DEVELOPMENT OF FIELD SAMPLING PROTOCOLS FOR A SPECTRAL LIBRARY OF AGRICULTURAL CROPS IN THE PHILIPPINES

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ABSTRACT

Spectral signatures of different materials are important reference data for remote sensing applications and characterization of earth surface features. Modern portable systems have made measurements easier to acquire specifically of *in situ* targets. This paper describes the standardized methodology for field measurements using portable field spectrometers of primarily agricultural targets, including field crops in different stages of growth, in various sites in the Philippines. Using OceanOptics spectrometers with a wavelength range of 350-1000 nm and optical resolution of 1.5-2.3 nm FWHM, targets were sampled using a standard viewing geometry at nadir and acquisition time at or near solar noon with 25 scans. A metadata sheet was also formulated and accomplished during field campaigns detailing on location, time, target characteristics and acquisition settings. The Spectral Calculator, a custom program in Java, to average and clean the data was used and descriptive statistics computed for each sample. A total of 8 targets were acquired, namely corn, rice, okra and tobacco in different stages of growth. The construction of a spectral library with sampling protocols allows for intercomparisons of data acquired at different areas and dates and also has potential to be used to estimate vegetation health and growth status for precision farming.

INTRODUCTION

Advances in the technology of spectrometry and hyperspectral sensors have led to the development of highly portable sensors that is applicable to a wide variety of analysis, monitoring and research activities. These are useful for linking laboratory-acquired data to satellite- and field-obtained samples, determining optimal bands for analysis and study of biophysical attributes of the objects under study (Milton, 1987). However, sampling methodologies vary widely and with the organization of more spectral libraries, which are repositories of spectral signatures, there is a need to establish measurement protocols that will allow for comparisons between different samples taken at different locations. Setting protocols will minimize errors and variations due to the influence of sampling geometry, environmental conditions and instrument error. Additionally, obtaining metadata, often overlooked, is critical to ensuring quality, usability and completeness of data collected *in situ* (Rasaiah et al., 2014).

The paper will present a methodology that will standardize the spectral signatures that will be acquired by the Phil-LiDAR 2 Program. Specifications on the use of spectrometers, environmental conditions during sampling and the metadata to be obtained were determined. This study will be useful as a reference for future validation activities, design of remote sensing devices and assessment of crop condition.

PROTOCOL METHODS

The protocol of acquiring spectral signatures for a spectral library involves the following: a) preliminary considerations and preparations before field activities, b) procedure in acquiring digital numbers and surface reflectance measurements, and c) metadata sheets standards.

Ocular surveys must be performed in the areas that will be sampled. Movement within the study area must be accounted for as valid measurements can only be obtained within the high solar noon, which is from 10:00 AM to 2:00 PM. Measurements acquired beyond this time may be erroneous and subject to high atmospheric influence and noise (McCoy, 2005). Also, the cloud cover is to be considered, with no more than 2 oktas (25%) of the sky be covered with clouds during sampling. The sun must also not be obstructed by structures, clouds or even significant air particles such as smog and smoke. Clothing worn during field sampling must consist of dull colors and not be too reflective as these may influence the readings. Finally. inventory of equipment must also be accomplished, including GPS units and accessories to house the spectrometer unit.

The OceanOptics USB4000 was the main unit used for measurements. The OceanOptics USB4000 is a modular spectrometer with a wavelength range of 350 nm to 1000 nm with an optical resolution of 1.5-2.3 nm FWHM. A fiber optic connector of various configurations can be attached to the unit and for this study, a 2-meter aluminum-coasted cable for VIS-NIR applications was utilized. A Spectralon white standard was also used for nominal radiance measurements. The OceanView spftware suite was used. The software, by default, obtains digital number measurements but can also be configured to directly measure reflectance. For the protocol, the default mode of DN measurements or intensity counts is prescribed, where the nominal radiance from the white standard is measured and then three measurements from the target specimen to get nominal irradiance is recorded. 25 readings per measurement is set in the software, having comma-separated ASCII files outputs of the same number. For each sample, there would be a total of 100 files that will be produced. The duration of a single round of measurements should not exceed 5 minutes. This is due to the rapidly changing atmospheric conditions (clouds, gaseous particles, etc.) that can influence the readings considerably. For the viewing geometry, the probe must be at nadir around 3 cm above the surface of the white standard and 30-50 cm from the target specimen. Casting shadows on the sample is also avoided. Finally, five individuals of the target specimen are acquired as representative of the crop. For example, to get the representative spectral signature of rice in the booting stage in Municipality X, 5 individuals will be selected and each individual having 3 replicate samplings, each of which produced 100 files—25 for the white reference and 25 each for a single replicate.

Metadata

Metadata information is a vital component of the archiving process since it contains information on the quality, completeness and usability of the acquisitions. Table 1 presents the different metadata to be acquired in the field with sample data as if taken in an agricultural area. This has been designed in reference to other spectral libraries (Hueni et al., 2006; Rasaiah et al., 2014). The metadata sheet has been optimized for use in the field targets composed of agricultural resources or marine environments.

Table 1. Metadata fields, sample dummy data for an agricultural study site, and their description and/or specifications.

GRP	FIELD	EXAMPLE	DESCRIPTION
General	**SITE ID**	**SAMPLE_S001**	Use a standardized syntax for site IDs
	Date	17/05/2016	Date of acquisition
	Purpose	Spectra	Indicate for what purpose data will be used (e.g. spectral library)
	Observer	John Doe	List all personnel involved in spectra acquisition in the field
Location	Time	10:00 AM	Time when sample was acquired. SAMPLE ONLY FROM 10AM-2PM.
	Waypoint	WPT101	Name of Waypoint in GPS Unit
	Latitude	12.123 N	in decimal degrees
	Longitude	121.123 E	in decimal degrees
	Altitude	2.5	in meters above sea level
	GPS Unit	GSMAP62C SN1234	Model and Serial Number or Item ID
	Province	NCR	Province of site
	City/Municipality	Manila	City or municipality of the site
	Barangay	123A	Barangay of the site
Target	Land Cover Class	GRAIN CROP	In reference to classification schema used
	Land Cover Type	RICE	In reference to classification schema used
	Spectrum/Target name	Fallow or rice	Name of the target (e.g. rice, mango, seagrass bed, coral reef)

	Target Homogeneity (% cover)	75%	Percent cover relative to the field of view of instrument (0-100%)
	Pictures File Name	DSC123.jpg	File names of pictures
Measurement Details	No. of spectra per sample	25	Number of samples acquired
	White Reference	WS-1 Spectralon	Name or description of white reference panel used
	Sensor	OOUSB4000 VIS-NIR	Brand and model of spectrometer used
	Instrument	SN00001	Serial number or Unit ID
	Length of fiber optic cable	2	in meters
	Reflectance	×	Indicate if reflectance processing in software was performed (✓/×)
	Digital Numbers	✓	Indicate if raw DNs was acquired (✓/×)
	Cloud cover	12.5% (1 oktas)	Use oktas method to estimate cloud cover
File Info	Target Irradiance Set 1 Filename	IR00-24	Set 1 of target irradiance/raw DNs files, if raw DN method was used
	Target Irradiance Set 2 Filename	IR25-49	Set 2 of target irradiance/raw DNs files, if raw DN method was used
	Target Irradiance Set 3 Filename	IR50-75	Set 3 of target irradiance/raw DNs files, if raw DN method was used
	White Reference File Names	WR00-24	Set of white reflectance files, if raw DN method was used
	File format	csv	Indicate the file format of the files saved from software
	Common Name	Rice	Common name in English or local language
	Species	*Oryza sativa*	Scientific name
	Leaf/Canopy	Canopy	Indicate if the target was the leaf or canopy
Vegetation	Ground to canopy distance	0	In meters
	Phenologic stage	harvest/fallow	Indicate stage of growth of the plant
	Presence of irrigation	✓	Indicate if irrigation support is available to the site (✓/×)
	Background (soil/other)	soil	Indicate any background materials (e.g. soil, water)
	Soil type / color	brown	Indicate the class/type and/or color of soil
	Depth		Bathymetric depth (in meters)
	Tide conditions		Indicate if site was high or low tide during sampling
	Wind conditions		Use Beaufort Scale (0-12)
Marine	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
	Depth of sensor		Depth of the sensor if probe was submerged (in cm)
	Horizontal visibility		Using the horizontal Secchi disc method (in meters)
Misc	Sketches		Viewing geometry sketch
	Remarks		Include any other pertinent information such as environmental conditions, problems encountered during sampling, etc.

Spectral Calculator

Calculation of the final reflectance values from the csv files was performed using Spectral Calculator, a custom Java-based software developed by Phil-LiDAR 2 PARMap Project (Figure 1). Averaging of the csv files per replicate are performed in the first step, “Get Average of Results”. This will produce an average file for the white standard, then each of the three replicate samples. Then in the “Get Ratio” portion, each nominal irradiance file will be divided by the white reference file, using the ratio of equation 1:

$$R(\lambda) = c[I(\lambda) / E(\lambda)] \tag{1}$$

Where $R(\lambda)$ is reflectance, c is the reflectivity of the white standard, $I(\lambda)$ is nominal irradiance or intensity of the target, and *E(λ)* is nominal irradiance or intensity of the white standard. *c* is usually 95-99% for specific wavelength ranges and can be approximated to 1.0. After the ratio is calculated, the average of the triplicate is the spectral signature of the individual.

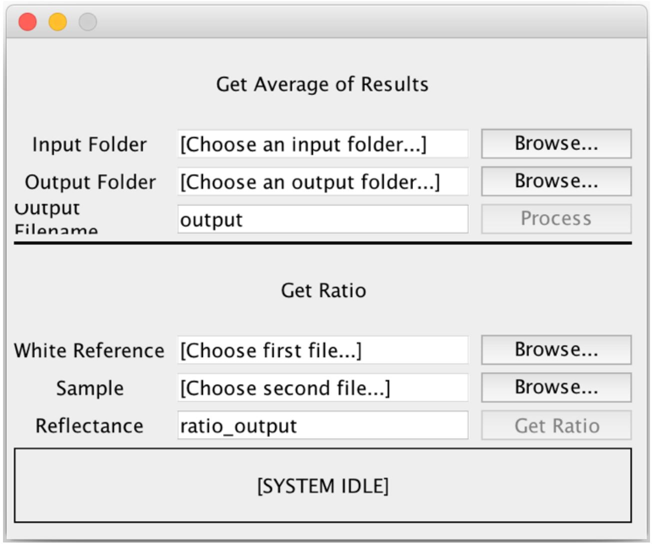

Figure 1. Interface of the Spectral Calculator.

PILOT IMPLEMENTATION OF PROTOCOLS

For this study and preliminary implementation of the protocols, two municipalities were selected and visited in 14-17 June 2016, Agoo in La Union and Sta. Maria in Ilocos Sur. In Agoo, corn in the newly planted and flowering stages, rice in the seedling stage and okra in the tillering and flowering stage was acquired. In Sta. Maria, newly planted rice, seedling rice, flowering corn and flowering tobacco signatures were obtained.

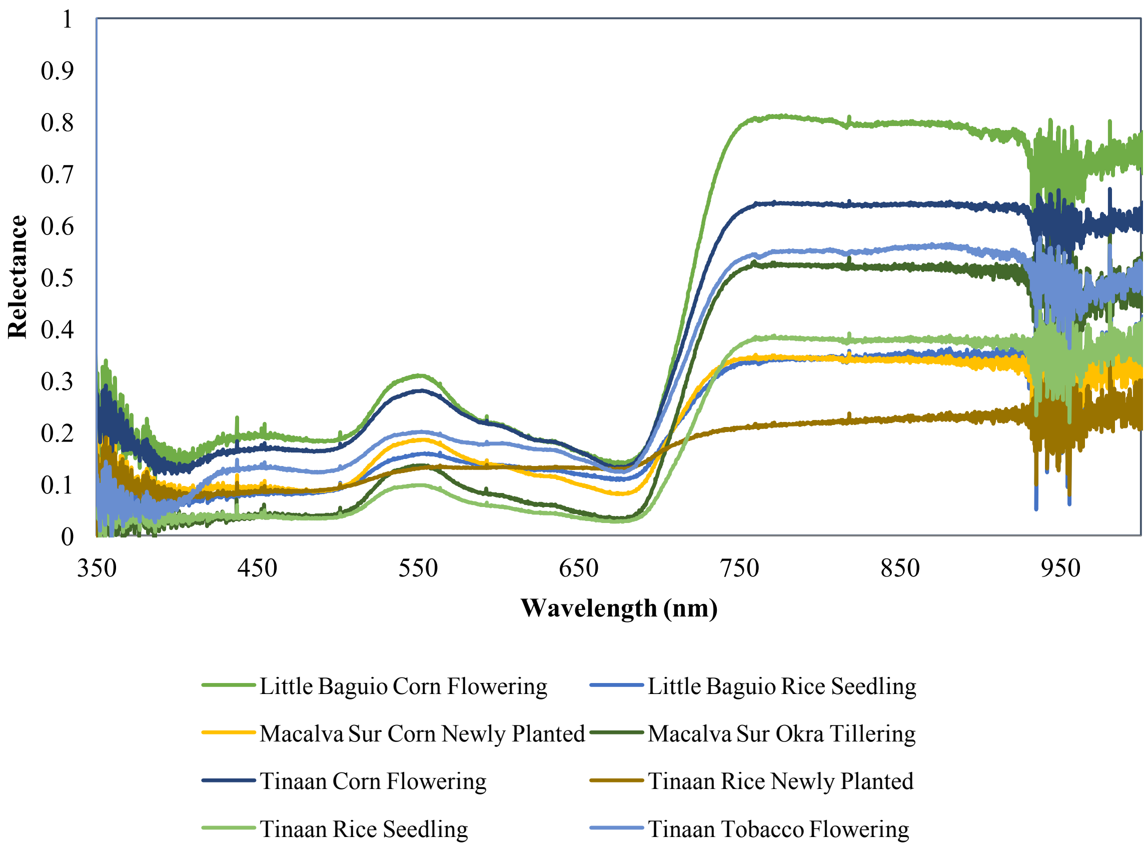

Figure 2. Representative spectral signature, based on reflectance, of the 8 target specimens.

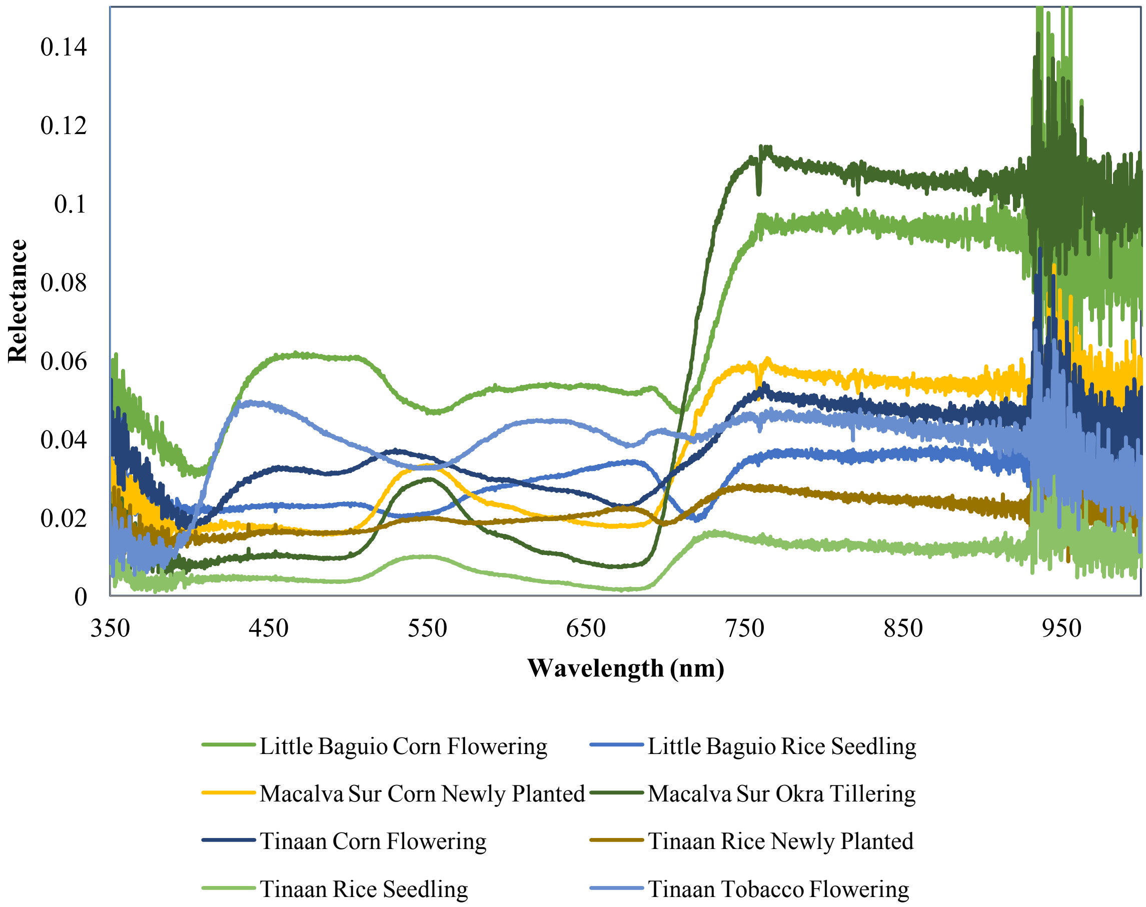

Figure 3. Standard deviation of each spectral signature.

Figure 2 displays the spectral signatures acquired at the 8 sites, covering different species and stages of growth. These were acquired by averaging the spectral measurements, which were able to remove some of the noise inherent in single readings. Further processing to the spectra through the built-in smoothing filter in OceanView, as well as moing average, can be performed. However, it is observable that there are persistently noisy regions, specifically in the tail ends of the wavelength range, <400 nm and >900 nm. These observations are consistent with other spectrometers and may be due to equipment error. Types that are in the flowering and vegetative growth stage have higher reflectance in the near-infrared wavelengths than those that are in the early part of the growth cycle. When computing for indices that measure crop vigor such as the Normalized Difference Vegetation Index or the Enhanced Vegetation Index, the large difference between the near-infrared region and visible region in plants that are at the peak of their vegetative growth would result into higher vegetation index values, indicative of high greenness and biomass production. This contrasts with samples that are in the beginning stages of the crop cycle, such as newly planted crops or seedlings, which has a smaller difference between the visible and near-infrared regions, as seen in Figure 2. Background substrate cause some samples to have a relatively flat profile such as for newly planted rice, which was also flooded when sampled. These would yield lower VI values as well. Figure 3 shows the standard deviation of each spectral signature obtained. Large variations are observed in the visible regions, specifically for flowering and tillering crops. At this stage, crops are much more developed and have more sources of background reflectance, such as lower layers of leaves and other structures in plants that develop as it matures, including flowers, fruits, and grains. Also, movement of the stems can contribute to the variability of the measurements.

CONCLUSIONS AND FUTURE WORK

This method sets groundwork on a database of spectral signatures for the entire Philippines. Due to the diversity in field methods and equipment available, comparisons of spectra obtained at different areas can be difficult and inaccurate. The protocol and tools developed will be useful in harmonizing and standardizing methodologies as well as provide a basis for quality checking to ensure usability and completeness of the data acquired. Future work in this spectral library can include the development of a web-based repository of spectral signatures integrated within webGIS platforms, which will enable the user to upload, view and download data. Metadata will also be submitted through this web portal. Quality checking may furthermore be performed by users with access to the library. Since spectra measurements have high value in precision agriculture and smart agriculture, data to be included in the database will be useful in determining crop growth, crop health, biomass and other biophysical characteristics of crops. Additonally, models and predictions on crop yield can be derived from the combination of spectra and other metrics such as LAI or fPAR. Spectral separability analysis can also be performed from the data, which will determine the bands that can be useful in discriminating between different target types or between stages. Furthermore, determining optimal bands can also be useful in the design of remote sensing devices and instruments.

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