A Comparative Analysis of Soil Characteristics in St. Croix's Waterways:

A Look at the Dirt in our Guts

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Introduction

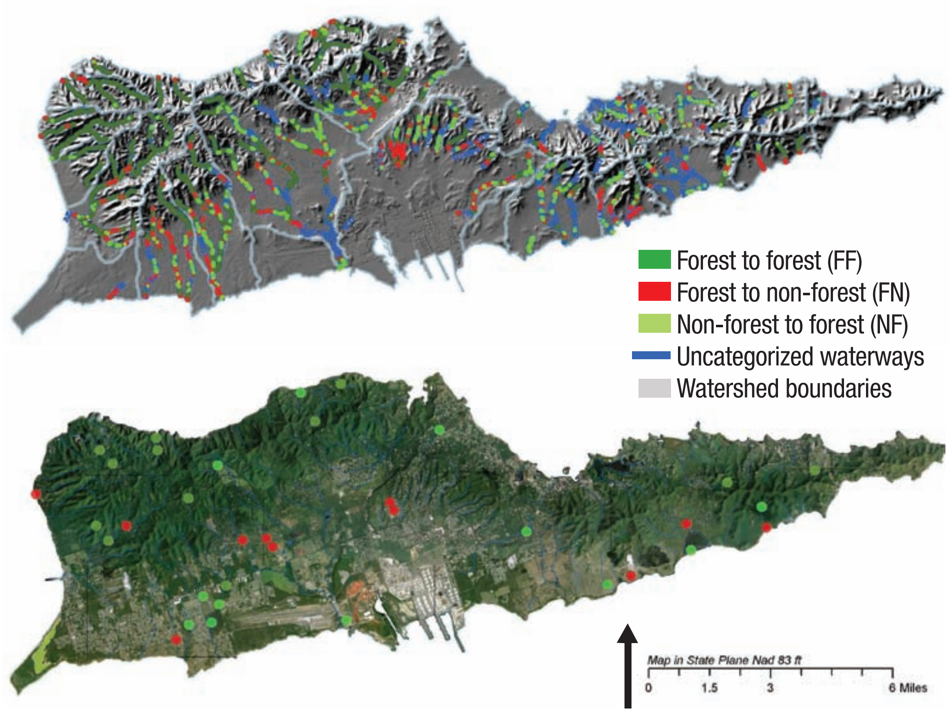
Waterways or guts channel rainwater downstream and connect marine terrestrial ecosystems. When forest is removed and bare soil is exposed, this often results in erosion. Guts with eroded or compacted soil have faster water flow and are less able to absorb rainfall and recharge ground water. When soil and other particles wash downstream, they are eventually deposited in coastal areas and can contaminate marine systems such as coral reefs. The purpose of this study is to examine the effect that human land-use and land-cover change has on the health of St. Croix's waterways.

A recent land-cover change analysis by the University of the Virgin Islands, Agricultural Experiment Station (UVI-AES) found that one half of St. Croix is still forested and that 15% of the island's surface experienced significant change during the 10-year study period (Technical Bulletin #13). This represents a relatively high percentage of change and is an important ecological measure because environmental damage often occurs during land-cover change. This research project compares forested sites with changing sites in order to determine if there is a difference in soil quality, which is a strong indicator of overall stream health. Comparing soil samples from guts in three land cover types (Forested, Deforested and Reforested) provides quantitative and descriptive differences between them. We hypothesize that; stable forests have healthier waterways while deforested and recently reforested sites will have degraded soil conditions.

Site Selection Methods

The primary tool for this project was a comprehensive Geographic Information System (GIS) containing multiple spatial data layers and field measurements. The research team consisted of AES staff and student employees, who were trained and certified to use the GIS software, ArcMap 9.2 and GPS (Global Positioning System) units by the firm, Geographic Consulting. The GIS was used to organize the entire project with a single system and accurately manage multiple data types.

Figure 1. Above, St. Croix's waterways are categorized based on an AES land-cover study. Below are the 30 soil sampling points.



The base layer for this project is the land-cover change map from the previous AES project (Technical Bulletin #13). In that study, satellite images of St. Croix from 1992 and 2002 were categorized as Forest (F) and Non-forest (N) and then compared. A map was created identifying areas of reforestation (NF), deforestation (FN) and stable forest (FF) which we used as a selection tool when choosing sample sites (Table 1). A USGS (United States Geological Survey) layer showing waterways was overlaid on the categorized map and a 15 foot buffer was created on each side. The area within the buffered guts was categorized or classified based on the surrounding land-cover type (Figure 1). We created 30 random points within the buffered gut areas, ten in each of the three land-cover types. The points were uploaded into GPS units and the field team navigated to each of them to collect soil samples.

Soil Sampling Method

St. Croix's waterways are ephemeral; containing water only during rain events, so sampling water is logistically difficult. Soil samples are considered a proxy for water quality and also provide additional information on the waterways' structure. Samples were collected using the "Soil Quality Test Kit" created by the USDA, Agriculture Research Service, Soil Quality Institute (Figure 2). Observations on land management, erosion, forest structure and tree species diversity were recorded as appropriate. Slope, water infiltration and soil temperature were measured in the field (Figure 3). Soil samples from each site were lab tested for soil moisture, bulk density, elec-

Table 1. Land-cover types and their descriptions

Land-Cover Change Type	Description
Stable Forest (FF)	Forests >15 yrs old. These are frequently comprised of multiple canopies, relatively high level of diversity and contain native species.
Deforestation (FN)	Classified as having no forest cover in 2002.
Reforestation (NF)	Sites that re-grew forest between 1992 and 2002. These forests tend to be young, with single-layer canopies under 15 ft tall, have relatively low species diversity and are dominated by invasive species such as tan-tan.

Figure 2. USDA Soil Quality Test Kit used to collect and analyze soil samples.

Table 2. A description of the eight measurement collected, their importance and the results by land-cover change type. Values followed by different letters with the row are significantly different (* P<0.1, ***P<.001)

Measurement	Description	Interpretation	Average values by land-cover change type		
			Stable Forest (FF)	Reforestation (FN)	Deforestation (NF)
Bank slope *	Percentage of the stream bank slope.	High values indicate channelization.	27.0% a	21.0% a	10.9% b
Hill slope *	Percentage of the slope of the stream bed.	High numbers indicate streams on steep hills and low numbers represent flatter land.	4.0% a	1.0% b	2.0% ab
Infiltration rate ***	The time it takes for a fixed volume of water in a tube to be absorbed by the soil (cm3/hr.).	High numbers mean more water is absorbed. This implies the soil has large particle size, such as in sand or organic material.	597.4 a	462.0 b	271.0 bc
Relative temperature	The difference between the full-sun measurement and a site temperature taken at the same time of the day (^{0} F)	A 0^0 value signifies the same temperature as full-sun, while negative numbers are cooler than full-sun.	-10.25 a	-9.36 a	-8.32 a
Soil moisture	Measures the weight difference for samples before and after they are oven-dried (g/g).	High values can mean high organic material content, but is highly influenced by rain/drought.	0.160 a	0.189 a	0.167 a
Bulk density	The ratio of dried soil mass to bulk volume (g/cm3). Sand and loam will have higher numbers than clay.	This can be used as a measure of soil compaction that can inhibit root growth. Several factors influence this test, but	1.181 a	1.061 a	2.486 a
Electro-conductivity *	Indicates the amount of salts in the sample. All soils have some salt, but high amounts can impede plant growth.	higher values are expected near farms with excess run-off, coastal areas, and very dry sites.	0.375 a	1.219 ab	2.486 b
pH *	The measure of acidity or alkalinity of a soil sample.	In the Virgin Islands, higher numbers may indicate loss of top soil and exposure to alkaline parent material.	7.49 a	8.21 b	7.66 a

tro-conductivity, and pH. Descriptions of the variables and their significance appear in Table 2. There were ten sample sites in each of three land cover categories. Three samples were collected at each site (from the center, left and right bank) for a total of 90 samples from 30 sites.

Results and Discussion

The results support our original hypothesis that soil in forested sites would have superior characteristics to soil in change areas. Forested guts have a higher average slope and their banks are significantly steeper than deforested sites (Table 2). Although steep slopes are more prone to erosion, we observed less erosion in the forested sites. Water infiltration rate is influenced by several factors such as soil particle size and soil organic material, but water infiltrated soil in stable forest sites significantly faster than in deforested and reforested sites. Average soil moisture did not differ between sites, with most sites registering on the lowest end of the range. We attribute this to the prolonged dry-period prior to sampling and not to an accurate measure of soil organic matter.

Average pH values in deforested sites were significantly higher than in other sites. This is likely due to erosion of pH neutral topsoil leading to exposure of the alkaline sub soil. There was also a trend of soil from forested sites having lower values for, electro-conductivity, temperature, and bulk density. These results are a trend only and did not meet the criteria for statistical significance. Electro-conductivity measurements for forested and reforested fell within the healthy range while deforested sites registered levels that begin to impede plant growth. Average relative soil temperatures were lowest for forested sites, but the results were not significant. This is somewhat surprising as we expected this simple and direct measure to provide strongly significant results. It is possible that increased sampling density could more clearly reveal the trend.

It is important to note that several factors may have contributed to confounding these results. Primary among these is that St. Croix's landscape is highly fragmented and the course of a gut passes through alternating forested and deforested sections. The conditions at the 30 data collection sites ranged from intact, native forest with deep organic soil, to exposed, treeless sites where the gut banks showed clear evidence of being previously leveled by a bull-dozer. The original classification of forested, deforested and reforested was completed in 2005. The 10 forested sites were still forested and the appearance and species composition indicated they were stable sites. Conversely, four of the reforested sites had recently been cleared and four sites classified as deforested had young patches of secondary forest establishing. These findings likely emphasize the variable and dynamic nature of land-cover change sites.

Figure 3. AES research team members collect soil samples. This site containing young trees was categorized as reforested (NF).

Conclusion

We conclude that land-cover change in St. Croix is directly linked to the degradation of ephemeral waterways or guts. Degradation can be measured by decreased water infiltration rates and increased pH, bulk density and electro-conductivity. This is a preliminary study and the relatively small number of samples contributed to high variability and inconclusive results for some variables. Sampling on a larger scale may verify the prediction that forest removal also leads to increased soil temperature, for example. To prevent damage to the island's waterways, we support the Virgin Islands law (Title 12, Chapter 3 section 123) prohibiting cutting of any trees within 25 feet of the edge of a watercourse. Enforcement of this code would simultaneously protect forests, fresh water, soil, and coastal marine systems.

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