia L.	0.15	0.62	0.31	1.59	2.21	0.22
Matthiola longipetala subsp. *livida* (Delile) Maire	0.11	0.09	0.06	3.08	3.17	0.38
Medicago polymorpha L.	0.09	0.11	0.06	2.53	2.42	0.56
Peganum harmala L.	0.12	0.30	0.15	1.40	1.70	0.30
Periploca angustifolia Labill.	0.14	0.29	0.22	1.14	1.43	0.33
Phalaris minor Retz.	0.12	0.50	0.22	1.42	1.92	0.23
*Phlomis floccosa*D.Don	0.13	1.05	0.61	1.46	2.52	0.26
Pseudorlaya pumila (L.) Grande	0.12	0.39	0.13	1.01	1.40	0.13
Reichardia picroides (L.) Roth	0.11	0.80	0.24	0.65	1.45	0.06
Rumex dentatus L.	0.09	0.01	0.01	1.41	1.39	0.22
Solanum nigrum L.	0.11	0.97	0.47	2.25	3.22	0.30
Stipa capensis Thunb.	0.12	1.02	0.38	1.13	2.15	0.14
Suaeda vera Forssk. ex J. F. Gmel.	0.13	0.77	0.37	0.93	1.70	0.19
Teucrium polium L.	0.14	1.16	0.63	1.34	2.51	0.10
Thymelaea hirsuta (L.) Endl.	0.20	0.87	0.47	0.84	1.71	0.14
Thymus capitatus (L.) Link	0.11	0.19	0.07	1.00	1.19	0.24
Traganum nudatum Delile	0.15	0.22	0.13	1.33	1.55	0.33

Table 7: Red edge vegetation index; RENDVI, MRENDVI, MRESR and REPI.

Plant Species	**Red edge vegetation index**		
	RENDVI	**MRENDVI**	**MRESR**
Anacyclus monanthos (L.) Thell.	0.32	0.46	2.65
Aristida funiculate Trin. &Rupr.	0.17	0.32	1.93
Asparagus stipularis Forssk.	0.21	0.44	2.44
Centaurea alexandrina Delile	0.21	0.37	2.12
Chiliadenus candicans (Delile) Brullo	0.21	0.30	1.82
Citrullus colocynthis (L.) Schrad.	0.12	0.20	1.47
Ebenu sarmitagei Schweinf. & Taub.	0.20	0.31	1.87
Globularia arabica Jaub. &Spach.	0.23	0.43	2.46
Gymnocarpos decandrus Forssk.	0.24	0.43	2.48
Heliotropium supinum L.	0.31	0.47	2.70
Herniaria hirsuta L.	0.24	0.34	2.00
Hordeummurinum L. subsp. *leporinum* (Link) Arcang.	0.14	0.33	1.96
Ifloga spicata (Forssk.) Sch.Bip.	0.18	0.29	1.79
Kickxia egyptiaca (L.) Nabelek.	0.31	0.56	3.46

Launaea capitata (Spreng.) Dandy	0.17	0.32	1.91
Limonium pruinosum (L.) Chaz.	0.08	0.13	1.27
Malva aegyptia L.	0.22	0.33	1.93
Matthiola longipetala subsp. *livida* (Delile) Maire	0.38	0.49	2.86
Medicago polymorpha L.	0.56	0.74	6.32
Peganum harmala L.	0.30	0.49	2.84
Periploca angustifolia Labill.	0.33	0.53	3.20
Phalaris minor Retz.	0.23	0.40	2.26
Phlomis floccose D. Don	0.26	0.39	2.22
Pseudorlaya pumila (L.) Grande	0.13	0.29	1.78
Reichardia picroides (L.) Roth	0.06	0.17	1.40
Rumex dentatus L.	0.22	0.43	2.47
Solanum nigrum L.	0.30	0.42	2.42
Stipa capensis Thunb.	0.14	0.26	1.66
Suaeda vera Forssk. ex J. F. Gmel.	0.19	0.34	1.99
Teucrium polium L.	0.10	0.16	1.37
Thymelaea hirsuta (L.) Endl.	0.14	0.23	1.58
Thymus capitatus (L.) Link	0.24	0.48	2.84
Traganum nudatum Delile	0.33	0.49	2.86

Table 8: Correlations between chlorophyll content and RENDVI, MRENDVI, REPI and MRESR.

Correlations						
		Chl	**RENDVI**	**MRENDVI**	**MRESR**	**REPI**
Chl	Pearson Correlation	1	1.000**	0.932**	0.918**	0.790**
	Sig. (2-tailed)		0.000	0.000	0.000	0.000
	N	33	33	33	33	33
RENDVI	Pearson Correlation	1.000**	1	0.932**	0.918**	0.790**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	33	33	33	33	33
MRENDVI	Pearson Correlation	0.932**	0.932**	1	0.916**	0.850**
	Sig. (2-tailed)	0.000	0.000		0.000	0.000
	N	33	33	33	33	33
MRESR	Pearson Correlation	0.918**	0.918**	0.916**	1	0.766**
	Sig. (2-tailed)	0.000	0.000	0.000		0.000
	N	33	33	33	33	33
REPI	Pearson Correlation	0.790**	0.790**	0.850**	0.766**	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	
	N	33	33	33	33	33
**. Correlation is significant at the 0.01 level (2-tailed).						

Remote Sensing for soil Status Detection:

Spectroscopic techniques became attractive tool in assessing prosperities of soil for they are fast and required little labour and decrease amount of laboratory waste produced when compared to conventional methods. Also, spectroscopy techniques may also have additional advantages compared to a laboratory such as providing high density, spatially continuous information. However, the accuracy of the predictions derived from spectroscopic techniques decreases when the soil's spectral mix with other targets occurs. Various hyperspectral soil indices (HVI) were selected to assess the extent of soil salinity as shown in (Table 9). Soil Adjusted Vegetation Index (SAVI) shows low values indicating the desert habitat with low vegetation. For 16 stands, SAVI calculated showed amaximum value of 0.106 and aminimum value of 0.063. Stand 10 showed good vegetation cover with higher values and attained the lowest salinity value, (George & Kumar, 2015). The values of DSI ranged from 1.498 minimum to 1.823 maximum. George & Kumar, 2015suggested that DSI values are increasing with salinity increasing (Wu, *et al.*, 2010) founded that desert soil has the highest values of DSI, whereas, wild grass ground and cultivated land having medium values whereas the low values attained by vegetation and water bodies, therefore all the measured stands of the study had low DSI values.

The desertification soil index for all stands showed that, all soil samples ranged in normal salinity condition which asserted by the low values of the salinity index. Salinity Index of the studied stands showed that the higher SI values, the higher salinity. Stand 1 attained the highest value of SI (0.388), Kumar et al., 2015 suggested a high correlation between the index of salinity and values of electrical conductivity. Also, results showed that the maximum value of NDWI (-0.055) was found in stand 1 and minimum (-0.089) in stand 14. All the studied stands had negative NDWI values, which showed soil contribution and very low moisture in soil.

Table 9: Different soil hyperspectral indices (SAVI, DSI, SI and NDWI,) used in the study.

Stand No.	**SAVI**	**DSI**	**SI**	**NDWI**
S 1	0.063	1.498	0.388	-0.055
S 2	0.08	1.562	0.245	-0.075
S 3	0.084	1.742	0.249	-0.076
S 4	0.085	1.799	0.23	-0.088
S 5	0.088	1.713	0.247	-0.086
S 6	0.079	1.618	0.230	-0.078
S 7	0.09	1.753	0.238	-0.079
S 8	0.096	1.672	0.221	-0.084
S 9	0.081	1.731	0.250	-0.08
S 10	0.106	1.77	0.215	-0.089
S 11	0.096	1.684	0.221	-0.084
S 12	0.087	1.596	0.219	-0.085
S 13	0.089	1.716	0.238	-0.083
S 14	0.09	1.823	0.23	-0.089
S 15	0.086	1.667	0.238	-0.083
S 16	0.085	1.809	0.239	-0.084

The correlation between the different soil indices and chemical analysis of soil as presented in Table (10), table 10 showed a negative correlation between E.C. and SAVI (low values of SAVI indicate low vegetation). In the present study, a significant positive correlation has been found between E.C. and DSI and SI as the E.C. increase salinity index, as well as the desertification index increased.

The SAVI values varied under various salinity classes, indicating the effect of salinity on vegetation (George & Kumar, 2015). Such a result coincided with results gained in the present study as there was a negative correlation between SAVI and the SI, the same relation was found with E.C. with increasing salinity.

Table 10: Correlation between the different soil hyperspectral indices and their chemical analysis.

Correlations										
		SAVI	**DSI**	**SI**	**TDS**	**Ca^{+2}**	**HCO_3^{-}**	**PH**	**Cl^{-}**	**E.C.**
SAVI	Pearson Correlation	1	-.103-	-.775-**	.196	.448	.321	.284	.174	-.103-
DSI	Pearson Correlation	-.103-	1	.496*	.018	.070	-.008-	-.073-	.028	1.000**
SI	Pearson Correlation	-.775-**	.496*	1	-.038-	-.175-	-.198-	-.505-*	-.036-	.496*
TDS	Pearson Correlation	.196	.018	-.038-	1	.897**	-.030-	-.289-	.992**	.018
Ca^{+2}	Pearson Correlation	.448	.070	-.175-	.897**	1	-.110-	-.319-	.911**	.070
HCO3^{-}	Pearson Correlation	.321	-.008-	-.198-	-.030-	-.110-	1	.428	-.140-	-.008-
pH	Pearson Correlation	.284	-.073-	-.505-*	-.289-	-.319-	.428	1	-.323-	-.073-
Cl^{-}	Pearson Correlation	.174	.028	-.036-	.992**	.911**	-.140-	-.323-	1	.028
E.C.	Pearson Correlation	-.103-	1.000**	.496*	.018	.070	-.008-	-.073-	.028	1
**. Correlation is significant at the 0.01 level (2-tailed).										
*. Correlation is significant at the 0.05 level (2-tailed).										

Conclusion

This work was performed to track the spectral reflectance characteristics of wild plants in Wadi Al- Afreet. The main objective was to identify the spectral zone and wavelength/s most significant for the wild plants. Results from the statistical analysis of Tukey test showed that NIR and Red spectral zone were optimum for discrimination between plants in the Wadi. The wavelength provided by hyperspectral techniques can be considered as numerical and positional fingerprints; useful and efficient tool for identifying the samples studied. Calculated values of (NDVI) and (CI) showed the close relationship between chlorophyll and red and infrared spectral reflectance regions. High chlorophyll content in plant leaves results in the use of much of the red spectrum in photosynthesis resulting in very low reflectance in the red spectral zone which is eventually translated into high (NDVI). Remote sensing approach can be considered useful in studying plant diversity in Wadis.

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