CREATING A SPECTRAL LIBRARY OF COASTAL RESOURCES IN THE PHILIPPINES

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ABSTRACT: Mapping of coastal resources using the remote sensing approach provides information to support the wide-scale monitoring, protection and conservation of these vulnerable resources. Spectral library of coastal resources is an important reference data for its remote sensing applications including high characterization of various features. This paper described the field protocols in collecting spectral signatures of coastal resources (corals, seagrass, seaweeds, mangroves) throughout the Philippines. Field data collection was carried out in various sites of the country. Spectral measurements were conducted using a 10-meter optical fiber probe cable attached to a portable visible-near infrared spectrometer unit which covers approximately 345 – 1036 nanometer wavelength range. Twenty-five in-situ spectral measurements for each sample were calculated and filtered using the Savitzky-Golay algorithm. This method fits a least square polynomial curve in smoothing the spectral graph. Metadata sheet was prepared to indicate the characteristics of the features, the equipment used, the sampling location, the acquisition settings, and the environmental conditions at the time of measurement. A standardized methodology of spectral measurements was developed and sample spectra of various coastal resources in the Philippines were also acquired. The creation of spectral library could be used as an aid in creating a detailed and accurate resource maps for the better ecological assessment and has the potential to compare data acquired at different times and locations.

INTRODUCTION

The Philippines, being an archipelagic country with approximately more than 7,100 islands and located at the apex of the Coral Triangle also known as the World's Centre of Marine Biodiversity, is rich in coastal ecosystems characterized by dense mangrove forests, and large areas of seagrass and coral (Philippine Coastal Management Guidebook Series, 2001). Despite its ecological and economic services for the people, the coastal resources of the country continue to experience serious threats of degradation over the years, mainly because of the unsustainable human exploitation, but progressively by global climate change-related stressors. With the growing concern of protecting the country's coastal resources, there is a need to accurately map the coastal environment to provide rapid assessment of these habitats which is critical for developing management strategies and marine spatial planning. Mapping of coastal resources using the traditional field-based method produces high accuracy. However, to cover a larger area, the activity would be expensive and would need a longer time. Approach on researches using latest technologies such as remote sensing provides information that could support the wide-scale mapping of these resources for monitoring, protection, and conservation, provided that they are distinguishable by their optical properties. In addition, one of the fundamental parameters for coastal resource mapping using remote sensing is spectral reflectance, a ratio of the light reflected from a target and to that incident on it at every wavelength.

Recent advances in remote sensing are useful in a more detailed characterization of coastal features. Hyperspectral sensors could reveal the subtle characteristics of the features that the multispectral data cannot resolve. Aside from high spatial resolution data, high spectral resolution is also needed in mapping benthic habitat accurately since only the visible range of electromagnetic spectrum can penetrate well in the shallow water. The use of a reference spectral library, a collection of spectral signatures of various features, is essential in a higher level of classification using a hyperspectral remote sensing image. The potential of analyzing spectral signatures has already been studied for several coastal applications such as in coral reef mapping (Nurdin, Komatsu, Yamano, & Akbar AS, 2012), seagrass species discrimination (Fyfe, 2003), and benthic algal mapping (Kutser, Vahtmäe, & Metsamaa, 2005). Nevertheless, the methods of measuring the reflectance spectra in the field are widely varying. Thus, there is a need for a protocol in acquiring spectral signatures in the field that will minimize errors due to different sampling techniques and varying environmental conditions.

The aim of this paper is to present a standardized methodology in acquiring spectral signatures of various coastal resources in the Philippines that will be used to create a spectral library of such resources. The spectral signatures will be gathered *in situ* throughout the country by fifteen universities that are implementers of Phil-LiDAR 2, a nationwide program that aims to create a spectral library of agricultural and coastal resources in the country, as well as to produce high resolution resource and vulnerability maps using airborne Light Detection and Ranging (LiDAR) data. Each university is set to acquire spectral signatures of different coastal resources in their respective areas. The compilation of data will be useful as a reference for the future design of remote sensing instrument dedicated for coastal applications, identification of features using data from the satellite sensors, optimal band selection for analysis, comparison of data taken at different locations and times, and assessment of the features' biophysical attributes by examining its spectral information.

FIELD PROTOCOLS

Spectral measurements were taken at generally clear skies and between ten in the morning and two in the afternoon with the period of high sun to minimize the error due to high atmospheric influence and noise (McCoy, 2005). The areas for spectral measurements underwater were sampled using the manta tow technique. This technique is useful to provide a general description of the large area of consideration for a short period of time. It involves an observer towing using a rope tied to the boat. A natural illumination was provided by direct sunlight covering the target of interest. The main instrument used for spectral measurement was USB4000 VIS-NIR-ER Ocean Optics which consisted of a 10-meter optical fiber probe cable attached to a portable spectrometer unit. The spectral range of the instrument was 345 nm – 1036 nm with an optical resolution of 1.5-2.3 nm FWHM. The device was connected to a field computer with the processing software OceanView which displayed the spectral curves and allowed the operator to modify some important parameters for measurement such as the integration time. The filter values were also modified to smoothen the spectrum in order to improve the signal-to-noise ratio. To minimize the loss of pertinent spectral details, the boxcar width value was set at 0 to obtain the raw spectral signature values, and do the smoothing later in the laboratory for the purpose of spectral library creation. The software acquires the digital number (DN) measurements by default, but it can be changed to directly measure the reflectance values of the target. A white reference panel measurement and a background reference measurement were taken prior to the reflectance measurement of each sample. The tip of the cable was positioned at approximately 45 degrees over the target. The measurement time length was minimized to reduce the error brought by the constant movement of the sun which in effect has illumination difference between the reference and target measurements. The integration time used varied for each sample depending on the intensity of the incoming radiation at the time of measurement. Reflectance spectra were measured just above the substrate at approximately 5 – 10 cm from the surface to minimize the effect of the water column. The software was set to collect twenty-five (25) spectral signatures for each sample. To avoid the occurrence of shadow over the target and to minimize its reflective influence to the measurements, other objects such as boats must be kept in distance and the operators must wear black or dark clothing.

Metadata

Challenges in developing a spectral library include the complexity and variability of the environmental conditions during field measurement. A consideration in performing field spectroscopy is the accomplishment of a complete metadata to report about what has been measured and the condition of the environment at the time of measurement. The use of a comprehensive and complete metadata of the samples collected is necessary to properly report and identify the sample during data processing, to assess the measured spectral data quality and to maximize the usability of the field spectral measurements (Jiménez, González, Amaro, & Fernández-Renau, 2014). In this study, important parameters such as location and measurement details were recorded in a field metadata sheet as shown in Table 1.

Table 1. Metadata for spectral measurement describing the target, sampling location, set-up geometry, and environmental conditions at the time of measurement

<table>
<tr><th>GRP</th><th>FIELD</th><th>DESCRIPTION</th><th>EXAMPLE</th></tr>
<tr><td rowspan="4">General</td><td>SITE ID</td><td>Use a standardized syntax for site IDs</td><td>SAMPLE_001</td></tr>
<tr><td>Date</td><td>Date of acquisition</td><td>09 July 2016</td></tr>
<tr><td>Purpose</td><td>Indicate for what purpose data will be used (e.g. spectral library)</td><td>Spectral library</td></tr>
<tr><td>Observer</td><td>List all personnel involved in spectra acquisition in the field</td><td>Laurence, Joy, Mark</td></tr>
<tr><td rowspan="2">Location</td><td>Time</td><td>Time when sample was acquired</td><td>10:26 AM</td></tr>
<tr><td>Waypoint</td><td>Name of Waypoint in GPS Unit</td><td>Point_001</td></tr>
</table>

	Latitude	in decimal degrees	10.191080 °N
	Longitude	in decimal degrees	125.525925 °E
	Altitude	in meters above sea level	15.50
	GPS Unit	Model and Serial Number or Item ID	Garmin Oregon 650
	Province	Province of site	Dinagat Islands
	City/Municipality	City or municipality of the site	Tubajon
	Barangay	Barangay of the site	Imelda
Target	Land Cover Class	In reference to classification schema used	Mangrove
	Land Cover Type	In reference to classification schema used	Mangrove
	Spectrum/Target name	Name of the target (e.g. rice, mango, seagrass bed, coral reef)	Mangrove
	Target Homogeneity (% cover)	Percent cover relative to the field of view of instrument (0-100%)	100%
	Pictures File Name	File names of pictures	Image001.jpg
Measurement Details	No. of spectra per sample	Number of samples acquired	25
	White Reference	Name or description of white reference panel used	Spectralon
	Sensor	Brand and model of spectrometer used	Ocean Optics USB 4000 VIS-NIR-ES
	Instrument	Serial number or Unit ID	SN012345
	Length of fiber optic cable	in meters	10
	Reflectance	Indicate if reflectance processing in software was performed (yes/no)	yes
	Digital Numbers	Indicate if raw DNs was acquired (yes/no)	No
	Cloud cover	Use oktas method to estimate cloud cover	20%
File Info	Target Irradiance Set 1 Filename	Set 1 of target irradiance/raw DNs files, if raw DN method was used	-
	Target Irradiance Set 2 Filename	Set 2 of target irradiance/raw DNs files, if raw DN method was used	-
	Target Irradiance Set 3 Filename	Set 3 of target irradiance/raw DNs files, if raw DN method was used	-
	White Reference File Names	Set of white reflectance files, if raw DN method was used	-
	Reflectance Set 1 Filename	Set 1 of reflectance files, if reflectance processing was used	REF_01-25
	Reflectance Set 2 Filename	Set 2 of reflectance files, if reflectance processing was used	REF_26-50
	Reflectance Set 3 Filename	Set 3 of reflectance files, if reflectance processing was used	REF_51-75
	File format	Indicate the file format of the files saved from software	txt
	Common Name	Common name in English or local language	Bakawan
	Species	Scientific name	*Rhizopora Mangle*
	Leaf/Canopy	Indicate if the target was the leaf or canopy	Canopy
Vegetation	Ground-canopy distance	In meters	3.36 m
	Phenologic stage	Indicate stage of growth of the plant	
	Presence of irrigation	Indicate if irrigation support is available to the site (yes/no)	no
	Background (soil/other)	Indicate any background materials (e.g. soil, water)	Water
	Soil type / color	Indicate the class/type and/or color of soil	
Marine	Tide conditions	Indicate if site was high or low tide during sampling	
	Wind conditions	Use Beaufort Scale (0-12)	
	Height of sensor	Distance of sensor from the surface (in cm)	
	Distance of target from surface	Distance of target from surface (in cm)	
	Depth of sensor	Depth of the sensor if probe was submerged (in cm)	
	Horizontal visibility	Using the horizontal Secchi disc method (in meters)	

	Sketches	Viewing geometry sketch	
Miscellaneous	Remarks	Include any other pertinent information such as environmental conditions, problems encountered during sampling, etc.	Low tide, DBH = 24cm 

Processing of Spectral Signatures

Data smoothing is an important step to remove the noise in the acquired spectral data. These noises can obscure the important curve details such as the peaks, slopes, widths, and valleys. It is crucial, however, to choose the method of smoothing a hyperspectral data to minimize the disturbance from the original data. There were two smoothing techniques implemented in this study – mean filter and Savitzky-Golay methods. The mean filter, or sometimes called as the running mean or mean average filter, takes the mean value of all points within a window as the new value of the middle point of the specified window (Tsai & Philpot, 1998). One key parameter for mean filter algorithm is the filter size. On the other hand, the Savitzky-Golay used a localized polynomial least-square curve to smooth piece-by-piece the spectral data. Its two key parameters are the degree of the polynomial orders and the window size.

A custom Python-based program was developed to perform an interactive smoothing computation by allowing the users to input the parameters (i.e. filter window, degree of polynomial) for mean filter and Savitzky-Golay algorithms. Comparisons were made by using varying filter sizes for both the smoothing methods and compared the results against the original spectral curve. The comparison reveals that between the two filtering techniques, Savitzky-Golay shows better results which smoothed the data without much disturbance from the original data. A good selection of filter size should also be considered because the higher its value, the smoother the result and this may cause loss of the important spectral features. Figure 1 shows a sample of spectral data smoothing using Savitzky-Golay algorithm.

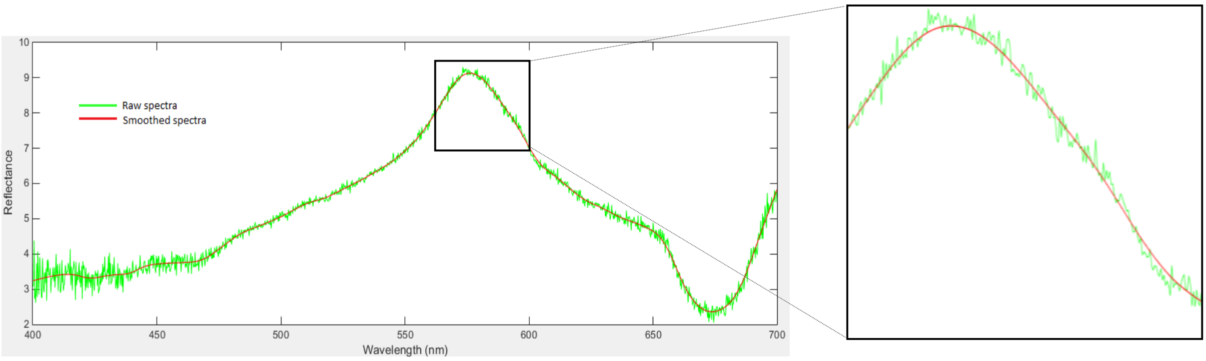

Figure 1. Result of smoothing a live coral spectrum using Savitzky-Golay algorithm (filter size = 50, degree of polynomial = 3); before smoothing (green); after smoothing (red)

IMPLEMENTATION OF PROTOCOLS

Field data collection was carried out in various sites of the Philippines. Figure 2 shows the geographic locations where the spectral signatures were initially acquired.

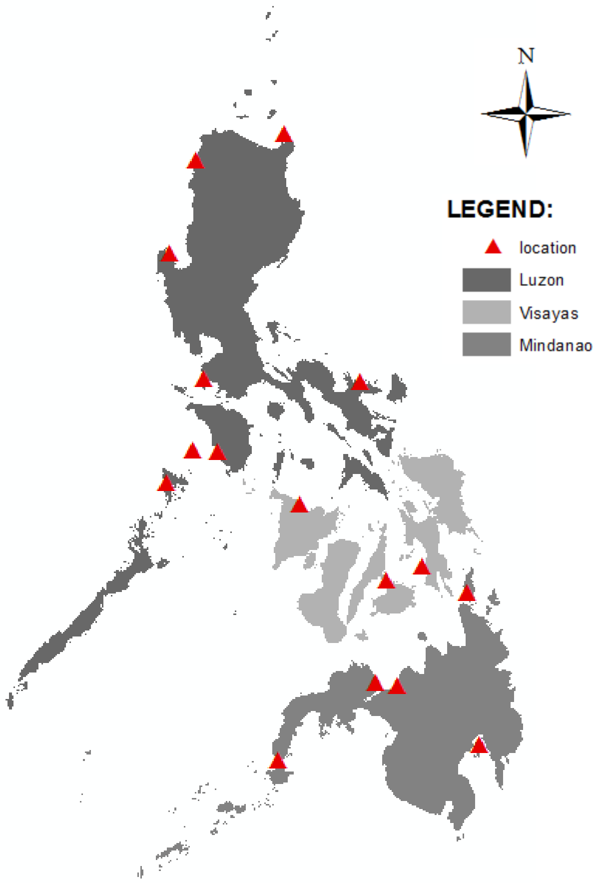

Figure 2. Spectral measurement sites where the data were initially acquired

Figure 3 shows a sample of spectral signatures of different coastal resources over the wavelength range 345 – 1035 nm. Generally, it has been observed that there were consistent noisy regions at both ends of the spectral signatures, particularly regions with wavelength less than 350 nm and above 900 nm. This may be due to instrument limitations.

Light was mostly absorbed by water above 900 nm wavelength. Thus, bands higher than this may not be useful for discriminating underwater features. Sand displayed higher reflectance values compared with other benthic features. Live corals showed measured spectra that follows the "triple-peaked pattern of corals" (Fonseca Escalante, 2004) with reflectance peaks around 560 nm, 610 nm, and 650 nm. The spectral shape and magnitude can be directly related to the pigments present or absent on the features. A significant absorption band was observed around 670 nm which is dependent on chlorophyll-a presence (Myers, Hardy, Mazel, & Dustan, 1999) and can be used to discriminate bare sand and bleached coral from chlorophyll-a containing benthos. There was an obvious reflectance peak of corals at 700 nm. Moreover, reflectance values change very little for the wavelengths shorter than 450 nm.

The general trend of spectral curves of mangroves appeared similar to one another with low reflectance in visible part of the spectrum and increasing reflectance around 700 nm, known as the red edge band, which is common to vegetation spectra. Nevertheless, variations on the slope of red-edge band and magnitudes on visible and near infrared bands are useful for discriminating mangrove classes.

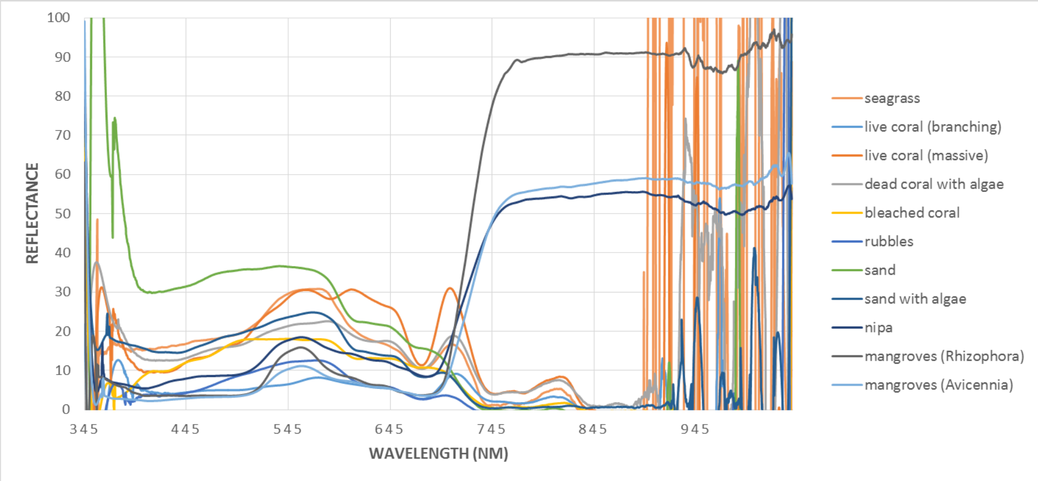

Figure 3. Sample filtered spectral reflectance curve patterns of various coastal resources over the wavelength range of 345 nm – 1035 nm

CONCLUSION AND FUTURE WORK

The developed field protocol and metadata for acquiring spectral signatures of coastal resources serve as a preliminary database of the spectral library of coastal resources in the Philippines. A digital spectral reflectance library has been produced with documentation to be used for future remote sensing applications. The library includes samples of spectral signatures of corals, seagrass, seaweeds, and mangroves. Every feature has its distinct spectral curve patterns (i.e. reflectance peaks, absorptance, slopes, peak widths, magnitude) which are useful for fine-scale identification and mapping.

This spectral library with proper documentation will be used as the basis of detailed characterization of the coastal resources by providing high resolution spectral information. For future work, a web-based repository of spectral signatures with its corresponding metadata should be implemented that will allow the users to view and download data. The spectral data can also be used in future studies to identify the optimal bands in discriminating classes, particularly the health conditions of the coastal resources which, in combination with hyperspectral remote sensing image, is important in large-scale mapping for better ecological assessment and management. Contributions to this spectral library are also encouraged. Comparative analysis can also be employed to determine the optimal size of the filter window which will remove the noise without sacrificing the spectral details. Further characterization of spectra can be implemented by using derivative analysis to produce well-defined peaks at the wavelength locations that contribute to the original shape of reflectance spectra. Various vegetation indices (e.g. normalized difference vegetation index, enhanced vegetation index) can be computed from the spectral reflectance values. Moreover, a spectrometer with a longer range of wavelengths could also be used to utilize the information beyond the near infrared region of the spectrum.

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