Report as of FY2007 for 2006VI67B: "Impervious Surface Analysis of Terrestrial Watersheds of the U.S. Virgin Islands with Application to the East End Marine Park, St. Croix "

Publications

- unclassified:
  - None as yet.

Report Follows

Problem and Research Objectives

In the U.S. Virgin Islands, housing, roads, and commercial and industrial development are increasingly replacing natural terrestrial environments such as grasslands and forests. Increased sediment loading and nutrient enrichment from development activities in upland watersheds often results in degradation of inshore marine communities, particularly coral reefs and seagrass beds, which require clear water and high light levels to persist. Rogers (1990) has suggested that the primary cause of coral reef degradation in coastal areas of the U.S. Virgin Islands is development activities, especially land disturbances and dredging.

The natural landscape typically is made up of pervious surfaces - areas vegetated with trees, shrubs, and grasses - which under normal conditions allow precipitation to infiltrate the soil. One of the principal effects of development and urbanization is the conversion of pervious surfaces into impervious surfaces - man-made surfaces that inhibit the infiltration of water into the soil. This is complicated on the US Virgin Islands by the diversion of rainwater from roofs into private cisterns which limits run-off.

Research over the past two decades has indicated that increased quantities of impervious surfaces are closely associated with environmental degradation, specifically that the quantity of impervious surfaces in a watershed is inversely correlated with the health of that watershed and the health of waterbodies, such as coastal environments, that receive discharges from that watershed (Center for Watershed Protection, 2003). On St. John, for instance, MacDonald *et al*. (1997) demonstrated that unpaved roads may contribute the majority of sediment to marine ecosystems.

The goal of the proposed study is to use impervious surface analysis as a methodology for effectively monitoring and managing water quality and habitat health of a watershed and to apply this as a case study to one or more of the watersheds on St. John where non-point source pollution from incompatible upland development has been identified as a major threat. To attain this goal, it will be necessary to accurately map terrestrial impervious surfaces at a watershed scale. The objectives of the proposed study will be to:

1. Establish land-use categories and evaluate infiltration coefficients that are consistent with the U.S. Virgin Islands landscape and currently used land-use categories;

2. Establish baseline and current impervious surface cover datasets within one or more terrestrial watersheds on St. John using remote sensing;

3. Execute a change analysis of impervious surfaces using remote sensing information and classification mapping;

4. Document a protocol for monitoring changes of impervious surfaces, based on one or more of the terrestrial watersheds on St. John, to enable land managers to assess land-use changes and focus on different landscape levels for protection and/or restoration;

5. Provide an educational brochure for minimizing impacts due to impervious surfaces which could be disseminated to private landowners and other members of the community through the Cooperative Extension Services of the University of the Virgin Islands.

Principal Accomplishments and Results to Date

Impervious surface land cover in the US Virgin Islands can be linked to five currently-used land-use categories that are consistent with the National Oceanic and Atmospheric Administration's (NOAA) Coastal Change Analysis Program (C-CAP). These categories and their corresponding land use in the Virgin Islands are shown in Table 1.

Table 1. NOAA C-CAP land-use categories and corresponding land use in the Virgin Islands and the Coral Bay watershed, St. John

NOAA C-CAP Classification Category	**Land Use U.S. Virgin Islands**	**Land Use Coral Bay Watershed, St. John**[1]
Developed Land – High intensity	Commercial, paved roads, paved parking	Paved roads
Developed Land – Low intensity	Residential, paved driveways	Residential (including house roofs which catch water), paved driveways
Cultivated Land	Cropland	N.A.[2, 3]
Grassland	Parks, golf courses, lawns	Lawns, parks, playgrounds [3]
Bare Land	Unpaved roads and driveways	Bare rock, unpaved roads and driveways, cleared land[3]

[1] Identified from remote sensing images

[2] Not applicable

[3] In the Coral Bay watershed the thin, bare soil is volcanic in origin and has a fast runoff potential due to steep slopes. Agriculture is insignificant, and lawns are infrequent due to water scarcity.

Surfaces determined to be impervious are often located in areas of mixed land use that support combined impervious and pervious cover, and as a consequence percent of imperviousness, also known as the infiltration coefficient, can be overestimated. Construction sites, for example, are often reported as having an imperviousness of 100% when studies have indicated that imperviousness may be more in the order of 50-70% (Dougherty et al., 2004). Imperviousness varies depending on a number of variables, including slope, soil moisture (more impervious when the ground is saturated), soil type and local or regional land-use practices, such as the inclusion of open space within urban residential and commercial sites and the collection of rainwater in cisterns in the USVI. Some ranges of imperviousness reported for major land-use categories outside the USVI are: major paved roads, 50-100%; paved parking, 100%; unpaved parking, 90%, construction sites/disturbed land, 50-70%; commercial/industrial land, 35-85%; high density residential, 35-65%; medium density residential, 20-38%; low density residential, 5-20%; urban open land, 3%; agricultural land/golf course, 2-7%; forested land, 0-7%; bare ground, 14%; surface rock/fractured rock, 2-7%; embedded rock, 67% (Dougherty et al., 2004; Center for Watershed Protection, 1998; Li et al., 2004). On St. John, unpaved roads is an important land-use category, and Ramos-Scharron and MacDonald (2005) have reported that erosion (which for this study can be broadly equated with imperviousness) is greatest in graded roads, 42% less in ungraded roads and 10% of ungraded roads in abandoned roads. Although modeling as undertaken by Ramos-Scharron and MacDonald is not part of the present study to determine imperviousness, values of land-use cover imperviousness on St. John will be established by refining reported values through on-site observations during ground-truthing.

In order to develop our methodology for this study, the study data components and the principal impervious surface categories were assessed in ERDAS Imagine 8.7. The initial data components consisted of:

- Cloud free IKONOS satellite imagery from late 2005 and early 2006 courtesy of NOAA;
- Overlays of watershed boundaries, shoreline, and roads;
- High resolution aerial photographs from 1994 (1 ft), courtesy of the US Army Corps of Engineers (USACE) and September 2004, courtesy of the Natural Resources Conservation Service (NRCS) and the USACE.

Both remote sensing imagery sets were found to have advantages and disadvantages. The aerial photography imagery from September 2004 was our initial target imagery as it was both high quality and high resolution. Because it is generally limited to three color bands, or may only have one band (black and white), aerial photography imagery is very restricted in the digital image processing that can be used. For instance, unless the color bands include a near infra-red band, the generation of standardized vegetation indices, such as discussed below, is not possible. The color bands available from the NRCS/USACE 2004 aerial photography were the traditional red, green and blue bands.

The other major disadvantage of aerial photographic imagery is that it is expensive and generally commissioned at infrequent intervals. Aerial photography in the USVI generally is commissioned by federal agencies, such as the USACE, and is dependent on departmental budgets of the USACE as well as collaborating agencies such as the NRCS. This makes it difficult to predict future availability of imagery sets for comparative purposes.

IKONOS satellite imagery from late 2005 and early 2006, purchased by NOAA, became available during the project. One advantage of the satellite imagery is that equivalent imagery should be available in the future allowing comparisons to be made between data sets. The future cost of these data sets is unknown, but they will be substantially less than commissioned aerial photography, and it is quite possible, as with the 2005-2006 IKONOS imagery used in this study, that they may be available at no cost.

Additionally, IKONOS satellite imagery produces four bands (red, green, blue, near-IR, 4 meter resolution) as well as a panchromatic (1 meter resolution). As noted above, sufficient bands allow digital imaging techniques to be utilized. The use of the near-IR band in the IKONOS data allows Normalized Difference Vegetation Index (NVDI) to be readily calculated. Forested / vegetated areas on St John should be discriminated through the use of the NDVI (NDVI = near IR band - red band) / (near IR band + red band), however a sharp distinction was not found, possibly because the vegetation seems to reflect a high amount of light in the intense tropical sunlight.

Further analysis of the IKONOS image showed that impervious surfaces are bright and vegetation is dark. The blue band of IKONOS provided the cleanest distinction between vegetation and impervious surfaces. The IKONOS pan reinforced the blue band but had much more variation due to its panchromatic spectral responsivity.

Techniques to separate paved roads from unpaved roads were also evaluated. While the discrimination between tarmac roads and other types of roads appears to be relatively easily done, discrimination amongst concrete roads, other man-made surfaces and rock outcrops, based on their spectral signatures, has not been accomplished. Further work on refining the spectral signatures will be necessary to achieve this.

A brochure to educate homeowners on simple actions that can be taken to minimize the effects of impervious surfaces has been drafted. Information provided in the brochure includes a simple explanation of what impervious surfaces are and the effects these have on the environment. The brochure briefly describes the project and highlights the main actions that homeowners can take to minimize the impacts from impervious surfaces.