Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 23(1): 27 – 36 (2019)
www.ejabf.journals.ekb.eg

Identification of mangrove plant using hyperspectral remote sensing data along the Red Sea, Egypt

Manar A. Basheer*[1]; Sameh B. El Kafrawy[1] and Amal A. Mekawy[2]

1- Marine Science Department, National Authority for Remote Sensing and Space Sciences, Egypt.
2- The Regional Centre of Mycology and Biotechnology, Al-Azhar University, Egypt.

***Corresponding author:** mmanarmm2015@gmail.com

ARTICLE INFO

Article History:
Received: Dec.16, 2018
Accepted: Jan. 21, 2019
Online: Jan. 28, 2019

Keywords:
Mangrove
Avicennia marina
Hyper-spectral signature
Remote sensing
Red Sea

ABSTRACT

The mangrove ecosystem is one of the most productive habitats that support many marine species and its adaptation to adverse environmental conditions, increase the demand to map, manage and monitor this ecosystem. The presence of hyperspectral remote sensing techniques can potentially improve the ability to measure the spectral signature of mangrove to differentiate mangrove from the other vegetation and to get detailed information about this ecosystem. This study has been carried out for mapping, monitoring and managing the Red Sea mangrove ecosystems through measuring their spectral properties using advanced hyperspectral remote sensing techniques. The spectral signature data were measured using Analytical Spectral Devices (ASD) Fieldspec spectroradiometer on November 2016 then the data were tested using statistical measures namely One-way Analysis of Variance (ANOVA) along with Tukey's HSD test. The hyperspectral signatures of *A. marina* mangrove at the different sites showed that mangroves recorded a high reflectance at the visible and NIR region of the spectrum than the other regions and there are similarities at certain wavelengths and some differences at other wavelengths used for differentiation between mangroves in various environments. ANOVA and Tukey's HSD test results showed that NIR region is the best region for the differentiation of mangrove from the other vegetation.

INTRODUCTION

Mangroves are plant forests live between land and sea in tropical and subtropical regions. In Egypt, mangroves occupy many sites along the Sinai Peninsula and the Red Sea coastline; they are highly adapted to the stiff conditions of salinity and high temperature dispersed in numerous locations along the Red Sea coast, but the overall area is relatively small. Mangroves ecosystem located at extreme environment between land and water. They have submerged roots, trunks and branches. These features attract fungal and bacterial communities (Shebany 2012).

There are two species of mangroves in Egypt, *Avicennia marina* (black or gray mangrove) and *Rhizophora mucronata* (red mangrove). Mangroves extend into temperate regions between 30^o north and 30^o south of the equator. Mangroves ecosystem considered as one of the most productive ecosystems. They act as a rich habitat for different organisms and a breeding site for birds and other marine organisms. Mangroves plants participate in coastal protection by the prevention of erosion, protection against floods and hurricanes, and most importantly maintenance of biodiversity (Kairo *et al.,* 2003; Onn, 2013). Moreover, it remains as an ecosystem of a leading role for the ecological balance, being responsible for supplying nutrients to the marine environment and forms forests of salt-tolerant plant species with harbor a high number of marine microorganisms (Onn, 2013).

Mangroves maps at the species level are not easy due to difficult accessibility to mangroves. Remote sensing is an alternative technique for mangroves mapping. It is the only technique used for assessment of mangroves change detection over large areas (Vaiphasa, 2006). Satellite sensors can observe the earth in visible light region and infrared region. Spatial resolution of the satellite sensors ranges from more than one kilometer to less than one meter; high spatial resolution sensor gives more details about the area of interest (Karmaker, 2006).

Mapping of mangrove forests in coastal areas is important for the assessment of its temporal change. Remote sensing has a significant role in providing fast and efficient method for mapping and monitoring of inaccessible mangroves areas (Kamal *et al.,* 2011).

According to Heumann (2011), traditional remote sensing techniques unable to detect plant species due to low spatial resolution, but recent advanced remote sensing techniques as hyperspectral remote sensing techniques especially at very high spatial resolutions used to discriminate between mangroves species. The development of remote sensing techniques provides a way for mangroves mapping. Moreover, it decreases human energy, time and cost. Remote sensing satellite information has been recorded remotely and transformed into remote sensing images. The information produces images with spatial resolution (size of the pixel), spectral resolution (wavelength ranges). The reflectance of each pixel is measured at narrow, contiguous wavelength intervals. The spatial resolution of satellite images is too low to identify many objects by their shape or spatial detail. So, the measuring of spectral signature of vegetation, soil, and water is used to identify the object (Nanna *et al.,* 2012).

Several characteristics of mangroves have potential to be used as interpretation keys to identify mangrove forest from adjacent environments; this includes mangrove location and zonation patterns, textural properties of the canopy, and spectral reflectance characteristics of the canopy. In general, mangroves have distinct spectral reflectance characteristics that make them recognizable by the optical sensors as being different from adjacent land and sea features. Several studies have been carried out utilizing the mangroves spectral reflectance to map mangroves ecosystems and species differentiation. The spectral response of plants is a function of the optical properties of their constituents and structural attributes. The chemical properties of pigments, water, and dry-matter content create distinct absorption features across the reflectance spectra. Spectral reflectance can be defined as the ratio of incident to reflected radiation measured from an object or area over specified wavelengths. Most vegetation has unique spectral properties that making them easily identified by remotely sensed data (Kamal *et al.,* 2015).

Spectral reflectance of mangroves showed variations in the radiances between different mangroves species and also within the same species occurring in different sites during the same period of observation. Moreover, mangroves species can be differentiated using their unique spectral reflectance in the visible and NIR region (Parwate *et al.,* 2015). Vegetation indices as the Normalized Differential Vegetation Index (NDVI) are also used for assessment of the vegetation productivity. The NDVI represent the greenness of mangroves forests and hence, reflect their health and photosynthetic activity. Values of this index are calculated from the solar radiation that reflected in the near-infrared (NIR) and red (R) bands of the satellite image using the equation NDVI = [(NIR) - R]/ [(NIR) + R], which varies between -1 and 1. Low value close to zero indicates no vegetation while high value close to 1 represents a high density of green vegetation (Satyanarayana *et al.,* 2011; Kamal *et al.,* 2015& Guha, 2016). The aim of this study is to map, monitor, detect the changes, and identify mangroves by measuring the spectral signature using hyperspectral remote sensing and Geographical information system (GIS) techniques.

The Study Area

Two mangroves stands along the Red Sea were selected; 17 km South Safaga Stand and North Quseir (Wadi Abu Hamrah) Stand. South Safaga stand (26° 37' 01.04" N& 34° 00' 39.96" E) have a long series of compact mangrove patches that were clumped with sandy areas in between. Wadi Abu Hamrah stand 26° 23' 58.04"N& 34° 07' 01.19" E) located 35 km north of Quseir in which mangroves were clumped with vigorous growth (Figure (1) shows the location of the two study areas).

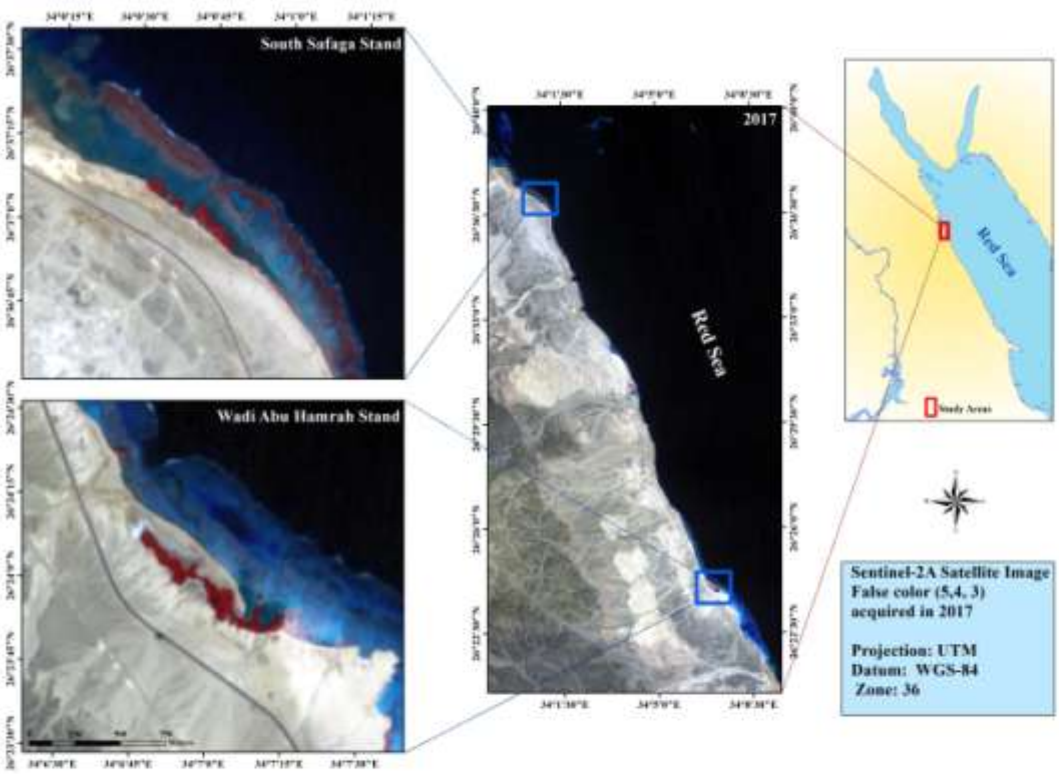

Fig. 1: Location of the two study areas along the Red Sea

MATERIALS AND METHODS

Hyperspectral field data Measurements

Spectral signature values were measured at an open area under clear, sunny and cloudless weather conditions at the canopy level using Analytical Spectral Devices (ASD) Fieldspec spectroradiometer that was equipped with three detectors (i.e., Visible, NIR, SWIR-1, and SWIR-2), covering 350 nm to 2500 nm, with sampling intervals of 1.4 nm between 350 nm and 1000 nm, and 2 nm between 1000 nm and 2500 nm. The measurements were conducted on November 2016 by two methods; by positioning the sensor at an average height of 40 cm above the target in nadir position using 25°angular field of view (FOV), and by measuring the spectral data directly using leaf clip. Five readings were recorded for each site (Figure 2& Table 1).

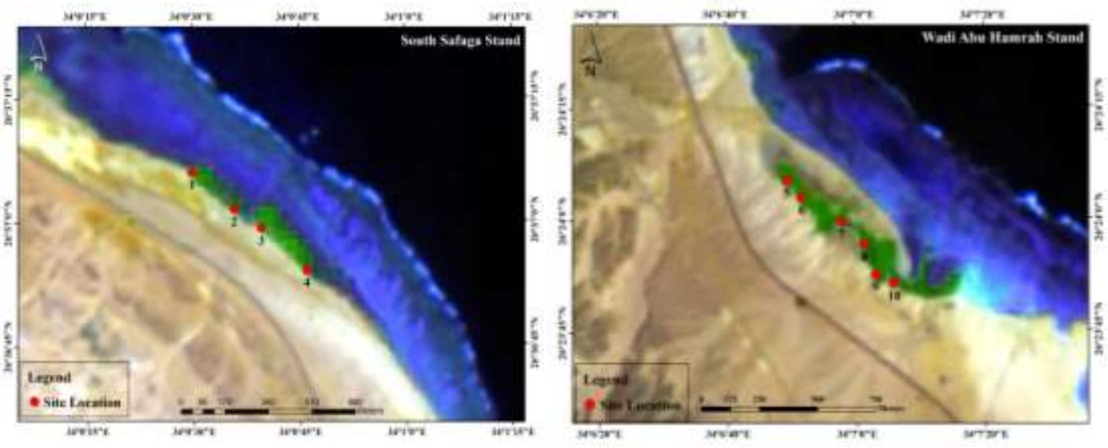

Fig. 2: The ten sites at the two study areas

Table 1: Coordinates of the ten sites at the two study areas along the Red Sea coast

Station No.	Latitude (N)	Longitude (E)
1	26° 24' 4.428"	34° 06' 49.607"
2	26° 24' 2.772"	34° 06' 51.299"
3	26° 23' 58.991"	34° 06' 57.887"
4	26° 23' 56.579"	34° 07' 0.948"
5	26° 23' 52.980"	34° 07' 2.567"
6	26° 23' 52.439"	34° 07' 5.087"
7	26° 36' 55.800"	34° 00' 43.019"
8	26° 36' 50.760"	34°00' 50.40"
9	26° 36' 58.679"	34° 00' 39.887"
10	26° 37' 2.568"	34° 00' 33.659"

Data Analysis

The spectral data of mangroves were processed using ASD Viewspec program then was managed to produce the graphs. The average of 5 spectral reflectance readings for each site was used to produce a reflectance curve which was then analyzed to differentiate amongst mangroves at each site. Spectral reflectance at wavelengths of around 1400 nm, 1940 nm, and 2400 nm was ignored because of the presence of undue noise made by atmospheric water absorption.

One Way ANOVA and Tukey's HSD Post Hoc Analysis

One-way ANOVA and Tukey's HSD analysis which performed using JMP software used for the assessment of the variability of the spectral signature data of mangroves at the different ten sites by identifying the electromagnetic spectrum range in which the mangroves most differ from each other. One-way analysis of variance (ANOVA) and then Tukey Honestly Significance Difference (HSD) test across blue (35- 450 nm), green (450 -550 nm), red (550 -700 nm), near infrared (700 -1000 nm), and shortwave infrared (1000 -2500 nm) bands was applied to detect the differences among spectral signature data means and to determine which groups of means are different from one another (Arafat *et al.*, 2013).

Satellite data used

Six remote sensing satellite images were used and acquired from (https://earthexplorer.usgs.gov/) (Table 2). Five optical Landsat satellite images acquired on 1984, 1990, 2000, 2003, and 2011 and one optical Sentinel-2A satellite image acquired on 2017 were used to map mangrove vegetation in the study areas.

Table 2: The remote sensing satellite images data

No.	Satellite	Sensor	No. of Bands	Date
1	Landsat5	TM (Thematic Mapper)	7	24/10/1984
2	Landsat4	TM (Thematic Mapper)	7	1/10/1990
3	Landsat5	TM (Thematic Mapper)	7	4/10/2000
4	Landsat7	ETM+ (Enhanced Thematic Mapper Plus)	9	28/4/2003
5	Landsat7	ETM+ (Enhanced Thematic Mapper Plus)	9	11/10/2011
6	Sentinel-2A	Sentinel-2A	13	12/11/2017

Normalized Difference Vegetation Index (NDVI)

In remote sensing analysis, vegetation indices e.g. the Normalized Differential Vegetation Index (NDVI) were used, by dividing near-infrared radiation minus red light by near-infrared radiation plus red light as shown in equation (1), NDVI value range is from -1 to +1 with higher values characteristic of the high vegetation (Guha, 2016).

$$\text{NDVI} = \frac{(NIR-R)}{(NIR+R)} \qquad (1)$$

Where NIR is the near-infrared band and R is the red band.

RESULTS

All hyperspectral signature values at the ten sites (Figures 3 and 4) showed that mangroves recorded the highest reflectance at NIR region (700 - 1300 nm), relatively low spectral reflectance in the spectral range (1450 - 1800 nm) while the lowest was in the spectral range (1950 - 2500 nm). The data also revealed that all hyperspectral signature values of mangroves in the visible region 350-450 nm (blue), 450-550 nm (green), and 550-700 nm (red) and NIR region have a big similarity.

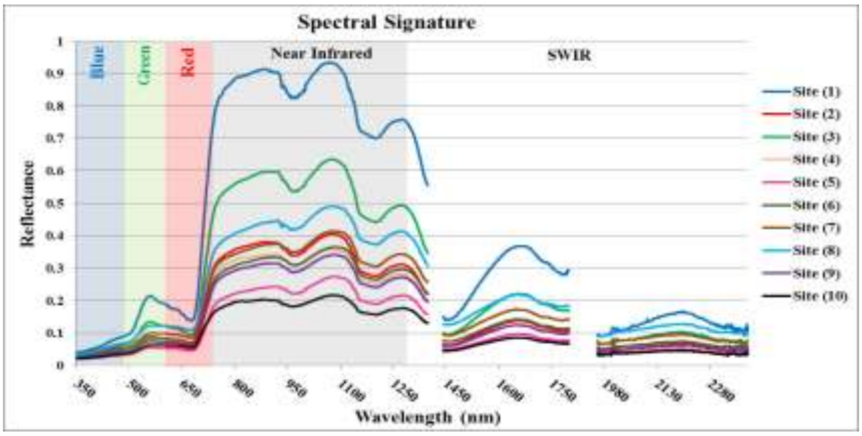

Fig. 3: Hyperspectral signature values of mangroves at the ten sites measured at an average height of 40 cm above vegetation at nadir position

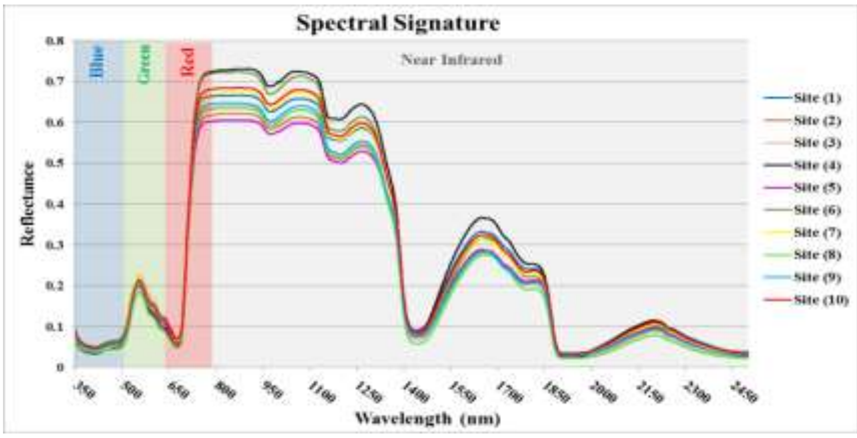

Fig. 4: Hyperspectral signature values of mangroves measured directly by leaf clip at the ten sites

It is noticeable that these data which was measured using leaf clip showed a big similarity in the spectral reflectance of mangroves at all sites with higher reflectance at visible and NIR regions than that measured at 40 cm above mangroves at nadir position.

The result of ANOVA test Figure (5) showed that all spectral reflectance data of mangroves in visible and NIR regions were slightly different. Tukey's HSD test showed that NIR spectral region is the best region for the differentiation among mangroves at the ten sites followed by blue and red region, while green and SWIR regions did not show a significant difference in the reflectance of mangroves.

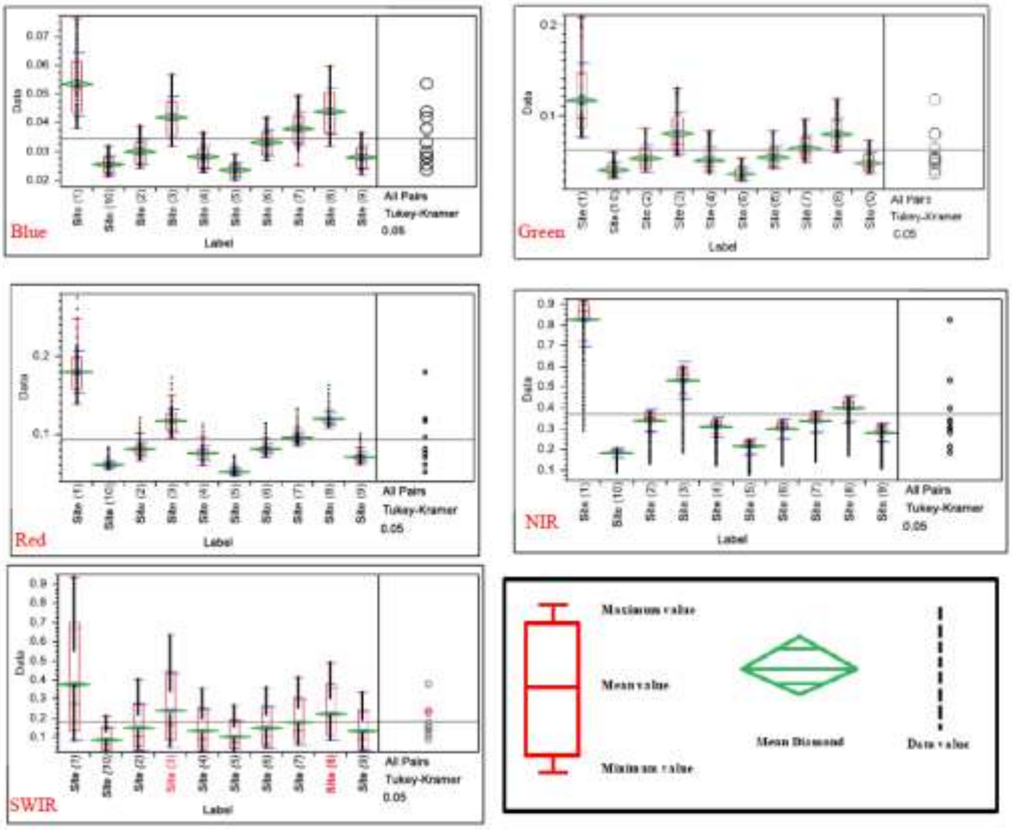

Fig. 5: ANOVA and Tukey's HSD graph of variance by blue, green, red, NIR and SWIR bands

NDVI results (Fig. 6) and change detection data of mangroves area from 1984 till 2017 showed that mangrove stands at both study areas increase clearly. Mangroves area at South Safaga stand was 11360.6 m^2 in 1984 and becomes

34219.35 m^2 in 2017, while the area at Abu Hamrah Stand was 30641.1 m^2 in 1984 and becomes 81106.25 m^2 in 2017. Table (3) and Figure (7) showing the changes in mangrove area at the two stands from 1984 till 2017.

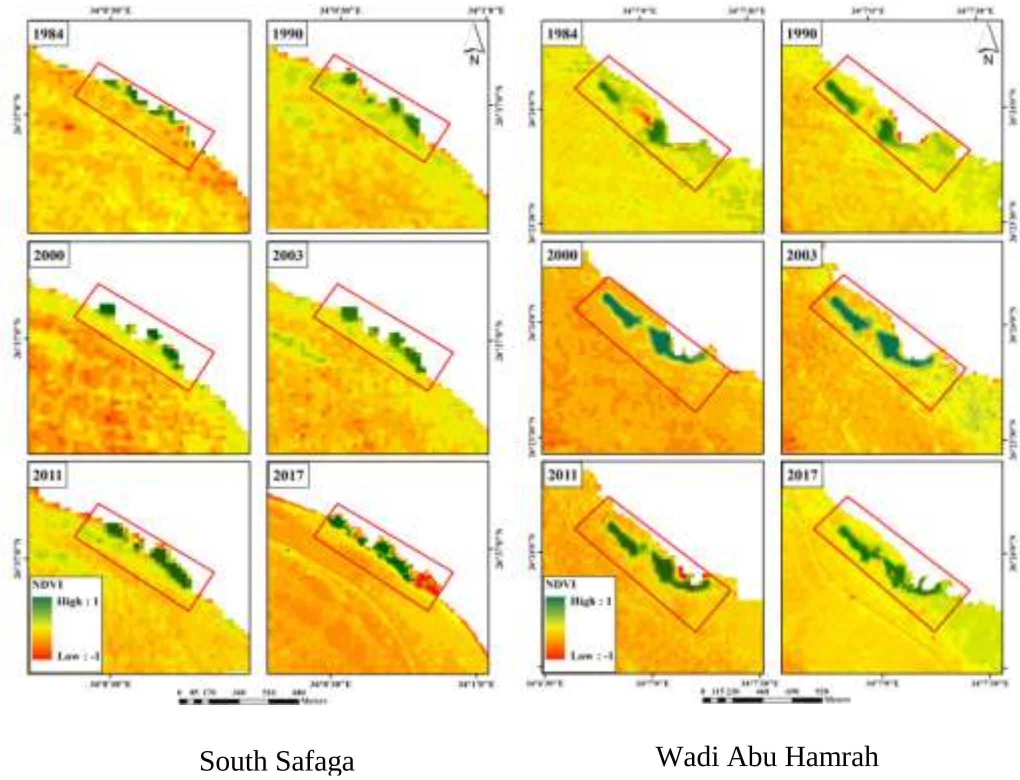

Fig. 6: Normalized Difference Vegetation Index from 1972 till 2017 at South Safaga and Wadi Abu Hamrah stands.

Table 3: Changes in the total area of mangroves at the two Stands from 1984 till 2017.

Date	Total Area (m^2) South Safaga stand	Total Area (m^2) Wadi Abu Hamrah stand
1984	11360.6	30641.1
1990	20055.73	40873.96
2000	21002.38	65092.57
2003	27799.45	76172.58
2011	30378.32	79720.86
2017	34219.35	81106.25

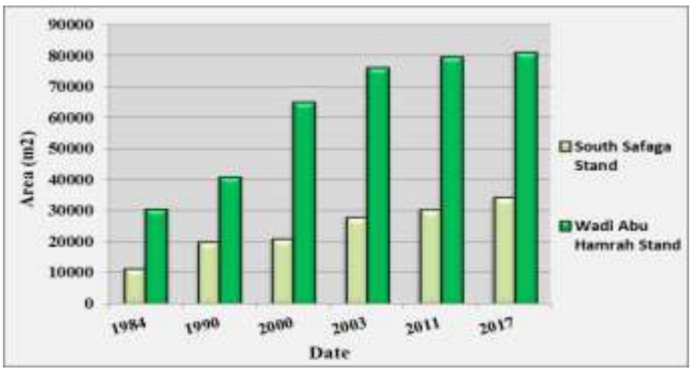

Fig. 7: Changes of mangroves area from 1984 till 2017 at the two study areas

DISCUSSION

These hyperspectral signature data results are consistent with the results of Kamaruzaman & Kasawani (2007) and Ajithkumar *et al.*, (2008). Results also verified that the two study areas have the same species. However, there are differences at a certain wavelength range. This may be due to the properties of the individual leaf such as pigmentation, leaf age, and chlorophyll contents.

According to Kuenzer *et al.*, (2011), the soil type affects the spectral signature of plants, so that mangroves stand with lower density are affected by the ground surface. This can explain the slight differences among the spectral reflectance values of the mangroves at the two study areas where the South Safaga stand has the lower density of mangrove than Wadi Abu Hamrah stand.

Hyperspectral signature values affected by several factors that affect the leaf reflectance measurement and cause the differences between the data measured directly by leaf clip and that measured at an average height of 40 cm above the target in nadir position. Data measured directly by leaf clip only affected by the leaf component while that measured at an average height of 40 cm above the target in nadir position affected by the other structures of mangrove tree such as the reflectance of branches (Kamal *et al.,* 2017), the reflectance from undergrowth, soil, and roots (Axelsson, 2011).

The increase in mangrove area may be explained by the results of Sheded *et al.*, (2013) who studied the effect of environmental conditions on the vegetation located between Safaga to South Quseir. Their study stated that the coastal zone of the Red that divided the Red Sea coastal area into saline (as mangrove swamps) and non-saline habitats (as coastal mountains) is controlled by soil salinity and ionic concentration. The measured cations and anions in the study area, the precipitation of clay, the decomposition of plant residues and the dissolved potassium and calcium that came with rain were higher and increased the organic matter content in the ecotonal zone. These conditions stimulate and enrich the growth of encouraged the species that can tolerate high salinity (halophytes) such as mangroves. Besides, the two study areas were not containing any construction activities (except Safaga-Al-Quseir road) which may have direct or indirect adverse effects on the mangroves. This may also explain the increasing of mangroves total area at the two study areas.

CONCLUSION

We can conclude that hyperspectral ground measurements can be used for giving timely information about vegetation in specific areas and contain adequate spectral details for discriminating most mangrove species and differentiating between the same species in different environmental conditions thereby providing valuable data for decision makers for generation of spectral library to support vegetation mapping using imaging spectroscopy. The results showed that mangrove species can be differentiated and separated using their unique spectral signature in the visible and NIR region. The result of ANOVA statistical analysis test revealed that species discrimination at the study area can be significantly discriminated by the NIR followed by blue and red spectral regions. The combination of remote sensing and GIS techniques is an advantageous tool for the detection of mangrove changes over time in response to both natural and anthropogenic forces. It is clear that in both study areas mangrove area increases due to absence of any construction activities so decision makers can take advantage of it for rehabilitation and plantation of mangrove in the suitable area.

REFERENCES

Ajithkumar, T. T.; Thangaradjou, T. and Kannan, L. (2008). Spectral reflectance properties of mangrove species of the Muthupettai mangrove environment, Tamil Nadu. Journal of Environmental Biology, 29(5): 785-788.

Arafat, S. M.; Aboelghar, M. A. and Ahmed, E. F. (2013). Crop discrimination using field hyper spectral remotely sensed data. Advances in Remote Sensing, 2(02): 63.

Axelsson, C. R. (2011). Predicting mangrove leaf chemical content from hyperspectral remote sensing using advanced regression techniques. University of Twente Faculty of Geo-Information and Earth Observation (ITC).

Guha, S. (2016). Capability of NDVI technique in detecting mangrove vegetation. International Journal of Advanced Biological Research, 6(2): 253-258.

Heumann, B. W. (2011). Remote sensing of mangrove composition and structure in the Galapagos Islands.

Kairo, J. G., and Hegazy, A. K. (2003). Rehabilitation, conservation and sustainable utilization of mangroves in Egypt. Ministry of Agriculture & Land Reclamation, Ministry of State for Environment, Food and Agriculture Organization of the United Nations (FAO), Cairo.

Kamal, M., and Phinn, S. (2011). Hyperspectral data for mangrove species mapping: A comparison of pixel-based and object-based approach. Remote Sensing, 3(10): 2222-2242.

Kamal, M.; Ningam, M. U. L. and Alqorina, F. (2017). The Effect of Field Spectral Reflectance Measurement Distance to the Spectral Reflectance of Rhizophora stylosa. In IOP Conference Series: Earth and Environmental Science (Vol. 98, No. 1, pp. 012059). IOP Publishing.

Kamal, M.; Phinn, S. and Johansen, K. (2015). Object-based approach for multi-scale mangrove composition mapping using multi-resolution image datasets. Remote Sensing, *7*(4): 4753-4783.

Kamaruzaman, J. and Kasawani, I. (2007). Imaging spectrometry on mangrove species identification and mapping in Malaysia. WSEAS Trans Biol Biomed, 8: 118-126.

Karmaker, S. (2006). Study of Mangrove Biomass, Net Primary Production & Species Distribution using Optical & Microwave Remote Sensing Data (Doctoral dissertation, Indian Institute of Remote Sensing).

Kuenzer, C.; Bluemel, A.; Gebhardt, S.; Quoc, T. V. and Dech, S. (2011). Remote sensing of mangrove ecosystems: A review. Remote Sensing, 3(5): 878-928.

Nanna, S.; Sahib, S.; Abdollah, M. F. and Selamat, S. R. (2012). Thresholding and Fuzzy Rule-Based Classification Approaches in Handling Mangrove

Forest Mixed Pixel Problems Associated with in QuickBird Remote Sensing Image Analysis.

Onn M. L. (2013). Screening of mangrove endophytic fungi for bioactive compounds. M.S. Thesis, Universiti Malaysia Sarawak.

Parwate, A. V. and Ramya.T. (2015). Mapping of Mangrove cover and Creation of Spectral Library for Pichavaram Mangroves in Tamil Nadu. International Journal of Research in Engineering Science and Management Technologies, 1.

Satyanarayana, B.; Mohamad, K. A.; Idris, I. F.; Husain, M. L. and Dahdouh-Guebas, F. **(2011).** Assessment of mangrove vegetation based on remote sensing and ground-truth measurements at Tumpat, Kelantan Delta, East Coast of Peninsular Malaysia. International Journal of Remote Sensing, 32(6): 1635-1650.

Shebany, Y. M. (2012). Antimicrobial Activity of Endophytic Fungi Isolated from Avicennia marina Plant, Red Sea, Egypt.

Sheded M. G.; Ahmed M. K. and Hammad S. A. (2013). Vegetation Analysis in the Red Sea-Eastern Desert ecotone at the area between Safaga and South Qusseir, Egypt. Helwan Conf. Egypt J Bot. 3rd Int. Conf. 17-18, Helwan Univ. 2013: 145-163.

Vaiphasa, C. **(2006)**. Remote sensing techniques for mangrove mapping.

ARABIC SUMMARY

التعرف على اشجار المانجروف عن طريق أستخدام تقنيات الاستشعار من البعد فائقة الطيفية في البحر الأحمر، مصر.

منار أحمد بشير[١] ، سامح بكر الكفراوي[١] ، أمل أحمد مكاوي[٢]
١- قسم علوم البحار ، الهيئة القومية للاستشعار من البعد وعلوم الفضاء ، القاهرة
٢- المركز الإقليمي للفطريات وتطبيقاتها ، جامعة الأزهر، القاهرة

المانجروف عبارة عن غابات ملحية موجودة بين الأرض والبحر في خطوط العرض المدارية وشبه الاستوائية كواحد من أكثر النظم الإيكولوجية إنتاجية التي تدعم العديد من الكائنات البحرية وتساعد في تكيفها مع الظروف البيئية الغير مناسبة، مما يزيد من الطلب على إنتاج خرائط و إدارة ومراقبة هذا النظام البيئي. تستخدم تقنيات الاستشعار من البعد فائقة الطيفية لقياس البصمات الطيفية لأشجار المانجروف للتمييز بينها وبين النباتات الأخرى والحصول على معلومات تفصيلية عن هذا النظام البيئي. أجريت هذه الدراسة لرسم خرائط ورصد وإدارة النظم الإيكولوجية لأشجار المانجروف في البحر الأحمر من خلال قياس بصماتها الطيفية باستخدام تقنيات الاستشعار من البعد المتقدمة. تم قياس بيانات البصمة الطيفية باستخدام جهاز مقياس الطيف التحليلي (ASD) Fieldspec في نوفمبر ٢٠١٦ ، ثم تم اختبار البيانات باستخدام المقاييس الإحصائية وهي تحليل التباين الأحادي (ANOVA) إلى جانب اختبار Tukey's HSD. أوضحت البصمات الطيفية للمانجروف في المواقع المختلفة أن المانجروف سجل انعكاسًا عاليًا في منطقة الضوء المرئي ومنطقة NIR للطيف عن المناطق الأخرى ، وكان هناك أوجه تشابه في أطوال موجية معينة وبعض الاختلافات في الأطوال الموجية الأخرى المستخدمة للتمييز بين أشجار المانجروف المتواجد في بيئات مختلفة. كما أظهرت نتائج اختبار ANOVA و Tukey's HSD أن منطقة NIR هي أفضل منطقة لتمييز المانجروف عن النباتات الأخرى.