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Title:
Developing a protocol to use remote sensing as a cost effective tool to monitor contamination of mangrove wetlands

Principle Investigators
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Undergraduate students employed:
Mr. Augustine Rodríguez-Román
Ms. Belyneth Deliz-López
Other undergraduate students involved
Ms. Almaris Martínez-Colón

Presentations:
"Usando Percepción remota como una herramienta para monitorear contaminación de mangles" Sociedad Horticultura del Oeste, San German, PR, 1 October 2006.

"Developing a protocol to use remote sensing as a cost effective tool to monitor contamination of mangrove wetlands" 2nd Annual Symposium for Coastal and Marine Research, UPR Sea Grant College program Mayagüez, PR, 5 October 2006.

"Can we use remote sensing to monitor contamination in mangrove wetlands?" Sociedad Geologica Estudantil, UPRM, Mayagüez, PR, 1 March 2007

Abstract published
2006: Schellekens, J.H., F. Gilbes-Santaella, A. Rodriguez-Roman, Yomayra Roman-Colon, Developing a protocol to use remote sensing as a cost effective tool to monitor contamination of mangrove wetlands: Abstracts of the 2nd Annual Symposium for Coastal and Marine Research, UPR Sea Grant College program October 5, 2006 Mayagüez, Puerto Rico, p. 9.

Unpublished reports:
Martinez-Colon, Almaris, 2006, Distribution of metals and leave reflectance in red mangrove (Rhyzophora mangle). Comparison between Joyuda and Guanica mangrove areas: Unpublished Undergraduate Research report Dept. of Geology, UPRM

Deliz-López, Belyneth and Rodríguez -Román, Augustine, 2006, Monitoring metal contamination of mangroves using remote sensing techniques: Guayanilla: Internal Research report Dept. of Geology, UPRM

Narrative:

In August 2006 we advertised two positions of undergraduate research assistants in the project. Four undergraduate students responded: 2 females and 2 males. We hired Ms. Belyneth Deliz and Mr. Augustine Roman. Both undergraduate students carried out leave reflectance measurements in the field and collected leave and sediment samples for chemical analysis. A third undergraduate student participated as part of her course GEOL 4055 Undergraduate Research II. The three students carried out chemical analyses in the Atomic Absorption Spectrometer (AAS) laboratory of Dr. Arturo Massol under the supervision of Ms. Elba Diaz.

In order to learn more about the movement of metals in the mangroves and the effect of these metals on the leave reflectance, a test was designed where the composition of the soils was compared to the composition and reflectance of leaves at three levels within the tree (lowest, middle and top level). In order to avoid difference due to mangrove species, only leaves of the red mangrove (*rhyzophora mangle*) were used for this test. This semester the leaves were analyzed for Cu, Co, Cd, Ni, and Pb. The AAS laboratory was equipped to do these analyses. The toxic metal As and Hg are planned for next semester after the special chemicals ordered have arrived.

Reflectance measurements were taken by cutting 5 leaves at each level (lowest, middle, and top) (figure 1). From each leave 10 reflectance measurements were taken (figure 2). Giving 5 x 10 x 3= 150 measurements per tree, in each area 3 trees were sampled, giving a total of 450 reflectance measurements per sample area. The leaves of the three levels were collected for chemical analysis. The sample areas selected for these tests were: Joyuda Lagoon (with natural Ni, Co contamination, and reported As contents), Guayanilla (possible industrial contamination, reported Hg), Guanica (probable pristine environment next to Tropical Dry forest reserve, with carbonate rocks and no substantial run-off).

Figure 1. Sampling of mangrove leaves using a pole-pruner

Figure 2. Measuring the reflectance of the leaves using the GER 1500 spectroradiometer.

Initial results

A number of analyses were carried out in the laboratory of Dr. Massol in the department of Geology with the help of Ms. Elba Diaz. Chemical results are listed in the tables 1 to 3.

Table 1. Summary chemical analyses substrates (Rodriguez, 2006) (all points are the average of four samples)

	Ni ppm	Cu ppm	Co ppm	Pb ppm	Cd ppm
Guayanilla	30	128	14	5	0
Guanica	4	70	1	11	0
Arecibo	15	72	5	15	0
Joyuda	141	63	11	5	0

Table 2. Chemical composition leaves of *Rhyzophora mangle* in the Guayanilla area (Rodriguez and Deliz, 2006)

	Cd ppm	Pb ppm	Cr ppm	Cu ppm	Ni ppm
GL1B	0	7	0	31	2
M	0	10	0	24	1
T	0	10	1	24	1
GL2B	0	14	8	29	1
M	0	12	2	25	1
T	0	7	2	27	0
GL3B	0	8	5	34	1
M	0	8	3	52	0
T	0	10	13	69	0

All analyses are the average of two analyses. B, M, and T refers to the level of the leaves in the tree: Bottom, Middle, and Top

Table 3. Chemical composition leaves of *Rhyzophora mangle* in the Joyuda area (Martinez, 2006)

	Cd ppm	Cu ppm	Ni ppm
JO1B	0	53	4
M	0	79	22
T	0	60	4
JO2B	0	65	12
M	0	19	6
T	0	100	4
JO3B	0	10	4
M	0	19	6
T	0	18	1

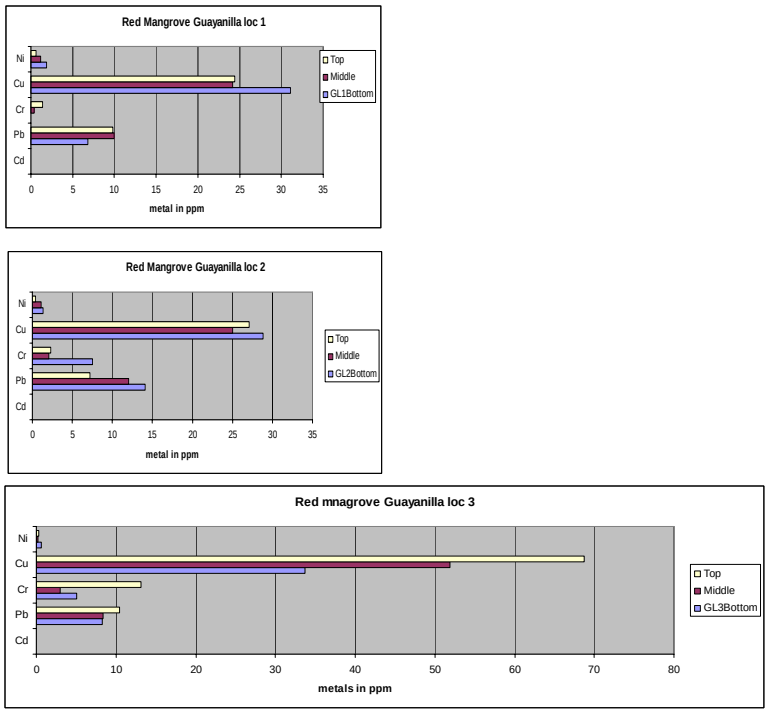

Figure 3. Chemical variation diagrams. Comparison of red mangroves (*Rhyzophora mangle*) of Guayanilla form three locations, separated in top, middle or lower leaves of the canopy.

Discussion of the chemical data

Table 1 shows the chemical analyses available for the substrate from previous undergraduate research projects. The sites were selected for their possible contamination: Joyuda (Acevedo et al, 2000), Guayanilla (Lopez and Teas, 1978), Arecibo or for their pristine nature, Guanica. If the Guanica area is indeed the non-contaminated site as was expected, the metal values may be base-line values for Puerto Rico. The Ni and Co are low as was expected, but the values for Cu (70 ppm) and Pb (11 ppm) are higher than expected. Cu may be always present in this amount, but the Pb is higher than in Guayanilla and Joyuda and may be a result of local pH conditions or contamination.

The high content of Ni and Co in the Joyuda Lagoon was expected next to the Guanajibo Ni-Co laterite deposit (Cram, 1972). The Arecibo area was selected because it formed part of the drainage basin of the porphyry copper deposits (Plaza-Toledo, 2005). Surprisingly the values for both Pb and Cu are comparable to the supposedly pristine Guanica area. Guayanilla, for which Hg contamination was reported (Lopez and Teas, 1978) shows a fairly high content in Ni and Co, also the Cu is twice as high as the other analyzed areas.

Leave analyses were carried out in order to determine the movement of metal in the trees. Did the metal move from the substrate into the plant and did the metal move to the top of

the canopy, where it satellite based detectors would be able to see influence of the metal on the chlorophyll production and hence on the reflectance pattern.
The most complete set of data at this moment are the chemical analyses of a red mangrove (*rhyzophora mangle*) in the Guayanilla Mangrove area. Cd and Ni are low and Cu and Pb show a considerable content. It is not clear yet how significant the difference between the lower, middle and top leaves is. Statistical analyses are planned to investigate this. The presence of Cu and Pb in the leaves probably reflects the presence of these metals in the substrate. Analyses for Hg and As will be carried out this semester. Chemical have been purchased to be able to do these analyses.

The data presented for Joyuda look suspect. The substrate contains considerable amounts of Ni and Co (Table 1). The Cu in the leaves may be a reflection of the Cu in the substrate, but previous analyses showed a high content of Ni, so there is a possibility of mix up of the analytical data. This possibility will be further investigated.

Reflectance measurements
The reflectance of the red mangrove leaves was measured using the GER 1500 radiospectrometer.

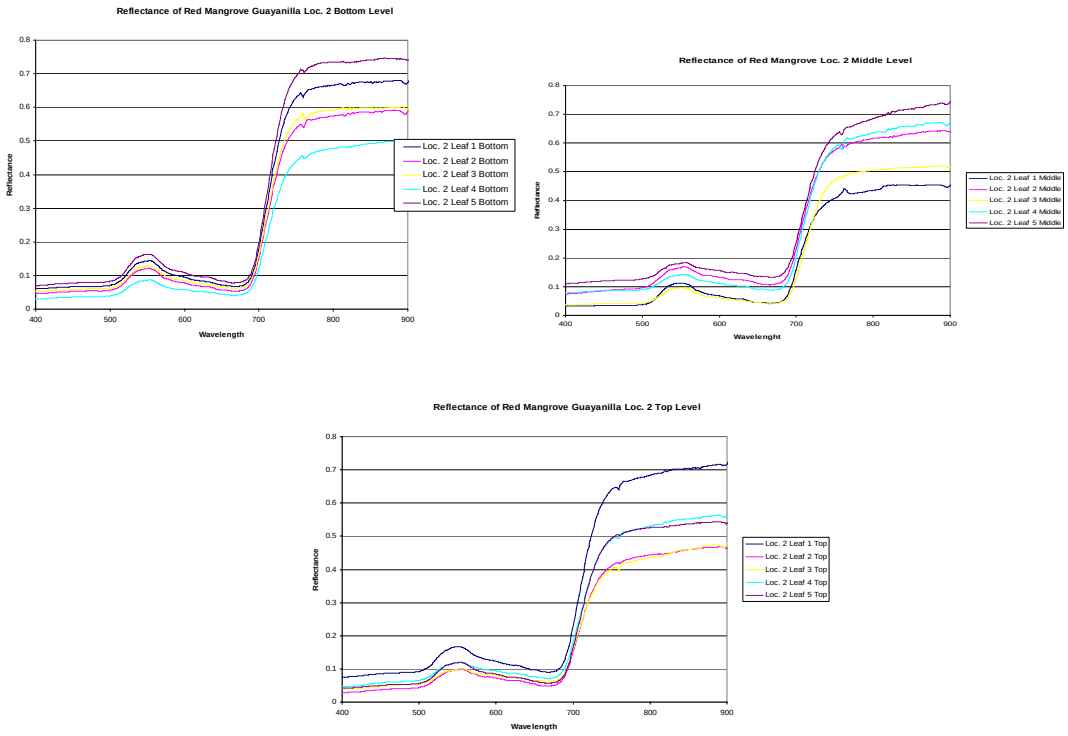

Figure 4 Reflectance patterns of Red mangrove (Rhyzophora mangle) of Guayanilla location 2. The three subfigures are the reflectance patterns of the lower, middle and top leaves of the tree.

Discussion of the reflectance patterns

An example of the reflectance patterns is given in figure 4. As is clear the variation between the reflectance patterns within one level of the tree is just as large as the variation between the different levels. Not all reflectance patterns collected have been corrected. In addition to a close look at the patterns to eliminate incorrect results, staitical analyses of the variation in patterns should be made. Metal content tends to affect chlorophyll production and as a result the location of the IR shoulder. This will be analyzed using the derivative of the curves

Future plans:

- A large amount of data is now available and the next step is to carry out quality control on the reflectance data. Many reflectance curves show anomalous values that will have to be checked and possibly eliminated.
- Statistical analysis of the reflectance patterns and the chemical data will be carried out in order to study the significance of the variation. The first derivative of the pattersn will be compared to the chemical composition in order to detect any correlation.
- Several areas will added to the study: Arecibo with possible Cu and Pb contamination, Ponce where DNRA reports contamination, Punta Verraco, where neighbors claim chemical test where carried out.
- Satellite images will be selected and purchased.
- Presently the project only employs undergraduate students. Graduate student will be recruited to continue and expand the research to fulfill the plans of the proposal.

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