The Effect of Field Spectral Reflectance Measurement Distance to the Spectral Reflectance of *Rhizophora stylosa*

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Abstract. Mapping mangrove species from remote sensing data through its spectral reflectance pattern collected in the field is challenging. There are high variations in light condition, leaf orientation, canopy structure, background objects and measurement distance when measuring mangrove spectral reflectance in the field. Spectral measurement distance to the object is one of the most important aspects controlling the result of spectral reflectance pattern. This research is aimed to assess the effect of spectral reflectance pattern of *Rhizophora stylosa* collected at various distances. Specific objectives of this research are to collect samples of mangrove spectral reflectance pattern in the field, to assess the effect of the observation scale to the result of the spectral reflectance pattern, and to characterize the mangrove spectral reflectance pattern resulted from different observation scales. Spectral reflectance data collection in the field was conducted using JAZ EL-350 field spectrometer at 2cm, 50cm, 1m, 2m, and 5m distance and was conducted in Karimunjawa Island, Jepara, Central Java, Indonesia. A visual comparison of the spectral reflectance curve was conducted to understand the effect of measurement distance. The results of this study indicate that the difference in the measurement distance of *Rhizophora stylosa* species was highly influential to the resulting spectral reflectance curve. The spectral reflectance curve recorded at close range to the leaf (i.e. 2 cm) has the lowest curve variation, as well as the furthest distance (i.e. 5 m). This study is a basic study that supports the development of the use of remote sensing imagery for mangrove species mapping.

Keywords: Spectral reflectance, *Rhyzophora stylosa*, JAZ EL-350

1. Introduction

Mangrove is one of the most important objects in the wetland ecosystem, which forms the relationship between terrestrial and oceanic ecosystems in the tropics and sub-tropics. Mangroves have many ecological and economical functions, such as keeping coastal areas from ocean currents and winds, providing spawning grounds for marine organisms, maintaining food cycles of marine organisms, maintaining coastal water quality, wildlife fauna and as tourist attractions [1][2][3][4][5]. Nevertheless, the health and existence of mangroves are under considerable threat from human disturbance and natural disasters. Major threats to mangroves include logging for fuels and timber [6], conversion of mangrove habitats to other land uses such as agriculture, ponds, industry and urban

development [7][8][9], and relative sea level rise [10]. These threats corroborate the importance of efforts to provide accurate and up-to-date data on mangrove status in Indonesia.

Over the past 20 years, remote sensing data have been used for mapping and monitoring of mangrove ecosystems [11][12]. Mangroves have distinct appearance in the optical remote sensing images due to their specific spectral reflectance pattern, and make them recognisable from their spectral reflectance pattern. The mangrove distinctive spectral patterns are mainly found in near infrared wavelengths (NIRs, 700-1200 nm) and shortwave infrared (SWIR 1200-2500 nm) [12][13]. This spectral pattern able to distinguish them from nearby objects, such as forested forests, brackish marshes, and mud flats. Several studies have been conducted using a spectral reflectance pattern to map the mangrove ecosystem [14][15][16] and identification of mangrove species [17][18][19][20][21], with varying degrees of success. The largest spectral-based species separability can be found at the NIR wavelength due to differences in the internal structure of the leaves of each species and the difference in the geometry of the leaves and canopy [12]. SWIR wavelength is also good for this study because there are no visible variations of pigment conditions among mangrove species at this wavelength, but the leaf components (salinity, sugar, water, protein, oil, lignin and cellulose) can be distinguished [20].

According to Hirano et al. [19] and Vaiphasa et al. [20], each mangrove species provides specific spectral reflectance characteristics that make it possible to be used as a key species identification of remote sensing imagery. However, when we examined more deeply, the mechanism of interaction between light (i.e. electromagnetic waves) and mangrove objects holds two major problems. First, the mangrove spectral reflectance pattern is strongly influenced by the tidal effect of sea level on the substrate of the mud soil at its base, thus causing mixed-pixel pixels. Secondly, many environmental factors influence the mangrove spectral reflectance so that the species identification based on spectral reflectance can be inaccurate [22][23]. According to Diaz and Blackburn [23], the spectral reflectance variation of mangrove canopy is a function of some optical characteristics of objects, such as leaf area index (LAI), substrate base reflectance, and leaf orientation direction. For a single species, the pattern of spectral reflectance is affected by the age, health, and phenological characteristics and plant physiology [22]. So, the measurement of the spectral reflect pattern for the identification of mangrove species should be done carefully to avoid reading errors due to the influence of reflectance other than mangrove objects.

It is therefore necessary to conduct a systematic study to assess the effect of distance measurement of spectral reflectance patterns of mangrove species in the field to the characteristics of the resulting spectral reflectance curves. This research is aimed to assess the effect of spectral reflectance pattern of *Rhizophora stylosa* collected at various distances. Specific objectives of this research are to collect samples of mangrove spectral reflectance pattern in the field, to assess the effect of the observation scale to the result of the spectral reflectance pattern, and to characterize the mangrove spectral reflectance pattern resulted from different observation scales. In Indonesia, research on these effects has not been conducted and it is important to establish a field spectral reflectance measurement procedure for the identification and mapping of mangroves. This research is a basic research that can be developed for mapping, inventory and monitoring of mangrove species using remote sensing imagery.

2. Methods

2.1. Study site

The location of this research is mangrove forest in part of Karimunjawa Islands National Park, Jepara, Central Java, Indonesia (between 110° 24' 10" - 110° 30' 10" E and 4° 47' 48" - 5° 50' 12" S). Karimunjawa islands consist of 22 islands with total area of 111,625 ha, where only five of these islands are inhabited [24]. This area has a wet tropical maritime climate with an average temperature between 26-30 °C and an average humidity between 70-85%. The mean annual rainfall is 2632 mm; while the average rainfall of dry months (April to September) is 60 mm and the wet month (October to

March) is 400 mm. Karimunjawa Islands represent several habitats including lowland rainforests, seagrass and algae, coastal forests, mangrove forests and coral reefs [25]. In general, along the coast of the island is composed of mangrove formations that protect the coast from the waves of the sea and wind. The largest mangrove area in Karimunjawa National Park is located in the west of the two main islands; Karimunjawa and Kemujan. Based on reports from Karimunjawa National Park Authority, there are 45 mangrove species in this area (27 true mangroves and 18 mangroves), where *Rhizophora stylosa* is the most dominant species.

2.2. Equipment

The equipment used to collect mangrove spectral reflectance in this study was JAZ EL-350 portable spectrometer. JAZ is a portable spectrometer product from Ocean Optics (https://oceanoptics.com/) that is designed to support fast, precise, non-destructive optical measurements and without direct contact with object. JAZ spectrometer system is designed in the form of modular structure consisting of several autonomous modules that form a whole spectrometer system. The JAZ module used in this study consists of a Data Processing Unit (DPU), battery, and VIS-NIR spectrometer modules. Other than that, the JAZ system is supported by several components, including 2 m fiber optic cable, collimating lens, and white panel (spectralon). The JAZ detector wavelength ranges from 350 to 1000 nm, which covers visible to near infrared spectrum of the light. A collimating lens is attached at the front of the fibre optic cable. This component used to align the scattering light coming into the JAZ sensor to optimize the light signal. It covers the spectrum range from 200 to 2000 nm, and the field of view is set up 14.25°. This system can be used for various spectral-based measurements, including absorption, reflectance, emission or transmittance of the object or irradiance. This system is designed to be used for spectra sample measurements both in the laboratory and in the field.

2.3. Field spectral reflectance measurement

Spectrometers and all supporting components need to be prepared and setup prior to the field measurements. The preparation includes what environment will we work in, what components are needed and whether they work well or need calibration. The field work was conducted on 5 April 2016 between 09.00 to 11.00 a.m. During the field campaign, we followed the procedure of spectral reflectance measurement developed by our Remote Sensing Laboratory [26] (Figure 1). To normalize the light condition, a white and dark calibration was performed prior to each measurement set. The angle of spectrometer sensor (collimating lens) was setup at 45° against the direction of the sun light to avoid the shadow on the target object. The selection of sample location was guided by WorldView-2 pan-sharpened image (0.5m pixel size), that is by identifying accessible *Rhizophora stylosa* at the edge of the mangrove forest where measurement of spectral reflectance at different distance can be performed. From previous research [27] *Avicennia marina*, *Rhizophora stylosa*, *Bruguiera gymnorrhiza*, and *Lumnitzera racemosa* can be distinguished by visual interpretation of WV-2 images because they have specific canopy patterns and clustered at specific locations. From this site, a single sampling point was taken purposively based on the availability of target species and measured at several distances.

Spectral reflectance measurements of object samples were performed at several distance variations to the spectrometer sensor, i.e. 2 cm, 50 cm, 1 m, 2 m, and 5 m. The 2 cm distance represents the measurement of individual leaf objects, 50 cm and 1 m represent the variation of leaf orientation in the canopy, and a distance of 2 and 5 m represent the object's canopy condition as seen by remote sensing image sensors. Each sample measurement was repeated at least 10 times to evaluate the variation of readings that can be used for further analysis.
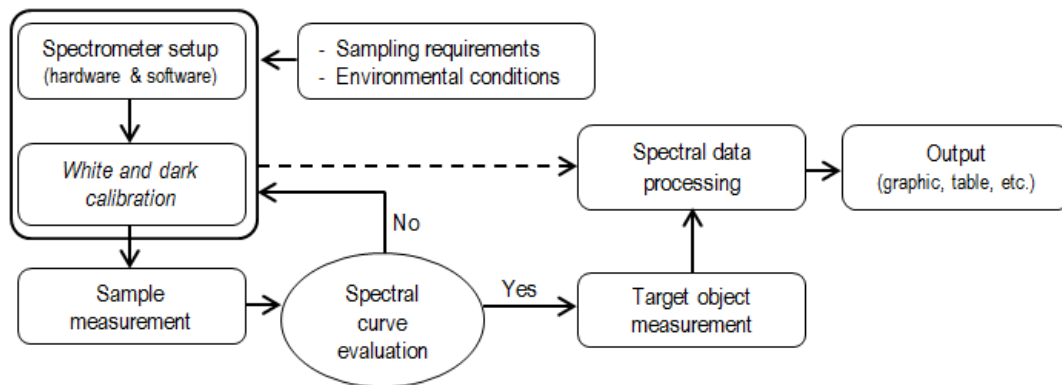
Figure 1. The procedure of spectral reflectance measurement.

3. Results and Discussion

3.1. Field spectral reflectance measurement

Measurement of the spectral reflectance sample of *Rhizophora stylosa* was performed on the part of mangrove forest adjacent to sea water where this species is commonly encountered. The optical measurement module performed by JAZ EL-350 for this research was reflectance, which measures the amount of reflected energy from the sun by an object at a wavelength of 350-1000 nm. Each measurement of spectral reflectance begins with the light calibration at the measuring location. The calibration requires the sampling of the 'white reference' obtained from spectralon to represent almost perfect reflection of incident light or energy, and the 'dark reference' spectrum to represent fully absorbed energy. Based on the comparison between the white and dark reference, the spectral reflectance sample of the object can be calculated. The magnitude of the reflectance of the object sample relative to the white reference and the dark reference is as follows [28]:

$$\%R_\lambda = \frac{S_\lambda - D_\lambda}{R_\lambda - D_\lambda} \; x \; 100\% \qquad (1)$$

where $\%R_\lambda$ is the percentage of object spectral reflectance, S_λ is the sample of the object's measurement, D_λ is the dark reference, and R_λ is the white reference.

Spectral reflectance measurements of objects using JAZ EL-350 in default mode produce a spectral reflectance curve that is full of noise in the near-infrared wave spectrum section (750-950 nm). In fact, this part of the light spectrum is theoretically very important to distinguish the spectral response between mangrove species [12][20]. Therefore, adjustments were made to the spectrometer setup; those were the 'boxcar width' and 'scan to average' options. Boxcar width averages the spectral values of neighbouring pixels along the wavelength axis. High value of boxcar width involved more neighbouring pixels involved in the averaging. This needs to be done primarily to minimize noise, but the implication of the increased value of boxcar is decreased its optical resolution. Another setup option, scan to average, allows the spectral reading of the object several times in one sample and then the readings are averaged. This step is generally not necessary, but is useful for reducing noise or increasing the reflectance of objects with low-intensity reflectance. Based on our experiments, the value of boxcar width and scan to average is 10. By giving this value, the resulting spectral reflectance curve is smoother and free of noise (Figure 2).
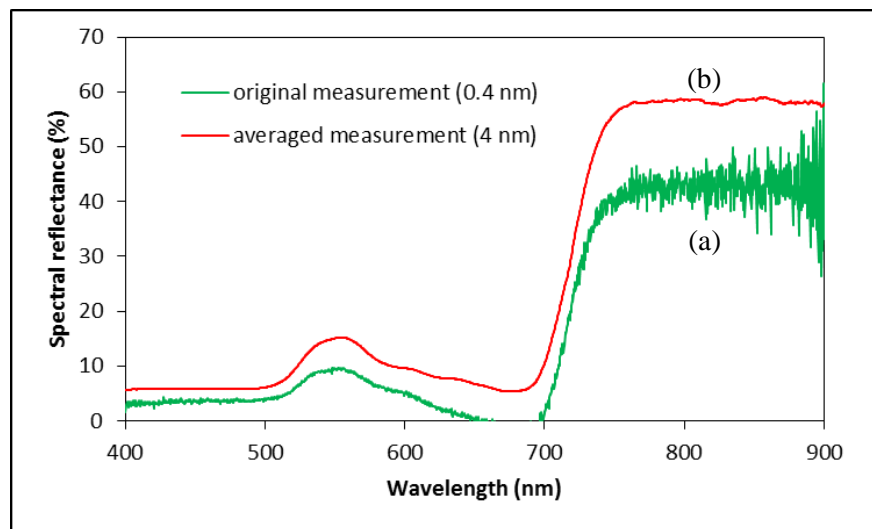
Figure 2. Spectral reflectance reading, (a) original reading at 0.4 nm spectral resolution, and (b) averaged reading at 4 nm.

3.2. Spectrometer measurement distance comparison

Spectral reflectance curve readings were performed at 2 cm, 50 cm, 1 m, 2 m, and 5 m range of sensors to simulate different recording levels of vegetation objects. Each measurement was repeated 10 times of consecutive recording to assess the consistency of reading results. From the plot of spectral reflectance results (Figure 3), it can be seen that the spectral reflectance pattern follows the spectral reflectance pattern of healthy and green vegetation. From the measurement results it is noticeable that there are variations of spectral pattern of objects caused by differences in the distance measurement of the spectrometer sensor. The reading of the spectral reflectance response at the leaf level with a distance of 2 cm provides a narrow variation of the curve, meaning that there is not much change in the readings between repeatability measurements. This indicates that at a measurement distance of 2 cm the consistency of measurement is high.

At 50 cm, 1 m, and 2 m variations in the pattern of spectral curves between repeated measurements were very large. Even at a distance of 50 cm and 2 m saturation effect occurred where the upper limit curve value exceeds 100% of reflectance. This high curve pattern variation shows inconsistencies of spectral reflectance readings. This is probably due to a combination of three things, (1) the measurement is done manually by hand, so that the possibility of the sensor's coverage was fluctuating, (2) a slight movement of leaves and canopy was noticeable at these distances, and (3) the sensor reading was influenced by other objects such as branch and soil or water background. At a distance measurement of 5 m, we found variation of spectral reflectance pattern but not as large as 50 cm, 1 m, and 2 m. The distance of the sensor away from the object causes the sensor field of view recorder the whole canopy and any movement occurred on the object was undetected by the spectrometer sensor, thus decreased the readings variations. From the resulted pattern, we found that variation of spectral reflectance is a function of distance measurement. It is also showed that the consistency of measurement results was obtained at close range distance at leaf level, or long-range distance at canopy level.
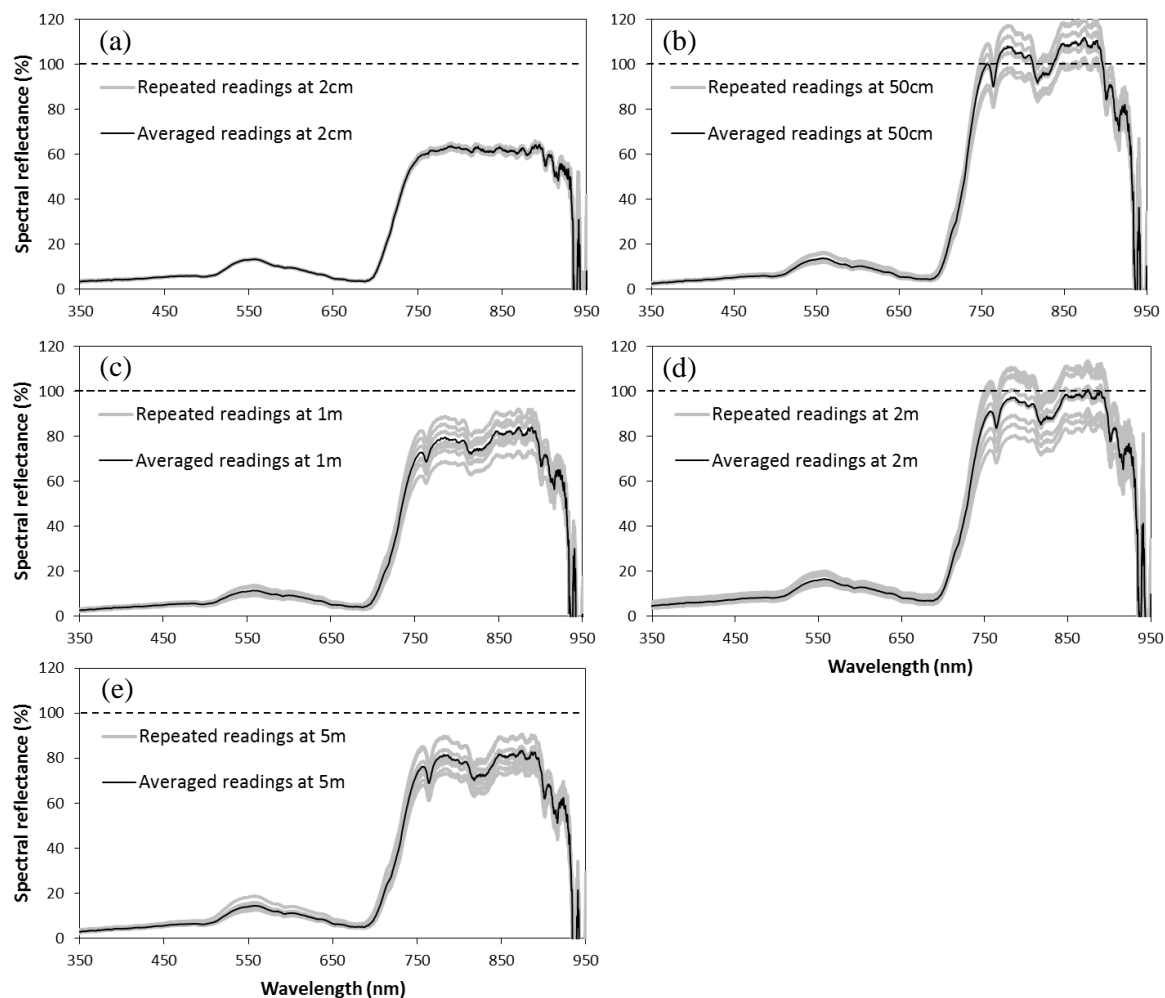
Figure 3. Results of the spectral reflectance measurement at different distances showing the repeated and averaged graph at (a) 2 cm, (b) 50 cm, (c) 1 m, (d) 2 m, and (e) 5 m.

3.3. Object spectral characteristics

The vegetation spectral reflectance pattern has a specific characteristic relative to the wavelength of the recording. In the visible spectrum ($\pm$ 300-600 nm) the interaction between sunlight and leaf energy is strongly influenced by leaf pigment, whereas in the near infrared spectrum is affected by the internal cell structure of leaves [12]. In blue bands ($\pm$ 300-400 nm) and red ($\pm$ 500-600 nm) the energy from the sun is absorbed by chlorophyll a, b, and leaf carotenoids for the process of photosynthesis of vegetation. While the green band ($\pm$ 400-500 nm) does not occur energy absorption so reflected by the surface of leaves and leaves appear green by our eyes [29].

In the near infrared spectrum, in theory there will be spectral reflectance spikes in the region between 700 and 1200 nm. The mesophyll sponge layer on the green leaves controls the amount of near infrared energy reflected by the leaf, ranging from 40-60% [29]. The main information that can be drawn on this spectrum are leaf and canopy structures, and water content in vegetation [12]. In the near infrared spectrum, the differences in the spectral reflect curve between the species of mangroves are strikingly different, so they can be used to distinguish mangrove objects from the surrounding environment [13], even among mangrove species [12, 21].

The spectral reflectance pattern of *Rhyzophora stylosa* recorded by the field spectrometer follows the healthy and green vegetation reflectance pattern in general (Figure 3a-e). The difference in the pattern

of spectral reflectance was due to variation in distance between the spectrometer and object sensor. In general, as described above, the near infrared spectrum is very sensitive to changes in spectral reflectance especially at the range 740-890 nm. So, the reading difference as a function of distance measurement can be seen clearly at that range.

When we look into a more detailed level, in both the visible and near infrared spectra (Figure 4b and c), there is no consistent correlation or sequence pattern of spectral reflectance curves. In the visible spectrum (Figure 4b) the highest spectral reflectance curve is at a distance of 2 m, the lowest being 1 m, and the others are somewhere in between. While in the near infrared spectrum (Figure 4c) the highest is the average of 50 cm, the lowest is 2 cm, and the others are in between. The results of this measurement indicate that: (1) the measurement distance strongly determines the shape of the spectral reflectance curve of the object, (2) there is no specific pattern showing the relationship between the measurement distance and the wavelength, and (3) the near infrared spectrum is very sensitive to the measurement distance indicated by high curve variations compared to visible spectrum.
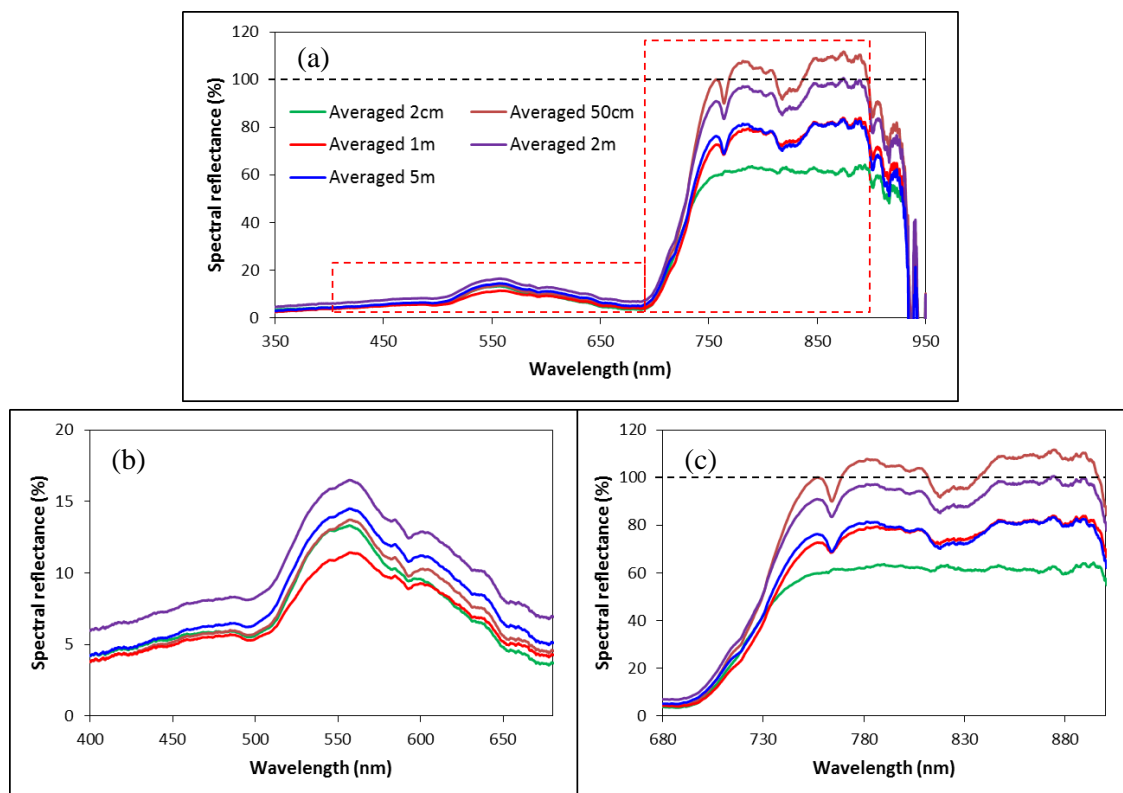

Figure 4. Averaged of *Rhyzophora stylosa* spectral reflectance (a) at different measurement distances, (b) in visible, and (c) in near infrared spectrum.

4. Conclusions and Future Work

This study was aimed to assess the effect of spectral reflectance measurement at various distances. The measurement distance between the spectrometer sensor and the target object greatly influence the pattern of spectral reflection curves of *Rhizophora stylosa*. At measurement distances of 2 cm and 5 m, the repeated readings of spectral reflectance have low variation, indicating the high stability of the readings. On the other hand, the measurement distance of 50 cm, 1 m, and 2 m have a large curve variation. In terms of the spectral differentiation, as expected, the near infrared spectrum region (680-900 nm) has the most significant curve spacing to distinguish between the measurement distances. Based on the current findings, some research agenda are proposed in the future, including (1) measurement of object spectral reflectance using several scenarios such as different sunlight,

measurement angle and tidal conditions, (2) field measurements using fixed and controlled measurement, and (3) measurement for various mangrove species.

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