Puerto Rico Water Resources & Environmetal Research Institute Annual Technical Report FY 2015

Introduction

Introduction

The Puerto Rico Water Resources and Environmental Research Institute (PRWRERI) is located at the Mayagüez Campus of the University of Puerto Rico (UPRM). The Institute is one of 54 water research centers established throughout the United States and its territories by Act of Congress in 1964 (P.L. 88-379) and presently operating under Section 104 of the Water Research and Development Act of 1984 (P.L. 98-42), as amended. The Puerto Rico Water Resources Research Institute was established in April 22, 1965, as an integral division of the School of Engineering at the College of Agricultural and Mechanic Arts, the official name of UPRM at that time. An agreement between the Director of the Office of the Water Resources Research Institute of the Department of the Interior and the University of Puerto Rico at Mayagüez was signed in May 25, 1965. This agreement allowed the Institute to receive funds as part of the Water Resources Act of 1964. In June 1, 1965, the Chancellor of the Mayagüez Campus appointed Dr. Antonio Santiago-Vázquez as the first director. The first annual allotment of funds for fiscal year 1965 was $52,297.29.

Since its inception 51 years ago, the Institute has had eight directors in nine appointment periods as shown in the list below.

No. Name Period of Appointment Years in Appointment 1 Dr. Antonio Santiago-Vázquez 1965 – 1968 4 2 Eng. Ernesto F. Colón-Cordero 1968 – 1972 4 3 Eng. Felix H. Prieto-Hernández 1972 – 1974 2 4 Dr. Roberto Vázquez (acting director) 1974 – 1975 1 5 Dr. Rafael Ríos-Dávila 1975 – 1980 5 6 Dr. Rafael Muñoz-Candelario 1980 – 1986 6 7 Eng. Luis A. Del Valle 1987 – 1989 2 8 Dr. Rafael Muñoz-Candelario 1989 – 1994 5 9 Dr. Jorge Rivera-Santos 1995 – Present 21

The official name of the Institute was changed in 2005 to Puerto Rico Water Resources and Environmental Research Institute.

The general objectives of the Puerto Rico Water Resources and Environmental Research Institute are (1) to conduct research aimed at resolving local and national water resources and environmental problems, (2) to train scientists and engineers through hands-on participation in research, and (3) to facilitate the incorporation of research results in the knowledge base of water resources professionals in Puerto Rico and the U.S. To accomplish these objectives, the Institute identifies Puerto Rico's most important water resources research needs, funds the most relevant and meritorious research projects proposed by faculty from island high level education institutions, encourages and supports the participation of students in funded projects, and disseminates research results to scientists, engineers, and the general public.

Since its creation, the Institute has sponsored a substantial number of research projects, supported jointly by federal, state, private, and University of Puerto Rico's funds. Through its website, the Institute's work is more widely known to the Puerto Rican and world communities and, at the same time, provides means of information transfer with regard to the reports produced through the institute's research activities.

The Institute is advised by an External Advisory Committee (EAC) composed of members from water resources related government agencies, both federal and state levels. This committee virtually convenes annually to established research priorities and to evaluate and recommend proposal for funding under the 104-B program. The EAC has representation from the private sector as well. During EAC meetings, members are supported by the Institute’s Director and Associate Director. Due to recent retirement of some of the members and continues changes in government directorate officials, the Institute’s Director is engaged in recruiting new members for next fiscal year. New agency representatives that may participate in the EAC include the PR Department of Natural and Environmental Resources (PRDNER), Federal Emergency Management Agency (FEMA), US Fish and Wildlife Service (FWS), and US Army Corps of Engineers (CoE).

Research Program Introduction

The Institute functions as a highly recognized advisor to the industry and government sectors on water resources and environmental issues. This role translates into multidisciplinary functions and activities that add relevance and impact to the research program the Institute supports. By virtue of the local relevance of its research and the prestige and leadership of the investigators it has supported, the Institute has become the focal point for water related research in Puerto Rico.

FY-2015 104-B base grant supported three projects, one continuing, one new and one technology transfer project. The continuing project, by PIs from our home campus, started in FY 2013. The project titled “Feasibility of sintered recycled glass functionalized with micro- and nanosized TiO2 particles for the degradation of trihalomethane precursors from surface waters,” is aimed at the development and implementation of a low cost pre-oxidation alternative made of sintered recycled glass functionalized with anhydrous titanium (IV) oxide powder (TiO2) for the degradation of non-organic matter (NOM) in raw waters for the control of trihalomethanes (THM’s). To accomplish such goal, the project is divided in three main parts: (1) structural evaluation of the glass/TiO2 composite in order to determine porosity and percolation rates; (2) mechanical analysis to determine compression characteristics of the composite; and (3) to evaluate the efficacy of the composite in degrading NOM under the influence of UV light for the photo-catalytic reaction. The project has produced essential data and information that set the foundations for a novel process in the degradation of THM’s precursors, and as a consequence, minimize THM’s formation in drinking water.

The second project is titled “Mapping Field-Scale Soil Moisture Using Ground-Based L-Band Passive Microwave Observations in Western Puerto Rico.” This is a new project also by PIs from our home campus. The proposed project length is three years, corresponding to three phases. Only first year was approved and funded. Other year phases are conditioned to demonstrated adequate performance and submission of a new proposal. In the first phase, the CREST L-band microwave observation unit will be used to establish 3 temporal soil moisture observational sites in Western Puerto Rico. The selected sites (Mayagüez, Lajas, and Isabela) are part of the Agricultural Experiment Station program and are under the footprint of the Puerto Rico Weather Radar Network. The radar network will provide the sites with a cohesive weather/climatological data sets. The main objective of this project in the first phase is to generate a data sets for calibration and validation activities of the upcoming NASA Soil Moisture Active Passive (SMAP) mission. As well, this research aims, to investigate the spatiotemporal variability of soil moisture in a field-scale area with a particular focus on the analysis of the effect land surface heterogeneity(important over tropical domains) on the retrieval of soil moisture from L-band passive microwave observations. The second and third phases, will expand over phase one and will focus on characterization of crop canopies and water stress related phenomena using microwave remote sensing methods. The results of this research will promote and open new areas research in Puerto Rico (i.e. Unnamed Aerial Vehicle Crop health monitoring). To our knowledge, this study constitutes the first attempt to study, in the Caribbean, the performance of soil moisture retrievals using passive microwave observations form a ground-based L-band radiometer that mimics the upcoming NASA Soil Moisture Active Passive (SMAP) mission that was launched in 2015.

A third project aimed at the transfer of technology among researcher doing work on tropical island water resources sustainability issues. The 2015 conference built on discussions and interactions from a previous conference hosted by the Island Institutes (WRRC, WERI, PRWRERI, and VI-WRRI) in Honolulu, Hawaii, from November 14–16, 2011. The intention of these discussions was to strengthen the synergism between researchers from various island and to develop solutions and ideas on water resources issues that are particularly relevant to tropical islands. The conference lasted for three days and was held from December 2-4, 2015 with poster and oral special sessions.

During FY2014, a new relationship was initiated with the PR Planning Board and resulted in a funded project. This government agency, among other responsibilities, is in charge of receiving, analyzing and resubmitting all hydrologic-hydraulic studies for flood plain delineations and modifications according to FEMA's regulations. A professional service contract issued to hire the Institute to provide expertize advice for the analysis of such study reports and submit comments about the correctness and appropriateness of such reports.

Continuing collaboration with the Puerto Rico Department of Natural and Environmental Resources (PRDNER) has resulted in various externally funded projects. The PRWRERI finished and submitted the "Hydrologic and Hydraulic (H-H) Studies Guidelines" for urban development projects, water body channelization and other engineering projects requiring an H-H study. This project consisted in the evaluation of current engineering practices for conducting hydrologic and hydraulic studies in the Island. The new guidelines included two reports, namely, "Hydrologic and Hydraulic Study Guidelines: Technical Manual" and "Hydrologic and Hydraulic Study Guidelines: Practice Handbook." Although the guidelines were prepared for the PRDNER use, the Planning Board evaluated and adopted its use for the agency's purposes of the flood control division. As a consequence, all H-H studies developed in Puerto Rico have to follow these guidelines in order to be admitted for consideration by these agencies.

A second part of this project has been approved for the development of guidelines for the hydrologic and hydraulic studies required for sand and gravel extraction operations in rivers in Puerto Rico. The products of this project will influence the DNER's decision making process related to the approval of new housing developments and other type of projects that affect natural water bodies.

The Institute continued seeking research funds through the submission of research proposals to federal agencies.

The Total Microbial Community Structure and Enterococci Population Dynamics During a “recent fecal contamination event” in Seawater samples of Puerto Rico

Basic Information

Title:	The Total Microbial Community Structure and Enterococci Population Dynamics During a “recent fecal contamination event” in Seawater samples of Puerto Rico
Project Number:	2013PR160B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	PR098
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Ecology
Descriptors:	Enterococci, fecal pollution
Principal Investigators:	Luis A Rios-Hernandez

Publications

There are no publications.

Annual Report PRWERI 2016

Title: **The Microbial Population dynamics and total community structure during a "recent fecal contamination event" in seawater samples of Puerto Rico.**

PARTICIPANTS

A) What people have worked on your project?

Name	Role	Time	Task
Luis A. Rios-Hernandez	Researcher	Fall 2015-now	Cultivation, enumeration, Mixtures, analysis
Jomar Medina	Undergrad researcher	Summer 2015	Marine samples

Name	Gender	Ethnicity	Race	Disability	Citizenship
Luis A. Rios-Hernandez (PI)	Male	Puerto Rican	white	No	US
Jomar Medina	Male	Puerto Rican	white	No	US

B) **What other organization have been involved as part of the project?**
Due to all the limitations, especially and most importantly the budget cut (more than 50% from original proposed work), I was obligated to modify the scope of the project. As I came to terms with the budget limitation, the lack of graduate students on this grant, and my sabbatical I decided to take some of the samples to the University Of Gdansk in Poland (Sabbatical Institution) where I performed part of the analysis.

C) Have you had other collaborations or contacts? None regarding this modified project.

ACTIVITIES AND FINDINGS

A) DESCRIBE THE MAJOR RESEARCH AND EDUCATIONAL ACTIVITIES.

In this occasion the educational activities are limited to training an undergraduate student to collect the marine samples and transport them to the lab. From that point I did the rest of the analysis: filtrations, enumerations, identification, mixtures and analysis. It must be clear that the original conditions agreed at the time of submission of this proposal were not the same as those at the moment of granting it. The PI was obligated to dramatically modified the scope of the project and was able to partially fulfill the original proposed work during his sabbatical.

B) DESCRIBE MAJOR FINDINGS RESULTING FROM THE ACTIVITIES.

Currently, we analyzed the population of viable enterococci at a beach in Mayaguez Puerto Rico during the morning and late afternoon at the shore and 100ft from shore in three sites. Furthermore, a limited number of selected isolates were further characterized by molecular analysis to describe the predominant pheromone responsive plasmids and the addiction modules present in the samples.

1) The population densities vary during the day; typically the morning (deep or shallow) has less viable enterococci regardless of the site (A, B, C).
2) The beach isolates do not have a diverse number of pheromone responsive plasmids as observed in clinical samples.

3) The most prevalent pheromone responsive plasmid within the Enterococci isolated in Puerto Rico is of the family pCF10 (Rep 9, regardless of environment isolated).
4) The most abundant addiction module in our isolates (regardless of the environment which was isolated from) belongs to the ω-ε-ζ family.
5) Beach isolates from Puerto Rico contain less PRP per cell than clinical isolates reported in the literature.

MATERIALS AND METHODS

1. The enumeration of enterococci from marine water, waste water treatment plant, and fecal samples.
The marine samples were be collected twice a day at 0800 hrs and 1650hrs, at the shore (ankle deep) and 100ft from shore (deep) in three different sites within the same bay. We have chosen the Mayaguez bay as our study site. The liquid samples from the beach were collected in triplicates using 250 ml sterile bottles leaving a head space for homogenization at the laboratory. In all cases a field blank containing 100 ml of sterile dH_2O will be used as a negative control during sampling. The **liquid samples** were mixed vigorously by hand for approximately 30 seconds and (30, 10, or 5 milliliters depending on sample and possible dilution) passed through a sterile 0.45µm nitrocellulose filter, rinsed once with 25 ml of sterile phosphate buffer saline (50 mM PBS, pH 7) and the filters were be placed on a petri dish containing mE agar (Difco). The plates were incubated at 41°C for 48 hrs, and then the colonies were counted using a stereo microscope. All manipulations in the laboratory were done in a Bacteriological safety level two hood and following aseptic techniques. At least 10% of the isolates were collected and saved in glycerol stocks for further analysis.

2. To detect the presence of pheromone responsive plasmids among the population of Enterococci.
The selected enterococci isolates were grown from glycerol stocks overnight in BHI at 41°C. Next morning, 50 ul were transferred unto a 5ml tube containing fresh BHI and incubated for approximately 2 hrs or until an OD of 0.8 to 1 (600nm) was reached. The cells in 1 ml were resuspended in 500 ul of TE (10 mM Tris pH=7.2, 1M NaCl, 50 mM EDTA) and mixed with 2% agarose. Then place approximately 225 ul of the homogeneous mixture (per plug) into the plug maker and incubate at 4°C for 15 minutes. The subsequent lysis of cells and enzyme digestions were performed as described in Wardal *et al.* (2013). Briefly, a 3mm X 5mm plug was digested with S1 and loaded in a 1% agarose at 15°C with 0.5X TBE, 1 to 12S at $6Vcm^2$ with 120° angle for 18 hours. The gel was then stained with ethidium bromide for 20 minutes and destained for 30 minutes before visualizing it in a versa-doc system (Bio-Rad).

3. To identify the plasmids based on Reps and addiction modules.
The selected enterococci isolates were grown from glycerol stocks overnight in BHI at 41°C. Once grown, a loop full was resuspended in 500 ul of H_2O molecular grade, boiled for 5 minutes, and cooled immediately on ice for 5 minutes. The samples were centrifuged at max speed for 5 minutes and the supernatant was transferred to a new and sterile microcentrifuge tube stored at -20°C until used. The rep's were identified by PCR using the procedures of Jensen (2010), the interpretation is summarized in table 3. Addiction modules were identified by PCR products see table 4.

The presumptive enterococci status of the isolates was confirmed by a PCR method that targets the *tuf* gene (Ke et. al. 1999). All isolates that produce a PCR amplicon of the correct size will be consider an entericocci. Furthermore, the DNA samples of the identified isolates will be used as template to identify Rep's and addiction modules of selected isolates (ref).

RESULTS

The enumeration of enterococci from marine water: The samples were collected in a period of 70 days from May to July (2015). We sampled 10 days, twice a day for a total of 720 water samples. Table 1 shows the averages of the triplicates per site, location and time of day. Over all the A site contained less enterococci than sites B and C. Sites A and B behave similarly, comparing shallow (shore) versus deep (100ft from shore), the shore had higher densities of enterococci than the deep location (note: all samples were taken at the surface). Site C had the higher density of enterococci in both shallow and deep samples. Interestingly, the morning samples (AM) were frequently within parameters and the densities of enterococci increase at all location in the afternoons (PM) deep or shallow.

Identification and characterization of plasmids: We were able to determine that our environmental isolates contain pheromone responsive plasmids and describe them based on size, addiction module, and *rep* gene grouping. Furthermore we determined the diversity and frequency of plasmids present within our limited environmental isolates. Our results suggest that 33% of our isolates belong to the replication-initiation gene group 9 (Rep 9) by PCR (Jensen 2010) suggesting the presence of Pheromone Responsive Plasmids (PRP) from the pCF10/pAD1/pTEF2 family of plasmids (Table 3). Furthermore, the most abundant subgroup within the Rep 9 positive isolates (Wardal *et al.* 2013) was 9 sub pTEF2 (52%), 9 sub_G and 9 sub pCF10 both with (25%) (Table 5). In addition, the only toxin-antitoxin module that we found belongs to the ω-ε-ζ family and was present in 21% of the collection and 50% of the Rep 9 positive isolates.

DISCUSION

The regulatory agencies (EPA) suggest that the evaluation of recreational waters should be done early in the morning when the enterococci density is higher. Interestingly, in this study, we find the opposite, typically the waters contains lower enterococci densities in the mornings that in the afternoon. This fact brings interesting questions: How would analyzing beaches at the end of the day (after 4pm) or at night could limit human exposure to "contaminated" waters? Does an enterococci density accurately describe a potential public health problem? The enterococci are the best indicators to safeguard public health in a subtropical beach? These are the important questions that we still do not know the answers to, and we must! Our results suggest that the beach environment is highly dynamic and the enterococci densities vary drastically in a few hours. In our beach, we would only alert the public of a possible health risk (using the 104CFU/100ml parameter in the morning) in two occasions. While if we had done it in the afternoon, we would have alerted the public in six different occasions out of the 10 days sampled (in site C). This location in particular is impacted by a creek/river that influences the water quality. This location is typically more turbid (sedimentation) and contains more vegetative input (leaves, tree trunks, etc) which contribute to increase the organic matter/nutrients available within the seawater. This input alone might alter the natural carbon flow in the system triggering a higher density of enterococci than the ones entering the beach simultaneously in this site.

In an attempt to try to differentiate the enterococci in the beach samples and to try to predict their origins we looked at their pheromone responsive plasmids and addiction modules present in the population. Interestingly, only very few beach isolates (2/18) have PRP suggesting that only a limited number of isolates have a common origin with clinical isolates, since these genetic traits are strongly associated with clinical enterococci. Furthermore, these traits were also found in isolates obtain from farm animals (chickens and goats) complicating the possible identification of the origins of the population of enterococci within the beach samples. In addition, we can also identify these genetic traits in commensal isolates from fecal samples of healthy humans (F26, M20). These finding really complicate the interpretation of the origin of the enterococci, but it argues that these organisms are not limited to a particular host or environment, suggesting that they are highly mobile complicating the assessment of natural habitats.

The fact that all of our Rep 9 positive isolates only contain one addiction module seems to be unique to our isolates as compare to publish clinical literature. Interestingly, this stabilization system is typically associated with pRE25 (Rep 2, which was not present in our collection), or in pSL1 and stabilizing plasmids containing Vancomycin resistance in *E. faecium* (Moritz *et.al.* 2007). The relationship between the ω-ε-ζ system and the Vancomycin resistance was observed in 50% of the isolates positive for the stabilization system (3 clinical and 2 beach isolates, but in our case our isolates were *E. faecalis* (Table 5). None of these isolates were 9 Sub_pCF10 positive, not supporting the possibility of cross reaction with pTW9 (Wardal *et al.* 2013). Taken together, these results suggest that our PRP collection seem to be different than those reported in the literature, thus making them unique and worthy of further characterization.

In conclusion, we determine that in this location the enterococci density change in less than 12hrs (we got evidence that in beach samples the density could change in as little as 4hrs) and that the morning samples have less enterococci than the afternoon water samples. We also show that the "deep" (100 ft from shore) water samples contain less enterococci than the shore samples. In addition we gather evidence that supports the fact that simply enumerating enterococci to predict water quality in subtropical beach samples might limit our capacity to protect the public. Furthermore we found that enterococci isolated from natural environments contain traits similar to the traits that ill causing organisms contain, but in very limited numbers. We were able to find similar traits in clinical isolates as well as from fecal samples of farm animals (chickens and goats), as well as from healthy humans, and beach isolates. In fact, we were able to identify an isolate from a beach sample that it is identical (based on PFGE) to two isolates from clinical infections suggesting a common origin and that these organisms can travel between these two distinct environments (data not shown). How they are achieving this movement and in which direction still needs to be studied, but we could argue that it is possible that an anthropogenic route be the cause. Furthermore, our results suggest a limited diversity of Rep's and addiction modules in our samples that might support the hypothesis that they all have a common origin, but their combination seems to be unique for our geographical area. We need to further our research efforts to confirm these results and comprehend the ecology of the enterococci.

References

Jensen, L.B, L. Garcia-Migura, A.J.S. Valenzuela, M. Lohr, H. Hasman, and F.M. Aerestrup (2010). A classification system for plasmids from enterococci and other Gram-positive bacteria. J. Microbiol. Methods 80 p25-43

Ke, D., F. J. Picard, F. Martineau, C. Menard, P. H. Roy, M. Ouellette, and M. G. Brgeron (1999). Development of a PCR Assay for rapid detection of enterococci. J.Clinical Microbiol.37(11):3497-3503.

Moritz, E. M. and P. J. Hergernrother (2007). Toxin-antitoxin systems are ubiquitous and plasmid-encoded in vancomycin-resistant Enterococci. PNAS 104(1):311-16.

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Wardal, E., Gawryszewaska, I., Hryniewicz, W. and E. Sadowy. (2013). Abundance and diversity of plasmid-associated genes among clinical isolates of *Enterococcus faecalis*. Plasmid 70(3):329-42.

Table 1. Enterococci enumeration from Mayaguez Bay using the filtration method on mE.

Date	Time (24hr)	AO	AP	BO	BP	CO	CP	Blank
5/12/2015	8:00	35.52	12.21	6.66	0	8.88	2.22	0
5/12/2015	18:00	68.82	28.86	**140.97**	97.68	58.83	37.74	0
5/19/2015	8:00	24.42	7.77	34.41	7.77	64.38	35.52	0
5/19/2015	18:00	67.71	32.19	75.48	57.72	**215.34**	**212.01**	0
5/27/2015	8:00	28.86	14.43	22.2	19.98	**TNTC**	**TNTC**	0
5/27/2015	16:30	**972.36**	**190.92**	**412.92**	**501.72**	**TNTC**	**TNTC**	0
6/2/2015	8:00	11.1	1.11	1.11	29.97	73.26	53.28	0
6/2/2015	18:00	**TNTC**	**TNTC**	**TNTC**	**TNTC**	**TNTC**	**TNTC**	0
6/9/2015	8:00	55.5	4.44	31.08	35.52	19.98	24.42	0
6/9/2015	17:00	52.17	22.2	**118.77**	17.76	**256.41**	**224.22**	0
6/24/2015	8:00	**107.67**	27.75	72.15	**316.35**	**220.89**	**168.72**	0
6/24/2015	17:00	95.46	22.2	67.71	14.43	42.18	4.44	0
7/1/2015	8:00	39.96	8.88	32.19	54.39	25.53	**108.78**	0
7/1/2015	17:00	**678.21**	35.52	**157.62**	64.38	78.81	25.53	0
7/7/2015	8:00	29.97	1.11	22.2	23.31	36.63	17.76	0
7/7/2015	18:00	34.41	1.11	73.26	21.09	**119.88**	**261.96**	0
7/15/2015	8:00	21.645	0	**111**	25.53	7.77	3.33	0
7/15/2015	18:00	31.08	16.65	27.75	11.1	42.18	47.73	0
7/21/2015	8:00	**111**	0	39.96	1.11	26.64	8.88	0
7/21/2015	18:00	36.63	33.3	**214.23**	2.22	**461.76**	**338.55**	0

Enumerations represent the average of triplicates. Three different sites (A, B, C) at shore (O) and at 100ft from shore (P). Numbers in red represents samples with enterococci counts higher than 104CFU/100ml (parameter limit). TNTC represents too many colonies to count.

Table 2. Per cent of samples within parameters per sites and time of day.

Time of day	AO	AP	BO	BP	CO	CP
AM/PM	75.00	90.00	65.00	85.00	60.00	55.00
AM only	90.00	100.00	95.00	95.00	90.00	85.00
PM only	85.00	90.00	70.00	90.00	70.00	70.00

Samples were taken twice a day for 10 days in a period of 70 days. The per cents were calculated by dividing the number of exceeded samples by the total number of samples times 100.

Table 3. Description of Rep's amplicons and targets

Rep	Size of amplicon	Annealing Temp	Targets
1	624 bp	56	pIP501 (Inc family)
2	604 bp	56	pRE25
4	430 bp	52	pMBB1 family (lactic bacteria)
6	551 bp	56	pS86 (cryptic plasmids)
7	227 bp	55	pT181 family (*S. aureus*)
8	394 bp	56	pAM373, pEJ97-1 (PRP)
9	201 bp	56	pCF10 pheromone Responsive plasmid family
9 sub G	197 bp	46	pAD1, pTEF1
9 sub pTEF2	165 bp	49	pTEF2, pEF62pC, pBEE99, pMG2200
9 sub pCF10	210 bp	46	pCF10, pPD1, pEF62pB, pTW9
10	382 bp	56	pIM13 (*B. subtilis*)
13	402 bp	55	pC194 family (*S. aureus*)
17	604 bp	52	pRUM

Table 4. Description of addiction modules amplicons and targets

Module	Size of amplicon	Annealing Temp	Target
mazEF 1	496 bp	54	Originally found in *E. coli*
mazEF 2	443 bp	54	Originally found in *E. coli*
relBE	456 bp	54	Originally found in *E. coli*
ω-ε-ζ	348 bp	49	Associated with *E. faecium* most frequently
Axe-Txe	556 bp	54	Typically limited to *E. faecium*
Par system	735 bp	54	pAD1
urvA	895 bp	49-54	pAD1, pTEF1, pMG2200, pCF10, pPD1, pEF62pB
Tuf	112 bp	49-54	Enterococci specific (Ke et al 1999)

Table 5. Rep 9 positive isolates from diverse places in Puerto Rico

Isolate	plasmids by S1	ω-ε-ζ	VanR	urvA	1VF	2VF	3VF	4VF	5VF	9 sub G	9 sub pTEF2	9 sub pCF10
12-1921	1											
12-2332	2											
12-744												
12-5268	2											
12-1983	3											
12-2364												
12-3526												
12-1767	1											
F26	2											
M20												
Ave 1	2											
Ave 5	2											
Cabra24	1											
PS33												
Beach24	1											
Beach35	1											

Figure 1. Multiplex PCR to identify Rep 1 (624bp), Rep 9 (201bp), and Tuf (112bp)

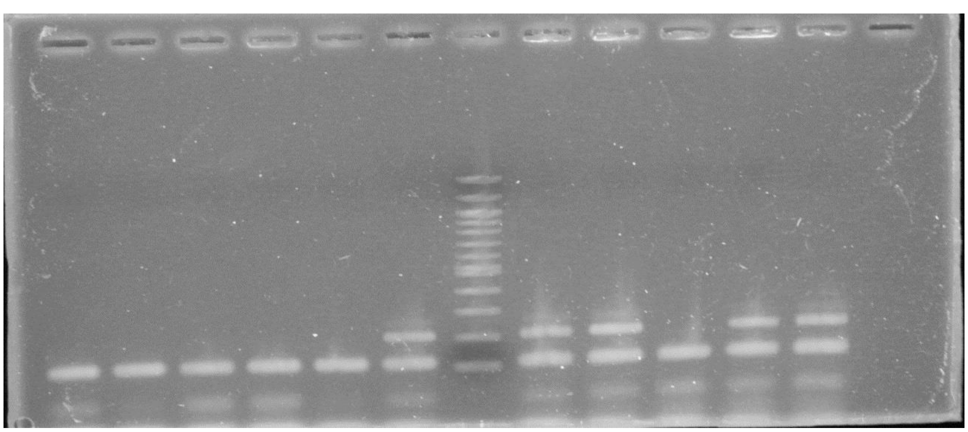


Figure 2. Multiplex PCR to identify mazEF1 (496bp), urvA (895bp), Tuf (112bp)

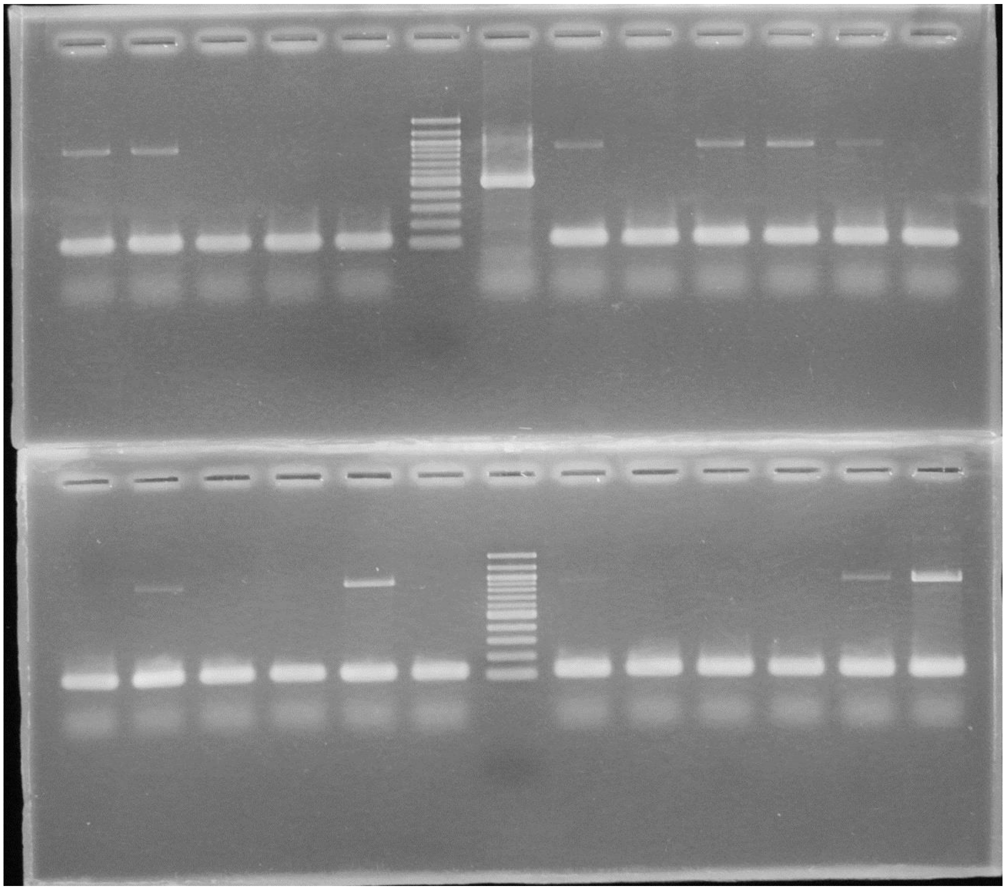


Figure 3. Multiplex PCR to identify ω-ε-ζ (348bp), Tuf (112bp)

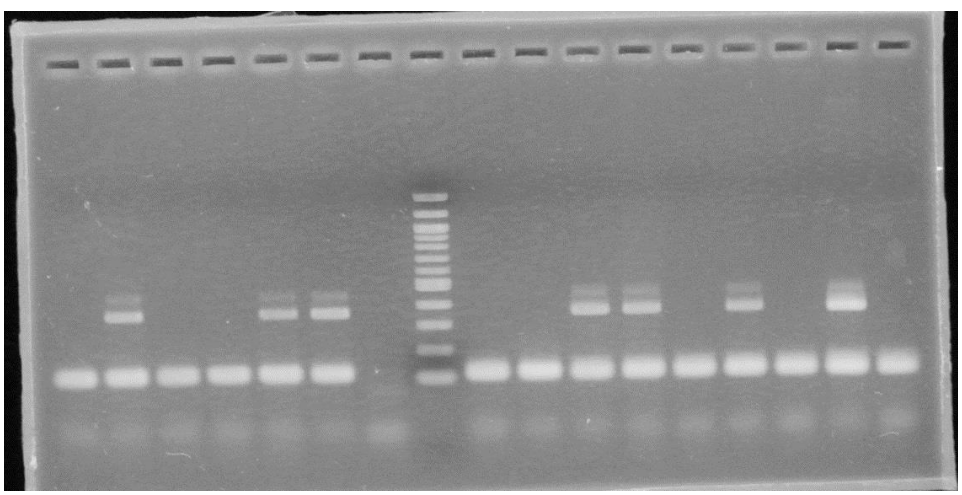
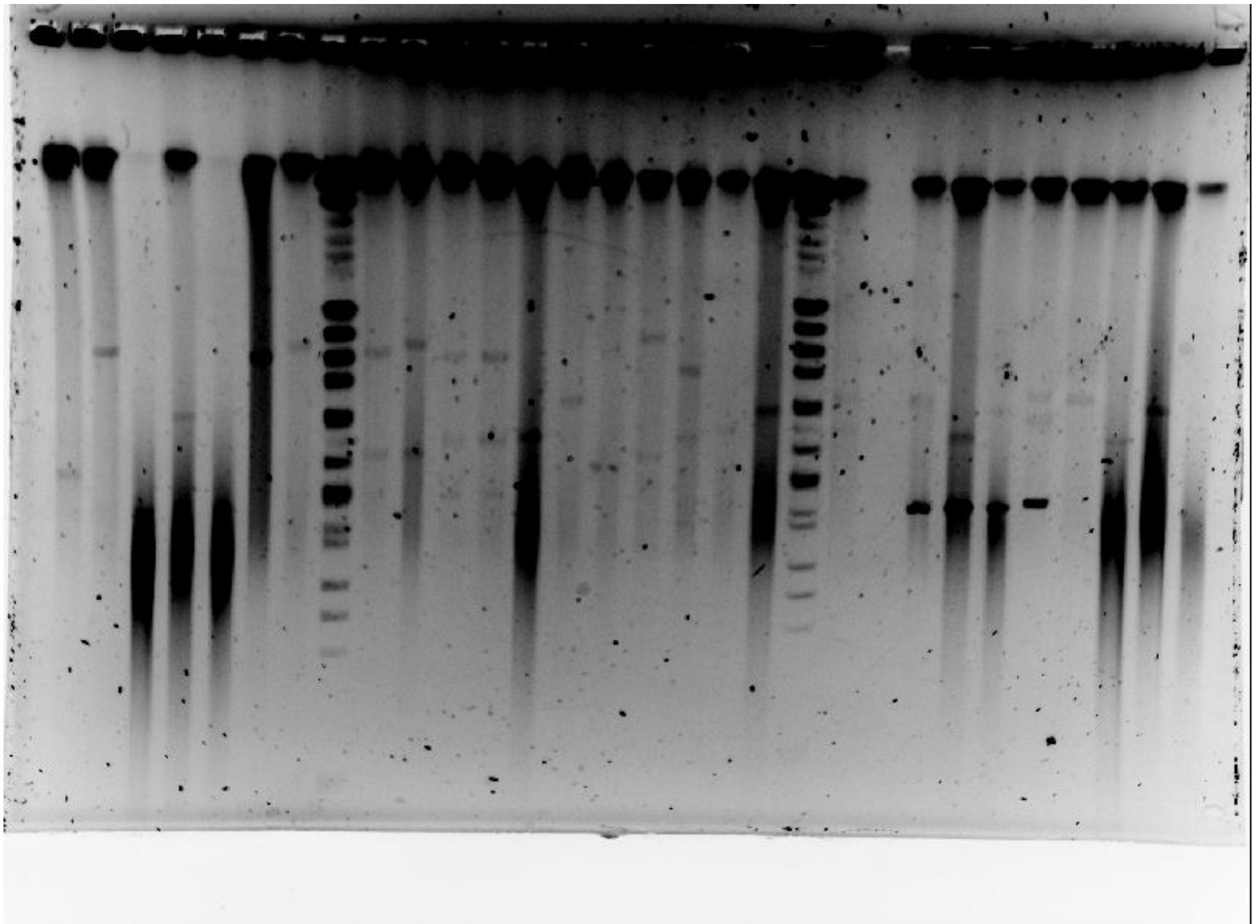


Figure 4. PFGE of S1 digested samples showing the plasmids (bands)



Development and evaluation of a hybrid multimedia-filter prototype (HMP) for the degradation of natural organic matter (NOM) and bacteriological control from raw waters.

Basic Information

Title:	Development and evaluation of a hybrid multimedia-filter prototype (HMP) for the degradation of natural organic matter (NOM) and bacteriological control from raw waters.
Project Number:	2015PR165B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Treatment, Surface Water, Groundwater
Descriptors:	None
Principal Investigators:	Pedro Javier Tarafa, OMarcelo Suarez

Publication

1. Arias, S., A. Avilés, L. Goñez, J. de Jesús, O.M. Suárez and P. Tarafa, 2015. Feasibility of Sintered Recycled Glass Functionalized With TiO2 Nanoparticles For Degradation of Organic Pollutants. Poster presented at the 2015 Sigma Xi Poster Day, UPRM, Mayaguez.

Final Report

PI:	Pedro J. Tarafa, PhD
Project Number:	2015PR165B
Title:	Development and evaluation of a hybrid multimedia-filter prototype (HMP) for the degradation of natural organic matter (NOM) and bacteriological control from raw waters.
Submission Date:	April 27, 2016

Brief Introduction

This report is intended to provide a summary of the most relevant results and accomplishments for the aforementioned research project. The research comprises the evaluation of the sorbent physical parameters as stated in the proposal such as the recycled glass grain size distribution, sintered glass substrate (SGS) percolation rate and surface porosity, immobilization techniques of the nanosized TiO_2 particles in the SGS, and degradation potential of the glass/TiO_2 composite (GTC) for humic acid (HA) solutions. In addition, it was carried out the design and construction of a lab-scale intermittent biosand filter (IBSF).

Student Training for the Entire Project Period

Below there is a list of all the students (graduate and undergraduate) that have been involved in the project, either funded or non-funded.

1. Sheila Arias, MS student from Civil Engineering
   Sheila is the lead student for this endeavor and the one sponsored by the project. She is in charge to design and conduct the tasks stated in the proposal regarding the recycled glass physical parameters such as sieve analysis, percolation rate, adsorption, TiO_2 incorporation into the glass matrix optimization process, and degradation potential of TiO_2/glass substrate. She has been mentoring a group of undergraduate students and a high school student that are helping in the development and execution of few components for this research. Among other tasks, Sheila is getting trained in the use and operation of the following key instruments: total organic carbon analyzer (TOC), UV/Vis Spectroscopy, radiometers (light intensity sensors) for UV irradiation, X-ray diffraction analysis (XRD), infrared spectroscopy (FTIR), HACH spectrophotometer.

2. Amarillys Avilés, MS student from Civil Engineering
   Amarillys is a graduate student that works with Dr. Marcelo Suarez and Dr. Pedro Tarafa research group. She was sponsored by the Center for Education and Training in Agriculture and Related Sciences (CETARS) and has been giving support to this endeavor. She has been involved in the manufacturing of the glass/TiO_2 composite, studying the mechanical properties of the glass composite and devising alternatives to optimize the deposition of TiO_2 particles onto the glass surface. As a CETARS student, she is looking for potential applications in the remediation of polluted soils. In addition, along with Sheila, she also mentors and provides guidance for undergraduate students and high school students for science fair projects.

3. Wadson Phanord, Undergraduate student from Civil Engineering
Wadson is an undergraduate student that is being financially sponsored by the project. Wadson has helped in the design and construction of the IBSF and provided support with the photodegradation studies. He also learned and incorporated the EPA protocols and membrane filtration technique for E. coli and Enterococcus (pathogens indicators) detection for pathogens quantification in water.

4. Leroy Goñez, Undergraduate student from Chemical Engineering
Leroy joined and worked in Dr. Tarafa's research group during Spring and Fall 2015. He was involved in the glass sintering and studying filtration characteristics such as percolation rate and surface porosity for the SGS.

5. José Colon Martínez, Undergraduate student from Civil Engineering
José enrolled in INCI 4998 (undergraduate research) under my supervision for the Fall 2015 term and joined our research team. His main duties consisted in conducting XRD analyses for the TiO_2 particles, percolation evaluations for the SGS and GTC, among others.

6. Gabriel Laboy López, Undergraduate student from Chemical Engineering
Gabriel joined Dr. Tarafa's research group through the course INCI 4998 (undergraduate research) for the Spring 2016 term. He has been working in the design of a reliable method for conducting porosity analyses for the bulk SGS and GTC composites. Within these tasks, Gabriel has developed skills in working with vacuum pumps and high precision analytical balances.

7. Jaime Pérez Rivera, Undergraduate student from Civil Engineering
Jaime also joined Dr. Tarafa's research group during the Spring 2016 term to conduct undergraduate research. Jaime has been involved in the project by providing assistance to Sheila in the evaluation of immobilization techniques to effectively fix TiO_2 particles onto the SGS. His main duties consist in designing a method for conducting porosity analyses for the bulk SGS and GTC composites. During this experience, Jaime has been trained in the sintering protocol of crushed glass dealing with muffle furnaces, TiO_2 suspension and coating preparation, high precision analytical balances, among others.

8. Valeria Santana Pruna, Undergraduate student from Chemical Engineering
Valeria joined our research group in the Spring 2016 to conduct undergraduate research through the course INCI 4998. Valeria has been involved in the project providing assistance for preparing the synthetic HA solutions and carrying out degradation experiments for HA in TiO_2 suspensions under the influence of UV light. She has been trained in the use of sophisticated instruments such as TOC and UV/Vis spectrometer. She has been also working in the optimization of the photocatalytic reactor boxes to increase the UV light incidence.

9. Sochi Uwakweh, High School Student
   Sochi is a student from the Sergio Ramirez de Arellano High School in Añasco. She is in her 11th grade. As part of her Science class, she was required to conduct a science fair project. Therefore, she worked during the Fall 2015 semester in our project under Sheila's tutelage to design an experiment for her science project.

10. Lorraine Ramos, High School Student
    Lorraine is a high school student from Academia Inmaculada Concepción of Mayaguez. Lorraine came to our research group interested in developing a science project to participate in the Science Fair program of her school. She, specifically, worked in the design of a filter case packed with crushed, powdered glass to evaluate the efficacy of the system to decrease turbidity levels in water.

Results Dissemination

Feasibility of Sintered Recycled Glass Functionalized With TiO_2 Nanoparticles For Degradation of Organic Pollutants. S. Arias, A. Avilés, L. Goñez, J. de Jesús, O.M. Suárez and P. Tarafa. Poster presented at the 2015 Sigma Xi Poster Day.

Micro- and Nanosized TiO_2 Particles Immobilized in Sintered Recycled Glass for the Degradation of THM Precursors in Surface Waters, Pedro Tarafa, Sheila Arias, Leroy Goñez and Marcelo Suárez. Oral presentation at the 2nd Conference on Water Resource Sustainability Issues on Tropical Islands, Honolulu, HI. December 2, 2015.

Work Performed

1. Recycled glass particle size distribution
   This evaluation aims to explore the percentage of different grain size contained within the powder recycled glass. The particle size distribution is determined according to the Standard Test Method for Particle-Size Analysis of the ASTM. The test consists of a sieve analysis in which a pre-weighted sample of the material is placed upon the top of a group of sieves. The sieve with the largest screen opening is placed at the top and the screen opening size decrease with each sieve down to the bottom sieve. Once the sieves are placed in the appropriate order the sample is shaker for a period of time in order to promote that the particles is either retained on a sieve or passed through. After shaking the sample the material retained on each of the sieve is weighed.

   Table 1 and Figure 1 shows the data obtained for the crushed glass sieve analysis and the grain size distribution, respectively. The sample had a total mass of 576.5 g.

Table 1. Crushed glass sieve analysis data

Sieve No.	Sieve Opening (mm)	Mass of Glass Retained (g)	% of Glass Retained	Cummulative %	% Passing
4	4.75	0.00	0.00	0.00	100.00
10	2.00	0.00	0.00	0.00	100.00
20	0.85	140.20	24.32	24.32	75.68
40	0.43	423.90	73.53	97.85	2.15
60	0.25	11.70	2.03	99.88	0.12
100	0.15	0.00	0.00	99.88	0.12
200	0.07	0.00	0.00	99.88	0.12
	Tray	0.70	0.12	100.00	0.00

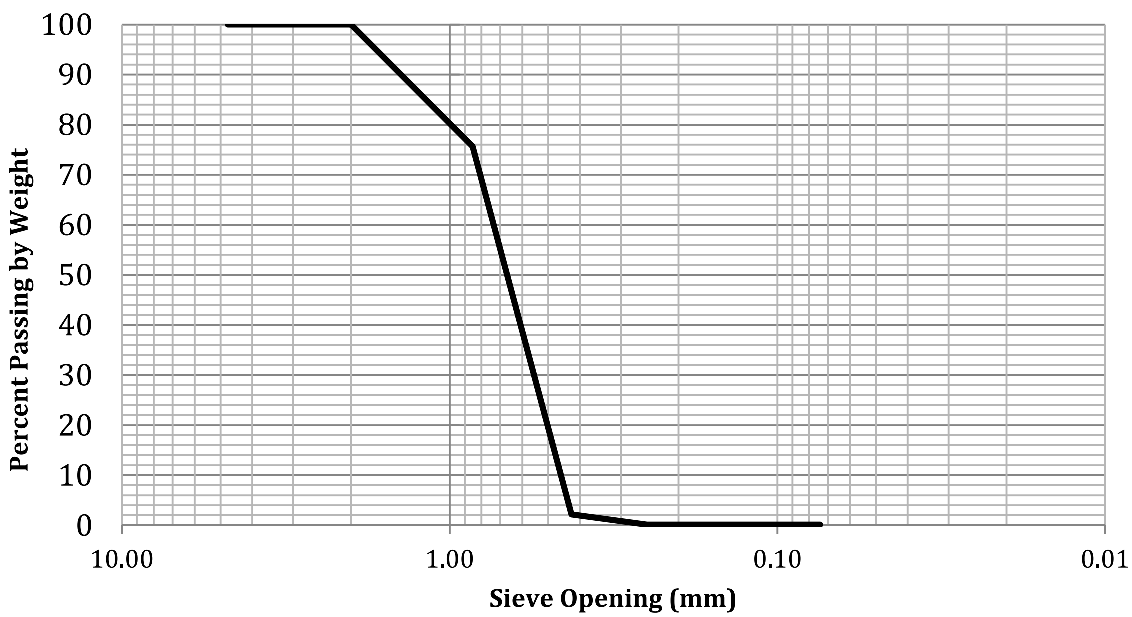


Figure 1. Grain size distribution for the powdered, crushed recycled glass

According to the data the grain size distribution of the powdered, crushed glass have the following characteristics:

- Effective Size (d_{10}): 0.47 mm
- Finer Size (d_{60}): 0.74 mm
- Uniformity Coefficient (UC): 1.57

2. <u>Percolation through the SGS, GCT and powdered glass</u>

Percolation is defined as the ratio of water volume change over time through the porous media. The purpose of this assessment is to evaluate the ability of the SGS and GTC to percolate water at different sintered temperature and times, and compare the data to that of powdered glass (i.e. not sintered glass). The ultimate goal is to identify the optimal combination of sintering time and temperature for a better percolation.

In Fall 2015 a percolation test for both the SGS and GTC was conducted. The SGS consisted of 30 grams of recycled glass sintered at temperatures ranging from 950˚C to 1000˚C at 25˚C intervals at times of 45, 60 and 75 minutes; while the GTC consisted of a mixture of 30 grams of recycled glass and 0.3 grams of TiO_2 sintered at 950˚C and 975˚C for times of 60, 75 and 90 minutes. Percolation was determined by recording the elapsed time (in seconds) to obtain a given volume of water. The analysis was carried out by a hand-made apparatus built by our team. It consisted in a PVC pipe with an adapter to store a glass composite sample and a funnel (in the top of the pipe) to keep a constant hydraulic head over the tested sample (refer to Figure 2). The system is sealed with clear silicon and once dried; water is fed into the system. The GTC and SGS samples are placed at the opposite side of the pipe. The percolation system allows obtaining one directional water flux with a constant head. The ratio of water volume change and time will be determined by measuring the time to obtain a volume of water.

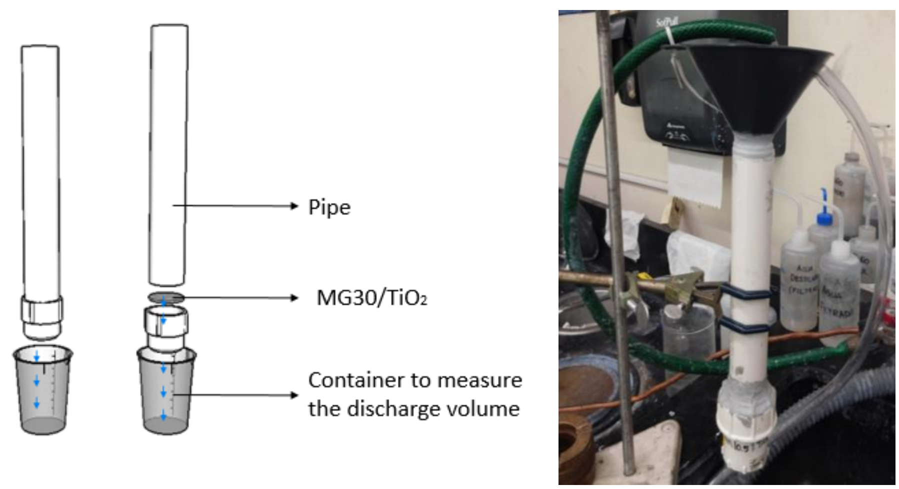


Figure 2. Hand-made PVC apparatus to measure percolation.

Table 2 and 3 shows the percolation fluxes (gpm/ft^2) obtained for both the SGS and the GTC. As it can be observed from the data, temperature and time affect the percolation rate. As expected, the higher the temperature and time for sintering, the less percolation rate achieved. Another interesting observation is that the percolation rates were higher in the composites with TiO_2 particles (GTC) than in the SGS. This suggests that the TiO_2 particles are getting trapped between the glass beads, preventing enough bonding between the glass particles creating larger pore size; hence, higher percolation. In addition, higher sintering times for the GTC were required in order to obtain a strong composite. In summary, for the SGS, the highest percolation rate was 17.71 gpm/ft^2 and the lowest 0.059 gpm/ft^2 for sintering temperatures and time of 950 °C, 45 minutes and 1000 °C, 75 minutes, respectively. For the GTC, the highest percolation rate was 36.20 gpm/ft^2 for 950 °C and 60 minutes, while the lowest percolation rate observed was 12.66 gpm/ft^2 for 975 °C and 90 minutes.

Table 2. Percolation data for the SGS with time and temperature

Sintering temperature (°C)	Sintering time (min)	Average Percolation flux (gpm/ft^2)
	45	**17.71**
950	60	15.58
	75	12.06
	45	9.01
975	60	7.06
	75	3.64
	45	5.59
1000	60	0.17
	75	**0.059**

Table 3. Percolation data for the GTC with time and temperature

Sintering temperature (°C)	Sintering time (min)	Average Percolation flux (gpm/ft^2)
	60	**36.20**
950	75	32.83
	90	27.88
	60	25.85
975	75	15.36
	90	**12.66**

In order to avoid large standard deviations in the percolation fluxes, a new second generation of SGS was developed. It consists in placing the powdered glass for sintering inside the furnace once the desired sintering temperature is reach in the oven and is kept constant. In this case percolation tests were repeated for SGS, which consisted in sintering the glass for temperatures of 950 and 975 ˚C at times of 45, 60 and 75 minutes. The tests were done in triplicate for a total of 18 substrates. The results are presented in Table 4.

Table 4. Percolation data for a second generation of SGS

Sintering temperature (°C)	Sintering time (min)	Average Percolation flux (gpm/ft^2)
	45	29.30
950	60	27.26
	75	21.73
	45	22.13
975	60	16.03
	75	7.73

3. Porosity Analysis

The selected temperature and time to achieve the sintering process has a direct impact in the substrate porosity. It is expected that as the sintering temperature and time increase, there will be a reduction of the pore size in the SGS. The scope of this analysis is to assess the effect of sintering temperature and time to obtain a performance map for the SGS porosity.

An evaluation of the structural characteristics of the SGS that comprises surface and bulk porosity is conducted. The surface porosity is evaluated by applying remote sensing methods. The data collected are surface micrographs at different locations on the SGS prepared at different sintering temperatures and time. The SGS bulk porosity is evaluated by the saturation and weight difference method.

3.1 Surface porosity

SGS sample were obtained by placing the recycled glass powder in a cylindrical ceramic mold. The sintering temperatures were 950, 975 and 1,000 C for times from 45 to 75 minutes with 15 minutes intervals. The surface area of the SGS is embedded in epoxy resin to produce epoxy laminates. All SGS samples are finally polished with sandpaper with grit sizes of 60, 240, 320, 400, 600, 800 and 1,200.

The SGS samples are divided in 4 sections and surface micrographs are obtained randomly at five locations using an optical microscope with 5x magnification. Hence, 20 micrographs are obtained for each sample.

The SGS surface porosity is estimated using ImageJ, which is a Java software. The surface porosity is evaluated by drawing manually a polygon over the pore. Then a proper threshold to gray-scale is applied to the image to extract the pore based on the degree of contrast between the components. The surface porosity, ε (%), is calculated with the following equation:

$$\varepsilon = \frac{A_p}{A_t} x\ 100\%$$

where A_p is the total area of pore in the optical microscope image and A_t is the total area of optical microscope image.

Figure 3 shows the surface micrographs for three different SGS samples. Table 5 present a summary of the surface porosity observed for the different SGS as function of temperature and time.

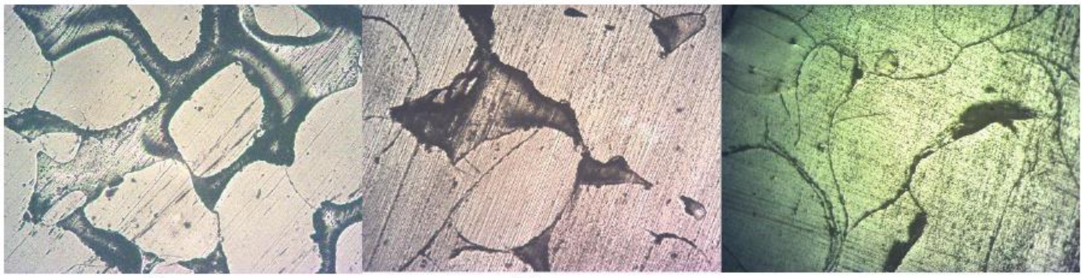


Figure 3. Surface micrographs for the SGS samples sintered at: (a) 950 C; (b) 975 C: and (c) 1000 C.

Table 5. Surface porosity data as function of sintering temperature and time

Time (min)	**Average Porosity (%)**		
	Temperature (°C)		
	950	975	1000
45	30.43 ± 3.04	26.21 ± 6.07	14.11 ± 5.12
60	29.40 ± 4.44	17.40 ± 11.26	13.39 ± 6.30
75	17.90 ± 3.14	15.75 ± 6.72	7.86 ± 2.69

3.2 Bulk porosity

The objective of this analysis is to obtain the total porosity of the sintered glass with temperature and time. Evaluated SGS were sintered at 950˚C and 975˚C for 45, 60 y 75 min. For this test it was used the saturation and weight difference method. The pore volume is determined by the weight difference between the wet/saturated and dry SGS divided by the water density ($V_p = \frac{M_w - M_d}{\rho_w}$). The porosity is then determined by

$$\varepsilon_T = \frac{M_w - M_d}{AT\rho_w} x\ 100\%$$

where M_w is the substrate saturated weight, M_d is the substrate dry weight and A and T are the area and thickness of the SGS, respectively. Results are presented in Table 6:

Table 6. Bulk porosities in the SGS

Sintering temperature (°C)	Sintering time (min)	Average Percolation flux (gpm/ft^2)
	45	24.54
950	60	27.56
	75	23.58
	45	23.54
975	60	19.15
	75	14.69

4. TiO_2 immobilization

Different immobilization techniques to fix the TiO_2 particles onto the glass surface are being evaluated. The first technique consisted in mixing together a mass of TiO_2 particles with glass powder particles. Then the mixture is sintered in the oven at selected temperature and time. The mixing was carried out by adding 0.30 g of titanium (IV) oxide anhydrous powder to a mixture of 10 mL of ethanol and 20 mL of water in order to get a TiO_2 suspension. Then the suspension was mixed with 30 g of powder glass and sintered in the oven at the desired temperature and time. However, the capacity for degradation of humic acid (HA) yield in very low or zero destruction. Refer to section 6.

Another approach that is being evaluated for the effective immobilization of the TiO_2 particles onto the SGS was by sedimentation and re-sintering. First, a TiO_2 suspension is prepared with 40 mL of ethanol. The initial mass of TiO_2 ranges from 1 to 5 grams. Nitric acid (10%) is added to decrease the suspension's pH to 1.7. The mixture is stirred for one hour and then transferred to a vessel having the SGS in the bottom. The TiO_2 suspension and SGS are allowed to keep in contact for approximately 6 hours until all the ethanol is evaporated at room temperature. The vast majority of the TiO_2 particles settled over the SGS surface. Then the SGS with the settled particles was returned back to the oven to allow the TiO_2 to stick together with the glass by re-sintering at 900 C for two different time periods (45 and 75 minutes). The average TiO_2 mass immobilized in the glass is quantified by weight difference of the SGS before and after TiO_2 deposition. Table 7 shows the experimental data.

According to the experimental data, it is observed that the higher the mass initially added of TiO_2 the higher it is immobilized in the SGS.

Table 7. TiO_2 particles immobilized in the SGS

Sintering time (min)	Initial TiO_2 mass (g)	Average TiO_2 mass immobilized (g)
45	1	0.1467
	3	0.3776
	5	0.9124
75	1	0.2566
	3	0.701
	5	1.5423

5. Degradation of HA by TiO_2 in suspension under the influence of UV light

It is first desired to determine whether or not the TiO_2 particles will be effective in the degradation/destruction of HA. Hence, the photodegradation capability of the TiO_2 was first assessed in suspensions rather than attached or immobilized in the SGS. The experiments were conducted in photocatalytic reactors that consisted in closed, sealed boxes to avoid the passage of light from their surroundings. Three different reactors or configurations were built. The first one was made of naked wood, the second consisted of wood coated with aluminum foil in the interior of the walls, and the third involved a dark plastic container. All reactors housed a UV lamp (wavelength = 365 nm; intensity = 1,000 $\mu w/cm^2$) and a beaker to hold the solution to be treated. The reactors are designed to allow the UV irradiation at controlled conditions. The HA levels in the solution to be evaluated will be quantified by means of TOC concentration and absorbance at 254 nm by spectroscopy.

A stock solution of HA is first prepared by diluting 0.03 g of HA (powder) in 100 mL of distilled water. Then a HA solution for a desired concentration is obtained from the stock solution by dilution. Hydrochloric acid (HCl) is also employed to decrease the solution's pH to a level of 5. For the degradation experiments, 200 mL of HA solution is deposited in a beaker with 0.16 g of TiO_2. The suspension is placed in reactor providing continuous agitation. A sample is collected at different time intervals to monitor HA levels. Table 8 shows HA residual levels with time in the suspension after exposure to UV light.

Table 8. Residual HA levels and % destruction with TiO_2 in suspension after UV light irradiation quantified by means of TOC and absorbance: (a) naked wood box reactor; (b) aluminum foil coated wood box reactor; (c) Plastic box reactor

(a) Wood reactor

time (min)	ABS/ABS_0	HA destruction (%)
0	1.00	0
30	0.85	15
60	0.81	19
90	0.74	26
120	0.62	38

(b) Aluminum foil coated wood reactor

time (h)	TOC/TOC_0	HA destruction (%)
0	1.00	0
2	0.55	45
4	0.23	77

(c) Plastic reactor

time (h)	TOC/TOC_0	HA destruction (%)	ABS/ABS_0	HA destruction (%)
0	1.00	0	1.00	0
1	0.94	6	0.72	28
2	0.90	10	0.56	44
3	0.78	22	0.39	61
4	0.57	43	0.16	84
5	0.39	61	0.06	94
6	0.30	70	0.02	98

The poor or low degradation of HA observed in the naked wood reactor suggests that a large portion of the irradiated UV light was absorbed by the wood itself. Hence, eluding a large degradation percentage of HA in the solution when compared against the other two reactor configurations. This finding was critical in order to optimize the photodegradation process.

6. Degradation Potential of GTC samples as function of UV light

The photodegradation capability of the GTCs was assessed by means of the degradation/destruction of HA solutions under the influence of UV light as well. At this stage we have performed trials using the naked wood box reactor. Studies with the other two reactors are in progress.

Degradation studies were carried out by placing a GTC sample in contact with 120 mL of HA solution. The solution and the GTC are irradiated with UV light for a maximum of 120 minutes. Samples from the solution are collected every 20 min in order to determine the effect of the irradiation and contact time. Figure 4 and 5 show the residual HA levels in solution as quantified by TOC after been in contact with the GTC and exposed to UV light for 120 minutes. Figure 4 depicts experiments run with a GTC sintered at 950 C for 60, 75 and 90 minutes while Figure 5 displays the results when using a GTC sintered at 975 C for 60, 75 and 90 minutes, as well. As seen in Figure 3, the HA residual levels in the solution are still quite high (< 10% degradation in average) suggesting that the TiO_2 particles are restricted within the glass composite making the UV light hard to penetrate and photoactivate them. In addition, we have to point out that the experiments were run in the naked wood box reactor, which was proved to be less effective due to UV light absorption within the wood. In contrast, for similar HA solution concentrations, but having the TiO_2 particles in suspension, high degradation or destruction of HA are detected (refer to Table 8a). This confirms that alternative TiO_2 deposition techniques should be evaluated in such a way that the UV light can easily reach and photoactivate the TiO_2 particles in the GTC.

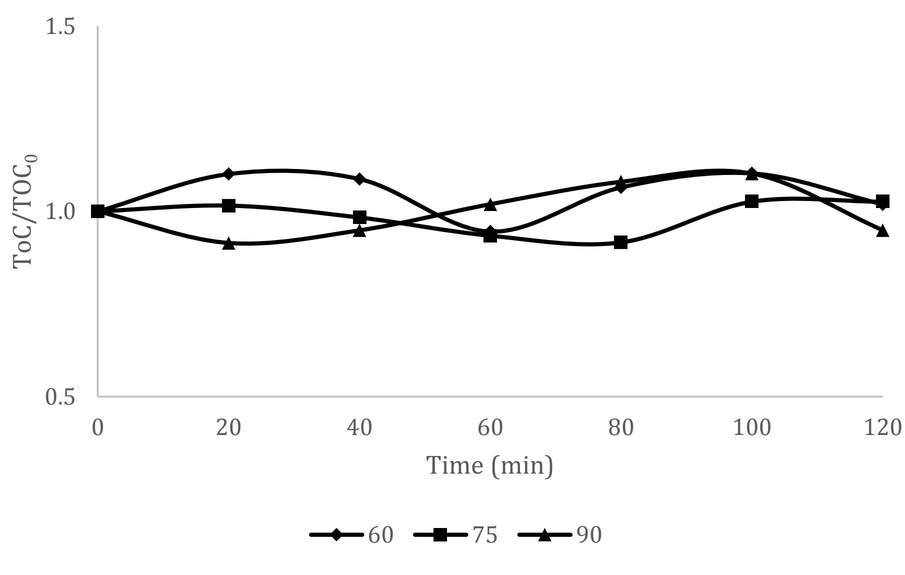


Figure 4. HA residual levels denoted as TOC/TOC_0 as function of irradiated time when in contact with a GTC sintered at 950 C for 60, 75 and 90 minutes.

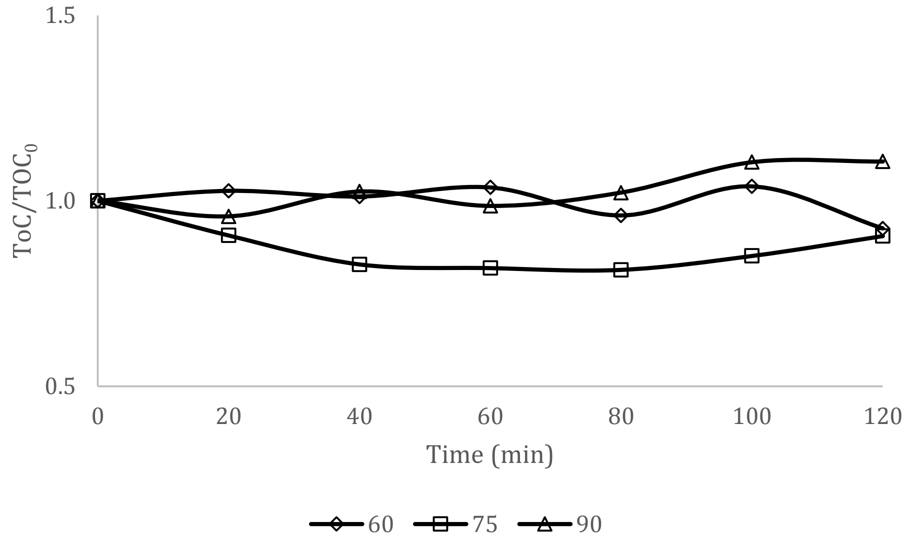


Figure 5. HA residual levels denoted as TOC/TOC_0 as function of irradiated time when in contact with a GTC sintered at 975 C for 60, 75 and 90 minutes.

7. Polymorph Structure of Titanium (IV) Oxide (TiO_2) Phase:
There was a concern regarding whether or not the polymorph structure of TiO_2 will remain or change after been exposed to such high temperatures in the sintering process. According to literature, the TiO_2 is a photocatalytic material that exhibits three polymorphs phases: rutile, anatase and brookite. Each of these polymorphs presents different properties that impact the photocatalytic performance of the material. In our case, the TiO_2 particles being used are in the anatase phase, which is the phase that has the best photocatalytic performance. An X-ray diffraction (XRD) instrument was used to determine the polymorph structure of the TiO_2 phase before and after the sintering process. For this purpose, three representative TiO_2 samples were exposed to the same harsh conditions as the particles used for sintering the GTC (i.e. mixed with water and ethanol and then sintered). Each TiO_2 sample were placed in the oven and exposed to 900, 950 and 975 ^{o}C for one hour, respectively. According to the analysis, no change was observed in the XRD spectrum, suggesting the TiO_2 anatase phase remains after these conditions. Refer to Figures 6 and 7.

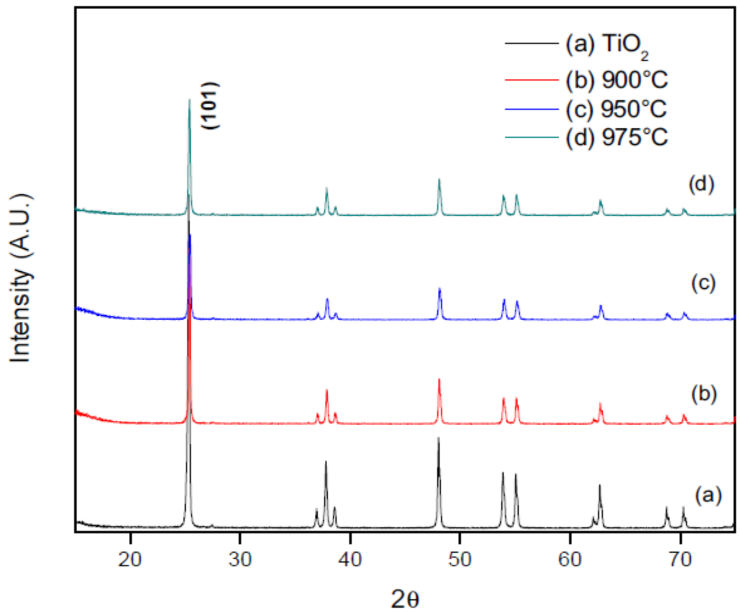


Figure 6. XRD spectra for pure TiO_2 samples been exposed at different temperatures. Sample (a) represents a TiO_2 sample in its original form (not placed in the oven).

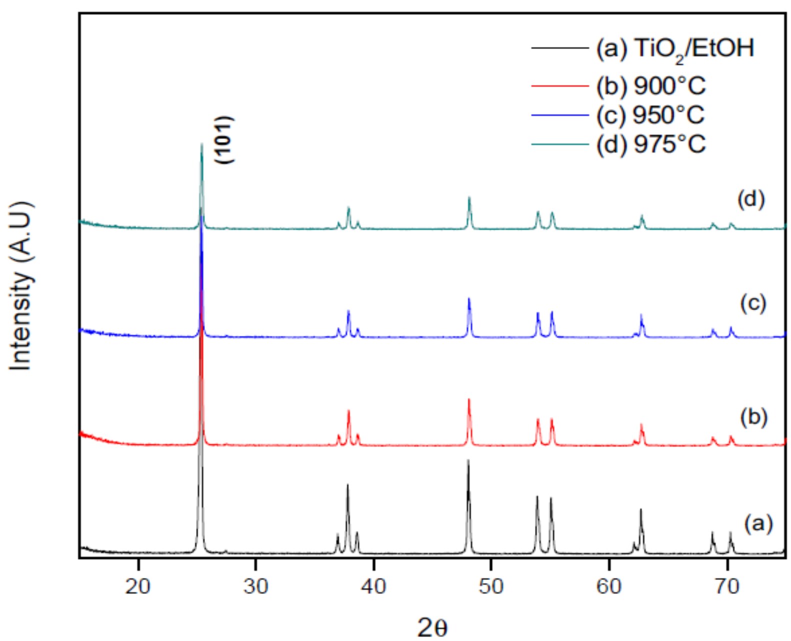


Figure 7. XRD spectra for samples of TiO_2 mixed with ethanol and then exposed at different temperatures. Sample (a) represents a sample not placed in the oven.

8. Evaluation of the crushed glass (non-sintered) as a filtration media for turbidity removal
   In order to evaluate the effect of crushed, powdered glass (non-sintered) for turbidity removal, a filter-like apparatus was built using the glass as a filtration media. A PVC pipe (4 inches in diameter and 48 inches long) was filled/compacted with 12 inches of crushed, powdered glass to simulate a rapid sand filter. Six (6) inches of gravel were also kept at the bottom of the pipe to support the glass. Muddy water with an average of 150 turbidity units (TU) was fed to the PVC filter apparatus at a filtration rate of 2 gpm/ft^2. The average effluent turbidity was 27.17 TU for an average turbidity removal of 81.89%.

9. Design and construction of a lab-scale intermittent bio-sand filter (IBSF)
   So far, the design and construction of six lab-scale IBSF have been completed. The filters were designed and built to keep a filtration rate of 400 L/h/m^2 or 0.258 L/h/in^2, which is the typical filtration rate on an IBSF. The filters were designed to receive a volume of 200 mL of raw water, which require a surface area of 1.23 in^2 (i.e. 1.25 inches in diameter) to keep the desired hydraulic loading. This cross sectional area is smaller than the typical area in an actual IBSF because we need to reduce it in order to provide convenience in the experimental procedure reducing the volume of water needed to feed the filter in 1:1 pore volume (including the volume of the standing water zone). The filters were built of PVC tube. From the total of the six filters, three of them have 38 inches in height while the remaining three are 28 inches. The bigger filters are packed with 21 inches of sand and the smaller with 11 inches. Both type of filters (big and small) have 4 inches of coarse and fine gravel to bring support to the sand. The purpose of having two different heights is to evaluate the filters efficacy by reducing the filtration medium depth. Currently, it is been working in the establishment of the biolayer. Figure 8 shows a picture of the six IBSF.

Figure 8. Picture of the six lab-scale IBSF

Mapping Field-Scale Soil Moisture Using Ground-Based L-Band Passive Microwave Observations in Western Puerto Rico

Basic Information

Title:	Mapping Field-Scale Soil Moisture Using Ground-Based L-Band Passive Microwave Observations in Western Puerto Rico
Project Number:	2015PR169B
Start Date:	3/3/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Climatological Processes, Agriculture
Descriptors:	None
Principal Investigators:	Jonathan MunozBarreto, Tarendra Lakhankar, Xiwu Zhan

Publication

1. Muñoz, J., 2016. Mapping Field-Scale Soil Moisture Using Ground-Based L-Band Passive Microwave Observations in Western Puerto Rico, American Meteorological Society's 30th Conference on Hydrology, January 11-14.

Final Report (As of Feb 2016)

PI: Jonathan Muñoz-Barreto, PhD
Project Number: 2015PR169B
Title: Mapping Field-Scale Soil Moisture Using Ground-Based L-Band Passive Microwave Observations in Western Puerto Rico.
Submission Date: May 15, 2016

Brief Introduction

This report is intended to provide the final update on the progress of the aforementioned research project. It comprises Task 1: Sites identification and delimitation. (Mapping GIS activities-to replicate point and field Scales); Task 2: Preliminary data collection (SMAP /SMOS data, Precipitation, Temperature, and Soil Moisture); Task 3: Construction (observation Tower-Figure 3), Site Preparation and Logistics; & Task 4: Instrument Calibration and Field Experiment.

Student Training

1. Jonathan Nuñez, MS student from Civil Engineering
   Jonathan is the lead student for this endeavor and the only graduate student sponsored by the project (2015PR169B). He was in charge of design and conduct the tasks stated in the proposal regarding the collection and interpretation the passive microwave data. He will continue working in the phase II of the project.

   Jonathan is getting trained in the use and operation of the following key instruments: L-band Microwave Radiometer for SM detection, Soil reflectometers for in-situ SM detection and data loggers programing. Additionally, Mr. Nuñez will spend summer 2016 at the Engineering, Research and Development Center of the U.S. Army Corp of Engineering working with soil moisture sensing science.

2. Grace M. Diaz (Leverage), MS student from Civil Engineering
   Grace is a graduate student that works with Dr. Jonathan Muñoz research group. She is currently sponsored by UPRM College of Engineering (Dr. Muñoz-SEED Money) and was giving support to this endeavor. She has been involved in the Mapping and GIS activities of this work. This endeavor overlaps her research work; Assessing the Impacts of Climate Variability and Land Use: A case study of Puerto Rico Watersheds

3. Carlos Neris, Undergraduate Student from Land Surveying and Topography
   Carlos is an undergraduate student that works with Dr. Jonathan Muñoz research group. He was sponsored by the project (2015PR169B) and his work was related to the field data collection.

4. Steven Aviles Undergraduate Student from Land Surveying and Topography

Steven is an undergraduate student that works with Dr. Jonathan Muñoz research group. He was sponsored by the project (2015PR169B) and his work was related with the acquisition of the Satellite data.

5. INCI 5995/6997- As proposed, the special topics course Remote Sensing Analysis and Applications was created and offered during spring 2015. 7 graduate students and 5 senior undergraduate students were enrolled. As part of the course they learned remote sensing sample collection methods (Active & Passive), basic analytical techniques and data processing.

Results Dissemination

1. **Muñoz, J**., 2015. *High Resolution Soil Moisture mapping using L-Band Passive Microwave Observations*, III Congress on Remote Sensing and Geographic Information Systems, Havana, Cuba, September 23-26. (*Oral-Presentation*)

2. **Muñoz, J.**, 2015. *Satellite Data for Hydrological Applications – Study Case Puerto Rico*, Meeting of The Committee on Radio Frequencies – National Academy of Science, Engineering and Medicine, Arecibo Observatory, Arecibo, P.R, October 15th. (*Oral-Presentation)*

3. **Muñoz, J.**, 2016. *Mapping Field-Scale Soil Moisture Using Ground-Based L-Band Passive Microwave Observations in Western Puerto Rico*, American Meteorological Society's 30th Conference on Hydrology, January 11-14. (*Poster Presentation)*

4. **Muñoz, J.**, 2016. *Microwave Remote Sensing of Soil Moisture for Hydrological and Agriculture Applications,* Congress of Engineering, Surveying and related disciplines (COINAR 2016), College of Engineers and Surveyors of Puerto Rico, San Juan, P.R , March 8th. (Oral -Presentation

Work Performed

1. **<u>Task 1:</u>** Sites identification and delimitation. (Mapping GIS activities-to replicate point and field Scales).

   For task 1 Collaboration was established with UPRM Agriculture Extension Program. As proposed 3 of their facilities were selected as observational sites: (1) Isabela Experimental Station; (2) Alzamora Estate & (3) Lajas Substation. At each site Radiometric, Meteorological and Soil moisture observations were conducted.

   Support Instrumentation & Data:

   1 Microwave Radiometer 1.45 GHz (Agreement)
   45 10-HS Soil Moisture Sensor (Acquired-UPRM)
   5 Em50 Digital Data Logger (Acquired-UPRM)
   1 Weather Station-HOBO (Acquired-UPRM)

Real time and archive data will be available via www.uprm.edu/prsmart

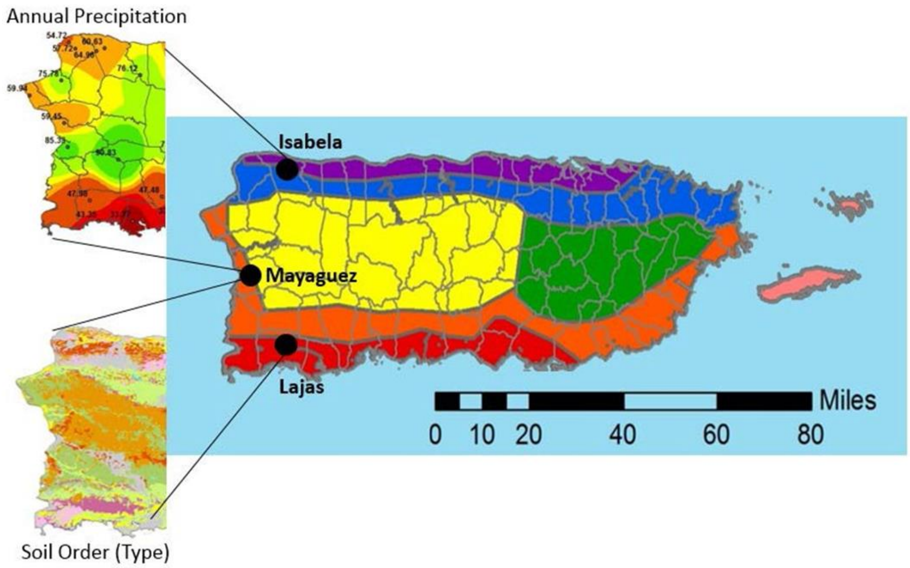


Figure 1 Established soil moisture observational sites

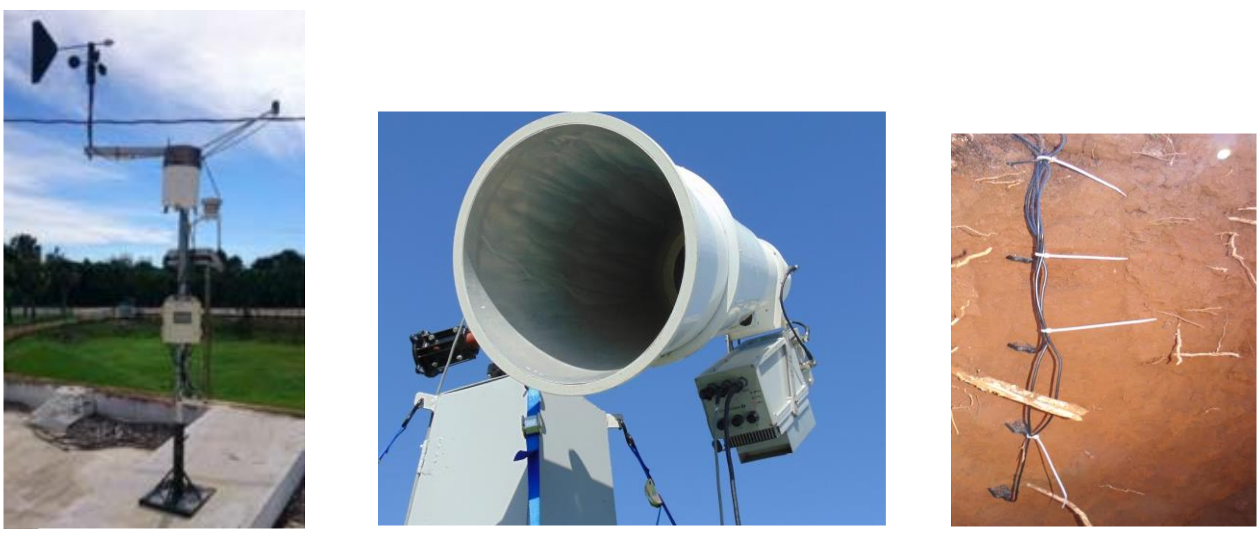


Figure 2 Instrumentation deployed as part of project-2015PR169B (: (a) Weather Station, (b) L-Band Microwave Radiometer & (c) TDR sensors

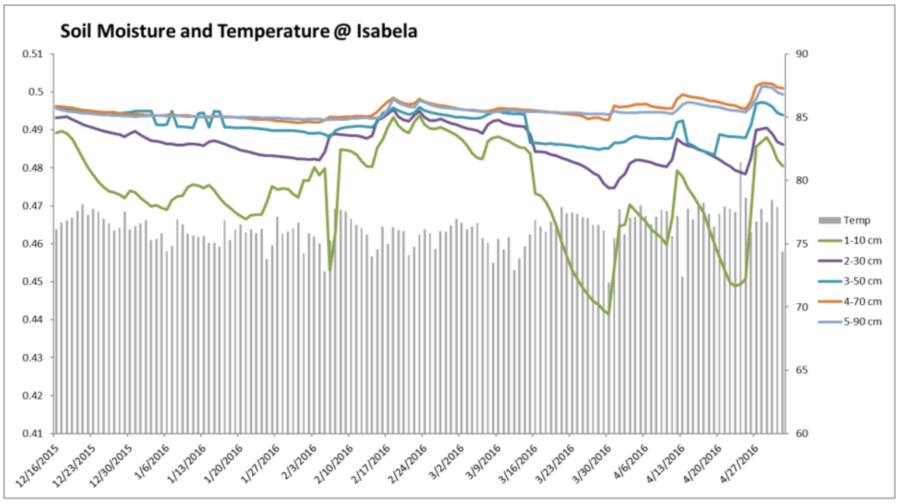
data)

One of the main purpose of the project (phase 1) was to assemble a cohesive dataset for SMAP testing, the scope was expanded to include JPSS/GCOM-W. Also, in-situ soil was used to conduct basic research and examine the impact of vegetation cover on the microwave emission. Most of the studied soil moisture footprints were highly heterogeneous.

In-Situ Data

The main objective of this sub-task was to obtain in-situ soil moisture data; by the means of time domain reflectometry. The data collection was carried out during the months of December 2015, and January - April 2016.

Discussion of Results:



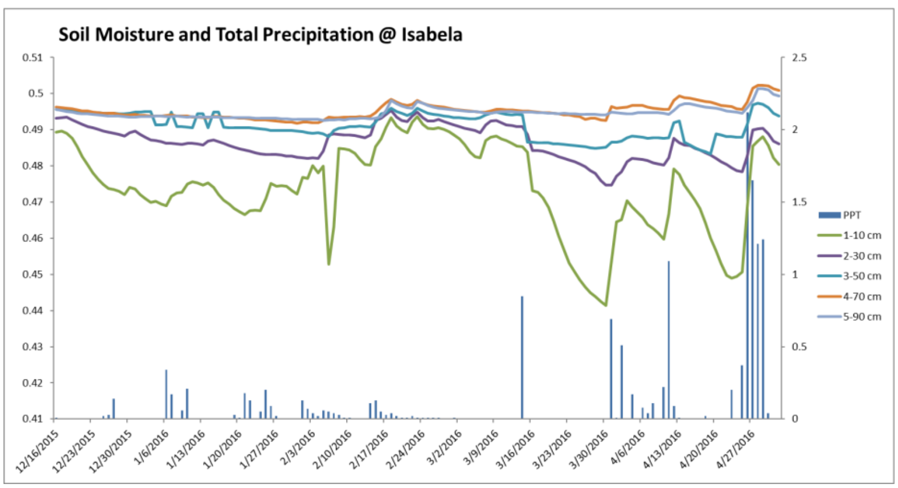


Figure 3 Comparison of in-situ Soil Moisture alongside Meteorological data

Early results of the in-situ data collection illustrate the expected behavior when compared with meteorological datasets. The data shows a positive correlation between soil moisture and precipitation and a negative correlation between soil moisture and surface temperature. However, in terms of the volumetric measurements, the TDR are overestimating the data; showing the soil saturated (50% of water content) at most of the time. The overestimation is being investigated and a recalibration of the sensors may be needed.

Satellite Data

The main objective of this sub-task was to obtain and compare different soil moisture content datasets (satellite and modeled). Data from GCOM W, SMSAP and GOESPR-WEB was analyzed for the months of December 2015 and January - April 2016. Phase II of this work will cross validate ground data against satellite and modeled information.

Products:

GCOM W L2
Amount of soil wetness near the ground surface as volume water content. Coverage of the product is over land only, and unit is [%]. Soil moisture cannot be estimated near the coast, around big lakes and marshes, or areas with wide spread dense forests. Since microwave radiometer can get data constantly and frequently, this product is used in monitoring of large-scale cultivation areas in the continents. (Not well suited for Puerto Rico)

SMAP L3 PASSIVE
This Level-3 (L3) soil moisture product provides a composite of daily estimates of global land surface conditions retrieved by the Soil Moisture Active Passive (SMAP) passive microwave radiometer. SMAP L-band soil moisture data are resampled to a global, cylindrical 36 km Equal-Area Scalable Earth Grid, Version 2.0 (EASE-Grid 2.0).

GOES PRWEB
GOES-PRWEB, is an energy balance approach, is used to estimate actual evapotranspiration, which is then incorporated into a water balance calculation.

Discussion of Results:

According to the data obtained from SMAP, soil moisture in Puerto Rico ranges from 0.4739 % to 0.5567 %, while the data provided by the GCOM - W varies from 0.3320 % to 0.9999 %. The Satellite data have a tendency to overestimate soil moisture when compared with GOESPR (local energy balance) for which soil moisture results range from 0.2524 % to 0.3319 %. In order to validate the results, a longer period of time will be analyzed (5 years). Furthermore, in-situ data from the established sites (Isabela, Lajas & Mayaguez) will be interpolated at the appropriate spatial resolutions for validation.

Note: *Pixel A Western PR; Pixel B West-Central PR; Pixel C East-Central PR; & Pixel D Eastern PR.*

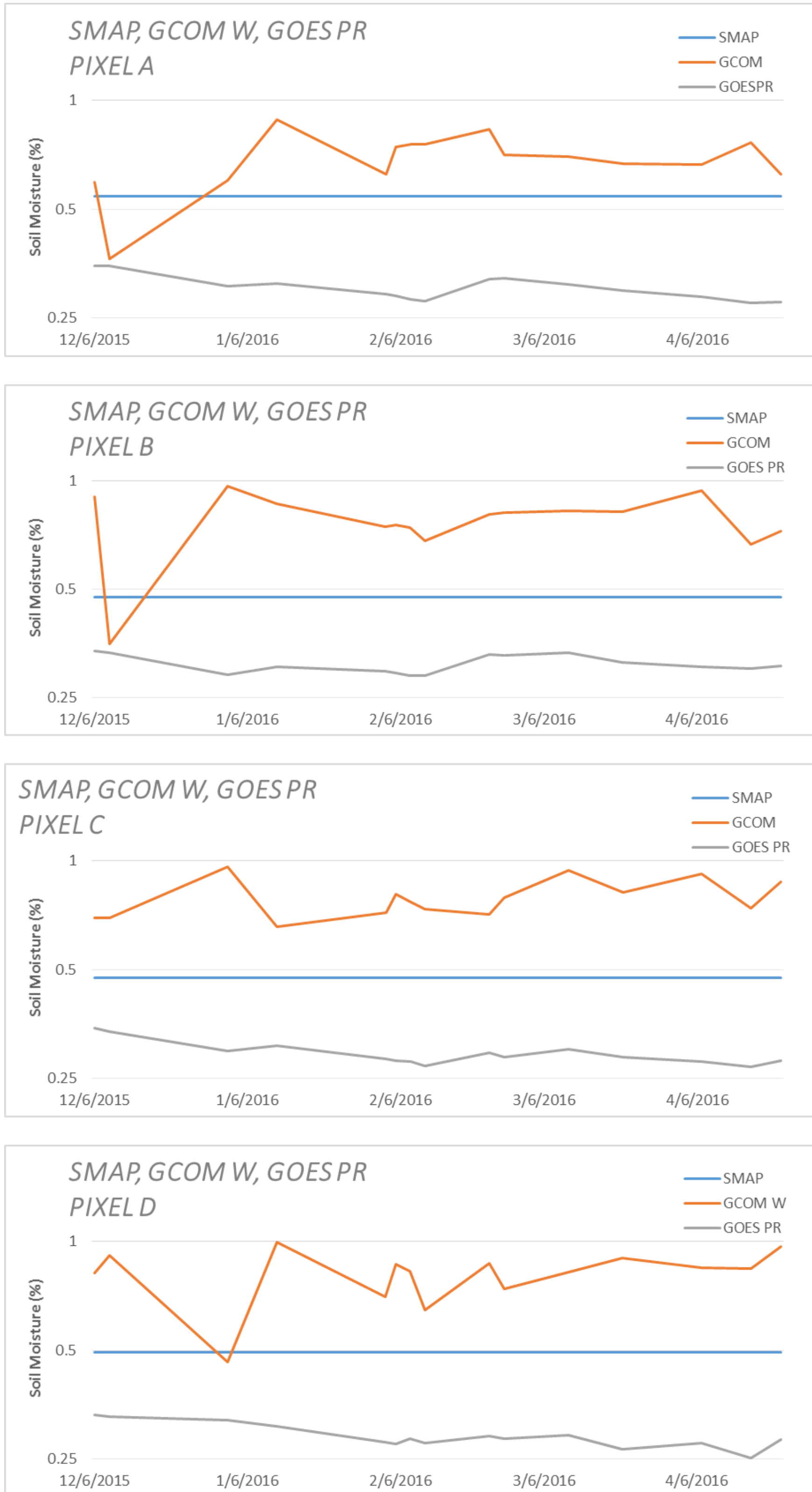


Figure 4 Inter-comparison of satellite based soil moisture products

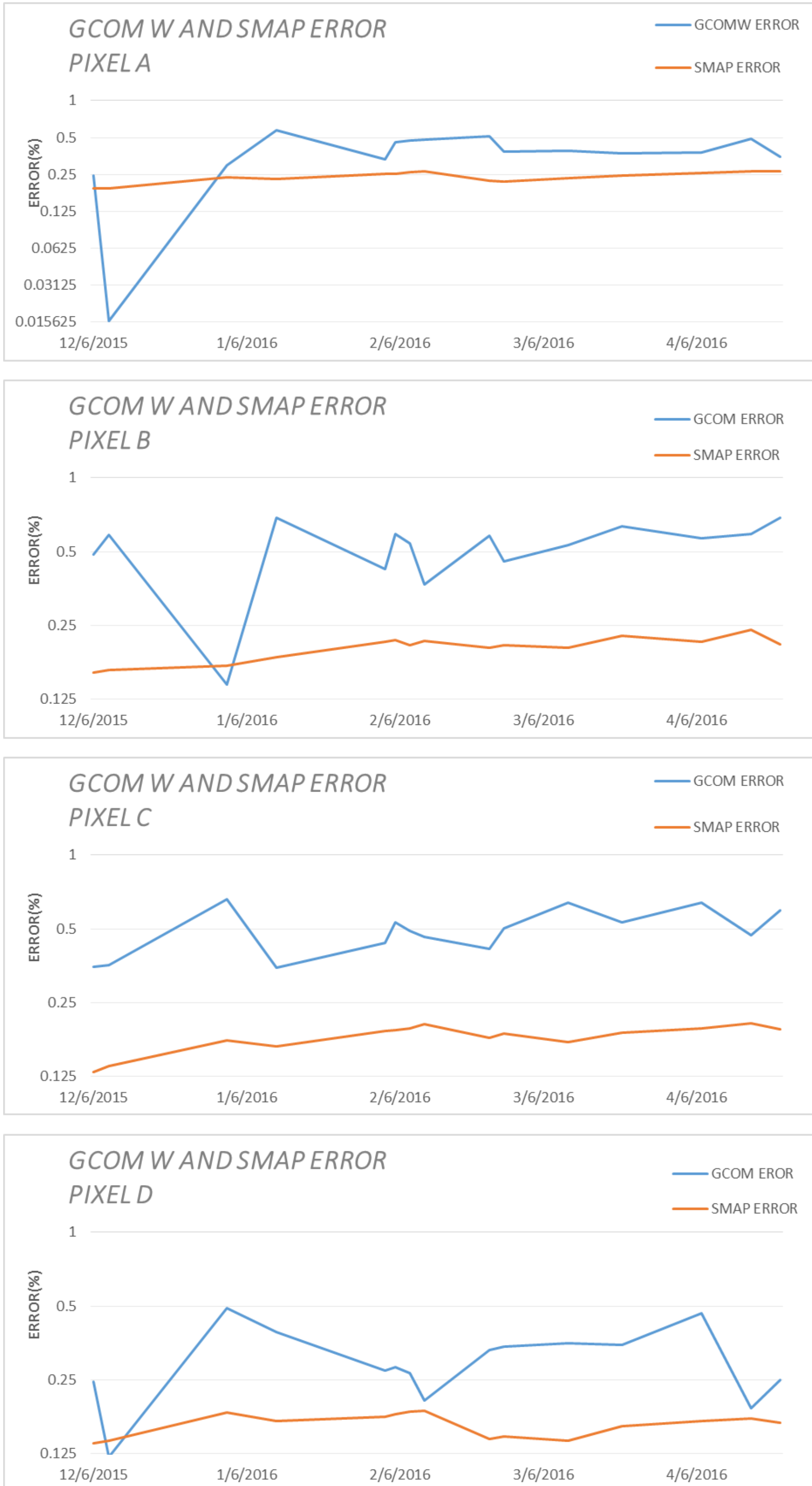


Figure 5 Errors in Satellite Soil Moisture Estimation using GOESPR as Proxy

3. **<u>Task 3 & Task 4:</u>** Instrument Calibration and Field Experiment

The CREST L-band microwave observation was used at three temporal sites for the soil moisture monitoring. The observations include spatiotemporal measurements of L-band brightness temperatures, surface temperature, and soil moisture. These observations were collected on soils under variable conditions like bare soil and soil under a variation of crops.

<u>Assessment of Surface Heterogeneity:</u>

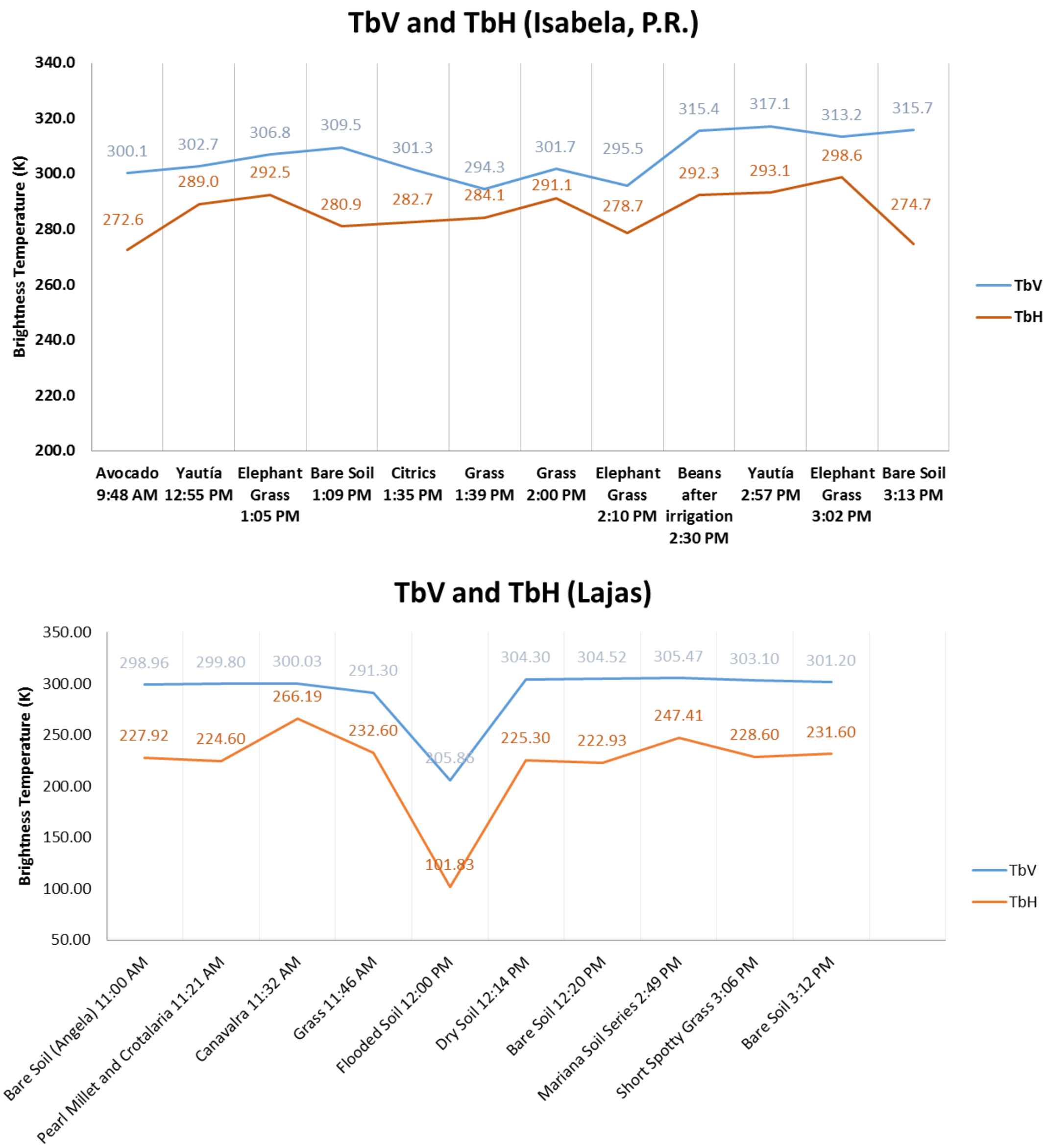
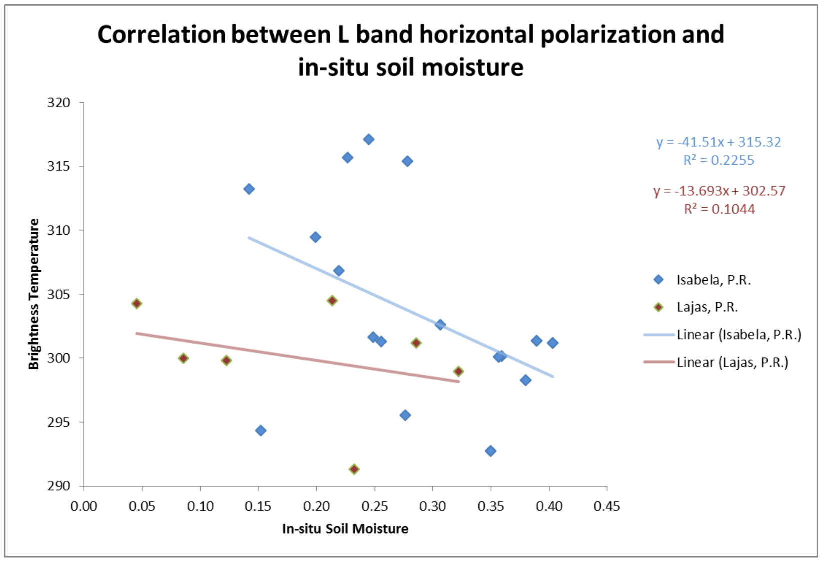


Figure 6 Brightness Temperature at Different Crop and Vegetation Types

Discussion of Results:

Early results quantify the effect of surface heterogeneity in the soil moisture retrievals (See Figures 6 - 7). Irrigation patterns and the vegetation fraction under the observed area; results in variation in soil moisture. During the next phase is planned to asses and quantify the impact into the satellite pixel. Correlation between brightness temperature and in-situ soil moisture was studied to make preliminary inferences on the attenuation effect of the radiometric response due to the presence of different types of vegetation. Further studies will include the determination of the attenuation factor for each crop studied, the implementation of the microwave emission model Tau-Omega to determine the soil moisture content, and the testing of satellite-based radiometers.



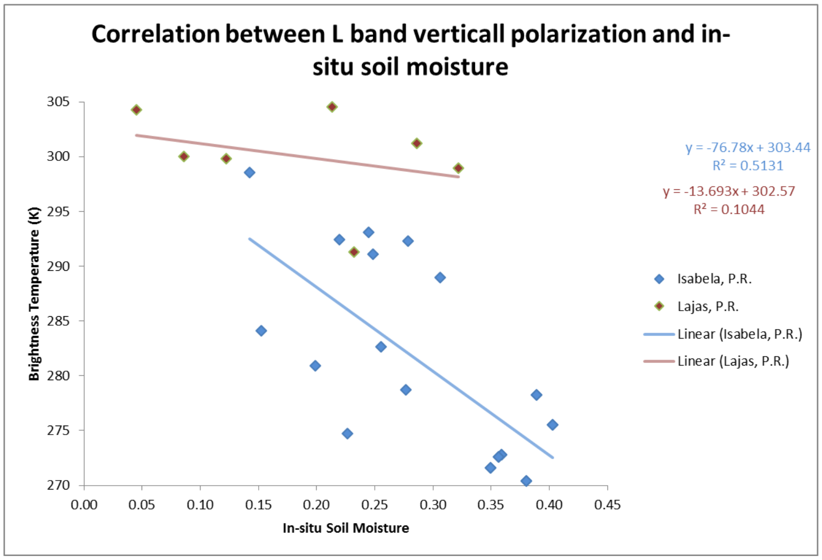


Figure 7 Relationship between Brightness Temperature and Soil Moisture

As expected the correlation (figure 7) between the brightness temperature and the soil moisture tends to be negative. This indicates that an increase of the soil moisture leads to a decrease in the brightness temperature. Attenuance on the radiometric response of the soil was perceived with the low values of the regression. These low values illustrate how different crop and vegetation conditions reduce the sensitivity of the microwave sensor to the soil moisture

<u>Mapping Products:</u>

Spatially distributed maps (figure 8) of the soil moisture, soil temperature and brightness temperature were generated. The resulting maps are being used to quantify the effect of surface heterogeneity at each observational site (pending work).

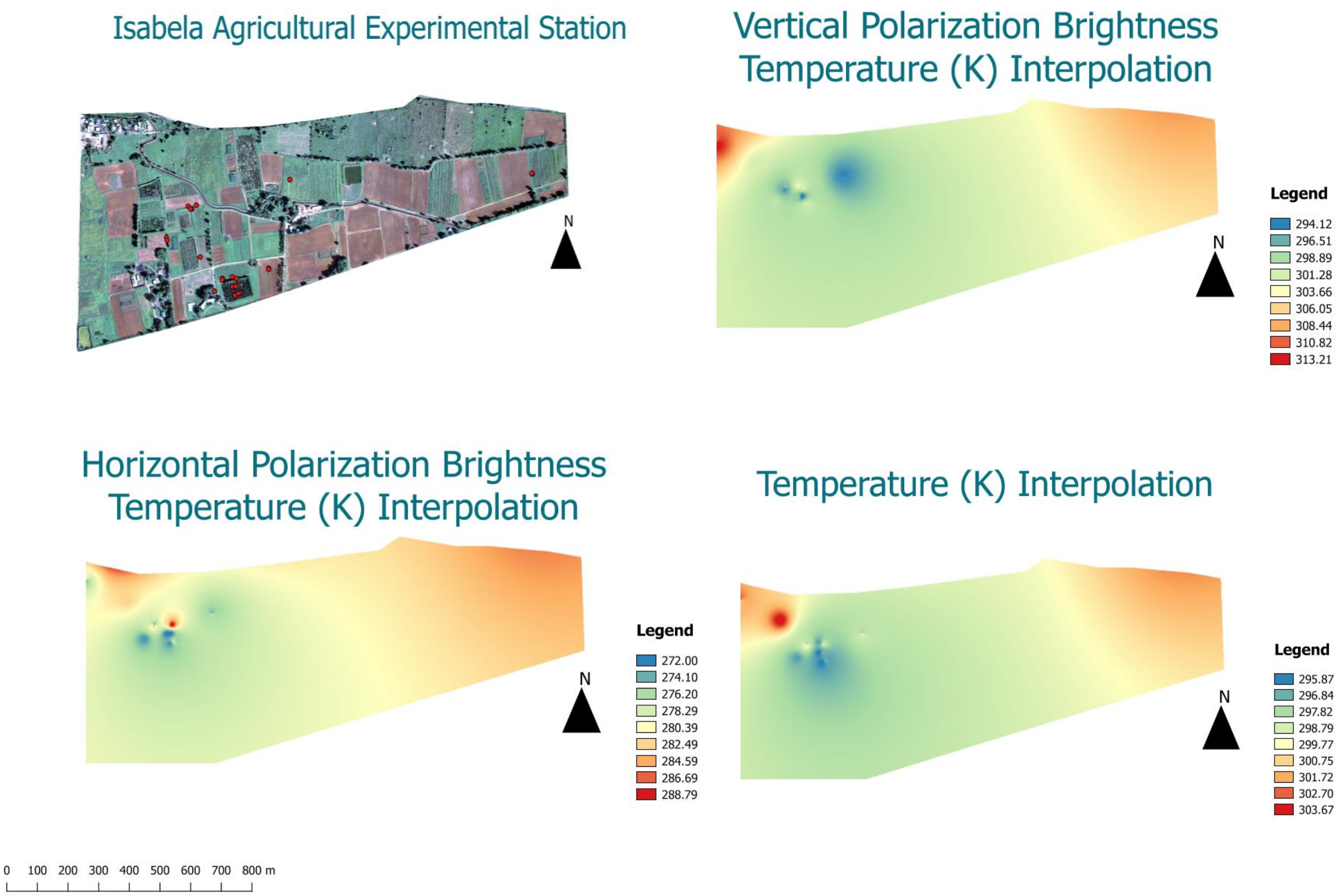


Figure 8 Sample Mapping Product at Isabela

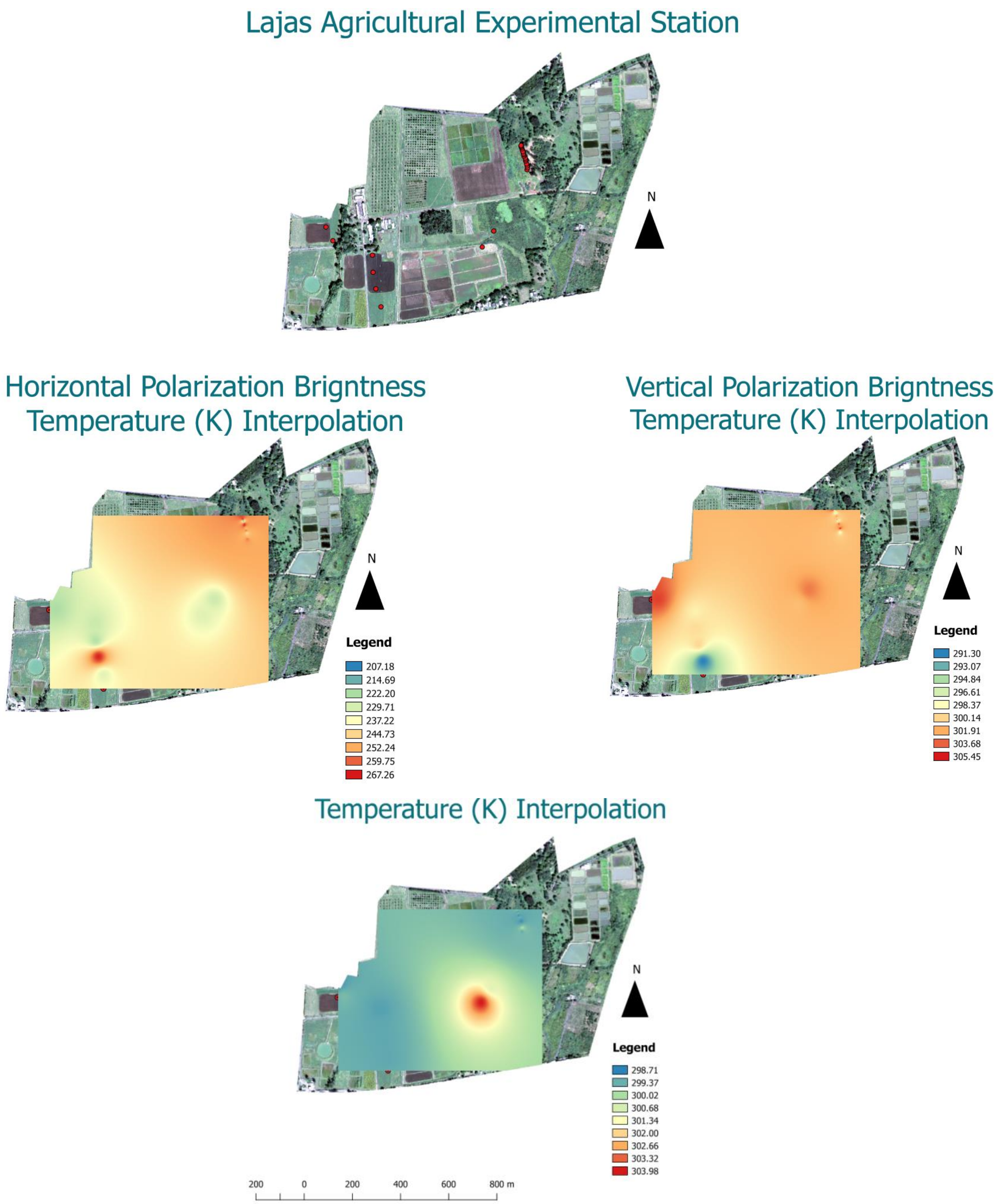


Figure 9 Sample Mapping at Lajas

Summary

- It is known that high densities of crops and vegetation affects the sensitivity of the radiometric measurements, leading to misleads in the data collection both of ground-based and satellite-based passive microwave observations.

- Accurate soil moisture readings will only be possible if the contribution to the attenuance generated by the different species of crops and vegetation is known.

- Further investigation, analysis of data, and application of mathematical models will provide a broader range of results, leading to new discoveries and new applications that will help mitigate many anthropological and environmental disasters to a new degree of significance to hydrology, agricultural productivity, and weather climate forecasting in Puerto Rico and the tropics.

The main research question still to be address: **How in situ and satellite observations in the microwave are related?**

- Large FOV of satellite microwave radiometers.
- Variability of land surface cover and of physical properties around the station.

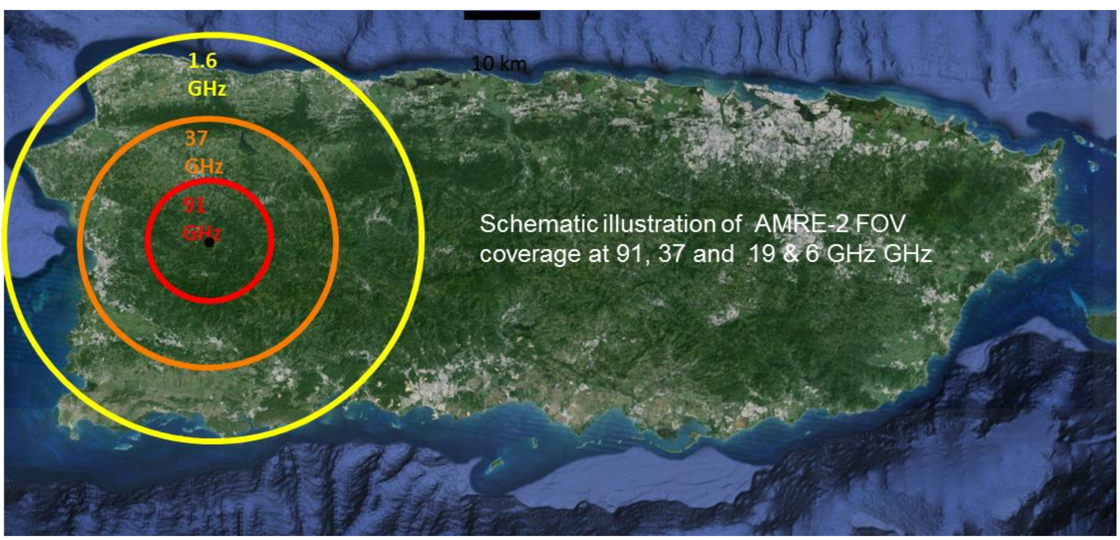


Figure 10 Satellite Foot-Print Over Western PR

Comments:

1. Leverage Funding

Using this project as leverage; another related project was funded by NOAA/JPSS. The project Validation and Application of JPSS/GCOM-W Soil Moisture Data Product for operational flood monitoring in Puerto Rico, received $75K in funding for FY2015 and $75K for FY2016. Two additional students were impacted. The synergy between projects is going to be used to develop a comprehensive soil moisture dataset for Puerto Rico.

2. Collaborative Research between CREST-UPRM-GRL

A joint collaborative soil moisture field experiment carried out during Feb 2016 at Western part of Puerto Rico in collaboration with CREST – UPRM - GRL/ERDC/USACE faculty/scientists and students as a part of JPSS funding received by CREST scientists. The participants were Dr. Tarendra Lakhankar (CREST), Prof. Jonathan Munoz and Rebecca Tirado-Corbalá (UPRM), and Clint Smith and AndMorgan Fisher (GRL/ERDC/USACE). During the field experiment microwave brightness temperature and soil moisture were observed for different irrigation pattern and vegetation conditions including: bare soil, short grass, tall grass, beans field, banana and avocado field. In collaborative activity, parallel soil moisture observations are being conducted with GRL/ERDC/USACE using Cosmic-ray Soil Moisture Observing System (COSMOS). It is planned to permanently establish a COSMOS unit by GRL/ERDC at the Isabela Agricultural Station of UPRM, Puerto Rico. The variation in scales between the observing systems (in-situ soil moisture, L-band Observations and COSMOS) represent a unique opportunity for the validation of satellite (G-COM) soil moisture. Currently, we are in the process to generate a high resolution soil moisture map of western Puerto Rico.

Figure 11 Research Group UPRM, CUNY and ERDC/GRL

Information Transfer Program Introduction

Meetings, seminars, technical reports, and a web site are used by the Institute to keep the water resources community and general public informed about advances in research. Approximately once every three or four years, the Institute organizes a major conference on water-related research in Puerto Rico and the Caribbean Islands, in collaboration with US Virgin Islands Water Resources Research Institute, Caribbean office of the USGS, and professional organizations in the region. All these activities facilitate the translation of research sponsored by the Institute into practical applications of direct benefit to industry, government, and the general public. In 2015, the last conference held, the Puerto Rico Water Resources and Environmental Research Institute joined the Hawaii Water Resources Research Center, the Virgin Islands Water Resources Research Center, and the Environmental Research Institute of the Western Pacific in Guam to organize the conference titled “2nd Water Resource Sustainability Issues on Tropical Islands.” Next conference is being planned for December, 2017. This information transfer project was partially funded from 104B program.

Second Conference on Water Resource Sustainability Issues on Tropical Islands

Basic Information

Title:	Second Conference on Water Resource Sustainability Issues on Tropical Islands
Project Number:	2015PR170B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	PR098
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	Jorge Rivera-Santos, Walter Silva

Publications

There are no publications.

FINAL REPORT

Second Conference on Water Resource Sustainability Issues on Tropical Waters

by

Jorge Rivera Santos, PI

Walter Silva Araya, Co-PI

Project Number: 2015PR170B

Puerto Rico Water Resources and

Environmental Research Center

University of Puerto Rico at Mayagüez

Mayagüez, Puerto Rico

May 2016

Preamble

This technology transfer effort is the result of the collaborative work between the Island Institutes of the Water Resources Research Institutes Program of the USGS under Section 104 of the Water Research and Development Act of 1984 (P.L. 98-242). The lead institute was the Water Resources Research Center of the University of Hawaii at Manoa. The participation of the PR Water Resources and Environmental Institute was the involvement of the director and associate director in the organizing committee and by covering the expenses for material and supplies as well as the travel and lodging expenses of two keynote speakers. The following sections were written by Aly I. El-Kadi, conference chair, and his staff and are submitted herein as a common report for the conference and in compliance of the reporting requirement of the Water Resources Research Institutes Program of the USGS.

Abstract

Fresh water resources in island states are under threat from both overuse and contamination. On some islands, climate change and sea level rise are already degrading water resources. However, researchers in these mostly isolated places do not have the opportunity to share knowledge and experience with one another. Hence, there is less frequent exchange between researchers on the islands and their colleagues in the major population centers. Enhanced communication and collaboration between island researchers can provide a vital, synergistic link, which will strengthen all the researcher programs. A common platform is always needed to discuss these pressing issues and potential solutions.

To meet these needs, the Second Water Resource Sustainability Issues on Tropical Islands conference was held in Honolulu, Hawaii, December 1–3, 2015. The conference was sponsored by the four water resources research institutes in the Islands Region of the United States (Guam, Hawaii, Puerto Rico, and The Virgin Islands), which are part of the Geological Survey's National Institutes for Water Resources Program. The conference was aimed at providing a platform for discussion between water resources researchers and others on existing water resources issues facing tropical islands and those issues that are likely to develop in the future, particularly due to the anticipated changes in climate.

The conference was a great success and achieved its objectives. All presentations were of high quality and well received by participants. The Conference Organizing Committee decided to have the next meeting in 2017.

Problem and Research Objectives

Island states are faced with a unique set of environmental and cultural issues pertinent to the management of water resources. Fresh water resources are under threat on many islands from both overuse and contamination. Ocean waters in these tropical regions are ecologically sensitive and valuable, and similarly threatened by pollution. On some islands, sea level rise is degrading groundwater resources. Specific problems are related to the following.

- Island states are heavily dependent on importing essentials, such as food, fuel, and manufactured goods to satisfy their resource needs. On most of these islands, population growth is placing increasing pressure on water resources. t is imperative that these threats to the welfare of island communities be addressed by sound scientific research before they reach crisis proportions. Sustainable management and protection of island water supplies is even more critical than it is on the continents, as island communities have no resources to import in the event of failure of their water supplies. Officials dealing with resource protection and management need access to scientifically sound research that is specific to island environments.

- The projected growth in population on tropical islands will add further stress to these islands in regard to water supply, wastewater disposal, management of solid wastes, and meeting energy needs. Reliable supplies of high quality water are essential to sustain development and quality of life in any community, but tropical islands face unique challenges to maintaining sustainable water resources. Another concern is that land clearance and obsolete land use practices continue to induce erosion in watersheds, which impacts coral reefs in near shore environments.
- Drought associated with El Niño creates significant stresses on all islands in the western Pacific, particularly "low" atoll islands. During drought conditions, there is little recharge to the groundwater, so the thin freshwater lens can become contaminated with saltwater. Atolls are also vulnerable to wash over events, especially during times of heightened sea levels and storm passages. Flooding of the island by seawater can displace many or all of the residents and ruin crops and infrastructure, but may also leave the shallow aquifers contaminated with salt water even after residents could otherwise return and resume normal activity.

The above issues are universal to island states yet researchers in these far flung and isolated places seldom have the opportunity to share knowledge and experience with one another. They work largely in isolation. The great distances that separate most island states from larger centers of academia and government means that there is less frequent exchange between researchers on the islands and their colleagues in the major population centers. Enhanced communication and collaboration between island researchers can provide a vital, synergistic link, which will strengthen all the researcher programs. It is a truism that the greatest scientific advances usually result from the collaboration of groups of researchers working together. A common platform is always needed to discuss these pressing issues and potential solutions. There is a need to present the state of research and its applications concerning water resources of tropical islands and to provide a platform to address water sustainability challenges therein.

Methodology

To meet the above mentioned needs, the Second Water Resource Sustainability Issues on Tropical Islands conference was held in Honolulu, Hawaii, December 1–3, 2015. The conference was sponsored by the four water resources research institutes in the Islands Region of the United States (Guam, Hawaii, Puerto Rico, and The Virgin Islands), which are part of the Geological Survey's National Institutes for Water Resources Program. The Hawaii WRRC is also representing American Samoa. The conference, a follow-up to a conference held by the institutes in November 2011, was aimed at providing a platform for discussion between water resources researchers and others on existing water resources issues facing tropical islands and those issues that are likely to develop in the future, particularly due to the anticipated changes in climate.

The conference was organized and sponsored by:

- Water Resources Research Center, University of Hawaii at Manoa, Honolulu, Hawaii.
- Water and Environmental Research, Institute of the Western Pacific, University of Guam.
- Puerto Rico Water Resources and Environmental Research Institute, University of Puerto Rico.
- Virgin Islands Water Resources Research Institute, University of the Virgin Islands.

Co-sponsors are:

- American Samoa Power Authority.
- Department of Geology & Geophysics, University of Hawaii at Manoa.
- Sea Grant College Program, University of Hawaii at Manoa.
- USGS Pacific Islands Water Science Center, Honolulu, Hawaii.
- United States Geological Survey.

Organizing Committees

Regional/Technical Advisory Committee

Conference Chair
Aly El-Kadi
Associate Director
Water Resources Research Center
Professor
Department of Geology and Geophysics
University of Hawaii at Manoa

Co-Chair
Darren T. Lerner
Interim Director
Water Resources Research Center
Director
Sea Grant College Program
University of Hawaii at Manoa

Co-Chair
Stephen Anthony
Director
USGS Pacific Islands Water Science Center

Co-Chair
Utu Abe Malae
Executive Director
American Samoa Power Authority

Co-Chair
Roger Fujioka
Researcher (emeritus)
Water Resources Research Center
University of Hawaii at Manoa

Co-Chair
Jorge Rivera-Santos
Director
Puerto Rico Water Resources and
Environmental Research Institute

Co-Chair
Earl Greene

Co-Chair
Henry Smith

Chief
Office of External Research
United States Geological Survey (USGS)

Former Director
Virgin Islands Water Resources Research Institute

Co-Chair
Shahram Khosrowpanah
Director
Water & Environmental Research Institute of the Western Pacific (WERI)
University of Guam

Local Organizing Committee

Enjy El-Kadi
Barbara Guieb
Patricia Hirakawa
April Kam
Philip Moravcik

The conference program covered the following subjects.

- Sustainability groundwater and watershed studies
- Sustainability integrated programs
- Climate change and variability and impacts on water resources
- Protection strategies for island watersheds and aquifers
- Managing demands and supplies, including water conservation and reuse
- Water resources exploration
- Water quality: Application of technology and adaptive management
- Water quality: Groundwater
- Water quality: Surface water
- Water quality: Outreach and Education
- Coastal Groundwater

Figure 1 contains the program at a glance.

Principal Findings and Significance

Wrap up of conference can be found at the link:

http://www.wrrc.hawaii.edu/2015conference/2015conferencewrapup/2015conferencewrapup.shtml

The listed information includes:

- Video message from U.S. Senator Mazie Hirono

- Conference abstract volume
- Copies of slides from the opening session
- Copies of other oral presentation slides
- Copies of posters

It should be noted that copies of slides or posters are posted with author's consent. Authors of these presentations or others not listed should be contacted for more information.

The conference was a great success and achieved its objectives. All presentations were of high quality and well received by participants. The Conference Organizing Committee decided to have the next meeting in 2017.

Unfortunately, we are not able to publish a conference proceedings volume as was planned. We tried a few options including submitting the papers for potential publication in the Journal of Contemporary Water Research and Education. After selecting the top 15 presentations by the Conference Organizing Committee and Technical Advisors, a large majority of authors opted not to submit. Many have indicated their desire to submit elsewhere, due to the lack of the Journal's impact factor, or expressed difficulty in meeting the deadline. This has motivated our decision to change the process next time by asking for submitting the manuscripts before the meeting.

CONFERENCE AT A GLANCE

2015 Water Resource Sustainability Issues on Tropical Islands

Tuesday, December 1, 2015

07:00 – 09:00	Registration / Continental Breakfast
08:00 – 09:30	Welcome/Introductions by Conference Chair Aly I. El-Kadi – Video welcome from Hawaii Senator Mazie Hirono – Presentations by Earl Greene (USGS) and Center/Institute Directors (Shahram Khosrowpanah, Jorge Rivera-Santos, Kristin Wilson Grimes, and Darren Lerner) – Panel discussion by Center/Institute Directors, Earl Greene (USGS), Stephen Anthony (USGS PIWSC), and David Sumner (USGS Caribbean-Florida Water Science Center)
09:30 – 10:45	SESSION A: Sustainability Groundwater and Watershed Studies, Part 1 (Session Chair: Henry Smith)
10:45 – 11:00	**Break**
11:00 – 12:15	SESSION B: Water Resources Exploration (Session Chair: Darren Lerner)
12:15 – 13:15	**Lunch**
13:15 – 15:20	SESSION C: Protection Strategies for Island Watersheds and Aquifers (Session Chair: Jorge Rivera Santos)
15:20 – 15:35	**Break**
15:35 – 16:25	SESSION C (*continued*)
16:25 – 17:15	SESSION D: Water Quality: Application of Techology and Adaptive Management (Session Chair: Roger Fujioka)

Wednesday, December 2, 2015

07:00 – 09:00	Registration / Continental Breakfast
08:30 – 09:20	SESSION E: Water Quality: Surface Water (Session Chair: Roger Fujioka)
09:20 – 10:10	SESSION F: Water Quality: Outreach and Education (Session Chair: Roger Fujioka)
10:10 – 10:25	**Break**
10:25 – 12:05	SESSION G: Climate Change and Variability and Impacts on Water Resources, Part 1 (Session Chair: Stephen Anthony)
12:05 – 13:30	**Lunch/Speaker: Senator Thomas Ada (invited)**
13:30 – 15:10	SESSION H: Coastal Groundwater (Session Chair: Shahram Khosrowpanah)
15:10 – 15:25	**Break**
15:25 – 16:15	SESSION I: Water Quality: Groundwater and Surface Water (Session Chair: Roger Fujioka)
16:15 – 17:05	SESSION J: Sustainability Groundwater and Watershed Studies, Part 2 (Session Chair: Henry Smith)
17:05 – 19:00	SESSION P: Poster Session (Session Chair: Philip Moravcik) **Poster Session/Reception**

Thursday, December 3, 2015

07:00 – 09:00	Registration / Continental Breakfast
08:30 – 09:45	SESSION K: Sustainability Groundwater and Watershed Studies, Part 3 (Session Chair: Earl Greene)
09:45 – 10:10	SESSION L: Sustainability Integrated Programs (Session Chair: Earl Greene)
10:10 – 10:25	**Break**
10:25 – 11:40	SESSION L (*continued*)
11:40 – 12:05	SESSION M: Managing Demands and Supplies, Including Water Conservation and Reuse (Session Chair: Shahram Khosrowpanah)
12:05 – 13:30	**Lunch/Speaker: Josh Stanbro (invited)**
13:30 – 14:45	SESSION M (*continued*)
14:45 – 15:10	SESSION N: Climate Change and Variability and Impacts on Water Resources, Part 2 (Session Chair: Stephen Anthony)
15:10 – 15:25	**Break**
15:25 – 16:15	SESSION N (*continued*)
16:15 – 17:30	SESSION O: Sustainability Groundwater and Watershed Studies, Part 4 (Session Chair: Henry Smith)

ORGANIZED BY: Water Resources Research Center, UHM • Water and Environmental Research Institute of the Western Pacific • Puerto Rico Water Resources and Environmental Research Institute • Virgin Islands Water Resources Research Institute

Figure 1. Conference at a glance

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	9	0	0	0	9
Masters	8	0	0	0	8
Ph.D.	3	0	0	0	3
Post-Doc.	0	0	0	0	0
Total	20	0	0	0	20

Notable Awards and Achievements

None during this reporting period.