Applying Remote Sensing Techniques to Detect Metal

Contamination in Mangrove Wetlands: Cayo Aurora and Caño Tiburones

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Abstract

The purpose of this study is to determine if remote sensing techniques can be used as a tool to monitor heavy metal contamination of mangrove vegetation. Two areas of study were selected in Puerto Rico, one with high levels of heavy metal contamination (Caño Tiburones, Arecibo) and one with normal levels of metal presence (Cayo Aurora, Guanica). This study applied satellite imagery with various resolutions from IKONOS satellite and in situ GER1500 spectroradiometer for leaf analysis. The analytical results indicate that satellite imagery discerns with the in situ data from GER1500 spectroradiometer. Possible causes for this discrepancies where reviewed: atmospheric corrections and satellite imagery precision where primarily approached. Follow-up research must be done in order to determine if remote sensing can be used as a tool for this type of experiments.

Keywords: Remote sensing techniques, Mangrove vegetation, NDVI, IKONOS, Heavy metal contamination, Puerto Rico.

1. Introduction

The use of remotely sensed data has been a growing method to monitor mangroves and other vegetation (Kovacs et al 2005). This method is preferred by scientist because it requires less time and budget. New technologies are rapidly evolving giving way to new research capabilities in multiple areas of study (Lee and Yeh 2009). The use of remote sensing has opened many doors in the scientific community, and the continuous use of these methods will not only help increase our knowledge, it will also let us now its limitations (Lee and Yeh 2009).

Remote sensing has been applied in land use to monitor changes of wetlands distribution, and in the estimation of leaf area index in mangrove forests (Kovacs et al 2005). Mangroves are

of critical importance to the environment serving as habitat to various species and providing 10% of the dissolve carbon in the oceans (Souza et al 2006). Lee and Yeh (2009) state wetlands are considered to be some of the most important ecosystems on Earth. This is because wetland vegetation can rapidly adapt to changes in the environment and are great modificators of chemical and biological material (Lee and Yeh 2009). The mangroves in this study are red mangrove, which is one of the four species in Puerto Rico. Mangroves along the Caño Tiburones are being used as biological filters for the treated waters of the AAA (Autoridad de Acueducto y Alcantarillado). Even though mangroves can help cleanse these waters, excess pollution due to a growing community has contaminated the area. Chemical components and metals in the soils can affect the appearance and growing behavior of any vegetation. The detection of these anomalies will put to the test the capabilities of remote sensing.

One of the methods used by scientist to detect variations in the vegetation, which in this case will be used to detect metal contamination, is the calculation of a vegetation index (Cicek et al 2010). The most used method to calculate vegetation index is NDVI (Normalized Difference Vegetation Index) (Kovacs et al 2004). In various studies NDVI has been used to determine leaf area index, which helps compare changes in the environment through periods of time (LeMarie et al 2006). The calculation of NDVI can be done using satellite imagery but it can be affected by the resolution of the images which can influence the results of the study (LeMarie et al 2006). This is why in situ spectral analysis has been integrated in this study to compare and ensure accuracy in the results. The images used in this study are from IKONOS satellite. These images have a multi-spectral range and provide a pixel resolution of approximately 3 meters. The images from IKONOS are constantly available which makes it a useful tool for continuous monitoring if

the study is successful (Kovacs et al 2004). These images were processed using ENVI 4.7 program.

The purpose of this research is to test if there is a relation between the two methods used, in situ spectral data and satellite imagery, to determine if remotely sensed data from satellite imagery can be used as a cost effective tool.

2. Materials and Methods

2.1. Study sites

This study focuses in two areas: Caño Tiburones in Arecibo and Cayo Aurora in Guanica, Puerto Rico (Figure 1). Each of these areas has ten sampling places which were divided into four zones (Figure 2 and 3). These zones are:

- Arecibo
  - Zone 1 – Caño Tiburones 1,2,3 and 4
  - Zone 2 – Pescaderia
  - Zone 3 – Nautico 1,2 and 3
  - Zone 4 – Int. 681 Faro-Puente and Car. 681

- Guanica
  - Zone 1 – Aurora West 1,2, and 3
  - Zone 2 – Aurora Centro 1,2 and 3
  - Zone 3 – Aurora East 1,2 and 3
  - Zone 4 – Aurora North

Both this places have been chosen because they hold the same species of mangrove (red mangrove) but have differences in contamination. Caño Tiburones in Arecibo is an affected area where metal contamination levels are high due to anthropogenic processes. Cayo Aurora in Guanica is a protected area where metal levels are at normal values.

2.2. Instruments and data analysis

In situ measurements were taken using the GER1500 Spectroradiometer on the dates of November 13, 2010 and February 5, 2010 in Guanica and February 27 and October 30, 2010 in Arecibo. GER1500 measures the amount of solar radiation absorbed. The data obtained was used to create reflectance averages at wavelengths ranging from 283nm to 1091nm, which were then used to create a vegetation index (NDVI). To calculate NDVI values we took into consideration wavelengths in the Red and NIR (Near-Infrared), at 650nm and 800nm respectively. The formula for NDVI calculation is $\frac{(NIR-RED)}{(NIR+RED)}$. This equation gives us a number between cero and one always positive. Since there were three different reflectance values for each area an average had to be calculated (Figure 4). Once this averages where calculated I determined zone averages for the two areas. This was done to observe if there was variance in reflectance so comparison could be made. The variance per zone in Guanica ranged from 0.79 to 0.85 and in Arecibo from 0.79 to 0.89. The variance in NDVI between the two areas is 0.0266. This is not a significant difference in the vegetation index.

Two IKONOS satellite images where used in this study to estimate changes in vegetation. The image of Guanica was taken in Decenber 12, 2010 and the image of Arecibo was taken in January 3, 2010. This images show the differences in reflectance along the areas selected. The images were processed using ENVI 4.7 software. The program enables us to transform the images for faster and precise pixel location (GPS point). There are many variables that have to be considered when working with these images to ensure data quality (Proisy et al 2007). This program allows us to extract NDVI values at the coordinates of the in situ samples. The first NDVI values were extracted from the unprocessed image, which gave me values that did not show a relationship with the ones processed from the field data. After noticing this we decided to do an atmospheric correction to the image. The atmospheric correction was done but the new

NDVI values still in the majority of the cases did not matched the values obtained from the field data, Figure 5. The variance between zones for the IKONOS NDVI values range from 0.50 to 0.58 in Arecibo and 0.16 to 0.62 in Guanica. Comparing these values to the ones obtained from the in situ samples we notice a clear difference. The values obtained using satellite imagery was significantly lower and did not coincide with the calculated values from the samples. These discrepancies in the analysis can be attributed to differences in the time of sample collection and date when the image was taken (Kovacs et al 2004). Another factor I notice was that the precision of the coordinates in the IKONOS images was not as exact as the measured coordinates in the field. IKONOS would locate the coordinate at a specific pixel that sometimes was of by 0.4 to 0.8 seconds, which does not seem like much but it can be seen as a possible error.

When comparing the sediment grab to the calculated NDVI of the in situ samples, the data showed that in Guanica the levels of metal contamination where very constant. The most noticeable change was that as vegetation index increased arsenic levels also increased. This can be a possible interpretation if arsenic gets transported more effectively into the leaves and affects the reflectance, but that has to be proved by further research. In the Arecibo samples the metal presence was very high which makes it difficult to see any patterns. Arsenic in this area behaves almost in the same manner that in Guanica but the levels are significantly higher.

3. Conclusion

There were various discrepancies in the use of satellite imagery to determine precise to the point NDVI values. Further studies can be done to see if IKONOS satellite images can be taken to such precision (Kovacs et al 2004). The in situ sampling proved to be more effective at detecting reflectance values to determine NDVI. More studies have to be done to see if there are

any relations between some metals absorbed by the leaves and the reflectance calculated in the study. Remote sensing has been used effectively in the monitoring of mangrove biomass because it comprises large areas where NDVI calculation is more precise and it can be calculated taking into consideration several periods of time (Proisy et al 2007). For this study the time lapse was one of the factors that could have affected the data processing since it has been done to a precise to the point area and remotely sensed data tends to be used for large areas over periods of time for comparison (Kovacs et al 2004). Future research and the help of constantly evolving technology will allow proving if remotely sensed data can be used to determine metal contamination in mangrove wetlands.
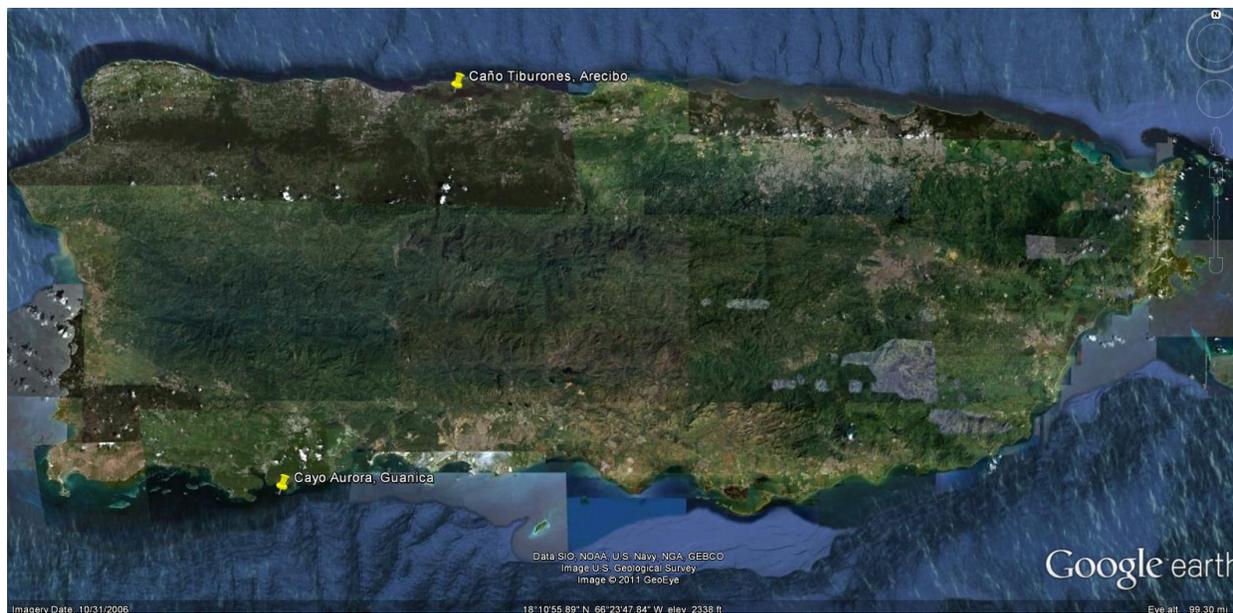
4. Acknowledgements

5. Figures

Figure 1: Image of Puerto Rico showing location of Arecibo and Guanica sites of study. Courtesy of Google Earth.

Figure 2: Study area in Arecibo. The colored boxes indicate the different zones, and the red points indicate where the samples were taken. Zone 1 is blue, zone 2 is yellow, zone 3 is red and zone 4 is the two green boxes. This image was bought by Prof. Gilbes and it is from IKONOS satellite.

Figure 3: Study area in Guanica, Cayo Aurora. The colored boxes indicate the different zones, and the red points indicate where the samples were taken. Zone 1 is red, zone 2 is yellow, zone 3 is black and zone 4 is orange. This image was bought by Prof. Gilbes and it is from IKONOS satellite.

Arecibo				
Location	% refl 650nm(red)	% refl 800nm(NIR)	NDVI	NDVI Average
Caño Tiburones 1	8.77	62.39	0.75	0.79
	7.10	57.64	0.78	
	4.91	54.63	0.84	
Caño Tiburones 2	3.19	58.68	0.90	0.88
	3.04	55.61	0.90	
	4.45	50.29	0.84	
Cano Tiburones 3	2.88	45.84	0.88	0.87
	3.82	52.41	0.86	
	3.43	43.22	0.85	
Caño Tiburones 4	3.98	64.59	0.88	0.87
	4.01	63.82	0.88	
	3.64	47.47	0.86	
Pescaderia	4.96	48.45	0.81	0.80
	9.91	62.19	0.73	
	2.77	34.47	0.85	
Nautico 1	3.66	52.67	0.87	0.86
	5.58	73.66	0.86	
	5.90	81.20	0.86	
Nautico 2	4.17	53.28	0.85	0.87
	4.76	63.10	0.86	
	2.98	47.94	0.88	
Nautico 3	8.89	84.07	0.81	0.81
	5.99	54.52	0.80	
	4.64	43.55	0.81	
INT. 681 Faro-Puente	3.79	58.41	0.88	0.87
	6.87	100.15	0.87	
	7.35	88.14	0.85	
Car. 681 I	2.00	44.59	0.91	0.89
	3.28	49.62	0.88	
	2.99	50.37	0.89	

Figure 4: An example of the NDVI averages at the different sampling sites.

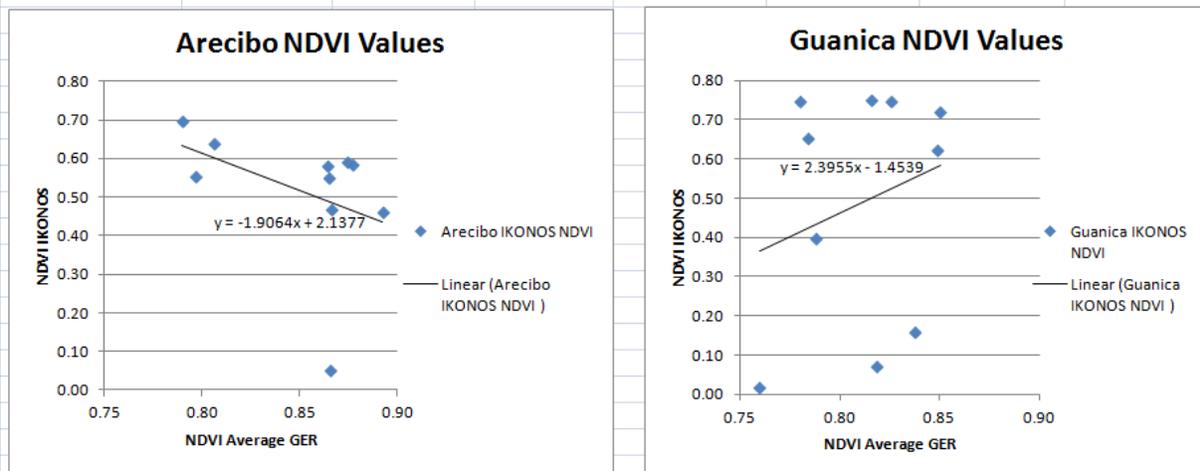| Arecibo	Arecibo GPS-GER	Arecibo IKONOS			Guanica	Guanica GPS-GER	Guanica IKONOS
Location	NDVI Average	NDVI			Location	NDVI Average	NDVI
Caño Tiburones 1	0.79	0.70			Aurora West 1	0.79	0.40
Caño Tiburones 2	0.88	0.58			Aurora West 2	0.76	0.02
Cano Tiburones 3	0.87	0.47			Aurora West 3	0.82	0.07
Caño Tiburones 4	0.87	0.59			Aurora Centro 1	0.83	0.75
Pescaderia	0.80	0.55			Aurora Centro 2	0.85	0.72
Nautico 1	0.86	0.58			Aurora Centro 3	0.78	0.65
Nautico 2	0.87	0.05			Aurora East 1	0.84	0.16
Nautico 3	0.81	0.64			Aurora East 2	0.82	0.75
INT. 681 Faro-Puente	0.87	0.55			Aurora East 3	0.78	0.75
Car. 681 I	0.89	0.46			Aurora North 1	0.85	0.62

Figure 5: This image shows the differences between calculated NDVI values of the hand samples and the values approached in IKONOS image. In the graphs can be seen that there is no pattern or relation between the two values calculated for each area.

6. References

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