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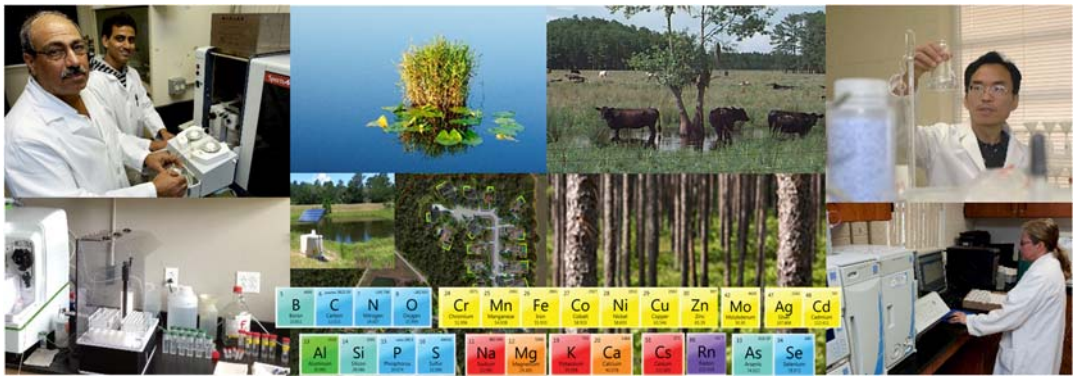
Soil and Water Chemistry: Agronomic and Environmental Applications



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From the Chair...

The discipline of soil and water sciences is supported by the basic sciences of biology, chemistry, and physics. The inter-relationships and mutual dependency among these basic sciences forms the core of the Soil and Water Science Department (SWSD)'s ability to address emerging issues in soil, water, and environmental sciences as related to sustainable crop productivity and protection of natural resources and the environment. In this newsletter, we showcase applications of **soil and water chemistry** to address: fate and transport of contaminants in surface and subsurface environments; water quality; remediation of contaminated soils and waters; environmental impacts of toxic metals and organic compounds; and nutrient management and associated BMPs in agricultural, forested, and urban lands.

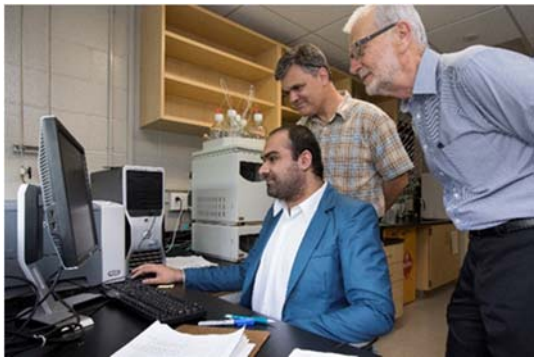
Soil, water, and environmental chemistry is changing at an exceptionally rapid rate, driven by the development of advanced instrumentation and methods and the recognition of the importance of chemical reactions to understand fundamental processes in soils and waters. Anthropogenic activities can impact many of these processes, and a clear understanding of the fundamental controls on chemical behavior is required to predict the directions and magnitudes of these activities. The SWSD has been well situated in applying soil and water chemistry concepts and principles to address various issues related to soil, water, and the environment. However, retirements of several key faculty have eroded our strength in developing foundational soil and water chemistry programs that support applications to solve much needed environmental issues that pose threats to agriculture and natural resources. Fundamental knowledge is useful in making sound and cost-effective decisions as we develop strategies to protect soil and water resources from contaminant impacts. Therefore, the department plans to fill a faculty position that will meet the critical need to focus on fundamental topical areas of soil and water chemistry.

In this newsletter we present a few examples of soil and water chemistry teaching, research and extension programs in which the department is engaged. Additional information on departmental programs can be found at: http://soils.ifas.ufl.edu.

What is Soil and Water Chemistry and What Do These Chemists Do?

Soil and Water Chemistry involves chemical reactions and processes occurring in soils and waters. Traditionally, the discipline has been largely laboratory-based and focused on fundamental chemistry, often inorganic chemistry. Today's soil and water chemists commonly work across disciplines and scales to address nutrient, heavy metal, trace organic, and waste management issues using computer modeling and laboratory, greenhouse, and field studies. Thus, Soil and Water Chemistry is highly interdisciplinary and closely linked with hydrology, physics, microbiology, and biogeochemistry. The range of expertise and skills required, and the impacts of work done, makes the field exciting and ever-changing for students and faculty alike. The Soil and Water Chemistry program in the SWSD at UF demonstrates all of these characteristics, many of which are highlighted in this issue.

The availability of chemicals applied to land, intentionally or otherwise, determines their potential benefit or damage to the environment and public health. The chemical reactions and processes in soils and waters are critical to determining their availability. Soil and Water chemistry research may focus on limiting availability of environmental contaminants through the addition of soil amendments (e.g., water treatment residuals, biochar, composts, biosolids), sometimes on improving assessment techniques to better judge contaminant fate and mobility, and sometimes on helping to develop regulations (e.g., Safe Soil Levels, Phosphorus-Index, and Biosolids or Wastewater Land Application Guidelines).



A relatively new application for Soil Chemistry is risk assessment, particularly formal comprehensive environmental and human health risk assessment. Several faculty listed in this newsletter conduct risk assessment related research programs. For example, Chris Wilson (center) and George O'Connor (right) co-advised MS student Harmanpreet Sidhu (left) on an assessment of the extent of endocrine disruptor chemical (EDC) contamination of "reclaimed" (waste) water and the potential transfer of EDCs to children playing on turf recently irrigated with "reclaimed" water. Sidhu learned the demanding sample preparation and GC/MS skills necessary to analyze for EDCs in Wilson's lab and the risk assessment approaches in O'Connor's course SWS 5551. Sidhu is now pursuing a PhD with O'Connor, examining the effects of soil-sorption of antibiotics applied in animal manures on the potential for spreading antibiotic resistance in amended soils. In this venture, Sidhu is co-advised by Max Teplitski, a Microbial Ecologist in SWS. Modern graduate study almost always demands interdisciplinary expertise from multiple faculty willing and able to stretch beyond their initial training – something Soil and Water Chemists are trained to do. For additional information, contact George O'Connor at: gao@ufl.edu.

COURSES IN SOIL AND WATER CHEMISTRY

Courses Offered on Campus

Undergraduate Courses
SWS 4451 Soil and Water Chemistry
SWS 4550 Soils, Water and Public Health

Graduate Courses
SWS 5406 Soil and Water Chemistry
SWS 5424 Soil Chemical Analysis
SWS 5551 Soils, Water and Public Health
SWS 6262 Soil Contamination and Remediation
SWS 6454 Advanced Soil and Water Chemistry
SWS 6464 Soil Mineralogy

Courses Offered Online

Undergraduate Courses
SWS 4204 Urban Soil and Water Systems
SWS 4451 Soil and Water Chemistry
SWS 4550 Soils, Water and Public Health
SWS 4800 Environmental Soil and Water Monitoring Techniques

Graduate Courses
SWS 5406 Soil and Water Chemistry
SWS 5551 Soils, Water and Public Health
SWS 5805 Environmental Soil and Water Monitoring Techniques
SWS 6134 Soil Quality
SWS 6209 Urban Soil and Water Systems
SWS 6262 Soil Contamination and Remediation

Environmental Soil Chemistry: Phosphorus

Understanding the principles of soil chemical reactions is essential for delivering science-based knowledge to the community for practical application of research findings. One interesting area of environmental soil chemistry research is the interaction of phosphorus in a soil with other soil components that would allow prediction of phosphorus storage and loss from that soil. Research by graduate students in the *Environmental Soil Chemistry Laboratory* has led to the development of procedures for obtaining such phosphorus retention parameters that are essential for developing predictive tools to forecast mobility and reactivity of phosphorus.

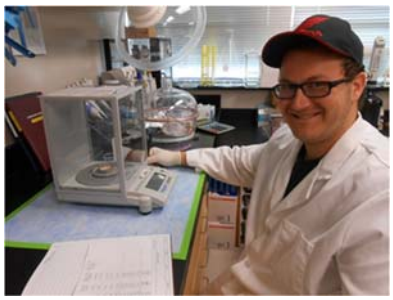
PhD graduate assistant Biswanath Dari (left) and Vimala Nair (right) determine phosphorus concentrations on a spectrophotometer.

Graduate student Biswanath Dari collects soil samples by depth to assess soil profile phosphorus distributions and loss potentials via subsurface drainage.

Another area of research is soil-biochar interactions. Application of nutrient-rich biochar as a soil amendment is becoming popular to promote plant growth by providing essential nutrients and improving the soil's water holding capacity. We have found that at environmentally-relevant phosphorus concentrations, phosphorus storage within the soil-biochar system depends on the properties of the soil and is independent of the nature of the biochar feedstock. Coupled with biochar's numerous beneficial properties, including its role in soil carbon sequestration, it might be possible to tailor land application of biochar for maximum agronomic and environmental benefits across a wide spectrum of conditions in tropical and temperate regions. We are communicating some applications of this research in EDIS publications (edis.ifas.ufl.edu) for the benefit of professionals and practitioners who are interested in phosphorus management practices. For additional information, contact Vimala Nair at: vdn@ufl.edu.

Environmental Chemistry and Toxicology Program

This program focuses on assessing the fate of organic contaminants in the environment and their effects on non-target biological resources. We study organic contaminants that include pesticides used in agricultural, aquatic, and residential environments; pharmaceuticals; suspected endocrine system disrupting chemicals; and other organic contaminants of concern. Current research projects are funded by the Florida Fish and Wildlife Conservation Commission, the National Science Foundation, and the USDA-Agriculture and Food Research Institute.



Matt Nance (left, MS graduate assistant) is currently investigating the influence of sediments on the fate of liquid and granular herbicide formulations used for control of aquatic weeds. Our working hypothesis is that as carbon content increases in the sediments, the bioavailability of the herbicides will decrease, especially for the granular formulations in contact with the sediment.

Noha Abdel-Mottaleb (right, PhD graduate assistant) is looking at the potential use of aquatic ornamental plants for removing organic contaminants from surface water within retention ponds. These studies are assessing the uptake, distribution, and disposition of a broad range of organic contaminants in Japanese Sweetflag and Canna lilies. Lessons learned in the lab will be confirmed with field scale evaluations using the plants in floating islands.

We are also investigating the influence of herbicide formulation and irrigation management practices on losses of pesticides from ornamental plant production nurseries. The goal is to identify sound management strategies for minimizing pesticide discharges with surface water.

Toxicology research is currently focused on characterizing the potential interactions of multiple contaminants on non-target biological resources. We are also setting up seagrass cultures to support future research focused on determining the effects of contaminants and other stressors on seagrass health and reproduction. For additional information, contact Chris Wilson at: pcwilson@ufl.edu.

Soil and Water Chemistry Program: Applications to Best Management Practices

All farms in the Everglades Agricultural Area (EAA) basin implement mandatory Best Management Practices (BMPs) that help reduce phosphorus (P) loads from drainage waters that enter the Everglades ecosystem. The Water Quality group at the Everglades Research and Education Center in Belle Glade has a long history of researching the development and implementation of BMPs in EAA. The goal of the program is to reduce P loads from the EAA basin by 25% or more compared to a ten-year pre-BMP baseline period. The UF/IFAS program focuses on working with EAA growers to adopt and implement BMPs to achieve the total phosphorus (TP) load reduction as required by the Everglades Forever Act. The program also focuses on new and innovative BMP research.

A current five-year paired farm study is evaluating the impact of floating aquatic vegetation (FAV) on sediment properties and P loads from eight cooperating farms within the EAA. Controlling FAV may help reduce P loads on certain farms by reducing the generation of highly mobile organic sediments. We hypothesize that FAV has a significant impact on the ability of farm canal sediment to retain and release P, and that controlling FAV will generate denser sediments with increased recalcitrant P. Improved light penetration into the water column from FAV removal is theorized to promote P co-precipitation with Ca and Mg carbonates into less labile minerals, while an increase in dissolved oxygen would raise redox potential and P-sorption with Fe-Al minerals. Sediment cores from the eight participating farms in the EAA are taken twice a year and tested for total P, pH, bulk density, and organic matter content. The 0-2.5 cm core section also undergoes a sequential P-fractionation analysis. We expect that recalcitrant Ca-Mg and Fe-Al bound-P will increase with a decrease in labile-P for treatment canals with no FAV. In addition, we are conducting x-ray diffraction analysis to assess any spatial and temporal change in mineral composition of canal sediment in response to FAV removal.

The EAA basin P load reduction has averaged greater than 50% yearly since the BMP program's inception. In 2014, the TP load reduction was 63%, corresponding to a flow weighted mean Total P concentration of 94 ppb exiting the EAA. This load reduction attests to the success of the partnership between the EAA growers, South Florida Water Management District, and University of Florida personnel. For additional information, contact Samira Daroub at: sdaroub@ufl.edu.

Soil Mineralogy Laboratory

Recent PhD graduate, Chumki Banik, positioning sample in the X-ray Diffractometer

The Soil Mineralogy Laboratory in the SWSD houses a Rigaku Ultima X-ray Diffractometer that provides definitive atomic structural information about crystalline solids. It enables identification of minerals as well as of artificial substances synthesized for various purposes. It can be used to document and monitor transformations of geochemical significance. It is routinely used to analyze powders but can be configured to accommodate irregular-shaped objects such as rocks. X-ray diffraction data have been central to the study of soil mineral distributions and transformations; dehydration characteristics and organic cation interlayer configurations of expansible soil minerals; mineralogy of soils and sediments in the greater Everglades region; lead transformations in shooting ranges; residue composition of aquifer rock; phosphate minerals recovered from flushed dairy manure; dietary influence on phosphate mineralogy as related to phosphorus solubility in dairy manure; mineral components of biochar and modified biochar, etc. For information on XRD and its potential application, contact Willie Harris at: apatite@ufl.edu.

Mass Spectrometer Core Laboratory

Inductively **C**oupled **P**lasma coupled to a **M**ass **S**pectrometer (Perkin-Elmer NexIon 330-X ICP-MS) is used to analyze metals. The axial plasma volatilizes the metals in a digestion solution while the MS can be used to identify as many elements as the analyst has standards. Currently, the number of elements simultaneously quantified stands at 27. This hyphenated instrument has been used on contamination studies involving CCA, a wood preservative consisting of copper, chromium, and arsenic. Another area of research is the characterization and leaching potential of 7 different elements found in coal fly ash. For additional information, contact Lena Ma at: lqma@ufl.edu.

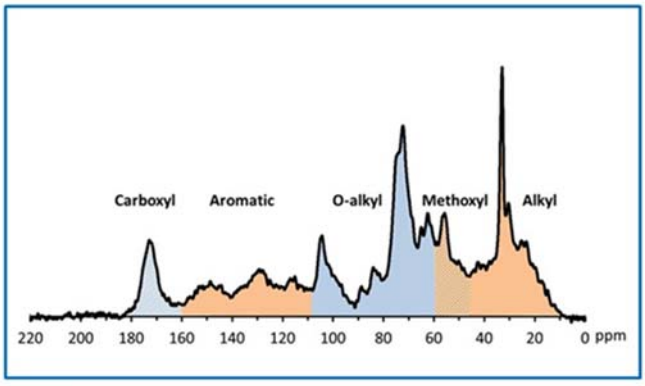
The second hyphenated Mass Spectrometer instrument is an LC-MS/MS (liquid **chromatograph** linked to a quadrapole mass spectrometer inline with a second mass spectrometer) which is managed by John Thomas. The LC and autosampler are the Finnegan Surveyor models, while the MS/MS is a Thermo-Scientific TSQ Quantum Discovery Max system. This hyphenated instrument is used exclusively for the separation and quantification of soluble organic compounds, including the anti-microbial ingredients in soap (triclosan and tricarban) and antibiotics such as tetracycline. For additional information, contact John Thomas at: thomas@ufl.edu.

A Varian gas chromatograph linked to an Agilent 240 Ion trap mass spectrometer has recently arrived. The gas chromatograph (GC) allows for the separation of volatilized compounds while the ion trap MS^n permits the analysis of multiple collision events. The current record for "n^{th}" is 3. Projects that have employed the GC-MS include research on the bioaccumulation of endocrine disruptors in fruit and vegetables, and environmental risk assessments for pesticides. For additional information, contact Chris Wilson at: pcwilson@ufl.edu.

Nuclear Magnetic Resonance (NMR) Spectroscopy

As technology advances, understanding soil chemistry on the molecular scale is critical for understanding soil processes. The Wetland Biogeochemistry Laboratory utilizes Nuclear Magnetic Resonance (NMR) spectroscopy to characterize organic carbon and phosphorus in wetland soils. Alex Cheesman (SWS PhD graduate 2010) created the first comprehensive analysis of organic phosphorus forms in wetland soils using ^{31}P NMR. Anna Normand (NSF Fellow) is using Solid State ^{13}C NMR to construct a meta-analysis of carbon forms in peatlands across the globe.

NMR analysis is like putting soil into a MRI and getting an image of its elemental (carbon or phosphorus) composition. The ^{13}C NMR image highlights carbon forms that can be easily utilized by microbes (blue) and decomposition byproducts and recalcitrant carbon forms (orange). The forms of carbon can then be related to greenhouse gas production, chemical sorption, and other soil processes. More information about University of Florida's NMR facilities at the McKnight Brain Institute can be found at http://mbi.ufl.edu. For additional details, contact Anna Normand at: evangeline@ufl.edu or K. Ramesh Reddy at: krr@ufl.edu.



Residential Exposures to Arsenic and Hexavalent Chromium from CCA-wood

CCA-wood is exterior lumber treated with water-soluble chemicals made from chromium, copper and arsenic (CCA). CCA-wood is resistant to biological decay and can last up to 40 years, which is why it is commonly used in decks, fences, outdoor staircases and exterior siding. It is also commonly found in non-residential settings such as park walkways, marine docks and in many agricultural applications. Recognition that CCA-wood leaches arsenic into nearby soil and water, leading to arsenic concentrations higher than risk-based regulatory limits, led to its withdrawal from use in new housing in 2004. Because it was so popular and lasts decades, any exterior wood structure built prior to 2004 is likely constructed from CCA-wood.

Julia Gress sampling soils near CCA-wood in a zoo.

At the Biogeochemistry of Trace Metals Laboratory, we evaluated exposure to arsenic and chromium in humans and animals living in areas impacted by leaching CCA-wood. We measured dislodgeable arsenic levels from CCA-wood staircases located in several apartment complexes. In soil sampled from areas surrounding staircases, arsenic concentrations ranged from 1.6–66 mg/kg, significantly higher than the Florida residential soil cleanup target level (2.1 mg/kg). Wipe samples collected from the wood surface contained dislodgeable arsenic residues over 100 µg/100 cm^2. Overall, cancer risk from living in apartments with CCA-wood staircases and arsenic-contaminated front yards was elevated and comparable to USEPA estimates.

In addition to staircases, many homes in Florida have a deck made from CCA-wood. Residents periodically clean the deck to remove mold and brighten its appearance. We evaluated the impact of three common deck cleaning methods on the leaching of arsenic and hexavalent chromium (VI) from CCA-wood decking. We found that wood wetted with water alone tripled the amount of dislodgeable arsenic on the wood surface. We also looked at arsenic exposures in zoo animals living in enclosures made from CCA-wood and found that soil arsenic concentrations showed contamination from leaching wood. Arsenic in biological tissues from reptiles, birds and primates at the zoo had levels higher than reference values, even though amounts in their food sources were relatively low. This study identified numerous pathways of arsenic exposure in these animals, and the zoo took significant steps to reduce and mitigate exposures as a result.

Overall, our studies indicate that human and animal exposure to arsenic from leaching CCA-wood still occurs, even though USEPA took steps over a decade ago to reduce such occurrences via regulatory action and consumer advice. With new wood preservatives on the market, many homeowners are unaware of the environmental health issues related to existing CCA-wood structures. For more information on the activities, contact Lena Ma at: lqma@ufl.edu.

Soil and Water Science – Endowments

The SWSD established several endowments with the generous support from the Carlisle, Graetz, Polston, Robertson, Skulnick, and Smith families. The **Soil and Water Science Department Program Enhancement Fund** was established from funds by private donors in support of various departmental activities. We thank all our donors for their kind and generous support of soil and water science programs. To our alumni and friends, please show your support for soil and water science by selecting and making your gift to a specific area of interest. Details can be found at: http://development.ifas.ufl.edu/online_giving.html.

Welcome New Students! Summer 2015

PhD	MS	BS
Claire Friedrichsen (Daroub & Wilkie)	Excy Herrera (Toor)	Karen Hatchell – IS-EMANR-UFO (Curry)
Kalindhi Larios (Gerber)	Adam Orndorff (Daroub)	
William Zaragoza (Teplitski)	Andrew Valenski (Gerber)	

Soil and Water Chemistry Program - UF-IRREC-Fort Pierce

The UF-IFAS Indian River Research and Education Center (IRREC) is located in south Florida, where nutrient and heavy metal losses from agricultural and urban areas contribute to ecological degradation of the Everglades and eutrophication of Lake Okeechobee and the Indian River Lagoon. Florida has a long history of citrus production, and repeated use of copper-based fungicides has resulted in soil contamination. That contamination negatively influences citrus production in this area and impacts water quality due to runoff transport of copper from land to the surrounding water bodies. Therefore, our research addresses issues related to sustainable agriculture and surface water quality. Specific research areas include development of best management practices to enhance nutrient use efficiency while minimizing environmental impact; phytoremediation of eutrophic stormwaters; remediation of heavy metal contaminated soils; water quality and produce safety; and development of nanotechnology to enhance efficiency of fertilizer and pesticide use. Our studies identified a number of soil amendments with potential to hold nutrients in soil and to remediate heavy metal contaminated soils. We also discovered that floating aquatic plants such as water lettuce (*Pistia stratiotes* L.) are effective in removing nutrients (N, P) and heavy metals (Cr, Cu, Fe, Mn, Ni, Pb, and Zn) at low concentrations due to their developed root systems. Our work has improved the understanding of hyperaccumulation mechanisms, including Cd uptake, translocation, and storage processes in the hyperacculumating plants, which can be used to develop remediation strategies.

PhD candidate Eduardo Chavez (right) is conducting a field survey to investigate cadmium contamination to cacao in Ecuador.

Heavy metal contamination of cacao has impacted the global chocolate industry. One of our projects identifies sources of the contamination in Ecuador to find potential solutions to this problem. For additional information, contact Zhenli He at: zhe@ufl.edu.

Soil and Water Chemistry Program: Applications to Urban Water Quality

The Soil and Water Chemistry program at the Gulf Coast Research and Education Center (GCREC) is focused on urban soil and water quality. Our ongoing projects are aimed at (1) investigating the sources, nature, and fate of nitrogen and phosphorus in surface water (urban stormwater runoff, streams, rivers) and ground water, and (2) understanding the occurrence, fate, and transport of pharmaceuticals and hormones in Florida waters.

In one ongoing project, we're closely looking at how nitrogen and phosphorus move from urban lawns to stormwater retention ponds and then into streams and rivers in the Tampa Bay watershed. We are employing stable isotopes of nitrogen and oxygen to differentiate sources of nitrate-nitrogen and using new tools to unravel the nature of organic nitrogen in urban stormwater runoff.

The picture shows spatial mapping of a residential neighborhood in Tampa Bay. At the pond inlet, instruments were installed to collect stormwater runoff samples at 5 to 15 minute intervals following a rainfall event. The samples are analyzed for nitrogen and phosphorus forms, along with stable isotopes of nitrogen and oxygen.

We are expanding the project to multiple sites (residential neighborhoods) to better characterize flow of nutrients in urban stormwater runoff to stormwater retention ponds. This project will generate data that will be crucial in making science-based decisions about how we can reduce nitrogen and phosphorus transport to Florida water bodies to avoid problems like algal blooms, and reduce costs associated with treating stormwater ponds with chemicals. For more information, contact Gurpal Toor at: gstoor@ufl.edu.

Faculty, Staff and Students

Congratulations to the following faculty and students for their outstanding achievements:

Teri Balser was selected as one of three finalists for Baylor University's 2016 Robert Foster Cherry Award. For details see: http://www.baylor.edu/mediacommunications/news.php?action=story&story=153413.

Zhenli He was a recipient of the University of Florida Research Foundation Professorship Award.

The **Wetlands Club** (Clark — Faculty Advisor) was recognized as the Club of the Year at the CALS Scholarship and Leadership Awards Banquet.

Pasicha Chaikaew (Grunwald) was the recipient of the 2015 SWSD award for Excellence in Graduate Studies—PhD level.

Kalindhi Larios (Gerber) and **Claire Friedrichsen** (Daroub & Wilkie) were selected by the Office of Graduate Minority Programs to participate in the Board of Education Summer Fellowship Program (http://graduateschool.ufl.edu/finances-and-funding/florida-boe-summer-fellowship-program).

Congratulations! Spring 2015 Graduates

PhD

Julia "Ky" Gress (Ma)
Christine VanZomeren (Reddy)
Neil Young (Wright)

MS

Odiney Alvarez-Campos (Daroub)
MichaelJohn Carnevale (Osborne)
Cynthia Gates (Clark)
Shannon Hudgins (Ellis)
Carl Koch (Kramer)
Keri Smith (Wright)

BS in Environmental Management (Curry)

Scott Clark
Erick Echeverria
Samantha Flodin
Joshua Keen
Andrew Land
Justin Zawodny

BS in Soil and Water Science (Bonczek)

Lacey Hancotte — Soil Science
Shima Suzuki — Water Science

SLS Minors (Bonczek)

Alexis Curtin
Joseph Geisel
Josiane Joseph
Brandi Sadler
Taylor Shekels
Kara Verge

16th Annual Soil and Water Science Research Forum

Mark your calendars for the 16th Annual Soil and Water Science Research Forum scheduled on September 17, 2015 in Gainesville, FL. Our Keynote Speaker will be Dr. Andrew Sharpley, Professor of Soils and Water Quality, University of Arkansas.