Spectral Signatures of Some Mangrove Species in Malaysia

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*Abstract:-*This study was conducted in Tok Bali, Kelantan and Setiu, Terengganu, Malaysia with the objectives to determine the spectral properties and to identify the significant wavelength in discriminating five mangrove species at different locations. The five mangrove species selected were *Rhizophora apiculata*, *Brugiuera cylindrica*, *Avicennia alba)*, *Heritiera littoralis)* and *Hibiscus tiliaceus.*. In the Near Infra Red (NIR) region, the mean spectral reflectance of five mangrove species at Tok Bali showed that the highest reflectance was recorded by *R. apiculata* with 84% and the lowest was recorded by *A. alba* with 69% spectral reflectance, respectively. Meanwhile at Setiu, the highest reflectance was represented by *H. littoralis* with 81% and the lowest was *B. cylindrica* with 73%. Spectral reflectance of five selected mangrove species were statistically tested using canonical stepwise discriminant analysis of SPSS program. Fifteen wavelengths were produced in discriminating among five selected mangrove species at both locations. Student t-test showed that there were no significant differences between spectral reflectance of mangrove species at Tok Bali and Setiu (P=0.345, P=0.778, P=0.753 and P= 0.513 greater than 0.05). These spectral signatures were also influenced by several factors such as cloud cover changes, atmospheric condition, leaf internal structure and chlorophyll content. This study therefore implies that individual mangrove species have a unique spectral reflectance and can be easily identified and mapped with a narrow contiguous wavelength bands in the NIR region.

Key-Words:- Mangrove, Spectral, Reflectance, Spectroradiometer, Wavelength, Stepwise analysis, Hyperspectral

1 Introduction

Mangroves are among the most productivity and biologically diverse ecosystem in the world. Mangrove plants form communities which help to stabilize banks and coastlines and become home to many types of animals. Management of mangrove is challenging and complex balancing act between ecosystem protections and enabling human to enjoy and use these natural resources. Knowledge to obtain information on wildlife stock, ecosystem including plant community is important. Remote sensing provides the alternative for better way of mapping because wider area of ground survey can be obtain. In fact it does reduce time and human energy. In this respect, understanding hyperspectral sensors spectral reflectance of mangrove species either in the laboratory or field measurements is critical. A number of portable field and laboratory spectroradiometers have been developed for this purpose with the more advanced spectroradiometers such as the Analytical Spectral Devices (ASD) Fieldspec Pro FR. This has enabled researchers to acquire high quality reflectance data rapidly in the field because spectroscopic measurement has an ability to resolve absorption feature by atmosphere. The spectral reflectance of leaves is the main factor in understanding the reflectance of full plant canopy. Spectral reflectance is the ratio of incident to reflected radiant flux measured from an object or area over specified wavelengths. Most vegetation has a unique characteristic of spectral properties that allowing them to easily identified and discriminated with remotely sensed data. The atmospheric effects such as moisture, smoke, dust, clouds, and carbon dioxide contribute a major degradation of any sensor response.

The leaves reflectance and transmittance that contribute most signals from vegetation are the main factors in understanding the reflectance of vegetation. As all chlorophyll of healthy leaves have different response of reflectance especially in the visible and near-infrared region, knowledge of these differences is very useful for separating different species using the spectral sensing. The differences in spectral response at leaf and canopy can be affected by several factors such as leaf internal structure, chlorophyll content, leaf age and phonological stages. Knowledge on these differences of wavelength is useful for individual species identification and mapping. The objectives of this study are two-folds, namely to determine the spectral properties of five mangrove species and to identify the significant wavelength in discriminating among five mangrove species in Tok Bali and Setiu.

2 Methodology

The spectral reflectance value for each mangrove species was determined using ASD Viewspec Pro-Analysis. The Canonical stepwise discriminant statistical analysis was used to determine significant wavelength in discriminating the selected mangrove species. A Student t-test was applied to show the significant differences between spectral values of mangrove species at both locations.

2.1 Site Description

The data were collected in two different locations, first at Tok Bali, Kelantan (05^0 51'N and 102^0 30'E) and second at Setiu, Terengganu (102^0 50'E and 5° 45'N). Five mangrove species were selected in this study, namely *Rhizophora apiculata*, *Bruguiera cylindrica, Avicennia alba* and *Heritiera littoralis* and *Hibiscus tiliaceus* (Figs. 1a-e).

a. Rhizophora apiculata

b. Bruguiera cylindrica

c. Avicennia alba

d. Heritiera littoralis

e. Hibiscus tiliaceus

Figs. 1a-e: Mangrove species

2.2 Field Data Collection

The five mangrove leaves species were collected in the natural mangrove forest where each spectral measurement of mangrove species was conducted using a field portable spectroradiometer. For each species five samples were collected with reading from different trees and locations. The wavelengths between 350 – 1,050 nm were used with 10 replicates for each reading were set for the spectroradiometer, equipped with a 10^0 Field of View, pointing downward to the leaf at a distance of 0.5 m. The object size was standardized using diameter breast height measurement depending on the species mature stages. For high mangrove tree, a branch with a lot of leaf was cut down from the trees just before spectral measurement in order to preserve the original leaf quality. The spectral reflectance was measured immediately at an open area. Spectral reflectance data of the mangrove species were measured under excellent, sunny and cloudless weather conditions between 1000 – 1400H to minimize view angle effects and the sun's optimized spectral radiation. Spectral studies were often performed near solar noon to decrease the effects of solar angle on canopy reflectance [1], [2] and [3].

2.3 Spectroradiometer Calibrations

The variable in the field which influences radiance should be taken into account when using a field portable spectroradiometer. As the sun's irradiance varies with the time of the day and atmospheric condition, a white calibration panel was used to eliminate the effect of differences in solar illumination. Before data were collected, dark current measurement was taken followed by the white. White reflectance calibration was done by taking white reference reflectance using sample provided along with the spectroradiometer. If the reading had little noise, the calibrations were repeated.

2.4 Data Analysis

The data were analyzed using ASD Viewspec program and it was managed to process up to 15 data per time with an in-build graph. A total of 10 readings were made for each species before the data was analyzed to obtain the average reading which represented one sample spectral reflectance value. The average process was repeated for another sample to get five average readings for a species. The average spectral reflectance was used to form a reflectance curve which was then analyzed to develop relationships or difference amongst the individual mangrove species. The five average data were calculated using ASD Viewspec Pro to get an average representing one species. The average for five selected mangrove species was identified into a percentage spectral reflectance curve.

2.5 Statistical Analysis

2.5.1 Canonical Stepwise Discriminant Analysis

The canonical stepwise discriminant analysis of SPSS program was performed over the reflectance range from 400-1,050 nm. This analysis identified the variables that maximize differences between statistical species group but at the same time minimize within group differences. In this analysis, the independent spectral variables were entered into the model if they meet certain significance level (F-test) during each run. In order to avoid over fitting and allow adequate discrimination, the α-level 0.05 was chosen as the significant level for variable for entry into the model. Finally, the best wavelengths to discriminate among five selected mangrove species were produced.

2.5.2 Student T-Test

A student t-test of SPSS program was used to show differences between spectral reflectance of each mangrove species at different locations. Wavelength data range within 700 – 725, 725 – 750, 750 - 775 and 775 - 800 nm were tested with the student t-test. H_0 showed there was no significant difference between spectral reflectance of mangrove species at different location. Meanwhile, H_1 showed there was significant different between spectral reflectance of mangrove species at different location. Null hypothesis for n, mangrove type and i, spectral channel:

$H_0 : \eta\ n\ (i) = \eta\ n{+}1\ (i)$, where
η = median reflectance, n = mangrove species number (N – 1) and i = wavelength channel (I), Student t-test, significant level of $\alpha = 0.05$

From the statistical analysis, the spectral reflectance of mangrove species at Tok Bali and Setiu can be determined if they were significant or not. If the P value was greater than 0.05, H_0 was accepted.

3 RESULTS

3.1 Leaf Spectral Reflectance between Species at Tok Bali, Kelantan

Fig. 2 showed the comparison of spectral reflectance at Tok Bali. The spectral curves for five mangrove species were similar in blue, green and red regions for the overall shape and had the same contour in those regions. In the blue region (400 - 500 nm), the graph showed that *B. cylindrical* recorded the highest absorbance with percentage of reflectance 0.12% while the lowest absorbance was *H. littoralis* with percentage of reflectance 0.26%. At the red region (600 - 700 nm), *B. cylindrica* recorded the highest absorbance with percentage of reflectance 0.10%, meanwhile, *H. littoralis* recorded the lowest absorbance with percentage of reflectance 0.22%. Reflectances had occurred at green region (500 - 600 nm) with highest reflectance recorded by *H. littoralis* with percentage of reflectance 0.70%, and the lowest reflectance recorded by *B. cylindrical* with 0.40%. NIR region (begins at 700 nm) recorded the highest reflectance *R. apiculata* with reflectance value 0.98% while *A. alba* recorded the lowest reflectance of 0.88%.

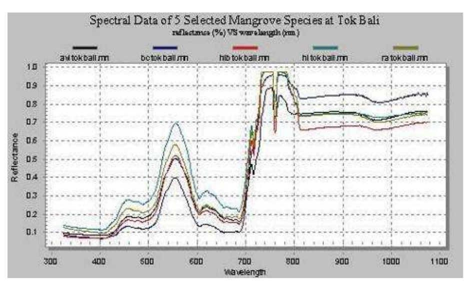

Fig. 2: Spectral reflectance amongst species in Tok Bali, Kelantan.

3.2 Spectral Reflectance between Species in Setiu, Terengganu

Fig. 3 showed the comparison of spectral reflectance at Setiu, Terengganu. In the blue region (400 – 500 nm), B. *cylindrica* recorded the highest absorbance with percentage of reflectance of 0.15% while the lowest absorbance was *H. tiliaceus* with percentage of reflectance 0.26%. In the red region (600 - 700 nm), *B. cylindrical* recorded the highest absorbance with percentage of reflectance 0.13%. Meanwhile, *H. tiliaceus* recorded the lowest absorbance with percentage of reflectance 0.24%. At the green region (500 nm to 600 nm), the highest reflectance was recorded by *H. tiliaceus* with 0.56%. Meanwhile, the lowest reflectance was recorded by *B. cylindrica* with 0.44%. NIR region recorded the highest reflectance by *H. littoralis* with reflectance value 0.97% while *A. alba* recorded the lowest reflectance at 0.92%.

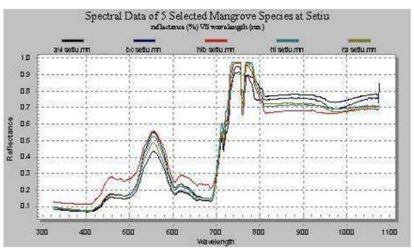

Fig. 3: Graph of spectral reflectance between species at Setiu, Terengganu.

3.3 Spectral Reflectance between Species at Different Locations

3.3.1 Rhizophora apiculata

Fig. 4 showed Rhizophora species at Setiu had a higher absorbance compared to Rhizophora species at Tok Bali. Absorbance at blue region for Rhizophora species at Tok Bali was 0.22% and 0.16% in Setiu. Red region showed absorbance at Tok Bali with a percentage reflectance of 0.18% while 0.14% at Setiu. Rhizophora species at Tok Bali recorded a higher reflectance of 0.58%. The lowest reflectance recorded was the Rhizophora species at Setiu with 0.48% at green region. For NIR region (700 - 800 nm), they recorded the same reflectance at Tok Bali and Setiu with a maximum reflectance value of 0.98%.

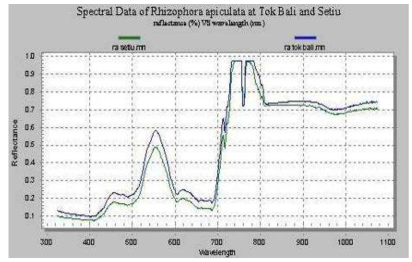

Fig. 4: *R. apiculata* spectral reflectance at Tok Bali and Setiu.

3.3.2 Bruguiera cylindrica

Fig. 5 showed that absorbance for Bruguiera species at Tok Bali with percentage of reflectance 0.12% while at Setiu with 0.14% in blue region, while in red region with reflectance 0.10% compare to 0.14% at Setiu. At green region highest reflectance at Setiu was 0.42% compared to Tok Bali, with 0.40%. In the NIR region, both locations recorded a maximum reflectance 0.94%.

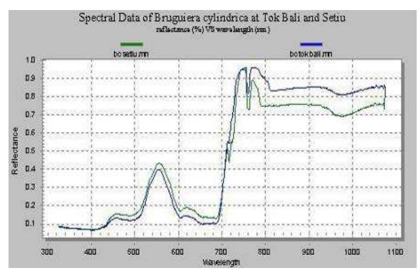

Fig. 5: *B. cylindrica* spectral reflectance at Tok Bali and Setiu

3.3.3 Avicennia alba

Fig. 6 showed the absorbance in blue region for *A. alba* at Tok Bali with a 0.16% reflectance slightly lower compared to Setiu with 0.18% reflectance. In the red region, absorbance at Tok Bali achieved a 0.16% reflectance compared to Setiu with 0.14%. Meanwhile, in the green waveband region, *A. alba* at Setiu showed a 0.54% reflectance slightly higher than Tok Bali of 0.50%. In the NIR region, both study sites recorded high reading reflectance values of 0.92% (Setiu) and 0.88% (Tok Bali).

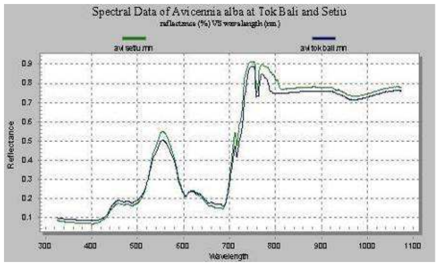

Fig. 6: *A. alba* spectral reflectance at Tok Bali and Setiu.

3.3.4 Heritiera littoralis
The blue region absorption of Heritiera species at Tok Bali, gave a reflectance of 26% and 0.16% at Setiu (Fig. 7). Meanwhile, the red region at Tok Bali reflectance was 0.22% compared 0.14% at Setiu. At green region, the highest reflectance (0.70%) was at Tok Bali and 0.54% at Setiu. In NIR region of 700 nm, both Heritiera species at Tok Bali and Setiu recorded similar spectral signature values at 0.96%, respectively.

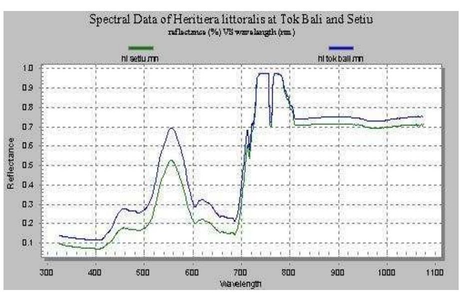

Fig. 7: *H. littoralis* spectral reflectance at Tok Bali and Setiu.

3.3.5 Hibiscus tiliaceus
The absorbance values in the blue region recorded a spectral reflectance of 0.16% and 0.26%, respectively at Tok Bali and Setiu (Fig.8). Meanwhile at the red region, the absorbances were 0.14% and 0.25%, respectively for Tok Bali and Setiu. At green region (500 - 600 nm), the highest reflectance was Hibiscus species at Setiu with 0.56% compared to reflectance at Tok Bali with 0.52%. For the NIR region, the spectral reflectance for both Hibiscus species was 0.96%.

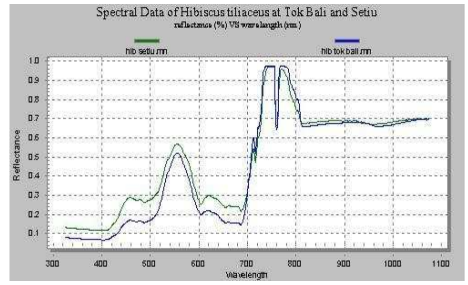

Fig. 8: *Hibiscus tiliaceus* spectral reflectance at Tok Bali and Setiu.

3.4 Data Analysis
3.4.1 Mean Spectral Reflectance at Tok Bali and Setiu
The mean of spectral reflectance at Tok Bali, Kelantan showed that all species recorded a high reflectance at NIR part of the spectrum than the visible wavelength (Table 1). The highest reflectance was showed by *R. apiculata* with 84% of reflectance and the lowest was *A. alba* with 69% of reflectance. In Table 2, the mean spectral reflectance value in Setiu, Terengganu, showed all species recorded higher reflectance in the NIR part of the spectrum than the visible wavelength. The highest reflectance was showed by *H. littoralis* with 81% of reflectance and the lowest was *B. cylindrica* with 73% of reflectance.

Table 1: The mean reflectance (%) for five mangrove species at Tok Bali

Region	Wavelength (nm)	Region	Wavelength (nm)
Blue	442	Red	603
Blue	451	Red	615
Blue	488	Red	630
Green	537	Red	693
Green	564	NIR	748
Green	580	NIR	758
Green	598	NIR	762
		NIR	782

Table 2: The mean reflectance (%) for five mangrove species in Setiu, Trengganu.

Region	Wavelength (nm)	Region	Wavelength (nm)
Blue	420	Red	601
Blue	448	Red	614
Blue	494	Red	652
Green	514	Red	693
Green	519	NIR	700
Green	539	NIR	703
Green	572	NIR	730
		NIR	731

3.3.2 Canonic Stepwise Discriminant Analysis

The canonical stepwise discriminant analysis of SPSS program was performed over the reflectance range from 400 nm to 1,050 nm to determine the spectral separability among mangrove species. In this study, reflectance range from 800-1050 nm was omitted because in this range all reading has little noise. The stepwise discriminant analysis with α-level of 0.05 produced a list of 15 wavelengths at both locations. The result indicated that leaf spectral reflectance was significantly different at specific wavelength and can easily be discriminated from each other (Tables 3 and 4).

Table 3: Significant wavelength in discriminating among five mangrove species at Tok Bali, Kelantan.

Species	Visible			NIR
	B (400-500 nm)	**G** (500-600 nm)	**R** (600-700 nm)	(700-800 nm)
R.a	13.68	33.71	16.65	78.75
B.c	12.13	30.46	16.04	72.59
A.a	13.27	38.22	19.20	75.74
H.l	13.75	36.71	18.52	81.18
H.h	22.14	43.26	25.98	77.09

Table 4: Significant wavelength in discriminating among five mangrove species at Setiu, Terengganu.

Species	Visible			NIR
	B (400-500 nm)	**G** (500-600 nm)	**R** (600-700 nm)	(700-800 nm)
R.a	17.79	41.04	21.32	83.68
B.c	10.62	26.56	12.35	80.60
A.a	14.69	36.49	20.10	69.48
H.l	21.58	50.43	27.26	83.45
H.t	13.03	35.83	18.52	80.68

3.3.3 Student T-Test

Student t-test was used to show the differences between spectral values of five selected mangrove species at different location. Wavelength data range within 700 - 725 nm, 725 -750 nm, 750 - 775 nm and 775 - 800 nm were tested with the student t-test. H_0 (null) with a significant level of αn = 0.05 showed that there was no significant amongst the spectral reflectance of the five mangrove species at different locations. However, H_1 indicated a significant difference between spectral reflectance of mangrove species at different locations. From the statistical test, wavelength data range between 700 - 725 nm was not significant with P=0.345, 725-750 nm with P=0.778, 750 - 775 with P=0.753 and 775 - 800 nm with P= 0.513. As a result, the null hypothesis was accepted. There was no significant difference between spectral reflectance of mangrove species at Tok Bali and Setiu.

4 DISCUSSIONS

Most of the healthy leaves had similar characteristic of spectral signatures that consisted of low reflectance in visible parts of spectrum (400 - 700 nm) but high in the NIR region (700-1,050 nm). But in this case, the overall hyperspectral curves from 800-1,050 nm were omitted due to the “noisy readings” as a results of the variable cloud cover changes, fluctuation of light source energy and also the chance of daily atmospheric states. Only wavelength between 400 - 800 nm was used in this study to discriminate the five selected mangrove species. Most of the measured species in this study showed significant differences in visible and NIR region between species at Tok Bali and Setiu (Figs. 2 and 3). At the first sight, spectral signatures for five selected mangrove species (400 - 800 nm) look very similar but the spectral properties for each mangrove species were different because of differences in absorption depth, as well as species showing differences of absolute reflectance. In this study, it was shown that these visual differences were also statistically significant. Considering that spectral signatures were generally similar in shape, the fact that all of the five selected mangrove species had significant differences for most wavelengths indicates that there had potential to discriminate between the five selected mangrove species based on spectral reflectance. Tables 1 and 2 showed the low mean spectral reflectance of five mangrove species at both areas with 11 to 50% and 12 to 43%, respectively in the visible part of the spectrum. At Tok Bali, the high reflectance was showed by *R. apiculata* (84%) and the lowest was *A. alba* (69%), while at Setiu the highest reflectance was showed by *H. littoralis* (81%) and the lowest was *B. cylindrica* (73%). This generally implies that the spectral reflectance for all species in both study areas have similar characteristic of healthy green leaves with high absorption in the Visible bands and high reflectance in the NIR. Generally, the low reflectance in the visible region was attributed to the presence of high amount of chlorophyll and this shown by the greenish mangrove leaves for all species in this study area. The high absorption in this visible part of spectrum also indicates the healthy conditions of the plant. The observation also indicated that variability of spectral reflectance of the mangroves at NIR region for the both study sites were high compared to the visible part of spectrum. Fig. 2 showed the percentage value of reflectance at NIR region between species at Tok Bali, Kelantan. The highest reflectance was *R. apiculata* with 0.98%, while *A. alba* recorded the lowest reflectance value with 0.88%. Meanwhile, Fig. 3 showed the highest percentage value of reflectance at Setiu, Terengganu recorded by *H. littoralis* with reflectance value 0.97% while the lowest reflectance with 0.92% recorded by *A. alba*. This was probably caused by two main factors, internal structure of the leaves which is quite similar across mangrove species and also phonological stages [4]. In the NIR region, the internal structure of leaves, the size, shape and distribution of air spaces and also the abundance of air water interfaces within the mesophyll layer exert the greatest influence on reflectance. Light reflection and transmission from mangrove leaves were two dominating factor of the NIR spectral response. Much of the radiation that was scattered within the leaf is reflected back through the leaf surface, with a proportion transmitted through the leaves [5]. The mechanism of NIR reflectance in leaves was based on the assumption that only the reflected spectrum at incident angle within the leaf structure can be considered for the high value of leaf reflectance [6]. In the NIR portion of the spectrum (700 - 800 nm), the vegetation displays a sharp rise in reflectance as compared to the absorption. The reflectance in this region increased because of the internal cell wall structure acts as strong diffused reflector to the IR spectrum. All the selected mangrove species had different reflectance within these wavelengths significantly different and varied between both study areas. There were several factors that influenced the spectral reflectance characteristics. First, external factors such as cloud cover changes and atmospheric conditions. In this study, both study areas were considerably large and sampling time was very limited, depending on the weather condition between 1000 - 1400H. These factors were greatly affected the incoming radiation on the leaves. Spectral studies often performed near solar noon to decrease the effects of solar angle on the leaves reflectance [1] and [2]. During this time the spectral radiation from the sun was optimized. In this study, it was not possible to collect the spectral reflectance data within a day, thus these external factors could affect the leaf reflectance measurement and contribute to the differences significant wavelength at both study sites.

From the canonical stepwise discriminant statistical analysis, five selected mangrove species at Tok Bali were discriminated according to four regions in the 400-800 nm. In the blue region, all five selected species were successfully discriminated at wavelengths 442, 451 and 488 nm. In the green region, all selected species were discriminated with wavelengths 537, 564, 580 and 598 nm. In the red region, all five selected mangrove species were discriminated at wavelengths 603, 615, 630 and 693 nm. Meanwhile, NIR region showed that all selected mangrove species were separated at wavelengths 748, 758, 762 and 782 nm. In Setiu, five selected mangrove species at 420, 448 and 494 nm were easily separated. In green region, all selected mangrove species were discriminated with wavelengths 514, 519, 539 and 572 nm. In the red region, all selected mangrove species were discriminated with wavelengths 601, 614 652 and 693 nm. Meanwhile, NIR region showed that all selected mangrove species were discriminated at wavelengths 700, 703, 730 and 731 nm. From the list, only wavelength 693 nm in the red region was used to discriminate all selected mangrove species at both locations. These entire wavelengths were significant wavelengths in discriminating among five mangrove vegetation species at different locations. Based on the statistical analysis at different locations, it was unfortunate that they could not be readily compared so as to draw any conclusion. This was mainly because these studies were not easily standardized in the field condition; the mangrove leaves used in this study were collected from different field conditions and influenced by limitation of time during the spectral measurement. The difficulties of field condition such as fluctuation of light source energy, the change of daily atmospheric states and cloud cover changes. It was also influenced by internal factors such as the differences in pigments concentration, leaf age and mesophyll structure arrangement which plays as an important role in plant photosynthetic activities and consequently determined their spectral response behavior [7].

4 Conclusions

This study showed that individual mangrove species can be differentiated and separated using their unique spectral reflectance in the visible and NIR region at Tok Bali and Setiu. The statistical analysis confirmed that species discrimination at Tok Bali, Kelantan can be significantly discriminated into four narrow wavebands spectrum which were in the blue (400 - 500 nm), green (500 - 600 nm), red (600 - 700 nm) and NIR regions (700 - 800 nm). It can also be inferred that the student t-test based on the P value indicated a non-significant difference between spectral reflectance of mangrove species in Tok Bali and Setiu.

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