Virgin Islands Water Resources Research Institute
Annual Technical Report
FY 2013

Introduction

The United States Virgin Islands (USVI) is a Territory of the United States of America and consists of a group of several islands and cays located in the Lesser Antilles which separate the Atlantic Ocean and the Caribbean Sea. The USVI is about 1,200 miles southeast of Miami, Florida and 80 miles east of Puerto Rico. The principal islands in the USVI are St. Croix, St. Thomas, St. John and Water Island. Several of the other smaller islands in recent years have undergone various stages of development. In total, the islands have a combined area of approximately 137 square miles. They are of volcanic origin and are mountainous. Tourism is the principal source of support for the economy.

With an annual rainfall of just over 40 inches, the USVI is one of the few places in the world where rain water harvesting is required by law. Buildings are constructed with cisterns that are sized and managed to provide a reliable and relatively safe water supply for users. Because of the hilly terrain, there are virtually no natural surface water supplies. Ground water is limited due to the geology and the risk of salt-water intrusion that could occur from coastal wells. Increasing potable water demands are met largely through use of desalination plants that provide water to the public water distribution systems. The islands experience challenges in collecting and disposing wastewater and water conservation and increasing efficiency in water-use are critical components of effective water resources management in the USVI.

The Virgin Islands Water Resources Research Institute (VI WRRI) is hosted by the University of the Virgin Islands (UVI). UVI is the Territory’s only institution of higher education and has campuses on the islands of St. Croix and St. Thomas and a research station and a learning center on St. John. It is a Historically Black College or University (HBCU) and has just completed celebrating its Golden Jubilee (50 year anniversary) and its 40th year as a land-grant institution. Though UVI is primarily an undergraduate institution, it offers graduate programs in teacher education, business administration, public administration, marine science and mathematics for secondary education teachers. The University’s demographics reflect the local population in that it consists of a diversified mix of USVI residents and persons from the Caribbean region, the United States’ mainland and other areas of the world.

The VI WRRI maximizes all resources available to it to serve the water resources research, information dissemination and training needs of the people of the U. S. Virgin Islands that might otherwise not be a priority in other settings. It works collaboratively with other units at UVI, with researchers in the U. S. Geological Survey’s Islands Region and others to address particularly, though not exclusively, those issues that might be peculiar to tropical insular regions. Areas of focus in the past have included quantity and quality issues of water harvesting, development of alternative on-site sewage disposal systems and non-point source pollution in island environments. This year’s program investigated human dimensions considerations in water quality degradation, plant nutrient management in aquaponic systems, anthropogenic impacts on mangrove lagoon systems and precipitation patterns and erosion indicators in local microclimates. Reports on these and some other activities of the VI-WRRI are summarized in this report.

Research Program Introduction

The Virgin Islands Water Resources Research Institute at the University of the Virgin Islands supported nine research projects with funding provided by the U. S. Geological Survey, during the period March 1, 2013 to February 28, 2014. Five of these were continuing activities from projects started during previous reporting periods.

All of the projects addressed water resources issues of current concern in the U. S. Virgin Islands and have relevance to other similarly situated tropical insular areas. Four of the projects focused primarily on water quality issues, three addressed agricultural questions and the remaining two projects dealt with water supply.

Research opportunities were provided for students in all of these projects to the greatest extent possible and public presentation of research findings was strongly encouraged. Project completion reports for all projects will be available from the Virgin islands Water Resources Research Institute's website.

Summaries of these research projects follow.

Evaluating Drought Tolerance of Virgin Islands Native Trees Suitable for Landscaping

Basic Information

Title:	Evaluating Drought Tolerance of Virgin Islands Native Trees Suitable for Landscaping
Project Number:	2011VI184B
Start Date:	3/1/2011
End Date:	5/30/2013
Funding Source:	104B
Congressional District:	VI
Research Category:	Not Applicable
Focus Category:	Drought, Conservation, Water Quantity
Descriptors:	
Principal Investigators:	Michael Morgan, Thomas W. Zimmerman

Publications

1. Cuffy, K., M. Morgan, T.W.Zimmerman, (2013) Evaluation of Drought Tolerance in 3 Native Tree Species with Landscape Potential, a Biometric Approach. Poster Presented at UVI Student Science Symposium (March 23, 2013).
2. Morgan, M., K. Cuffy, and T.W. Zimmerman. (2013) Evaluation of Drought Tolerance in 4 Native Tree Species Suitable for Landscaping: A Soil Water& Biometric Approach. Poster presented at UVI Research Day (April 6, 2013).

EVALUATION OF DROUGHT TOLERANCE IN SEVEN NATIVE TREE SPECIES WITH LANDSCAPE POTENTIAL: A BIOMETRIC AND SOIL-WATER RELATIONS APPROACH

Problem and Research Objectives

New urban and residential developments require landscape planting. Research in the Biotechnology and Agroforestry Program at the University of the Virgin Islands Agriculture Experiment Station (UVI-AES) supports the preservation of native flora through investigations into the propagation of native plant species. One of the program's goals is to provide research supporting local plant nurseries growing native plants for their use in landscaping around homes and businesses. The demand for ornamental plants is rising as the islands of St. Croix, St. Thomas, and St. John become more urbanized. Plant nurseries are a growing segment of the local economy. Programs that promote using native, ornamental plants within their native range have recently become successful in several states and a similar approach in the US Virgin Islands is strongly advocated by the US Forest Service (Overton, et al., 2006).

Fresh water is limited on the island of St. Croix. Rainfall is seasonal. There are no perennial streams or lakes to provide fresh water. Fresh water can be obtained by collecting rainwater in cisterns for later use, from wells that tap the subterranean aquifer, or buying it from the Virgin Islands Water and Power Authority. Fresh water provided by the Virgin Islands Water and Power Authority is expensive because it comes from a desalination plant.

Plant nurseries, particularly, those specializing in showy "tropical" plants such as species in the *Heliconaceae*, *Musaceae*, and *Zingiberaceae* families, need abundant water. They cannot depend on rainfall alone in the US Virgin Islands. During the dry season, access to well, municipal water or a pond is necessary to keep these plants alive. In order to remain profitable and stay in business, plant nurseries need to produce plants at a price people are willing to pay, while generating sufficient demand for landscaping plants. Two ways to reduce costs are to closely monitor water use and to grow native plants that are adapted to the dry environment of the U.S. Virgin Islands.

According to the American Nursery Growers Association, the minimum size of a tree for planting in a landscape setting is 4 to 5 feet or (120 to 150 cm) and 0.5inches or 12.5 mm diameter 6 inches above the root collar for land scape planting. We wanted to determine how much water is needed to produce a saleable tree. We also wanted to determine how much biomass was allocated between leaves, stems and roots for the different species, and under different treatments.

Methodology

We grew four native tree species, *Andira inermis, Bucera bucida, Jacquinia arborea*, and *Pimenta racemosa*, in 11.4 L pots filled with a substrate of 50% Promix, 25% top soil, and 25% sand. There were 18 trees per specie, and each tree was assigned a treatment: 1L, 2L or 3.8 L of water per week. The pots and plants receiving 3.8L of water kept soil at field capacity or close to it. Field capacity is the ability of a soil to hold water. We calculated field capacity subtracting the dry weight of a pot before watering and then the wet weight of the pot, after excess water has drained out. Each week, height and stem diameter was measured and recorded. As per the guidelines for land scape planting, stem diameters were measured at 6" above the root collar. At the end of the experiment, 9 plants of each species were harvested, dried, separated into its components and weighed. The data was statistically analyzed using JMP. Graphs were generated in Excel. The statistics of interest were: mean, ANOVA, and Comparison of Means. Kalunda Cuffy, a second year undergraduate in the computer science program helped with plant care, data collection and entry, along with making graphics.

Principal Findings and Significance

The project will be completed by May 31st, 2013.Research is continuing on White Cedar *(Tabebuia heterophylla),* Wild Frangipani (*Plumeria alba*), and Lignumvitae (*Guaiacum officinale*). The last collection of data for these species is Friday, May 3rd, 2013. The soil water relationship data is still being analyzed.

The minimum size of a nursery grown tree according to the American Nursery Growers Association is 4 to 5 feet or (120 to 150 cm) and 0.5inches or 12.5 mm diameter 6 inches above the root collar for land scape planting. Over 7 months, the *A. inermis* saplings treated with 3.8 L of water per week reached saleable height and diameter, none of the other tree species did so.

As far as total biomass production is concerned, *A. inermis* and *B. bucera* could be grouped together in one group, with *J. arborea* and *P. racemosa* in another group ($P \leq 0.03$). Only in the case of *A. inermis* was there a significant difference in biomass production depending on how much water the plants received (P=.0002). Total Biomass for the other species was not significant between treatments.

All four species have different growth responses to water stress or its abundance. Root shoot ratios are a good way to compare plants of different habits, species or size. *A. inermis* trees grow along stream sides and in other moist places. *J. arborea* grows along seaside cliffs whereas the other species grow on intermediate sites. The *A. inermis* trees which received 2L and 3.8L per week had root to shoot ratios of 0.5. The *A. inermis* trees which received 1L of water a week reacted to water stress by dedicating more of its biomass to roots with a root to shoot ratio of 0.8 (P=.07). Surprisingly, all the *J. arborea* saplings under all treatments had a root to shoot ratio of 0.4 or 0.5. It appears that a high root to shoot ratio is not one of J. *arborea*'s adaptions to droughty conditions. It dedicates half of its biomass to leathery leaves. *P. racemosa* has a slightly higher root to shoot ratios (0.7, 0.6., 0.6) than *J. arborea* under all treatment or *A. inermis* at 2L or 3.8L. *P. racemosa* splits its biomass evenly amongst leaves and roots, with lesser amounts for the stem. It appears to balance transpiration from the leaves with water uptake from the roots. *B. bucida* dedicates over 50% of its biomass its trunk and branches. In fact, it has many small, fine branches which are better to support lots of leaves.

We found that the amount of water absorbed by the soil and roots generally stayed the same week to week. There were, however, species and treatment differences. Differences amongst species at the 1L were not significant. It was significant, at the 2L level, (P=0.03) and the 3.8L (P=0.001). *A. inermis* absorbed the most water, and *P. racemosa, B. bucera* and *J. arborea* lesser but about the same amount of water (P. = 0.03). With trees receiving 3.8L/wk. of water species differences are more pronounced: *A. inermis >B. bucera>P. racemosa* and *J. arborea.*

Plant nursery managers want to grow trees to saleable sizes with the least amount of water. If one was to rank the trees by the water needed for growth the order would be: *B. bucera*, *A. inermis*, and *P. racemosa* and *J. arborea*. All four species tolerated low levels of watering; none of the trees shed their leaves due to water stress. However, the *B. bucera* trees were all wilted at the end of the week, and only put on additional height growth when it received 3.8L of water a week, which is surprising because the tree is often found on droughty sites such in sands on the edge of the beach. Once they received water, the leaves quickly regained turgor. Perhaps, watering twice a week with only 2L would prevent wilting and permit growth.

The *A. inermis* trees grew the fastest with 3.8L of water but continued to increase in height if they only received 2L of water a week. Therefore 3.8L a week would be needed to get the trees quickest to optimal selling size, but they can continue growth at 2L/week. If the trees were not being produced for a contract, and were just waiting for a buyer, watering the trees with 2L a week would save water and allow the trees to remain a longer time in the nursery. *Pimenta racemosa* grows best with 2L a week; 3.8 L seems to retard growth and health, particularly at early stages of plant growth. *J. arborea* grows at the same rate whether 3.8 L or 2L of water is applied during the week, so it is best to conserve water and apply 2L a week.

Conclusions

All four tree species tolerate low levels of irrigation. None of the trees lost their leaves during the course of the experiment, although there were differences in growth and biomass allocation. Irrigation in this case was performed by a hose and a bucket in the green house, but by extension could be considered as substitute for rainfall, if the trees were planted outside.

This study has implications for tree nursery managers. Ideally, they want to produce trees ready for landscape planting in the least amount of time possible with the least amount of water.

It would be worthwhile to continue this study with other tree species, and with the same species transferred into bigger pots. What was learned here can be improved and built upon. For example, increasing the sample size slightly will hopefully increase the significance of the results. With the experiences gained from the study, the techniques employed can be further refined.

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IDENTIFICATION OF WATERBORNE CONTAMINANTS ENTERING THE ST. THOMAS EAST END RESERVE

Basic Information

Title:	IDENTIFICATION OF WATERBORNE CONTAMINANTS ENTERING THE ST. THOMAS EAST END RESERVE
Project Number:	2011VI202B
Start Date:	3/1/2011
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	n/a
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Water Quality, Toxic Substances
Descriptors:	
Principal Investigators:	John F Barimo, Stanley L. Latesky

Publications

There are no publications.

IDENTIFICATION OF WATERBORNE CONTAMINANTS ENTERING THE ST. THOMAS EAST END RESERVE

Problem and Research Objectives

The St. Thomas East End Reserve (STEER) was established as a Marine Protected Area (MPA) to safeguard near-shore seagrass, mangrove and coral reef resources. It is also designated as 1 of 6 Territorial Areas of Particular Concern due to the MPA's proximity to the Bovoni landfill and the island's largest watershed. Anthropogenic disturbance and watershed transport of contaminants and sediments in near-shore coastal waters have been attributed to the degradation of tropical marine ecosystems as well as those within the U.S. Virgin Islands. Approximately one third of the island's population lives within this watershed which is the largest and most heavily developed watershed on St. Thomas which has been exacerbated by a 5-fold increase in the territorial population over the past 50 years.

The water and sediment samples will be analysed by state-of-the-art analytical equipment following standardized EPA methodology. Hydrocarbons, including PAHs, will be analysed using a gas chromatograph equipped with a Mass Spectrometer detector (GC/MS). Trace heavy metals will be analysed by Inductively Coupled Plasma Spectrometer equipped with a Mass Spectrometer Detector (ICP/MS). This study will also serve as training in analytical chemistry and Phase I of a graduate thesis for an enrolled student who also plans to also look at uptake of contaminants by lagoon biota; however, the later phase II is not part of this proposal. The graduate student will also act as a direct supervisor for undergraduate student workers who will also be directed by project PI's.

Data will be analysed using conventional statistical methods and identified compounds will be compared to reference sources such as commercial gasoline, dry cleaning fluids and pesticides. Metals detected will be compared to freshly sampled dust samples of African dust and if possible, ash from volcanic activity in the region. Variability due to seasonal factors will be considered as well.

Collection and operation of the analytical instruments will be used as a training tool for UVI students and they are expected to do most of the hands on work with sample collection and analysis, and will be involved with the STEER Core Planning Team regarding the selection of precise sampling locations.

Methodology

Stock solutions of standards for anions and cations were obtained from Metrohm and Inorganic Ventures respectively. The 10,000 ppb inorganic stock solution from Inorganic Ventures contained each of the cations measured in the study. Separate 1000 ppm stock solutions of each anion were used to prepare stock solutions of each concentration for anion analysis. Compressed gases (Ar, He, H_2) were supplied by Island Gas as ultra-high purity grade. Ultimal grade acids and bases (Fisher Scientific) were used for all acid or base matrix preparations. Reagent grade (18.2 MD) water was prepared using a Barnstead Diamond deionization equipped with a UV lamp to remove Total Organic Carbon from the water. Feedwater for the deionizer was supplied by a Barnstead RO water system with raw water supplied by the UVI water system. Data analyses were conducted using a point calibration curve based on the standards shown below (blank, 10 ppb, 100 ppb, 1, 5, 10, 15, and 20, and 100 ppm).

Cation analyses were conducted using one of two different methods. The first method involved the use of a Varian 820-MS ICP-MS equipped with a Varian SPS-3 autosampler and a collision reaction interface. Samples were nebulized directly into the Ar plasma torch, and the metals were analysed simultaneously over the full mass range of the instrument. The second method involved the use of a Metrohm Electrochemical analyser equipped with a rotating C electrode, a glassy C auxiliary electrode, and a Ag/AgCl reference electrode. Metal ions were analysed over the range of 10 ppb to 100 ppm simultaneously. Water samples were collected and stored in clean acid-washed plastic bottles. All glassware and plasticware were washed with 2% nitric acid in water and then rinsed with 18.2 MD ultrapure water (Barnstead Diamond RO system feeding into a Barnstead Diamond Deionizer). For both methods, triplicate runs were done for each sample. The triplicate data were averaged and data was fit to a standard curve for each element analyzed. A set of standards were prepared by serial dilution of the commercially obtained stock solution. Interferences in some cations (e.g. As) were minimized by using the Collision Reaction Interface (CRI), using ultra-high purity hydrogen gas.

In order to remove any organic materials, water samples for inorganic analysis were digested using a CEM MARS microwave digestion system. A 5.0 mL aliquot of water was placed in the Teflon digestion vessel, 5.0 mL of Ultima grade nitric acid was then added, the vessel was sealed, and then placed in the oven. Six samples were digested simultaneously using the following method: 20 minutes pre-heating to 473 K, held at 473 K for twenty minutes, and allowed to cool for an hour. Each of the samples were clear with some suspended solids, which were filtered using a 0.2 mm syringe filter.

Results

A total of twenty-five water samples were analyzed. These samples ranged from a series of Guts or from standing water. In all cases samples were collected from multiple points within the sampling area and if possible, from multiple depths. The samples analysed represented a cross-section of locations feeding into STEER on the east end of St. In all cases, standard curves met the criteria of a correlation of greater than 0.999 (The full analytical report is available, including standard curves, from the authors (pdf format, > 50 pages). In the metal ion cases where both ICPMS and electrochemical analysis could be used, data using either ICPMS or electrochemical analysis (stripping polarography) compared closely with each other.

The data demonstrated that in the majority of the samples, very small amounts (sub-ppb) level of heavy metal ion. The largest concentration of “heavy” metal contaminants were

Al, Zn, and Cu. Some samples did show more than a trace amount of Pb, more than likely from battery decomposition, either in Bovoni or from non-standard disposal of batteries.

Conclusions

The small data set indicates little or no unexpected concentrations of cation contaminants in any of the water samples collected and analyzed. The occasional sample containing high Al, Zn, and Cu can be explained by the presence of galvanized or aluminum roofing or copper plumbing, which would be expected in the run-off or from the septic systems. For numerous reasons (primarily the lack of a working instrument) we were unable to analyze any of the water samples for trace level organic contamination. We expect to get both our Varian GCMS and our Varian LCMS working and to analyze water samples both from STEER and from run-off leading into STEER for pesticide, herbicide, and other trace-level organic contaminants (e.g. Triclosan).

Microirrigation for Sustainable Vegetable Production in the US Virgin Islands

Basic Information

Title:	Microirrigation for Sustainable Vegetable Production in the US Virgin Islands
Project Number:	2012VI212B
Start Date:	3/1/2012
End Date:	4/30/2013
Funding Source:	104B
Congressional District:	Not Applicable
Research Category:	Biological Sciences
Focus Category:	Agriculture, Irrigation, Water Use
Descriptors:	None
Principal Investigators:	Dilip Nandwani

Publication

1. Nandwani D. Evaluation of sandea for weed control in transplanted eggplant. American Society for Horticultural Science-Southern Region, Orlando, FL, 2013 (poster).

MICROIRRIGATION FOR SUSTAINABLE VEGETABLE PRODUCTION IN THE US VIRGIN ISLANDS

Introduction

The main water delivery system for crops grown for both research at the University of the Virgin Islands and by many of the territory of the U.S. Virgin Islands farmers is through drip irrigation. During this time there is no water shortage problem; however the US Virgin Islands experiences drought from January through March, normal dry season. Through the use of drip irrigation we have been able to conserve fresh water which is truly a valuable resource. Energy required and associated costs to desalinate large quantities of water for farming purposes is truly substantial. Through the use of drip irrigation, researchers and farmers alike have been able to utilize above ground water storage tanks as well as water catchment ponds to store large quantities of rain water in the rainy season.

Problem and Research Objectives

The use of drip irrigation is a great asset when it comes time for the application of fertilizers. Unlike the common local application of granular fertilizer, which is spread around the field or around the base of a sizeable plant, drip irrigation affords the efficiency of applying water soluble fertilizers within inches of a relatively newly planted seedling and throughout the life of the plant. This allows for remediating specific nutrient deficiencies that can occur in local high pH calcareous soils. Chemigation through drip irrigation delivers pesticides in the root zone of the plants. The precision obtained through drip application is safer, more accurate and uses far less material due to the accuracy. Using pesticides such as DuPont Coragen, Venom other commercial pesticides and soluble fertilizers are more efficient use of drip irrigation which saves in labor costs.

Objectives

a) Develop and evaluate improved water management practices using microirrigation in selected vegetables.
b) Evaluate the effect of varying rates of irrigation on the yield and growth of selected vegetables.
c) Determine the minimum water requirements for selected vegetables.

Methodology

- Three experiments were conducted in field plots at the University of the Virgin Islands Agricultural Experiment Station, Albert A. Sheen campus and at the Sejah farm, Kingshill. Cucumber and eggplant trials conducted at the UVI-AES field plot in the growing season of 2012 and tomato trial conducted at Sejah farm, Kingshill in the growing seasons of 2012-2013.
- Seeds, potting trays, potting mix and drip supplies ordered off-island and locally after approval of project and project account establishment.
- An advertisement for the student aid prepared, circulated and applications invited for the position. Interviews conducted and a UVI Undergraduate student Ms. Vernecia Philips was

hired. Ms. Philip didn’t complete her appointment period, therefore, another student aid Mr. Mark Sinanan of UVI hired.

- Seeds of cucumber var. `Eureka’ planted in ‘seedling trays’ containing potting mix in the greenhouse. Seedlings were transplanted in the field approximately 10 days after germination.
- An experimental plot (90’x75’) selected at the USDA field and cucumber transplants planted in three rows spaced 1.2 m apart, with 12 plants per row spaced at 0.6m along the row. The experimental design was randomized complete blocks, with 3 replications. Standard conventional system applied for the production e.g. fertilizer applications, planting densities and pest control. Microirrigation: Water was applied to maintain soil moisture levels equivalent to 20, 40, 60 kPa. Tensiometers were placed at a depth of 15 cm, in the middle rows of plots, to monitor soil moisture in the plant root-zone. The irrigation system monitored daily and turned on when tensiometer readings exceed the specified level for each treatment.
- The weather station at the University of the Virgin Islands-Agricultural Experiment Station used to provide the necessary meteorological data for irrigation scheduling.
- Data were collected on rainfall, water used, yield, and other plant characteristics.
- In eggplant, three cultivars ca. ‘Nadia’, ‘Hansel’ and ‘Magal’ were grown in conventional management system at the Agricultural Experiment Station of the University of the Virgin Islands in St. Croix (Kemble *et.al*., 1998)
- The experimental design was complete randomize block in three replications. Weed control was done mechanically or with herbicide application.
- Data on plant height, marketable yield and fruit size were recorded.
- At the Sejah farm, field plot (30’x152’) selected, cleared and prepared for the tomato experiment. Untreated seeds procured from Harris seeds, NY and planted in compost in the greenhouse and other cultural practices adopted as per National Organic Program (NOP).
- A randomized complete block design with three replication used. Four cultivars of tomato (determinate type) `Mountain Fresh’ (MF), `Red Defender’ (RD), `Security 28’ (SY) and `Defiant’ (DF) used for the experiment. Tomato transplants of all four cultivars (4-5 weeks) planted in the field.
- OMRI listed fertilizers and insecticides ordered and applied. Drip irrigation (low pressure, gravity based) used and water requirement monitored.
- Data on yield (numbers and total weight) and marketable fruits collected from multiple harvests throughout the growing season.

Principal Findings and Significance

- Moisture level -30pka produced highest yield compared to -60pka and -90pka. -90pka moisture level was high and produced low marketable fruits.
- Injecting Malathion, Sevin or Venom on a rotation as needed once the pest reaches levels were they can no longer be controlled using topical application, often bring the situation under control.
- In eggplant, var. ‘Hansel’ produced highest yield (30.57ton/ha) and lowest in ‘Magal’ (12.16ton/ha). Average marketable fruits number was higher (14/plant) in `Hansel’. Spider mites infestation (2-3%) occurred in plots and controlled by miticides.
- All four varieties of tomato produced marketable fruits. Trial needs to be repeated in order to collect data and results.
- In tomato trial, total 18,750 gallon water used in drip irrigation from December 2012 to

March 2013 (Dec. 2012-2400gal, January 2013-4950gal, February 2013-6100gal, March 2013-6300gal).

- Frequent rainfall and insect pests damage was an issue and trial needs to be repeated in order to collect data and results.
- Water is a rare commodity on a semiarid island and the Virgin Islands stakeholders are concerned to use this precious resource as efficiently as possible. Fertigation and chemigation are new technologies for utilizing a drip irrigation system to apply fertilizer and pesticides.

Conclusions

- Drip irrigation has been very beneficial though it has not been easy to get 12 or 15ml drip tape. Regional supplier have only been able to get 8ml and 10 ml low flow drip tape, the 15ml is very difficult to obtain and generally has to be ordered off-island which can be very pricy once shipping to the Virgin Islands is added.
- Frequent rainfall and insect pests damage was an issue in cucumber and trial needs to be repeated in order to collect data and results.
- Water is a rare commodity on a semiarid island and the Virgin Islands stakeholders are concerned to use this precious resource as efficiently as possible. Fertigation and chemigation are new technologies for utilizing a drip irrigation system to apply fertilizer and pesticides.
- The study provided vegetables yield response with respect to irrigation amounts and method of determination of amounts and would be useful to producers for planning purposes and water management of the crops.

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Terrestrial Sediment Delivery and Nearshore Water Turbidity A Case Study From the East End of St. Croix, USVI

Basic Information

Title:	Terrestrial Sediment Delivery and Nearshore Water Turbidity A Case Study From the East End of St. Croix, USVI
Project Number:	2012VI220B
Start Date:	3/1/2012
End Date:	2/29/2014
Funding Source:	104B
Congressional District:	Not Applicable
Research Category:	Water Quality
Focus Category:	Hydrology, Sediments, Water Quality
Descriptors:	None
Principal Investigators:	Kynoch Reale-Munroe, Bernard Fernando Castillo, Carlos E Ramos-Scharron

Publications

1. Student poster presentation by Nathan Gubser, Threats to our Reefs: Sediment Based Pollutant Regulation and Mitigation. UVI 2012 Research Day. April 2012.
2. Student poster presentation by Anthonio Forbes, Shelsa Marcel, Bernard Castillo II and Kynoch Reale-Munroe. Threats to our Reefs: Establishing Baseline Data for Total Maximum Daily Loads (TMDLs) Development. UVI 2012 ECS Summer Research Symposium. July 2012.
3. Poster presentation by Kynoch Reale-Munroe. Threats to our Reefs: Quantifying Sediment and Organic Material Production Rates from Erosion Processes in Small Subtropical Watersheds on the East End of St. Croix. USVI. UVI 2012 Research Day. April 2012.

Terrestrial Sediment Delivery and Nearshore Water Turbidity – A Case Study From the East End of St. Croix, USVI

Problem

Over the past decades, the US Virgin Islands (USVI) and Puerto Rico (PR) have experienced rapid coastal development and a growing network of unpaved roads, which contributes increased sediment loading into the surrounding bays (Johnston, B. R. 1987; MacDonald, et al., 1997; Ramos-Scharrón, 2010). Terrigenous sources of sediment associated with land development consistently ranks among the greatest threats to coral reef health (Fabricus, 2005; Gardner et al., 2003; Mora, 2007; Rogers, 1990; Rogers, et al., 2008; Rothenberger, et al., 2008; Territory of the USVI & NOAA-CRPP, 2010). Studies conducted in the USVI show a clear and significant onshore-offshore sedimentation gradient; nearshore sedimentation rates were six times greater than at mid-shelf reefs, and nearly 50 times greater than at offshore reefs (Rothenberger, et al., 2008). Single-year sedimentation studies conducted in St. John imply that current sediment settling rates at the bottom of bays impacted by development are between 3 and 73 times above undisturbed conditions (Gray, et al., 2008). Studies relating landscape development intensity to nearshore coral reef condition in St. Croix found a negative correlation between taxa richness, colony size, colony density and anthropogenic activities (Oliver, et al., 2012). It is apparent that clean, clear water is critical to maintaining healthy coral communities and sustaining ecological integrity (Jeffery, et al., 2005).

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting their designated uses. In October 2010 EPA published a list of impaired and threatened waters in the USVI that are targeted for the development of future TMDL limits. The most common reported causes of impairment in near-shore waters were sedimentation, effluent discharges, dissolved oxygen (DO) deficiencies and bacterial contamination (US EPA, 2010). Of the 33 listed sites for St. Croix, 28 or 85% of the reported impairments were associated with high turbidity.

The government of the USVI approved legislature that allocated 155.4 km2 of offshore marine habitat to the St. Croix East End Marine Park (STXEEMP) to protect the largest island barrier reef system in the Caribbean, which was incorporated into a marine protected area (MPA) in 2003 (DPNR, 2008). Federal and territorial coastal managers consider the watersheds that drain into the STXEEMP to be priorities for protection and restoration (Horsley Witten Group, Inc. 2011). The study presented here was located on the small watershed that discharges into Boiler Bay, which is located within the STXEEMP. A 180-m long trail that leads to Boiler Bay has been identified as a chronic source of erosion and sedimentation. Recent studies have estimated that the existing trail is capable of delivering 2 metric tons of sediment annually into the bay (Reale-Munroe, et al. 2011). Boiler Bay is comprised of an array of different aquatic habitats, (seagrass beds, linear reef, sand patches, etc.) which contain protected and endangered species (sea turtles, coral, etc.) (Pittman, et al., 2013). Understanding the factors governing erosion and sedimentation in this area is important not only for TMDL development, but also for mitigating the impacts on the

Research Objectives

Although terrestrial erosion and water quality impairments, due to high turbidity are consistently reported as imminent threats to marine ecosystems, very little quantitative data is available. For this study, instrumentation designed to collect water quality data in high resolution, temporal scales was deployed in Boiler Bay to characterize two types of water quality conditions; 1) during dry conditions when no runoff was occurring from the watershed and 2) during sedimentation events resulting from terrigenous inputs (the eroding trial) when runoff was discharging into the bay. Specifically, the research objectives were:

- To determine ambient marine water quality parameters during dry conditions with no terrestrial inputs from runoff, and
- To assess the magnitude and duration of turbidity during a sedimentation event in Boiler Bay.

Methodology

Precipitation

A HOBO RG3-M Data Logging Rain Gauge system equipped with a HOBO® Pendant Event data logger was installed onsite. The data were used to determine 1-hr rainfall intensities, to calculate total rainfall during storm events and to summarize monthly rainfall data.

Water Quality Data

A YSI 6920 V2 multiparameter, water quality logging system (sonde) was used for long-term, *in situ* monitoring of Boiler Bay. The sonde was configured to log data in 2 – 5 minute intervals and measured temperature, dissolved oxygen (DO), salinity, pH and turbidity. The sonde was mounted 0.5 m below the water surface and approximately 70 m northeast from where runoff from the trail enters the bay. Boiler Bay has been classified as 'Class B' waters by the government of the USVI. Data collected were compared to 'Class B' territory water quality regulations (Table 1).

Table 1 Regulatory limits for temperature, DO, pH and turbidity for Class B waters. ***Table adapted from DPNR, 2010.***

Standard	*Class A*	*Class B*	*Class C*
Temperature	In no case shall Class B water quality standards be exceeded.	Not to exceed 32^{o} C at any time	Same as Class B
Dissolved O2	In no case shall Class B water quality standards be exceeded.	Not < 5.5 mg/l from other natural conditions	Not < 5.0 mg/l from other natural conditions
pH	In no case shall Class B water quality standards be exceeded.	< 8.3 Tolerable Limit>7.0	<8.5 Tolerable Limit>6.7
Turbidity	In no case shall Class B water quality	A maximum nephelometric turbidity	Same as Class B, but no NTU standard in Rules

standards be exceeded.	unit (NTU) reading of three (3)	& Regulations

Principal Findings and Significance

Baseline Water Quality

Total means and standard deviations encompassing both sampling periods are illustrated in (Figure 1). Mean values and standard deviations for temperature, DO, pH, turbidity, and salinity were, 28.6 ±0.4 °C, 6.7 ±0.7 mg/L, 8.0 ±0.1, 0.50 ±0.5 NTU, and 36.1 ±0.7 ppt, respectively. Mean values for all of the water quality parameters did not exceed or fell below established standard criteria for Class B waters.

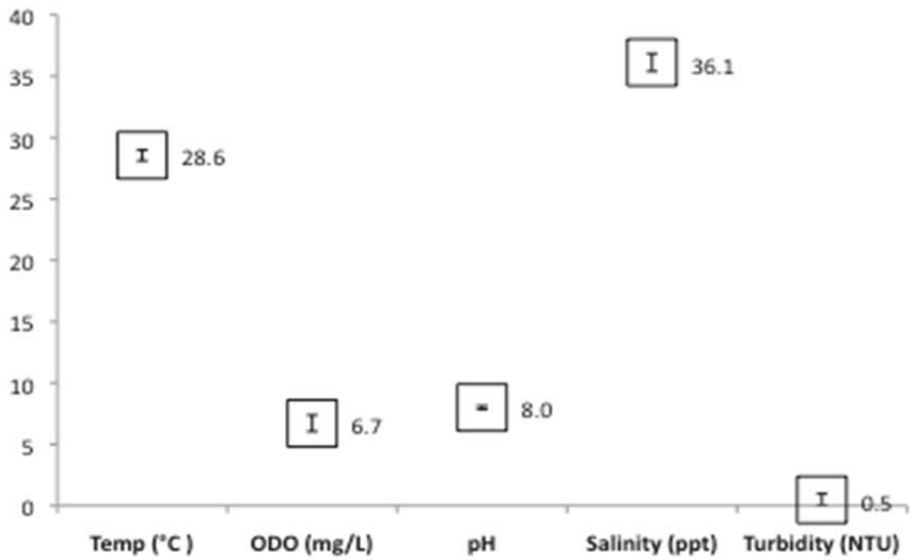

Figure 1 Total mean values and standard deviations for water temperature, DO, pH, salinity and turbidity during the study period.

Terrestrial Sediment Delivery

A really-weighted erosion rate for the trail that leads to Boiler Bay was calculated to be 2.4E-02 kg m^{-2} cm^{-1}. During the 48-hour period that TD Gabrielle was active over the USVI, 13.7 cm of precipitation fell on the watershed that drains into Boiler Bay. The total surface area of the eroding trail was 478 m^2. Based on this information, the trail alone generated an estimated 159 kg (351 lbs) of sediment in 48 hours that was potentially discharged directly into Boiler during TD Gabrielle.

The total rainfall associated with TD Gabrielle,13.7 cm/48-hours (5.4 in/48 hr) primarily occurred during two significant pulses of rain. The first pulse had a maximum 1-hr intensity of 2.1 cm/hr (0.83 in/hr) on Sept. 5th at 03:00 AM. The second pulse of rain had a maximum 1-hr intensity of 4.1 cm/hr (1.6 in/hr) approximately 24 hours later on Sept 6th at 03:00 AM (Figure 2).

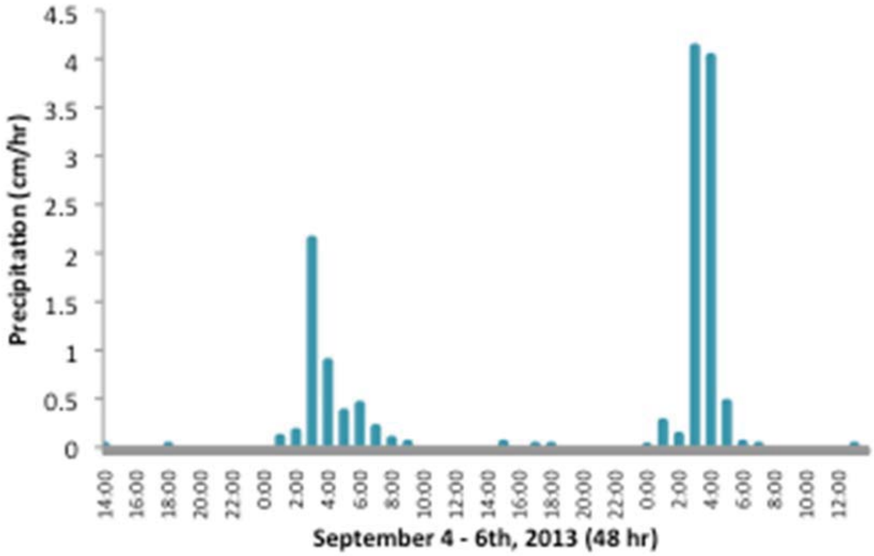

Figure 2 Storm events during TD Gabrielle.

The pattern, intensity and duration of precipitation caused by TD Gabrielle created runoff from the watershed and on the trail, which was able to completely penetrate the beach and produce a sedimentation event in Boiler Bay (Figure 3).

Figure 3 Beach flushing resulting from terrestrial runoff at the base of the trail leading to Boiler Bay.

To assess the duration and intensity of the sediment plume generated by the second pulse of precipitation, a 14-hr (0:00:00 – 14:00:00, September 6th 2013) dataset was analyzed. At 01:00:00 precipitation began with an intensity of 0.3 cm/hr and increased to 4.1 cm/hr, followed by an additional 4.0 cm/hr, which resulted in a sedimentation plume with a peak turbidity value of 19.0 NTU (Figure 4). During this time, turbidity exceeded 3.0 NTU (indicated by a red line) 105 times, or 24.25% of the 14-hour period. Turbidity remained above 3.0 NTUs for a continuous 2.5-hour period during the sedimentation event, however turbidity values greater than 3.0 NTUs occurred intermittently for a 5 – 6 hour period. Mean turbidity during the 14-hr period was 2.27 NTU, which was 4.54 times higher than mean turbidity over the study period (0.50 NTU). Turbidity in the bay remained above 0.50 NTU for 81.5% of the time during the 14-hr period (indicated by a blue line).

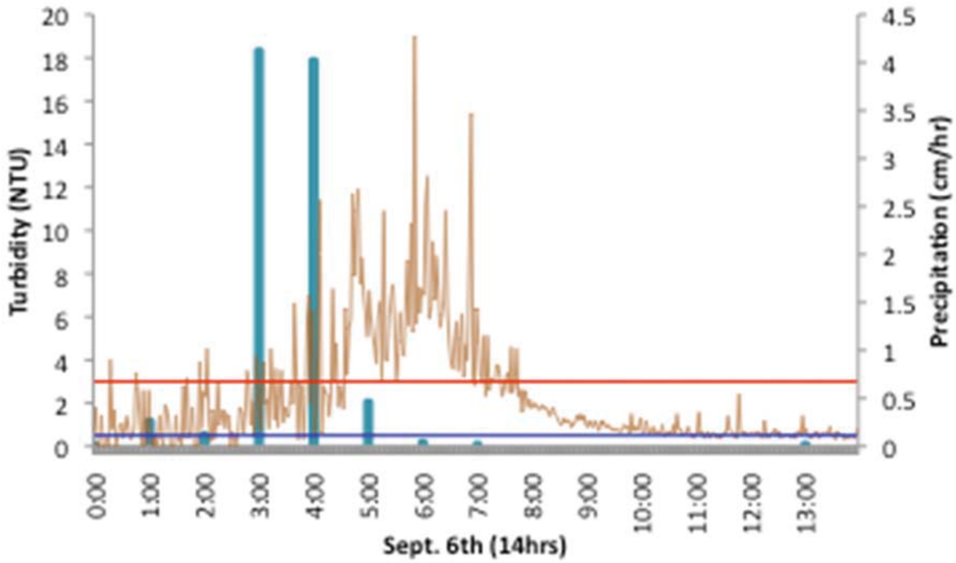

Figure 4 Turbidity intensity and duration resulting from a sedimentation event in Boiler Bay. Regulatory limit, 3.0 NTU (red line) and total mean over the study period, 0.50 NTU (blue line).

Conclusions

Results underline the importance of sustaining efforts to bring public awareness and enforce water quality regulations in the territory. Elevated erosion rates observed in the rather arid and pristine east end of St. Croix from a small eroding trail suggest an even greater need for caution and required use of Best Management Practices (BMPs) in the more developed, steeper and wetter areas of the USVI and PR. As coastal development and networks of dirt roads continue to expand, increased loads of sediment-laden runoff are inevitable. Public awareness and regulatory enforcement will become increasingly important to protect the valuable water resources of the region.

Results from this study provided high temporal resolution water quality data during both dry (ambient) and wet conditions when runoff was discharging into the bay (sedimentation). Since *in situ* monitoring for this project was located in the relatively pristine area of the STXEEMP, ambient data could be used as an established baseline to compare acceptable limits of change to in other areas of similar classification (Class B). This dataset could also be used to quantify potential impacts on marine ecosystem health during sedimentation events.

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High-Resolution Mapping of Rainfall Rates Across the St Thomas Microclimates

Basic Information

Title:	High-Resolution Mapping of Rainfall Rates Across the St Thomas Microclimates
Project Number:	2012VI222B
Start Date:	3/1/2012
End Date:	8/31/2013
Funding Source:	104B
Congressional District:	Not Applicable
Research Category:	Engineering
Focus Category:	Water Quantity, Water Supply, Models
Descriptors:	None
Principal Investigators:	David C Morris

Publication

1. Morris, David; Drost, Don; Richardson, Dwayne, 2013, High-Resolution Mapping of Rainfall Rates Across the St Thomas Microclimates , in Proceedings of the 11th International Precipitation Conference, Ede-Wageningen, The Netherlands, pages TBA.

High-Resolution Mapping of Rainfall Rates Across the St Thomas Microclimates

Problem and Research Objectives

Accurate and precise rainfall data with high spatial and temporal resolution are critical to a broad spectrum of public sector, private sector, and academic projects of great interest to Caribbean prosperity, yet such data are presently lacking in the USVI. Residential water supply construction (cisterns), drainage planning for public works projects, and environmental erosion studies, to name only a few applications all rely on an accurate understanding of the actual and predicted rainfall rates at varied sites around the USVI. While historical data are available online through the US Geological Survey website, these data are, themselves, derived from only a few collection sites around the VI and are now some 20-40 years old. As global climate change drives variation in weather patterns across the Caribbean, it is critical to the next generation of construction and development planning in the USVI to rebuild and maintain a modern, high-resolution precipitation database that accurately portrays the current microclimate conditions across the region. Similar data are available across urban and rural areas throughout the continental US and should be made available as well in the USVI.

A high-density network of low-cost tipping-bucket rain gauges installed across the island of St. Thomas will provide continuous monitoring of rainfall rates and accumulation. These rainfall stations will be monitored and maintained by a team comprising both UVI faculty and undergraduate researchers and will span all the major microclimates of St Thomas to provide both local rainfall data within each microclimate region and a dynamic picture of the evolution of rainfall events as they cross the island and encounter its varied topology.

Additionally, it is a well-known issue in rain microphysics that the structure of rainfall events at modest (~1 km) resolution is largely unknown yet is important to understanding storm-evolution, evaluating the utility of radar coverage, and identifying local microclimates within the larger macroclimate region. These issues are of particular interest in the Caribbean where the prevailing winds, steep geography, and sharp ocean thermal gradients contribute to extreme variation in weather characteristics within close proximity. The close configuration of the rain sensor network proposed here will provide research-quality data on a spatial resolution seldom before achieved anywhere (though see Larsen et al. 2010) and never before achieved in the Caribbean. This set of measurements will therefore be of great value to the meteorological research community.

Methodology

The rain gauge stations include a Hydreon Optical Rain Sensor (model RG-11) together with a Davis Vantage Vue weather sensor suite. Students Dwayne Richardson and Stanley Barbel spent (combined) 9 months, building an in-laboratory testing and calibration apparatus, testing the sensors in the lab, and later installing and testing the prototype sensor in the field. Since the precision of the rainfall event start and stop times is of high importance in modeling the weather pattern evolution, care was taken understand differences in start/stop signals from these two sensors. The Davis weather sensor suites will be used to collect a full suite of weather data (wind speed, wind direction, temperature, humidity) while the RG-11 sensors, which have a much faster rainfall response-time to rainfall event starts/stops, will be used in parallel to record precise event start and stop times.

A “verification suite” of 2 weather sensors has been installed and running for several months. These two weather stations have been recording weather data and archiving it both locally and on a centralized cloud server.

The full suite of 15 sensor stations is now being installed in the field by a team of graduate and undergraduate students. When installation is completed early this summer, all 15 stations will continuously archive data both locally and on a cloud server for use both by UVI students and researchers as well as those across the scientific community.

Principal Findings and Significance

Objectives

The short-term objectives of the project are to build a new archive of rainfall data and make that archive available to the public in well-documented form for use in scientific, private, and public sector projects. To this end, rainfall and weather data from a pilot network of weather stations is now connected to a publicly accessible Davis Instruments Inc. cloud archive. These data are accessible by researchers across the scientific community.

The long-term objectives of the project are broader-reaching and will be approached as the data archive collected through the new weather station network grows in maturity. The PI and Co-Is will investigate a range of scientific topics including those outlined below.

• A comparison of current monthly rainfall rates to historical rates as evidence of climate change in the Caribbean (student project) – Student Ariane Ramsundar will study this as part of a research experience for undergraduates (REU – advised by Morris).

• A comparison of relative rainfall rates across different geographical regions to quantify the contrast in water supplies across the island (student project) – Student Leo Jobsis will study this as part of an REU (advised by Morris).

• A study of the variation of rainfall rates within a single Doppler radar pixel to validate meteorological ”ground-truth” models – graduate student Pedro Nieves has made progress in developing a method of comparing radar images to rainfall point measurements. He continues work on incorporating a rainfall layer into the UVI GIS database (advised by Primack).

Scope and Significance of the Work

The original scope of this project was to install island-wide network of weather stations, both remotely powered (by solar cells) and reporting data remotely (via cellular data connection). During the installation phase of the project, it became clear that this original design would not be feasible due to the uncertain security of remote sensing stations left in the field and the sparseness of consistent cellular connectivity at expected remote sensing locations across the island.

As a result, a revised installation plan was developed in which remote sensing stations were placed at "host" locations. These hosts are identified as personal residences, private businesses or public facilities (schools, e.g.) where both consistent electric power and Internet connectivity is available.

The first five host sites chosen span the major microclimate regions of the island (see table below). These stations are now reporting data regularly and it is anticipated that the first scientific analysis of the data archive will in early 2014 when the network will have been collecting data for nearly 1 year.

Station ID	Station Location	Latitude	Longitude	Elevation
1	Botany Bay	18.354	-65.018	340 ft
2	UVI	18.342	-64.972	80 ft
3	Etelman Observatory	18.354	-64.966	1250 ft
4	St Peter Mountain	18.358	-64.949	1200 ft
5	Coral World	18.338	-64.853	20 ft

Table 1: Locations and elevations of participating weather stations on St. Thomas. Station ID numbers correspond to the map shown in Figure 1. Sites have been chosen to sample a range of micoclimatological regions across the island and to sample a range of elevations.

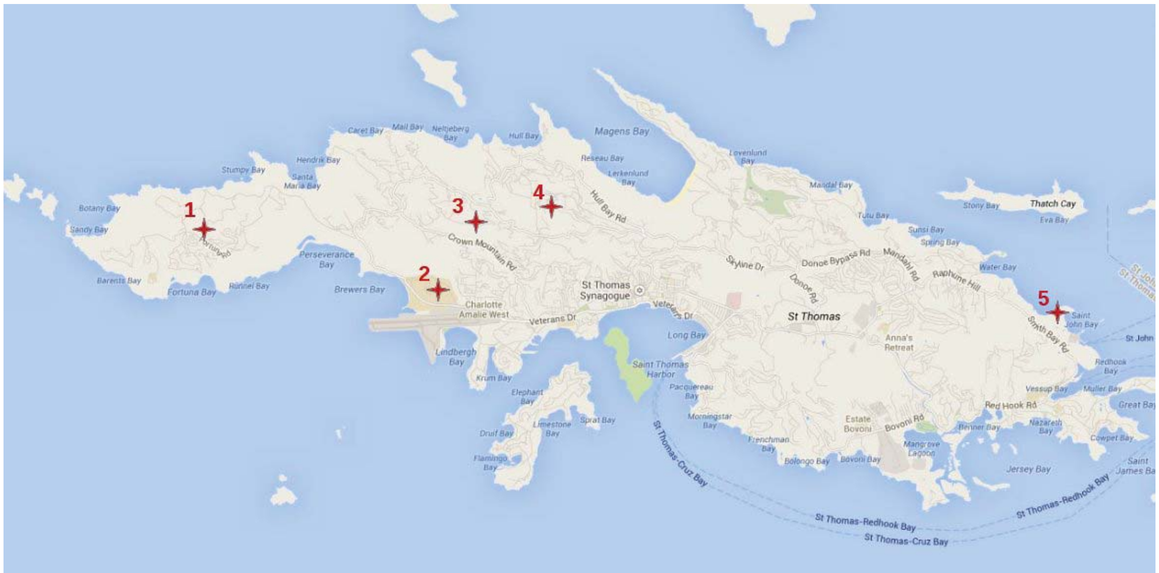

Figure 1: Locations of participating weather stations on St. Thomas. Weather stations are being installed at additional locations as time permits and as suitable additional locations are identified.

Conclusions

Despite challenges to the original design of the new weather station network to be installed on St Thomas, progress is being made thanks to a revision of the network infrastructure design and thanks to the support of local businesses and residents who will act as citizen scientists in hosting weather monitoring stations and providing both power and Internet access to the stations. We look forward to the first round of scientific results and comparison to historical Caribbean climatological data in early 2014.

Is Water Quality Degradation Inevitable in the VI? Linking the Human Dimension to the Governance of Water Resources Across the Territory.

Basic Information

Title:	Is Water Quality Degradation Inevitable in the VI? Linking the Human Dimension to the Governance of Water Resources Across the Territory.
Project Number:	2013VI242B
Start Date:	3/1/2013
End Date:	4/28/2014
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Water Quality, Management and Planning, Law, Institutions, and Policy
Descriptors:	None
Principal Investigators:	Wayne Archibald, Kala Fleming

Publications

1. Fleming, K.K. (2012). The Human Dimensions of Coastal Water Pollution – Project Kick-off. Presented to 30 UVI students in April 21, 2013 at the University of the Virgin Islands, St. Thomas, VI.
2. Doliotis, Anthonios and Kenisha Pascal, 2013, Correlation Between Human Dimensions and Impaired Water Quality, National Science Foundation Experimental Program to Stimulate Competitive Research 23rd National Conference, Nashville, Tennessee.
3. Doliotis, Anthonios and Kenisha Pascal, 2014, Correlation Between Human Dimensions and Impaired Water Quality, 2014 Emerging Researchers National Conference, Washington, D.C.
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Probing the Human Dimensions of Coastal Water Pollution in the U. S. Virgin Islands

Problem and Research Objectives

Land-based sources of pollution, sedimentation, overfishing and climate change pose major threats to coastal ecosystems and drive coastal water pollution. While there are both physical and anthropogenic contributors to these threats, coastal water management programs predominantly focus on the physical components, leaving the human, societal and cultural components poorly understood and inadequately accounted for. For example, when vegetation cover decreases in an area, soil stability also decreases and the potential for erosion and water pollution increases. Vegetation is more likely to be removed in locations where the presence of vegetation is not valued or where it conflicts with narrow development goals. A range of economic and socio-demographic factors may influence variations in these values and goals that can co-exist across various sub-populations in a community.

The success of policies to reduce coastal water pollution depends on the ability to persuade individuals to implement protective site strategies during construction, and to encourage ongoing interest in ensuring proper maintenance of onsite infrastructure such as septic tanks. In 2010, NOAA funded a green construction outreach and engagement project for the USVI[1]. The project produced training materials that targeted homeowners, heavy equipment operators, engineers and Department of Natural Resources Staff. While this was a positive step forward, the approach was still limited because it assumed homogenous values for homeowners and heavy equipment operators and also assumed that a lack of information was the only barrier to their adoption of more environmentally protective behaviours.

In this study, we explored how economic and socio-demographic factors might influence the potential for activities that increase coastal water pollution and provide clues about locked-in barriers to adoption of pro-environmental strategies. The underlying assumption was that economics and socio-demographics were linked to the conscious and unconscious environmentally-related activities of individuals that encompassed the so-called “human dimensions”.

Research objectives were twofold: i) determine the utility of demographic and socioeconomic indicators to predict the potential for coastal water pollution and ii) gauge the extent of knowledge, concern and engagement of individuals on environmental issues in general and coastal water pollution specifically. Accordingly, three research questions were used to guide inquiry and insight on these areas:

- Do spatial variations in demographic and social indicators explain variations in the occurrence of coastal water pollution?
- Can we develop a methodological approach for identifying the propensity for varying pro-environmental sentiment and tendencies among sub-populations?
- Does pro-environmental sentiment provide a useful indicator for gauging propensity to

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[1] Sep 2011. Contract No. EA133F11SE2956.NOAA Project Manager – Lisa Marie Carrubba.

adapt and evolve behaviours that increase community resilience?

Methodology

Economics and Socio-demographics as Indicators of Impairment Potential. A copy of the 2010 USVI census was obtained from the University of the Virgin Islands Eastern Caribbean Center[2]. The census consists of about 850 variables containing information on demographics, income and living conditions across more than 300 estates on the three islands. A subset of 136 demographic and socioeconomic variables was selected for analysis[3]. Additionally, seven new variables were added: estate area, population density, crude poverty rate[4], cistern proportion, cistern density[5], septic tank proportion and septic tank density.

Using principal components analysis (Rossiter, 2014), we further reduced the number of economic and variables under consideration. Estate polygon centroids were loaded with the variables and spatial regression was used to link economic and socio-demographic factors to watershed-level impairments. Data on watershed impairments was obtained from the US Environmental Protection Agency's National Summary of Impaired Waters website[6].

Classifying pro-environmental sentiment among sub-groups. Using a subsample of respondents from the first public opinion survey on climate change and coastal water pollution in the USVI (Wensing et al., 2014), latent class analysis was used to classify survey respondents into distinct categories based on individual response patterns to 24 questions. Individuals within a group are more similar than individuals between groups.

Principal Findings and Significance

Income, cistern density and septic tank density were strong predictors of watershed impairments. Additionally, using latent class analysis, we identified the following three sub-populations among survey respondents:

1. Strongly pro-environmental (46%). Very few in the sub-group believe nature is boring. They tend to believe humans are abusing the environment, would join an environmental organization and strongly believe in conserving natural resources.
2. Mildly pro-environmental (36%). Compared to Group 1, fewer in this group believe that the environment is more important than jobs, but many also believe humans are destroying the environment like their counterparts in Group 1.
3. Indifferent (18%). Members of this group did not show strong preferences for or against any of the questions that for or against "nature".

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[2] Mr. Stevie Henry provided invaluable assistance in facilitating our acquisition and understanding of the census data.

[3] Most of the excluded rows were raw counts used to develop the final subset of variables.

[4] The crude poverty rate was created by dividing the number of individuals with income below the 2009 poverty line by the total population per estate.

[5] Cistern proportion and density might indicate reduced run-off potential and might serve as a mitigating factor to reduce sediment transport and water pollution

[6] http://iaspub.epa.gov/waters10/attains_nation_cy.control?p_report_type=T

The identification of these subgroups provides new opportunities to better target and monitor interventions that address coastal water pollution. For example, using the approach employed, policy organizations can study how relative sub groups evolve over time in response to environmental marketing and other targeting approaches. Also, if the spatial distribution of respondents and external environments are linked to groupings of individuals, policies can be tailored to better address core beliefs and base pro-environmental tendencies.

Conclusions

In this study, we explored how economic and socio-demographic indicators might provide insight on the potential for activities that increase coastal water pollution and provide clues about locked-in barriers to adoption of pro-environmental strategies. We find preliminary evidence that suggests a causal connection between economic and socio-demographic factors and the patterns of coastal water pollution.

We also report on the development of a mixture model approach for identifying the range of pro-environmental tendencies and propensity to address coastal water pollution across the USVI. Using a subsample of respondents from the first public opinion survey on climate change and coastal water pollution in the USVI, survey respondents were classified into three propensity groups for pro-environmental behaviour: strongly pro-environmental, mildly pro-environmental and indifferent. The identification of these subgroups provides new opportunities to better target and monitor novel interventions that address coastal water pollution.

While this study has initiated our foray into asking empirical questions on how to influence adaptive behaviours that increase community resilience in the US Virgin Islands, clearly this area of research is ripe for further exploration. Future studies should seek to address questions such as "How do we adapt policies to account for the way sub-populations assimilate and respond to environmental information?" and "Can we develop robust and integrated coastal water pollution models that account for both physical and human components of risk?".

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Plant Nutrient Management in Aquaponic System for Zucchini (Cucurbita pepo) Production

Basic Information

Title:	Plant Nutrient Management in Aquaponic System for Zucchini (Cucurbita pepo) Production
Project Number:	2013VI243B
Start Date:	3/1/2013
End Date:	8/31/2014
Funding Source:	104B
Congressional District:	USVI
Research Category:	Biological Sciences
Focus Category:	Nutrients, Agriculture, Methods
Descriptors:	None
Principal Investigators:	Dilip Nandwani, Donald Bailey

Publication

1. Balkaran, Seti, Donald Bailey and Dilip Nandwani, 2014, Effect of Foliar Spray Application of Calcium and Phosphorus on Fruit Production of Zucchini (Cucurbita pepo), Poster presented at the Twelfth Annual Spring Student Research Symposium, University of the Virgin Islands, St. Croix, VI. (March 22, 2014).

Plant Nutrient Management in Aquaponic Systems for Zucchini (Cucurbita pepo)

Problem and Research Objectives

Plants grown in aquaponic systems rely on nutrients produced by fish waste which are dissolved in the system's water. The waste streams consist of metabolic waste, which is excreted from the gills, and fecal waste from digested feed. The metabolic waste consists mainly of ammonia-nitrogen (NH_4-N), the waste product of cellular protein metabolism. Through two steps of biofiltration the ammonia-nitrogen waste is converted to nitrate-nitrogen (NO_3-N). This is an abundant source of nitrogen for growth of plant leaves and is the reason leafy vegetable crops are the main crops grown in aquaponic systems. The solid waste is also a source of nutrients after trapping in filter tanks and mineralization over a period of up to seven days. The mineralization allows the raw fecal material to break down and dissolve inorganic compounds into the system water. Plants require 13 essential nutrients for growth. Fish waste provides 10 of these in sufficient quantity for growth. The three nutrients that need to be supplemented are calcium, potassium and iron.

Leafy vegetable crops grow well in aquaponic systems because their main nutrient requirement, nitrogen, is in abundant supply. Fruiting crops require calcium to be available at higher values than normally found in an aquaponic system. Fruiting crops also require phosphorus to be adequately supplied in a ratio to nitrogen.

This research is being conducted to determine at what concentration level a foliar spray of either calcium, phosphorus or both can be applied to zucchini leaves to enhance fruit production and reduce the occurrence of blossom end rot disease.

Methodology

The UVI Commercial Aquaponic System was used for this research. The system consists of 4 fish rearing tanks, clarifiers and net tanks for solids removal and mineralization, and hydroponic troughs for vegetable crop production. Normal operating procedures were used for fish production. They were fed 3 times daily with a manufactured feed containing 32% protein levels. Settable solids were removed from the clarifier at each feeding and trapped solids were washed from the net tanks weekly.

Zucchini seedlings (Cucurbita pepo var: Profit) were transplanted into 71.3 m^2 of growing area in the hydroponic troughs. The planting areas were further divided into control and treatment plots of 7.4 m^2 each. Seedlings were transplanted at a density of 2.7 plants/m^2. The study consisted of 8 treatment blocks and a control block. Calcium and phosphorus was applied as a foliar spray at 4 different application rates each. The control block was sprayed with water. Calcium sprays were made from dilutions of 1.0 M stock solutions of calcium chloride ($CaCl_2$). Phosphorus sprays were made from dilutions of 1.0 M stock solutions of mono-potassium phosphate (KH_2PO_4). Foliar spray was applied once weekly beginning at the onset of flowering and continuing through the production period. The spray was applied in the afternoon.

Treatment	Foliar Spray Concentration (mg/l)
Control	No nutrient addition
Calcium	1.25
Calcium	2.5
Calcium	3.75
Calcium	5.0
Phosphorus	0.5
Phosphorus	1.0
Phosphorus	1.5
Phosphorus	2.0

Zucchini fruits were harvested 3 times weekly. Target minimum size of fruits harvested was 13 cm. The fruits were counted and weighed collectively for each treatment. Three individual fruits were selected for individual measurements of mass (g), length (cm) and width at two points (cm). Unmarketable fruits with blossom end rot were harvested and counted.
Leaf tissue samples were taken from the control and each treatment and sent for analysis to a laboratory. Culture water samples were also taken and sent to a laboratory for analysis.

Principal Findings and Significance

A treatment effect was observed with a calcium treatment rate of 3.75 mg/l which increased the number of marketable fruit and the total biomass significantly over the control treatment. A total of 34/m2 marketable fruits with a mass of 7.5 kg/m^2 were harvested. The control treatment produced less marketable than unmarketable fruit (47% vs. 53%) showing the result if no calcium is applied. The treatment with 3.75 mg/l calcium application produced more marketable than unmarketable (74% vs. 26%).

A treatment effect was observed with a phosphorus rate of 1.0 mg/l which increased the number of marketable fruit and the total biomass. A total of 32/m^2 marketable fruits with a mass of 7.4 kg/m^2 were harvested. The treatment with 1.00 mg/l phosphorus application produced more marketable than unmarketable. (64% vs.36%).

Conclusions

This project is continuing. A second trial is being conducted with a control and treatments of calcium at 3.75 mg/l, phosphorus 1.0 mg/l and a combined treatment of both calcium and phosphorus.

Groundwater Chemistry, Flowpaths, and Flux Rates in the Mangrove System Surrounding Bovoni Landfill Within the St. Thomas East End Reserve (STEER)

Basic Information

Title:	Groundwater Chemistry, Flowpaths, and Flux Rates in the Mangrove System Surrounding Bovoni Landfill Within the St. Thomas East End Reserve (STEER)
Project Number:	2013VI244B
Start Date:	3/1/2013
End Date:	3/31/2014
Funding Source:	104B
Congressional District:	VI-01
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Wetlands, Sediments
Descriptors:	None
Principal Investigators:	Kristin Wilson, Andrew Reeve

Publications

1. Wilson, Kristin, 2013, Stories from Coastal Wetlands Around the World: Marshes, Mangroves, and Mud, Invited talk, Bates College, Department of Geology, Lewiston, ME.
2. Wilson, Kristin, 2014, Stories from the Wells National Estuarine Research Reserve and Other Coastal Systems Around the World, Invited talk, Dickinson College, Department of Environmental Studies, Carlisle, PA.
3. Wilson, Kristin, 2014, Research Activities at the Wells National Estuarine Research Reserve from Maine to the US Virgin Islands, Invited talk, Maine Maritime Academy, Corning School of Ocean Studies, Castine, ME.
4. Wilson, Kristin, 2014, Mangroves in the Virgin Islands, Invited talk open to the public, Wells National Estuarine Research Reserve’s Lunch N’ Learn Program.

Groundwater Chemistry, Flowpaths, and Flux Rates in the Mangrove System Surrounding the Bovoni Landfill Within the St. Thomas East End Reserve

Problem and Research Objectives

The St. Thomas East End Reserve (STEER) includes 9.6 km^2 of "significant coastal, marine and fisheries resources" on the southeastern end of St. Thomas. Mangrove Lagoon, within STEER, contains the island's largest intact stand of mangroves and is considered one of St. Thomas' most important fish nurseries and eco-tourism locations. Bovoni Landfill, an unlined landfill in operation since 1979 and under consent decree for non-compliance since 2012, abuts Mangrove Lagoon on the western edge of STEER. Preliminary results of the chemical contaminant and bioeffects assessment in sediments at 24 locations within STEER by the National Oceanic and Atmospheric Administration (NOAA) reveal consistently higher levels of contaminants (polycyclic aromatic hydrocarbons, polychlorinated biphenyls, total extractable hydrocarbons, tributyltin, chromium, cadmium, lead, mercury, nickel and zinc) within Mangrove Lagoon compared to other sampled areas within STEER. However, because of the stratified random design of the sampling scheme, the source(s) of these contaminants remain unclear (Tony Pait, NOAA, pers. comm., STEER Core Planning Committee, 9/3/2012). Furthermore, apparent loss of mangroves adjacent to Bovoni Landfill assessed from aerial imagery from 2002-2013, are of management concern (Anne Marie Hoffman, The Nature Conservancy (TNC), pers. comm).

This pilot study (1) measures groundwater chemistry and flowpaths across the mangrove system adjacent to Bovoni Landfill within Mangrove Lagoon and STEER (Figure 1), and (2) trains one graduate student from University of the Virgin Islands (UVI; Jessica Keller) in aspects of geology. Results will be shared with STEER, Virgin Islands Waste Management Authority (VIWMA), Department of Planning and Natural Resources (DPNR), and the Environmental Protection Agency (EPA).

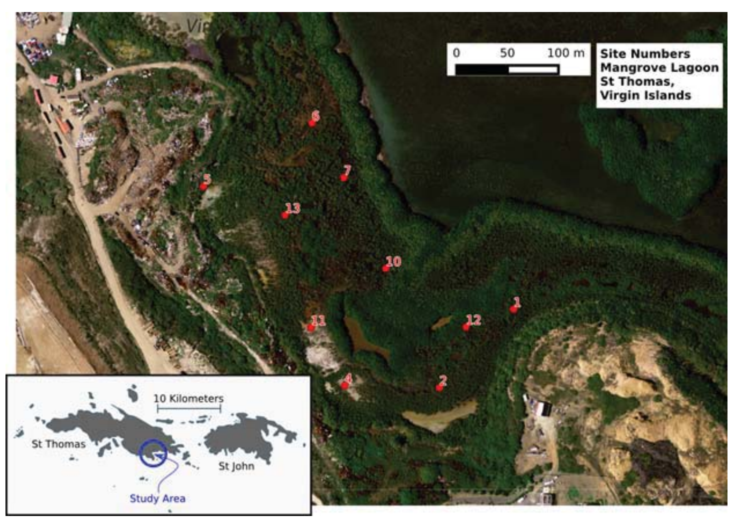

Figure 1. Location of study area and position of well clusters in the mangrove fringe adjacent to Bovoni Landfill. Well locations and site numbers are indicated with red dots and adjacent numbers. Each site includes both a shallow (5 ft.) and deep (10 ft.) well, except for site 7 which just includes a shallow well. Orthophotographs from U.S. Geological Survey (http://cumulus.cr.usgs.gov) published Dec. 2010.

Methodology

From January 5-11, 2014, we installed 19 groundwater wells in 10 locations (Figure 1) spread across the mangrove fringe adjacent to Bovoni Landfill. Wells were constructed from 2.54 cm nominal diameter flush threaded PVC pipe with 30 cm machine slotted screens. For all sites except 7, both a shallow (5 foot total length) and deep (10 foot total length) well were installed and developed on Jan. 7-8, 2014. Nineteen non-vented data logging pressure transducers (Solinst leveloggers) were deployed (one per well), along with one barometric pressure sensor to correct for changes in atmospheric pressure (site 11). All data loggers were downloaded (and re-started) on January 9 to make sure they were functioning correctly. Data loggers have since been downloaded and are working properly (late January, Keller) with the exception of the data logger in the deep well at site 6.

Four wells were surveyed using a Trimble NetR9 global positioning system (GPS) with Zephyr II geodetic antenna to establish the absolute position of the wells and provide reference points for manual surveying. The GPS data were post-processed using the GPS Precise Point Positioning internet service operated by Natural Resources Canada, Geodetic Survey Division. All wells (top of pipe) were manually surveyed using an automatic level and stadia rod to determine the relative elevation differences between wells and GPS coordinates for all wells were recorded with a hand-held GPS unit.

The depths to water in monitoring wells were manually measured on February 13 and March 6, 2014 using an electrical water-level indicator to characterize spatial patterns in vertical and horizontal hydraulic gradients. These data were converted to hydraulic head by subtracting the measured water depths from the surveyed elevation of each well.

Water pressures were autonomously measured at 20-minute intervals using non-vented data logging pressure and temperature sensors installed in all wells. These data were converted to water levels (height above sensor) by subtracting atmospheric pressure, recorded using a separate barometric pressure sensor, from the total water pressure and then correlating the sensor measurements to manual hydraulic head measurements.

Water samples were collected from shallow and deep wells at sites 1, 2, 4, 5, and 11 using a hand vacuum pump fitted to an erlenmeyer flask. These well clusters were chosen for initial water chemistry analyses because of their relative proximity to the landfill compared to other well sites. Samples were collected from wells, decanted into 60 ml plastic containers, and placed in a cooler on ice. Two surface water samples, one at site 5 and the other in a ditch adjacent to the landfill, were collected by directly dipping the 60 ml plastic container into standing water. Surface water at site 5 was collected because of a recorded “chemical smell” when flushing the well during installation (K. Wilson, field notes, January 2014).

Specific conductance and pH were measured using electrical probes in all water samples on the same day they were collected (January 9, 2014). Specific conductance (or salinity) of surface water at different sites were measured in the field as well. All water samples were transported to the Sawyer Environmental Chemistry Laboratory at the University of Maine, filtered (0.45 micrometer), and analyzed for total dissolved nitrogen, lead, zinc, tin, nickel, copper and chromium. Heavy metals analysis was performed using Inductively Coupled Plasma Atomic Emission Spectroscopy and nitrogen was analyzed using an ALPKEM flow solution IV autoanalyzer.

At four sites (1, 2, 5 and 7), we installed a vertical array of four thermochron 'i-button' temperature sensors to record daily temperature fluctuations to infer shallow groundwater flow (Anderson, 2005). I-buttons were deployed on February 2014 for a 13-day period. Vertical groundwater flow rates were estimated from this temperature data by fitting a one-dimensional heat transport model to the data. This one-dimensional heat transport model was based on the explicit finite-difference method with upwind difference method used for the convection term (Jaluria, 1996). This computer model simulates the conduction, convection, and dispersive transport of heat. Fixed temperature boundary conditions were assigned to the top (based on measured temperatures) and bottom of the model domain. The computer model was created using the Python scripting language (van Rossum and Drake, 2001), and calibrated to field data using the L-BFGS-B algorithm (Zhu et al., 1997) available in the Scipy computational library (Jones et al., 2001).

To place the groundwater measurements within a geophysical context we collected nine, 1-2 m Eijkelkamp "Dutch" hand-auger cores at all sites except site 12. Cores were not collected at site 12 because the sediment was so wet that material was lost from the bottom of the core barrel and was unable to be retrieved. Cores were brought back to the lab and archived for future analyses by UVI graduate student, Jessica Keller for her Masters thesis (beyond the time frame of this pilot study).

Principal Findings and Significance

Sediment Cores: Preliminary observations in the field reveal more inorganic clay-rich sediment in cores collected closer to the landfill with increasing organic-rich peats dominating cores collected further from the landfill. UVI graduate student, Jessica Keller, will describe these cores as part of her Masters' thesis (beyond the time frame of this pilot study).

***Groundwater Hydrology*:** Hydraulic head data (Figure 2) indicate shallow groundwater flows toward the center of the mangrove swamp, where open water occurs. Hydraulic head measured in deeper wells indicated flow toward the southern portion of the wetland (toward wells 2 and 4), and outward toward the ocean. The majority of the sites have upward hydraulic gradients, indicating groundwater is discharging to the mangrove swamp. Temperature data recorded at depth of 7 cm, 14 cm and 21 cm indicate a rapid damping of the diurnal temperature signal with depth. These data were best fit to a one-dimensional heat transport model when upward velocities were used to simulate the advective component of temperature transport. Upward velocities used to fit the heat transport model to the temperature data ranged from 7.1×10^{-6} to 1.7×10^{-5} m/sec.

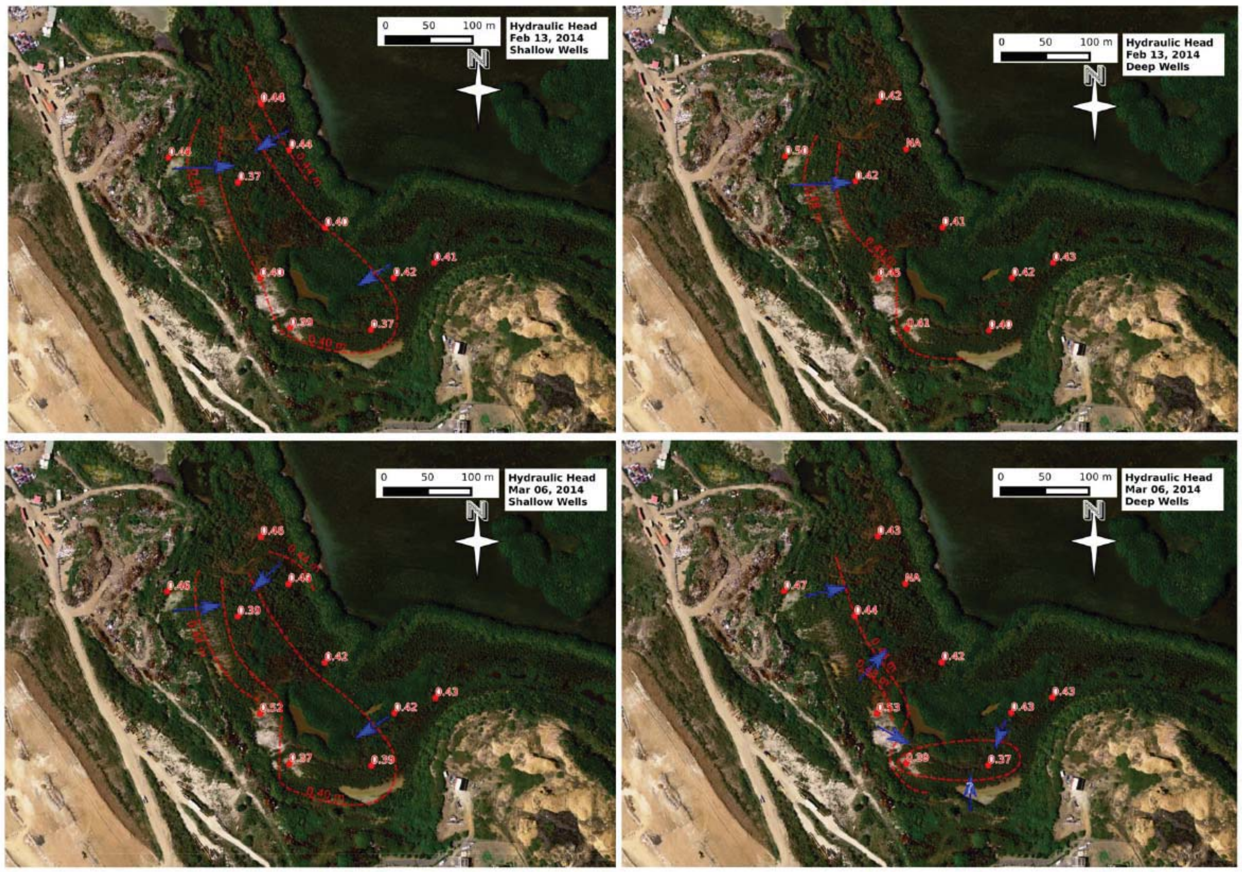

Figure 2. Hydraulic head measurements (red numbers) for shallow and deep wells from Feb. 13, 2014 and Marc. 06, 2014. Equipotentials (dashed red curves) and flow directions (blue arrows) interpreted from the hydraulic head data are superimposed on the well data. Orthophotographs from U.S. Geological Survey (http://cumulus.cr.usgs.gov) published Dec. 2010.

Time series water level data recorded at 20 minute intervals display a monthly signal, with a rapid increase in water levels followed by a month-long decline in water level. Data archived for the Bovoni Weather Station by Weather Underground (www.wunderground.com) indicate rainfall amounts exceeding 0.2 inches on January 12, 2014 (0.22 in) and February 22, 2014 (0.68 in). Predicted ocean tidal range peaked on January 13, 2014 (-0.4 to 0.8 ft), January 29, 2014 (-0.4 to 1.0 ft), February 11, 2014 (-0.4 to 0.7 ft), and February 26, 2014 (-0.3 to 0.9 ft). Rapid increases in water levels were recorded in data logging pressure sensors on January 28, February 22, February 26, 2014 indicating that rapid influx of water into the mangrove swamp occurs during the highest tides and during high rainfall events. These rapid changes in water level suggest the mangrove swamp is hydraulically isolated from the ocean.

Slow recovery of water levels in many of the wells (2 deep, 4 shallow, 5 shallow, 11 deep, and 13 deep) may be due to their installation in very low permeability sediment which is consistent with preliminary observations of geologic cores. Alternatively, the well screens may have become clogged with sediment despite efforts to scrub them and surge water into the well to clear sediment from the screen. Applying the Hvorslev method and assuming a 37% recovery of water over one day in a 2.5 cm diameter well with a 30 cm long screen results in a hydraulic conductivity of about 10^{-8} m/sec. This low hydraulic conductivity material (consistent with values for silt or clay), where present, will limit the rate of groundwater exchange with the mangrove swamp system.

***Water Chemistry*:** Surface water salinities varied across the study area from mesohaline at site 5 to metahaline at sites 2 and 7 (Table 1). Specific conductance varied from 7.3 (mS/cm) in the surface ditch to 101.2 (mS/cm in the site 5 deep well (Table 1). Samples varied in pH from 6.60-9.09 (Table 1). The surface ditch and site 5 shallow well were more basic than other sampled sites.

			Dissolved Metals								
		TDN	Cu	Cr	Ni	Pb	Sn	Zn	pH	specific conductance	salinity
Sample ID	Date	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	std.units	mS/cm	psu
Reporting Limit	-	0.1	100	20	40	80	100	40			
Site 1 Shallow	1/9/2014	6.21	<RL	35.5	<RL	<RL	<RL	<RL	6.65	71.7	
Site 1 Deep	1/9/2014	4.45	<RL	39.2	<RL	<RL	<RL	<RL	6.70	70.3	
Site 2 Surface	1/9/2014										42.7
Site 2 Shallow	1/9/2014	14.1	<RL	47.1	<RL	<RL	<RL	<RL	6.70	90.0	
Site 2 Deep	1/9/2014	4.71	<RL	41.7	<RL	<RL	<RL	<RL	6.93	86.9	
Site 4 Shallow	1/9/2014	4.94	<RL	23.4	<RL	<RL	<RL	<RL	7.46	58.6	
Site 4 Deep	1/9/2014	5.14	<RL	30.9	<RL	<RL	<RL	<RL	6.60	72.3	
Site 5 Surface	1/9/2014	20.9	<RL	37.3	130	<RL	<RL	67.7	9.09	12.9	5.1
Site 5 Shallow	1/9/2014	--	<RL	33.5	82.2	<RL	<RL	<RL			
Site 5 Deep	1/9/2014	15.0	<RL	51.7	<RL	<RL	<RL	<RL	6.75	101.2	
Site 7 Surface	1/9/2014										47.2
Site 10 Surface	1/9/2014										32.5
Site 11 Surface	1/9/2014										35.1
Site 11 Shallow	1/9/2014	15.2	<RL	47.1	<RL	<RL	<RL	<RL	6.92	84.6	
Site 11 Deep	1/9/2014	9.75	<RL	35.4	<RL	<RL	<RL	<RL	7.41	74.0	
Surface Ditch	1/9/2014	120	<RL	74.5	99	<RL	105	<RL	8.02	7.3	
Filter Blank	--	<0.05	<RL	<RL	<RL	<RL	<RL	<RL			

Table 1. Water chemistry data from surface water, shallow, and deep wells from select sites.

Total dissolved nitrogen (TDN) concentrations ranged from 120 mg/l in the surface ditch at the edge of the Bovoni Landfill to 4.45 mg/l in the deep well at site 1 (Table 1). The site 2 shallow well, site 5 surface water and deep well, and site 11 shallow had TDN concentrations ranging from 14.1-20.9 mg/l, which were much lower than the surface ditch, but greater than other sampled wells (Table 1).

Most samples contained heavy metal concentrations below analytical detection limits (Table 1). Nickel was measured at site 5 deep (82.2 ppb), 5 shallow (82.2 ppb), 5 surface water (130 ppb), and in the surface ditch adjacent to the landfill (99 ppb). Zinc was detected in the water sample collected at site 5 surface (67.7 ppb). Tin (99 ppb) was detected in the surface ditch water sample. Chromium concentrations were above reporting limits at all sites and ranged from 23.4 to 74.5 ppb, with the highest concentrations measured in samples collected at site 5 deep and 5 surface.

Conclusions

Water levels within the mangrove fringe were lower at its center, indicating that surface waters and shallow groundwater move toward the center of the study area. These low water levels suggest the mangrove swamp is isolated from the ocean by the thin strip of land visible in the aerial images, and that evaporation within the swamp is lowering water levels. This process may also be partly responsible for the discharge of groundwater to the lagoon. We hypothesize that this may be one mechanism resulting in the standing dead mangrove and open-water and muddy areas observed to occur within the mangrove fringe. Additional monitoring and measurements are needed to better understand this potential mechanism.

Groundwater discharge is likely also driven by groundwater mounding beneath Bovoni Landfill and other uplands adjacent to the mangrove swamp. The difference in hydraulic head between an upland and wetland (or surface water) system commonly drives groundwater discharge near the break in hydraulic gradient near the interface between the upland and surface water system. Despite strong evidence for groundwater discharge, supported by both hydraulic head and temperature data, the low hydraulic conductivity of silty sediments in portions of the mangrove swamp may limit the volume of groundwater that flows into the study area. Future work should include analyses of the geologic cores collected and archived in January 2014 to better understand the geophysical context and to assess potential stratigraphic control of groundwater flow paths.

Groundwater chemistry data suggest that site 5 receives runoff with elevated concentrations of heavy metals and nutrients. High concentrations of heavy metals and total dissolved nitrogen were not measured in the deeper groundwater wells, suggesting groundwater is not an important pathway for heavy metal and nutrient to the mangrove swamp from nearby sources. However, water chemistry data from surface samples and shallow wells indicate that surface discharge is likely the most important pathway for contaminants to enter the mangrove swamp. Future work should include additional water chemistry sampling with greater spatial and temporal resolution throughout the mangrove wetland and surrounding areas.

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Correlating Precipitation Patterns and Erosion Indicators Across the St. Thomas Microclimates

Basic Information

Title:	Correlating Precipitation Patterns and Erosion Indicators Across the St. Thomas Microclimates
Project Number:	2013VI245B
Start Date:	3/1/2013
End Date:	3/31/2014
Funding Source:	104B
Congressional District:	
Research Category:	Climate and Hydrologic Processes
Focus Category:	Water Quantity, Sediments, Models
Descriptors:	None
Principal Investigators:	David C Morris, Donald M Drost, Michael L Larson, Avram Gerald Primack, Raymond Torres

Publications

1. Ramsundar, Arianne and Morris, David, 2013 Rainfall Patterns on St. Thomas,2013 Ana G. Mendez University System Research Symposium, San Juan, Puerto Rico.
2. Ramsundar, Arianne, David Morris and Avram Primack, 2013, Rainfall Patterns on St. Thomas, Poster presented at Fifteenth Annual Fall Student Research Symposium, University of the Virgin Islands, St. Thomas, VI. (September 29, 2013).
3. Simmons, Kwame and David Morris, 2013, Examining Rainfall and Temperature Changes on St. Thomas, Poster presented at Eleventh Annual Summer Student Research Symposium, University of the Virgin Islands, VI. (July 26, 2013).

Correlating Precipitation Patterns and Erosion Indicators Across the St Thomas Microclimates

Problem and Research Objectives

Accurate and precise rainfall data with high spatial and temporal resolution are critical to a broad spectrum of public sector, private sector, and academic projects of great interest to Caribbean prosperity, yet such data are presently lacking in the USVI. Residential water supply construction (cisterns), drainage planning for public works projects, and environmental erosion studies, to name only a few applications, all rely on an accurate understanding of the actual and predicted rainfall rates at varied sites around the USVI. While historical data are available online through the US Geological Survey website, these data are, themselves, derived from only a few collection sites around the VI and are now some 20-40 years old. As global climate change drives variation in weather patterns across the Caribbean, it is critical to the next generation of construction and development planning in the USVI to rebuild and maintain a modern, high-resolution precipitation database that accurately portrays the current microclimate conditions across the region. Similar data are available across urban and rural areas throughout the continental US and should be made available as well in the USVI.

We have capitalized on work already completed and investment already made by extending operations of the sensor network and enhancing its data products.

Methodology

The rain gauge stations include a Hydreon Optical Rain Sensor (model RG-11) together with a Davis Vantage Vue weather sensor suite. Students Leo Jobsis, Kwame Simmons, and Arianne Ramsundar worked throughout the summer of 2013, funding through this grant as part of UVIs Emerging Caribbean Scientists (ECS) Program to install and maintain weather stations, collect data, and analyze results. Though the full suite of weather stations has not yet been installed due to delays in receiving permission from the required number and variety of suitable locations for installation, 7 stations have been installed and are collecting data while the remaining stations are being installed currently.

Erosion measurement data has been recorded through the use in-field sampling techniques. Student Leo Jobsis visited several sites cospatial to the rainfall instrumentation to collect soil samples for analysis in the lab. Comparison and correlation of the variation in rainfall across the local microclimates with the differences measured in the lab in soil composition are ongoing.

Principal Findings and Significance

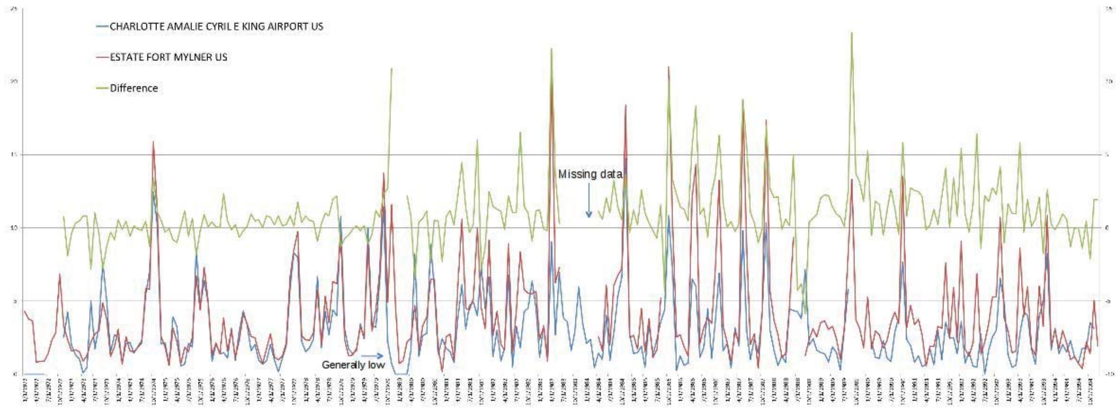
The main findings of this project have been detailed in reports presented at both the local UVI ECS research symposium and at the 2013 Ana G. Mendez University System (AGMUS) Research Symposium in San Juan, Puerto Rico.

Among the results of this work are:

1) Preliminary comparisons of the historical rainfall rates at the St Thomas East End Reserve to current rainfall rates measured in this region (the East End was chosen for this study because it had the most consistent historical data archive as well as one of the earliest installed WRRI-funded weather stations. These early results show general agreement between average seasonal rainfall amounts between the 2013-2014 operational seasons and the historical data, with allowances made for unique and unusual rainfall events (hurricanes). The one marked discrepancy between rainfall data in the current 2013-2014 period and historical data is a relatively wet summer, followed by a relatively dry hurricane season. Addition years of data will be required to determine the statistical significance of any perceived changes in these preliminary data. Nevertheless, the precision and regular collection intervals of the current data demonstrate the power of the newly established weather monitoring network.

Temperature comparison between weather stations at the St Thomas East End (Red Hook) and from the Airport region. Record of highs and lows show evidence for a modest continental effect believed to be produced from warming of airmasses by the St Thomas landmass as they cross the island (from Simmons and Morris, 2013).

2) Preliminary comparisons of cross-island weather differences. Weather monitoring stations installed at the East End of St Thomas (located at the Coral World Theme Park) and the West End (located at the Botany Bay Private Home Community) demonstrate marked differences in weather characteristics over a geographic span of only some 10 miles despite a difference in elevation of only about 200m. Data collected at these two locations appear to show evidence for continental weather effects on the small scale. Temperature patterns recorded at the West End (downwind of the prevailing Easterly winds) show generally higher high temperatures and lower low temperatures than do those recorded at the East End. Warming of the western flowing airmass at it crosses the landmass of St Thomas seems the most likely explanation for this noted trend. Further analysis is ongoing to confirm this interpretation.



Rainfall comparison between historical weather stations on St Thomas from the period spanning 1972-1994. As the current weather network baseline increases, we will be able to compare frequency of extreme events as well as search for global trends (from Ramsundar and Morris, 2013).

3) Analysis of soil characteristics at various locations in the Magen's Bay area of St Thomas were performed as a proof-of-concept technique for further future analysis of erosion characteristics associated with rainfall measurements at the location of the installed weather stations and rainfall monitoring equipment. Analysis of the Magen's Bay sites demonstrated that in-lab analysis techniques were able to identify differences in soil characteristics including clay content, water content, and organics content.

Objectives and Progress

Short-term objectives - make rainfall data available to the public in well-documented form for use in scientific, private, and public sector projects:

Rainfall and weather data from a network of weather stations is connected to a publicly accessible Davis Instruments Inc. cloud archive. These data are accessible by researchers across the scientific community. Locally, graduate students in the UVI Center for Marine and Environmental Science (CMES) center have already begun to take advantage of these new data. Graduate student Moriah Sevier is accessing these data to correlate rainfall and erosion rates with measurements of Seafan coral disease that she has measured through an in-situ observation campaign.

Long-term objectives - The PI and Co-Is pursue scientific objectives including:

• A study of the variation of rainfall rates within a single Doppler radar pixel to validate meteorological ”ground-truth” models – graduate student Pedro Nieves has made progress in developing a method of comparing radar images to rainfall point measurements. He continues work on incorporating a rainfall layer into the UVI GIS database (advised by Primack).

Remaining Tasks and Research Elements

Continuation of weather station operation to maintain island-wide network. Complete analyses begun as noted above. Collaboration with Co-I Larsen on scale-invariance of Caribbean rainfall events.

Conclusions

The results presented above are only the beginning of an ongoing monitoring campaign made possible through WRRI funding. Preliminary results have already confirmed some anecdotal expectations; The most recent annual seasons on St Thomas have agreed on gross average with historical weather patterns, but have disagreed on the more precise timing of rainfall events (the past season showed a wetter summer but drier hurricane season than usual). It is impossible to draw broad conclusions from such a short data collection timescale on questions of such long-term significance but the presence of the newly installed weather station network provides the infrastructure necessary to continue and expand these studies in coming years to build a more robust archive of weather pattern data more appropriate for answering the broader critical questions of how historical weather patterns may be changing in the current environment in the Caribbean.

Information Transfer Program Introduction

There were no projects in the 2013-2014 VI-WRRI program that were specifically dedicated to information dissemination or training. However, all investigators were strongly encouraged to use all possible opportunities to share the results of their investigations with the public by publishing their findings, presentations at conventional conferences and also through the several seminars, workshops, group presentations and similar activities that take place on a regular basis at the University of the Virgin Islands.

A recent focus at the University of the Virgin Islands has been recruitment of students into the science, technology, engineering and mathematics (STEM) disciplines. The water resources research projects have been active in this effort as witnessed by the number of undergraduate students who have participated as research assistants and received exposure and training in the 2013-2014 WRRI program.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	19	0	0	0	19
Masters	7	0	0	0	7
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	26	0	0	0	26

Notable Awards and Achievements

Publications from Prior Years