J. Int. Environmental Application & Science, Vol. 13(4): 194-203 (2018)

An Examination of Spectral Reflectance Properties of some Wetland Plants in Göksu Delta, Turkey

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Received January 18, 2018; Accepted November 26, 2018

Abstract: In recent years, the importance of wetlands better understood and included among the priority areas for conservation in Turkey and the world. A significant number of researchers have examined wetlands due to their various valuable aspects such as diverse vegetation, feeding and shelter areas for many species of birds and positive effects on water quality. Remote sensing data are becoming an important source of information for assessment of wetland health and quality. Traditional methods are time consuming, expensive and labor intensive. In this study, the spectral properties of some wetland plants (Phragmites, Typha, Scirpus and Juncus) found in wetlands located on the Göksu delta were examined in the scope of The Scientific and Technological Research Council of Turkey funded project (110Y295). Handheld spectroradiometer was used to determine the spectral properties of selected wetland plants. Reflectance measurements were conducted on May 28, July 16, September 18 and November 16 and on March 12 (2013). According to results, typical vegetation spectral curves were obtained for all species. All resembled typical upland vegetation curves, with higher reflectance values at wavelength of 700 nanometers (near infrared) as compared to visible wavelengths (400-700 nm) and a green peak around 560 nm.

Keywords: *remote sensing, spectral properties, spectroradiometer, wetland*

Introduction

Wetlands are geographically unique, ecologically and socioeconomically important, covering approximately 15 % of the terrestrial landscape of the world and supporting many species both plant and animal, Wetlands contribute greatly to biomass production and play a significant role in the biochemical cycle (Mitsch & Gosselink 1993; Özesmi & Bauer 2002). These valuable ecosystems are undergoing rapid and significant changes in composition, structure and size driven by human related activities. These dramatic and continuous changes hold the potential to greatly influence ecologic and socio-ecologic functioning within wetland systems. Wetlands of Turkey in particular are projected to be under risk of extensive change largely due to human related activities (Meriç & Kavruk, 2007; Karabulut, 2015). It is thus important that the quantification and characterization of types and conditions of wetland plants is required for sustainable use of such resources and for better understanding the impact of changes in those areas via technology based approaches (Özesmi & Bauer 2002; Zhang et al. 2011).

The data from remote sensing systems provide an alternative to field based vegetation studies and records landscape scale vegetation information (Özesmi and Bauer, 2002). Because of their continuous repetitive nature, remote sensing data are useful for monitoring changes in wetlands such as plant types and land cover over longer periods of time and at more varied temporal and spatial scales than what is commonly accomplished with field studies (Adam et al. 2010). Traditional field based data collection methods are time consuming, expensive and labor intensive. Those traditional techniques can also provide only point data which are generally not enough to cover entire habitat. In contrast, remote sensing is an economical way to monitor wetland areas, because it can cover large areas in a short time on a repetitive basis (Özesmi & Bauer, 2002; Adam & Mutanga, 2009; Adam *et al*. 2010).

Scientists and resource managers are therefore interested in wetland using such data, because this method provides continuous data for desired extents. Several studies represented that analysis of medium resolution data (such as Landsat TM, SPOT) can successfully provide the ecologic conditions of wetland plants (Zhang *et al*. 2011; Ghioca-Robrect et al. 2008; Gilmore et al. 2008; Hardisky et al.

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1986; Lunetta and Barlogh 1999; Rundquist et al. 2001; Silva et al. 2008; Adam et al. 2010; De Roeck et al. 2008; Mishra et al. 2006).

However, in highly heterogeneous wetland landscapes, it is limiting to purely rely on medium resolution data to collect information (such as plant types, canopy structure and photosynthetic activity) about individual plant (Ullah et al. 2000; Özesmi and Bauer 2002; Artigas and Yang 2005). The incorporation of close range data collected by field spectroradiometer, potentially offers the ability to bridge the scale gap between plot field studies and larger spatiotemporal analysis which rely on fine to medium resolution imagery (Gilmore et al. 2008; Adam et al. 2010).

Changes in plant conditions (for the purpose of this research we focus on spectroradiometric measurement of plants) requires repeated quantification of individual plant activities based on spectral properties. Furthermore integration of spectroradiometric data into analyses of wetland plants holds the potential to establish the relationship between plant types and patterns on the ground, high and medium spatial resolution pixel signatures of satellite data (such as IKONOS 4x4m and Landsat 30 m × 30 m) (Papadavid et al. 2011).

In the last fifty years, ground-gathered spectral reflectance data is used to produce signatures of wetland vegetation by many scientists (Best and Wehde 1981; Han ve Rundquist 1994; Anderson 1995; Rundquist et al. 1995; Rundquist et al. 1996; Penuelas et al. 1997; Cochrane 2000; Tolk et al. 2000; Fyfe 2003; Han & Rundquist 2003; Valta- Hulkkonen et al. 2004; Vaiphasa et al. 2007; Hunter et al. 2010). The spectral signatures of plants derived by field spectroradiometer are considered to represent the high quality data in that the reflected light does not pass through the atmosphere twice before reaching the sensor. Early researches concerned mainly with discrimination of plant types using spectroradiometer (Anderson 1995; Best and Wehde 1981; Emst Dottavio 1981; Anderson and Perry 1996; Everıtt et al. 1999; Ullah et al. 2000; Fyfe 2003; Schmidt and Skidmore 2003; Gilmore et al. 2008; Jiménez & Díaz-Delgado, 2015; Ling et al. 2017; Tesfamichael et al. 2017). Close range spectral data has been collected for several wetland plants (especially over the controlled experimental plots (Ullah et al. 2000).

In this study, the main goal is to investigate spectral separability and characteristics of four wetland species (*Pharagmatis, Typha, scirpus and Juncus*) using in situ data collected by hand held spectroradiometer. Emphasis is given to isolating spectral differences at various times during the growing season (late May to early November). These results will be important in the development of appropriate remote sensing techniques for mapping and monitoring wetland habitat health and functioning.

Material and Methods

The present study was carried out in the Göksu delta which is located in the Mediterranean region of Turkey (Figure 1). The climate of the area is typically Mediterranean characterizing with hot and dry summer, cool and rainy winter. The Göksu Delta is unique because the delta has one of the most important international wetlands that provide reproduction, nutrition and accommodation facilities for delicate, rare and in danger of extinction of many species (Gürkan et al. 1999). This area is also located on the one of the world's important bird migration route.

The delta has several small lakes (the largest one is around 1200 Ha) with abundant aquatic vegetation (Karabulut 2015). The maximum depth is about 2 m in very limited areas, but most of the lakes are very shallow (generally less than 1 m). This shallowness is suitable for growth of many emergent macrophytes. The most abundant aquatic plants consist of *Pharagmites australis, Thypha angustifolia, Scirpoides holoschoenus, Juncus acutus, Juncus maritimus, Schoenoplectus litoralis, Nasturtium officinale, Potamageton pectinatus, Lemna minör, Polygonum salicifolium, Lythrum salicaria, Ceratophyllum demersum and Ceratophylletum demersi* (Karaömerlioğlu 2010).

These lakes and wetlands, which represent distinct contrast to the sparsely vegetated coastal sand dunes and agricultural lands, are hydrologically connected, in varying degrees, to the surrounding areas. The sensitive balances that maintain lakes and associated wetlands will almost certainly be affected by human activities and natural processes (such as climate variations) that increases or decreases usage of water in the area (Karaömerlioğlu, 2010). Akgöl, Paradeniz and Kuğu lake wetland areas are the study site chosen to assess spectral examination of emergent plants. These lakes have 650, 500 and 30 surface hectares of water respectively and are surrounded on all sides by wetland vegetation, most notably around the Akgöl (Karabulut 2015). For the most of the experiment, test areas were chosen the wetlands around Akgöl for couple of reasons. Firstly, the wetlands surrounding the lake are dominated by four emergent wetland species; *Phragmites*, *Typha*, *Scirpus* and *Juncus*. *Phragmites* and Typha are the two species which aggregate huge amounts of biomass per unit area around the lakes. *Scirpus* does not represent much biomass on a unit area basis but covers a much larger area than *Juncus*. Secondly, being located between agricultural lands and sand dunes, Akgöl faces to human interventions due to closeness to the villages and other settlements. Only official fishermen are authorized access to the lake, unfortunately motorized boats are not prevented.

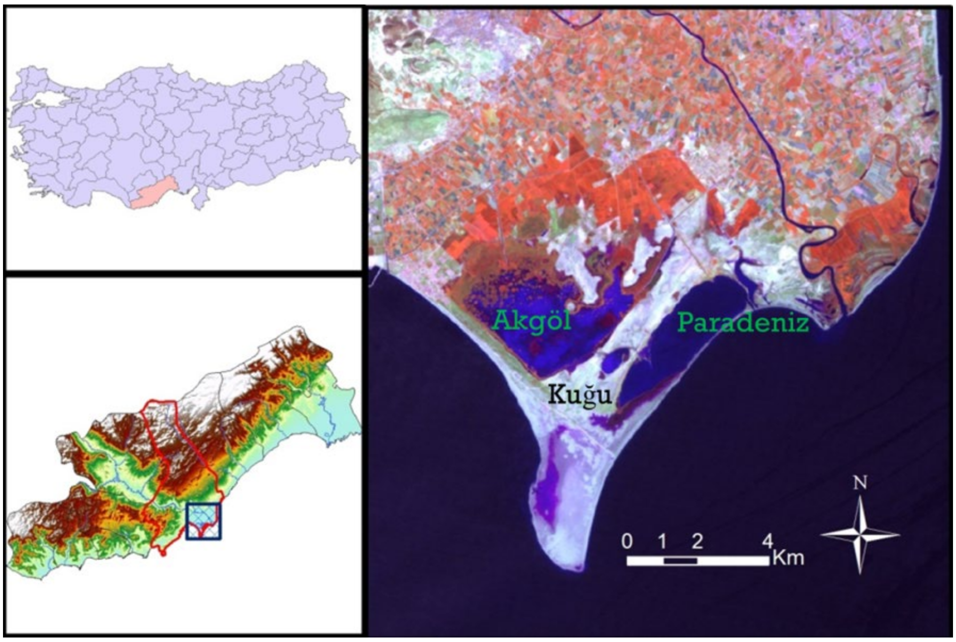

Figure 1. Location of the Göksu Delta

Those perennial wetland plants which are used in this study are common in different sections of the wetlands alone or mixed with together (espically Phragmites and Typha) and represent slightly different phenology. Phragmites species grow at or above mean high water (from wet sturated soil to 50 cm deep) which means that Phragmites exist in shallowest water. Typha species chose to grow intermediate water depths which means this plant require more water than Phragmites. Scirpus generally prefer deepest water (grow in more than 1m depth) in the study area, thus this plant does not tolerate less water conditions (Larson, 1993). Juncus grows where the soil is saturated not inundated which means that it often exist in meadows and swales mixed with grasses and sedges (Karaömerlioğlu, 2010).

Measurements

Handheld Fieldspec® ASD spectroradiometer was used to determine the spectral properties of selected wetland plants. The device has the ability to collect data from 750 continuous channels. Each band is approximately 1 nanometers wide. Sensor system consists of optical lens, control unit and the computer. The spectral range from 325 to 1075 nm comprises the visible through the near infrared region of the electromagnetic spectrum (ASD 2005).

To standardize the units of measure, spectroradiometer scans were taken with a 25°optic which resulted in a field of view of approximately at 75 cm above the canopy level (Figure 2). The instantaneous field of view (IFOV) was calculated with following formula.

$$IFOV(d)= h^* (TAN\ a) \qquad (1)$$

Here, *d* is the diameter of the IFOV, *h* is the height of the optic above the target and *a* is the angle of optic (Lillesand & Keifer 1994).

Figure 2. Spectral measurements standards

Canopy measurements were calibrated to a 100% Spectralon® panel at the start of each sampling sequence. Data collection for this study during 2012-2013 took place on 5 different dates. The measurements were completed between 10.30 and 14.30 o'clock to maximize solar illumination and to minimize reflectance anomalies due to low sun angles. Measurements were performed at various phenological stages. Reflectance data were collected on May 28, when plants were at early emergent stage; July 16, when plants were fully grown; September 18, the flowering stage; November 11, the senescence stage; and March 12, out of growing season.

The dates for collection of spectra and the concurrent meteorological observations are presented in Table 1. The sensor is mounted and positioned so the sensor collector is directly over the target in the nadir position to capture spectral radiance upwelling from the plant canopy. The entire set of spectral data on each date included several spectral samples, each the mean of three replicate scans, collected over the test field.

Table 1. Weather conditions during spectral measurements

Date	Time	Temperature C°	Humidity (%)	Wind speed (m/s)
18.05.2012	10:30-14:30	22.4-28.6	46.7-56.7	5.6
17.07.2012	10:30-14:30	32.3-38.5	50.1-60.0	2.3
14.09.2012	10:30-14:30	29.2-34.4	44.0-54.6	8.5
16.11.2012	10:30-13:30	22.1-24.3	45.8-57.8	6.8
01.03.2013	10:30-14:30	16.8-19.7	35.4-45.2	10.7

The research was conducted on separate monocultures of *Phragmites, Typha, Scirpus and Juncus* each of which had been growing in several parts of the study area. Standing litter and lying litter were not removed from the stands prior to commencing sampling. To facilitate repetitive sampling during the study period, 1 m^2 quadrats were established in a portion of each of the plant. The locations of the quadrats were selected to be within portions of the test areas having a fully homogeneous canopy. The measurements provided equal sampling replicates on each sample date.

The data were cropped to avoid the signals measured below the visible (325-399 nm) and in bands affected by atmospheric interference in the NIR (1000-1075 nm). Reflectance was calculated by dividing the radiance measured from the canopy by the radiance of the calibration panel as:

$$\boldsymbol{R(\lambda) = L(\lambda) \,/\, S(\lambda) * Cal(\lambda) * 100} \qquad \textbf{(2)}$$

Where, R(λ) is the percent reflectance at wavelength (X), $L_{(\lambda)}$ is the canopy radiance at wavelength, $S_{(\lambda)}$ is the Radiance from the calibration panel at wavelength and $Cal_{(\lambda)}$ is the calibration factor.

After percent reflectance was calculated for each quadrats for each plant, reflectance values were averaged for the mono-specific groups which covered more than one test area. Thus, a simple mean was used to represent a single reflectance value for each individual species. For example, reflectances from all test areas of *Phragmites* were averaged to obtain one single value for that species. These average reflectance values were then used to perform the analysis.

Results and Discussions

In this study, the spectroradiometric measurements were performed to determine the spectral characteristics of wetland plants such as *Phragmites*, *Typha*, *Scirpus* and *Juncus* which are commonly found in wetlands of Göksu delta. Measurements were repeated for locations having different environmental conditions for each species around the Akgöl, Kugu and Paradeniz lakes. Reflectance values were expressed as a percentage for each species and depicted in Figure 3. In addition, measurements during the phenological periods for each species were plotted in Figure 4. According to figures, values of measurements are made to characterize the typical vegetation reflection properties. All resembled typical upland vegetation curves, with higher reflectance values at wavelength of 700 nanometers (near infrared) as compared to visible wavelengths (400-700 nm) and a green peak around 560 nm. Chlorophyll reflection region depicted clearly for *Phragmites* and *Typha* as compared to *Scirpus* and *Juncus* due to higher green reflections. As can be seen from the Figure 3, even though, the reflectance curve for *Juncus* is also typical of vegetation, the reflectance is lower at all wavelengths and the green peak is much less pronounced as compared to the other three species. Green peak values obtained between 550 and 650 nm for all species. Low density chlorophyll absorption areas represented clearly in the visible wavelengths of blue (400-500 nm) and red (650-670 nm) regions (Spanglet et al. 1998; Ullah et al. 2000; Karabulut 2007). Red Chlorophyll absorption region is much more well-defined for *Phragmites* and *Typha* than the other plants.

Plants absorb sun lights, especially blue and red wavelengths, to perform photosynthesis. Therefore, the reflectance values of these wavelengths will always be low. In fact, the increases in the amount of reflection in these regions constitute evidence that the plant is unhealthy. For typical healthy green vegetation, the visible reflectance is controlled by leaf pigments such as chlorophyll; on the other hand, NIR reflectance values are mainly controlled by mesophyll spongy tissue and inner cell airspaces of leafs. Reflectance in the near infrared region was measured as 25-45% for all species; however, infrared reflectance of 50% seems to be relatively low compared to the terrestrial plants. This result is related to aquatic plant properties such as leaf characteristics (leaf angle), physiological structure and canopy architecture (Ullah et al. 2000; Gilmore et al. 2008).

A comparative study of reflectance values of the four wetland plants represents that *Phragmites* had the highest overall reflectance and *Juncus* the lowest during the study period. *Typha* (higher) and Scirpus reflectance were moderate with regard to *Juncus* and *Phragmites* both in the NIR and visible regions.

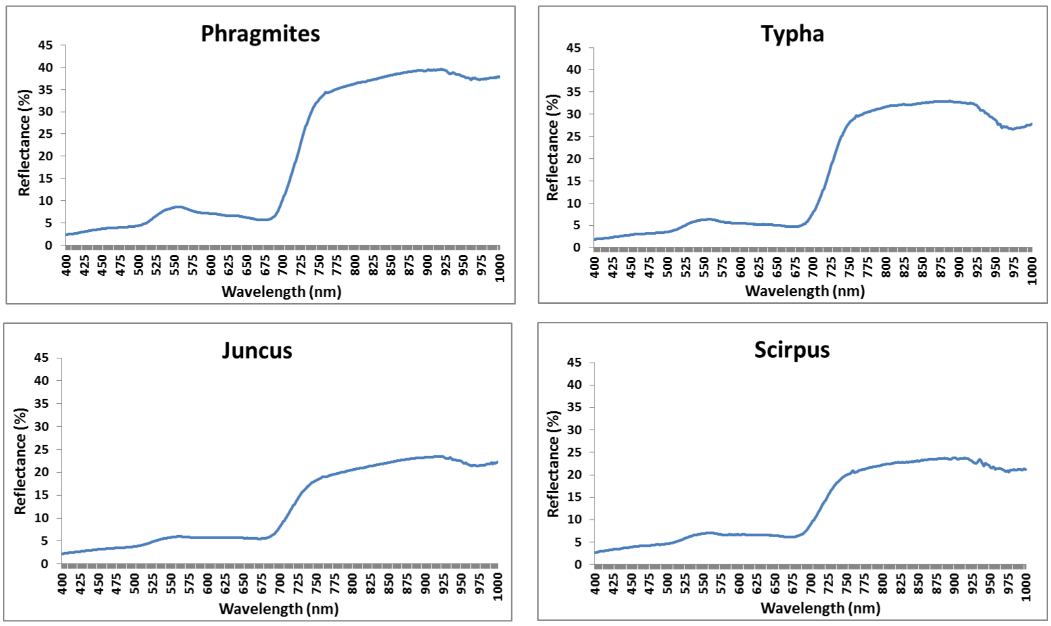

Figure 3. General reflection graphs of wetland plants.

According to analysis of the measurements made in May, the local maximum value of blue reflection appears around blue / green border at 520 nm for each species (Figure 4). The results reveal that the green wavelength reflectance is naturally higher than the blue and red for each plant type. In May, the maximum visible reflectances were 552 (%6.98) nm for *Phragmites,* 555 (%6.15) nm for *Typha,* 558 (%4.10) nm for *Scirpus and 562 (%5.58) nm* for *juncus*. It is understood that the green maximum occurs at similar wavelengths for all species throughout the study period.

The chlorophyll absorption region in the red wavelength has emerged between 667-674 nm wavelengths. Local minimum for each species were varied for the month of May (Figure 4). It seems that the red absorption region is well defined for *Phragmites* and *Thypha*. The local minimum in red region of the spectrum was observed for *Phragmites* 674 (2.69%) nm, for *Typha* 673 (4.23%) nm, for *Juncus* 667 (4.57%) nm and for *Scirpus* 671 (3.24%) nm (Table 2). The red reflectance troughs were seems to be more pronounced for all measurements for *Phragmites* compared to other plant types. Besides the chlorophyll concentration, plant density and canopy characteristics can be listed as causes of the emergence of this situation.

In May, the highest reflectance values measured in the near infrared wavelengths especially for *Phragmites* and *Typha*. Peak reflectance values in the NIR region for *Phragmites, Typha, juncus* and *Scirpus* were 917 (39.99%) nm, 875 (31.56%) nm, 889 (18.86%) nm and 898 (23.23%) nm, respectively (Table 2). NIR reflections for *Phragmites* and *Typha* are greater than the other two species in May and possibly indicating the higher rates of photosynthesis.

There are many causes of the reflectance values differ according to the various wavelengths. Due to the physiological structure and canopy characteristics of plants, the reflectance values were not exceeded 45% for four wetland species. Spectral response level is also strongly influenced by local environmental factors such as amount and quality of water, climate and other factors at a specific point in time. High reflectance values found in the green wavelength is often closely related to leaf pigments. Dark green looking plants provides low reflectance values in blue (400-500 nm) and red (600-700 nm) wavelengths due to high chlorophyll concentration as compared to light green plants. The appearance of the plants used in this study is changing from relatively light green (*Phragmites*) to dark green (*Juncus*).

Table 2. Maximum (green and purple) and minimum (red) reflectance values of Plants.

	May							
	Scirpus		**Juncus**		**Phragmites**		**Typha**	
Wavelength	Ref. %	λ	Ref. %	λ	Ref. %	λ	Ref. %	λ
Green(Peak)	4.10	558	4.63	562	6.98	552	6.15	555
Red (absorption)	3.24	671	4.57	667	2.69	674	4.23	673
NIR (Peak)	23.23	898	18.86	889	39.99	917	31.56	875
	July							
	Scirpus		**Juncus**		**Phragmites**		**Typha**	
Wavelength	Ref. %	λ	Ref. %	λ	Ref. %	λ	Ref. %	λ
Green(Peak)	7.05	558	5.96	559	8.60	556	6.33	557
Red (absorption)	5.49	671	5.49	671	5.64	672	4.66	672
NIR (Peak)	23.68	885	23.48	919	39.50	920	32.93	888
	September							
	Scirpus		**Juncus**		**Phragmites**		**Typha**	
Wavelength	Ref. %	λ	Ref. %	λ	Ref. %	λ	Ref. %	λ
Green(Peak)	7.34	560	8.02	562	11.26	557	6.64	556
Red (absorption)	6.08	670	7.97	667	7.29	674	4.47	671
NIR (Peak)	34.87	893	31.08	890	46.85	917	35.02	887
	November							
	Scirpus		**Juncus**		**Phragmites**		**Typha**	
Wavelength	Ref. %	λ	Ref. %	λ	Ref. %	λ	Ref. %	λ
Green(Peak)	8.50	559	5.12	562	8.96	559	7.40	563
Red (absorption)	6.58	675	5.06	669	6.33	674	6.66	669
NIR (Peak)	32.45	888	23.26	887	42.45	887	35.93	886

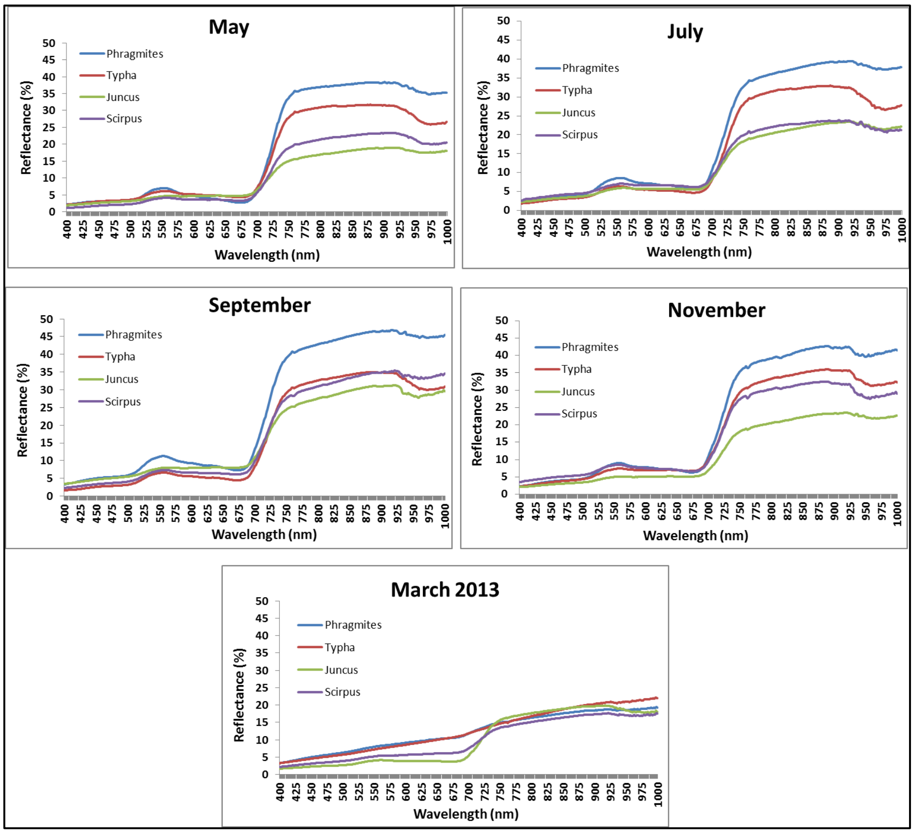

Figure 4. Spectral measurement values of the wetland plants in different sampling month

Wetland plant species appears different during the phenological events such as revival, flowering and senescence due to specific sensitivities of each plant to changing environmental conditions. These varying circumstances have a significant effect on the spectral measurement values. For example; the colour of flowers and biophysical properties of the plants used in this study have an effect on reflectance values. In this study, especially brown flowers (*Juncus*) cause a decrease in the reflectance value in the green wavelength. Phenology is also effective on the colour of the plant appearance depending on changes occurring in chlorophyll content.

Differences in infrared reflectance values are mostly affected by the structure of plant leaf and canopy characteristics (Spanglet et al. 1998; Gilmore et al. 2008). The density of plants per unit area and the level of biological activity lead to the emergence of high reflectivity in NIR wavelength. Therefore, it is possible to observe high NIR reflectance in the study area, especially for *Phragmites*. The results confirm that plant canopy architecture also has a significant effect on the reflectance values. *Juncus* with circular canopies have low reflectance values within the study area as compared to *Phragmites* that represent horizontal leaf structure with not too much space on canopy. In addition, a horizontally oriented canopy tends to reduce background effects. On the other hand, vertically orientated canopy characteristics cause the emergence of a moderate reflection for *Typha* and *Scirpus*. *Scirpus* with vertical canopy structure allows more reflections from the ground which is water mainly in our case. Thus, low reflectance values can be measured due to light reflected back from the water and dried plant remains. It is possible to see this effect clearly in the study area. Plant density which is another factor affecting the canopy architecture is emerging as an important parameter during the measurements. In the study area, *Phagmites* represent high canopy density as compared to other plants, thus, it also has the highest reflectance values. The most significant differences in plant density can be seen in the month of May because some species have incomplete canopy due to the beginning of the phenological stages of development.

As stated earlier, ground reflections increase in the NIR region of spectrum due to gaps in vertically oriented canopies such as *Scirpus* and *Juncus*. Low NIR reflectance is related to strong absorption of wet soil or water and dry plant litter.

In spite of being at the end of the phenological stages, *pharagmites* produced high NIR reflectance values due to compact canopy structure leaving no gaps between individual species. On the other hand, the results revealed the red wavelength reflection values have increased where some individual plant species died due to the absence of water. It is possible to observe the clear effect of the dead plant residues for *Juncus*, mostly. Spectral values which were collected over water abundant locations with gapless canopy characteristics were relatively higher in NIR region as compared to dry sites and hiatus canopy structure. The results showed that low vigor plants which are associated with absence of water and vertical canopies with abundant gaps produced low NIR and Visible spectra compared to flooded site high vigor plants. Beside, presence or absence of water in different sites, salinity appear to be the most important ecological factor by affecting the plant vigour and composition. Therefore, the amount of measurements around the Paradeniz Lake (where salinity is higher) produced low reflectance spectra. Along with plant properties, such as plant density, leaf shape and orientation, canopy structure and architecture, the sensor capabilities including IFOV and spectral resolution play important role in the determining the amount of radiation reflected from plants.

The results are generally parallel to previous studies. However, there are some differences due to effect of local conditions such as climate. Since the phenological characteristics of the plants are climate dependent, they are reflected in the results. The results show that the phenological time in the study area is relatively longer, whereas in the cooler regions of the world this period is shorter.

Conclusions

This study aimed to determine the spectral properties of some plants in wetlands. To achieve the necessary data, spectroradiometric measurements were done on selected wetlands plants in Göksu Delta. *Phragmites*, *Typha*, *Scirpus* and *Juncus* species are subjected to spectral measurements on different dates and in different ecological environment. The resulting reflectance values are converted into percentiles and then analysed.

Results indicate that there is a significant relationship between vegetative growth and the spectral reflectance values. At the beginning of phenological stages, it is observed that spectral values are increased in the green wavelength due to abundant chlorophyll and carotene pigments in green plant leaf. Similarly, as the phenological stages progressed, the spectral reflections in the NIR region have ascended clearly, depending on the increasing of photosynthetic activity in the leaves of the plants. It can be seen that this trend continued until the end of the phenological stages (until September). However, according to March measurements, this trend did not continue outside the phenological cycle. It is understood from March measurements that there was a continued slight biological activity for *Juncus* due to the acting as a perennial plant.

Consequently, this study revealed that various properties of plants living in wetlands can be understood by using the spectroradiometric measurements made in the real environment. In addition, the spectral measurement results clearly showed that the near infrared region of the electromagnetic spectrum (especially 720-1000 nm section) is useful during the determination of the characteristics of aquatic plants. The near infrared light reflection peak is varying depending on the characteristics of the plant canopy and leaf structure. However, this change also varies depending on the presence and chemistry (salty or fresh) of water.

Overall measurements revealed that the spectral reflectance of wetland plants vary depending different ecological conditions in the study area. Therefore, it is necessary to know ecological conditions of the plants for accurate and reliable assessment of biophysical properties based on spectral measurements. The results obtained from this study proved that conditions of aquatic plants can be easily detected with remote sensing methods. This study suggests that the data collected in the summer would be more appropriate to study wetland plants using remote sensing techniques.

Finally, this study has demonstrated that monitoring wetland vegetation using close range remote sensing methods could lead to better understanding of the biophysical properties of aquatic macrophytes and may improve our knowledge about environmental conditions of wetlands.

Acknowledgments: *This study was supported financially by the Scientific and Technological Research Council of Turkey (TUBİTAK- ÇAYDAG-110Y295).*

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