UF | IFAS
UNIVERSITY of FLORIDA
Soil & Water SCIENCE

A SOIL AND
WATER SCIENCE
DEPARTMENT
PUBLICATION

Myakka

VOLUME 14
NUMBER 3

FALL 2014

Biogeochemistry

contents

From the Chair…

Biogeochemistry refers to study of biological, chemical, physical, and geological processes that regulate cycling of elements in the environment. One may ask what the soil and water science program has to do with biogeochemistry. The article in the next page provides a brief historical perspective of biogeochemistry and its linkage to soil science, and its evolution as a discipline. To understand this linkage, we need to reflect back on how our programs started at UF. The soils program started in the 1880's with the newly established Experiment Station of the State Agricultural College in Lake City, Florida. In 1907, the Experiment Station was moved to Gainesville and housed in Newell Hall, and during 1910 to 1920 several detailed studies on nutrient leaching in Florida sandy soils were conducted. During that time, several sub-disciplines emerged including chemistry, physics, microbiology, pedology, and mineralogy to develop a fundamental understanding of soil, water, and plant relationships, soil fertility and plant nutrition. These programs continued to advance science in each of these sub-discipline and made remarkable contributions to support sustainable agricultural productivity and protection of natural resources and the environment.

The biogeochemistry discipline is now recognized by other disciplines including: ecology, limnology, geology, soil science, microbiology, hydrology, and others. The Soil and Water Science Department (SWSD) recognized the need to study many soil processes in an integrated fashion and introduced the biogeochemistry program during the early 1980s. Interest in this program grew, and several faculty now have research, teaching, and extension programs that involve application of biogeochemistry concepts. The department is committed to strengthening biogeochemistry programs to address current and future needs of our clientele, while advancing the science in this area. In this newsletter we highlight select programs related to biogeochemical cycling of elements in a range of ecosystems as related to water quality, climate change, carbon sequestration, greenhouse gas emissions, and sustainable plant productivity.

EDITORS:
Susan Curry
scurry@ufl.edu

Dr. Vimala Nair
vdn@ufl.edu

Michael Sisk
mjsisk@ufl.edu

GUEST EDITOR:
Dr. Patrick Inglett
pinglett@ufl.edu

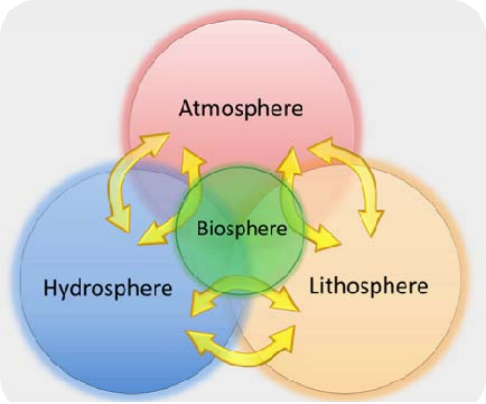
http://soils.ifas.ufl.edu

Dr. K. Ramesh Reddy, Chair, Soil and Water Science Department, 2181 McCarty Hall, Box 110290, University of Florida, Gainesville, Florida 32611.
Telephone 352-294-3151, Fax 352-392-3399, Email: krr@ufl.edu

A Brief History of Biogeochemistry

When asked about my occupation, I often receive puzzled looks when I mention that I am a biogeochemist. Most of the general public simply do not know the meaning of biogeochemistry, or the study of elemental cycling between living and nonliving earth systems. The same is somewhat true for many academics and even some in our own department who think biogeochemistry is only a very recent concept. While the term biogeochemistry was first coined only in the early 20th century, the concept and foundation for this discipline can be found centuries earlier in the discipline of soil science.

The early tie between soil science and biogeochemistry began with the strong need for scientific achievement in food production and agriculture. Many of the early scientists were also pioneers of science itself, and nature, soils, and plants were often the subject matter for their basic physics and chemical theories. As early as 1720, the derivation of materials for living biota were known to come from gaseous and soil components, and the father of chemistry, **Lavoisier**, correctly found that according to his conservation of mass theory the gaseous material required for living plants (carbon dioxide) was derived from the decomposition of plant biomass. In essence, this is the first documented biogeochemical cycle. Later work by **von Liebig** and others properly related the role of soil solution in supplying other water and particular or limiting nutrients to plant growth. Liebig's work was so important that his "law of the minimum" remain one of the central concepts of nutrient limitation theory in biogeochemistry.



Conceptual diagram of the study of biogeochemistry as an interaction of the non-living earth spheres (lithosphere, hydrosphere, and atmosphere) with life in the biosphere.

With the tie between plants and soils established, the concept of biogeochemistry gained more direction through the work of the founding fathers of soil science including **Vasily Dokuchaev** who linked the composition and creation of soil materials with the biota growing on them. Many of these scientists were interested in mineral composition and diagenesis so their studies centered on the relationship between biota living in ecosystems with the mineral matter of the rocks and soils on which they were based. In 1875, **Eduard Suess** coined the term 'biosphere', and gave us the idea that soils and their associated biota were really an intermediate in the flow of materials between the lithosphere, hydrosphere, and atmosphere.

Almost at the same time in the later part of the 19th century, important discoveries were being made on a much, much smaller scale. These were the great advancements leading to the birth of modern microbial ecology. Following the discoveries that microorganisms were involved in the putrefaction of organic matter and fermentation, scientists like **Winogradsky** and **Beijerinck** properly tied microbial identity and function to global elemental cycles with the discovery of processes like nitrogen fixation, nitrification and denitrification, and sulfate reduction. The discoveries of these processes were pivotal to complete our understanding of the cyclic nature of elements, and particularly that of nitrogen.

Vasily Dohuchaev, helped develop the idea that biota interacted with the lithosphere through weathering and pedogenesis.

The discoveries of microbial ecology were earth shattering leading scientists to begin to see the cycles and spheres of the earth as having the ability to be sustainable or self-regulating. In the early 1900s, a mineralogist and geochemist, **Vladimir Vernadsky**, saw the importance of these types of processes as they related to the recycling of elements at the ecosystem and global scales. His theories expanded on the biosphere concept of Suess where he not only acknowledged that biota were a "geologic force", but added that the biosphere was in unity with the cycling of elements through the other geologic spheres (the lithosphere, the atmosphere, and the hydrosphere). This idea is still at work today through concepts such as Gaia where the earth is viewed as a living organism.

Because of his advancement of the biosphere concept and his original studies of element budgets in ecosystems, Vernadsky is often credited as the father of modern biogeochemistry. But it was not until a few more pieces of the puzzle were added that our modern view of biogeochemistry was realized. Following the acceptance of continental drift theory in the 1930s and 40s, the final pieces of the modern biogeochemical puzzle were added by the emergence of ecology in the 1950s which linked the populations of biota in ecosystems with their physical and chemical environment.

In the 1980s and through today, we have seen the emergence of biogeochemistry as a proper scientific discipline complete with dedicated journals, textbooks and scientists willing to label themselves as biogeochemists. In our department, biogeochemistry was first introduced in wetlands and aquatic systems resulting in the creation of the Wetland Biogeochemistry Laboratory (WBL) during early 1980's. Since then, 130 students have obtained degrees with WBL faculty as graduate advisors. Originally there was only one SWS course (Wetlands Biogeochemistry SWS 6448) offered, now there are at least nine departmental courses at both graduate and undergraduate levels dealing directly with the subject. Biogeochemistry concepts are also now included in all thrust areas of the department, and the list of faculty with biogeochemistry in their job description has grown to six.

Many of the problems being addressed by biogeochemistry are large in nature (e.g., ocean productivity, climate change, etc.), and some may hold to an elitist view that biogeochemistry is only defined at the global scale. However, as I hope you can see from this brief history of the concept, many scales are involved in the cycling of elements, from microbes to air masses and continents. All of these related disciplines and their discoveries, and especially the foundation provided in soil science, are to be credited with developing this notion to understand elemental cycles and the interaction of life with the physical and chemical environments of the earth. For additional information, contact Patrick Inglett at: pinglett@ufl.edu

Courses in Biogeochemistry

We offer several undergraduate and graduate courses with emphasis on the biogeochemistry theme.

Courses offered on Campus:

Undergraduate Courses

SWS 2008 Land and Life
SWS 4180 Earth Systems Analysis
SWS 4223 Environmental Biogeochemistry
SWS 4800 Environmental Soil & Water Monitoring Techniques
SWS 4932 Soil Processes in the Earth's Critical Zone

Graduate Courses- Campus

SWS 5282 Earth Systems Analysis
SWS 5224 Environmental Biogeochemistry
SWS 5805 Environmental Soil & Water Monitoring Techniques
SWS 6448 Biogeochemistry of Wetlands and Aquatic Systems
SWS 6456 Advanced Biogeochemistry
SWS 6932 Journal Colloquium in Biogeochemistry
SWS 6932 Modeling Land Biogeochemistry
SWS 6932 Soil Processes in the Earth's Critical Zone
SWS 6932 Techniques in Biogeochemistry

Courses offered on Online:

Undergraduate Courses

SWS 2008 Land and Life
SWS 4180 Earth Systems Analysis
SWS 4223 Environmental Biogeochemistry

Graduate Courses

SWS 5282 Earth Systems Analysis
SWS 5224 Environmental Biogeochemistry
SWS 6448 Biogeochemistry of Wetlands and Aquatic Systems
SWS 6932 Modeling Land Biogeochemistry

Graduate concentration in Biogeochemistry is under development. For details contact: pinglett@ufl.edu

Grassland Biogeochemistry – Improving Carbon Sequestration and Sustainability

Grasslands occupy ~25% of earth's surface and are a major resource utilized for food production and environment sustainability. In Florida, grasslands cover ~2.5 million ha (17.5% of total land) and support 1.71 million cattle and calves (USDA-NASS, 2009). Grasslands and their associated biogeochemical processes provide multiple ecosystem services including soil carbon (C) sequestration and greenhouse gas mitigation. However, due to increased demand for food and energy, global estimates show that a significant portion of grassland area is being replaced by more intensive agriculture and urban development. This is particularly true in Florida, where urban development is increasingly competing with natural resources for land. Soil C sequestration can be largely influenced by land management, and therefore, changes in land use could have large, even global, consequences for the C cycle.

Our current projects are focused on better understanding the potential short- and long-term impacts of grassland intensification (e.g., fertilization, grazing management, and introduction of highly productive forage grass and legume species) on soil C stocks and characteristics. Specifically, we are looking at grassland management strategies that can be manipulated to enhance soil C sequestration potentials, without negatively affecting productivity or ecosystem function. The extent of soil C changes in response to improved grassland management conversion varies depending upon the region or management practice.

Although increasing C sequestration rates remain a major challenge in the subtropical regions of the U.S., application of best management practices and adoption of improved fertilization and grazing management, for instance, represent viable alternatives by which C sequestration rates can be enhanced in this region. In addition, because improved management practices are generally beneficial to forage and livestock production, they may also provide an incentive for producers to adopt strategies that promote soil C sequestration and ecosystem sustainability. Farmers are unquestionably important players in global efforts to increase soil C sequestration and grassland sustainability. For additional information, contact Maria Silveira at: mlas@ufl.edu

Welcome New Students!

Fall 2014—BS

Katherine Galluscio – SLS-WS (Bonczek)
Stephanie Fisher – IS-EMANR (Curry)
Adam Schineis – IS-EMANR (Curry)

Spring 2015—PhD

Noha Abdel-Mottaleb (Wilson)

Spring 2015—MS

Ibukun Timothy Ayankojo (Morgan)
Joshua Bott (Moore)
Richard Campanale (Wright)
Emily Gelder (Wilkie)
Kayla Parker (Reddy)

Spring 2015—BS

Sara Baker – SLS-WS (Bonczek)
Rachelle Berger – IS-EMANR – UFO (Curry)
Devin Bloom – IS-EMANR – UFO (Curry)
Austin Dartez – IS-EMANR – UFO (Curry)
Sara Harper – IS-EMANR – UFO (Curry)
Brittany Lehman – IS-EMANR – UFO (Curry)
Abigail Murphy – IS-EMANR – UFO (Curry)
Vladimir Pepen – IS-EMANR – UFO (Curry)
Amanda Turner – IS-EMANR – UFO (Curry)
Kimberly Tyll – IS-EMANR – UFO (Curry)

Using Microbes to Reduce Nitrate in Streams and Groundwater

Elevated levels of nitrate-nitrogen in surface and groundwater can result in undesirable impacts to water resources. Denitrification is an anaerobic (no oxygen) respiration reaction where bacteria gain energy from consuming organic carbon (leaf litter, sawdust, wood chips etc.), and predominantly convert nitrate to harmless nitrogen gas (N_2). Denitrification is a naturally occurring process prominent in wetlands, aquatic sediments and groundwater where oxygen is limited or absent. Conditions that favor denitrification can also be created by providing a source of carbon and saturated conditions to stimulate microbial activity that increases the consumption rate of nitrate. Several studies in the SWSD are actively investigating the application of "Denitrification Bioreactors" to reduce nitrate loads to streams and groundwater.


Denitrification wall trench excavation and backfill with sand:sawdust media completed. Topsoil was later backfilled on top of the denitrification wall media.


Excavation of denitrification wall trench (left) and backfilling with 50:50 sand:sawdust media (right)

In the fall of 2009 a denitrification wall consisting of 50% sand and 50% pine sawdust was installed downstream of a container nursery where groundwater nitrates concentrations ranging from 5-12 mg/L nitrate-nitrogen. This groundwater was seeping into a headwater stream that eventually flowed to the Santa Fe River. The denitrification wall was installed at a depth of 12 feet below the surface, was 5 feet wide and 180 feet long. After one year, nitrate concentrations in the stream had been reduced by 65% and monitoring wells upstream and downstream of the wall indicated that any nitrate passing through the wall was completely removed. Assuming a conservative 15-year longevity of the denitrification wall, the amortized nitrogen removal cost would be approximately $0.36 lb/N. Many unconfined areas and karst landscapes make it more difficult to intercept the water near the surface which is the focus of a new study being implemented. The new study will investigate the use of an array of groundwater wells placed in an area known to have elevated nitrate levels in the Floridan aquifer. Water from the top of the aquifer will be pumped to the surface to be treated in a lined denitrification bioreactor and then returned to the aquifer through an infiltration trench. The volume of water pumped up from the aquifer will be approximately equal to the volume leached from the surface theoretically intercepting the nitrate load and treating it before it is released to the aquifer. The objective of this investigation will be to test the application of the denitrification technique in areas that are not confined and therefore unable to support a denitrification wall. If successful this approach would significantly increase the locations where denitrification bioreactors could be applied to address elevated nitrate-nitrogen conditions.

Although by no means a single solution to nitrogen loading to the environment, this innovative approach provides additional measures that can be implemented in combination with BMPs and other source control measures to help reduce nitrate loads in surface and groundwater systems. For additional information, contact Mark Clark at: clarkmw@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. Recently, 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.

The Other Everglades:
A Biogeochemical Perspective of the Everglades Agricultural Area Peatlands

The Everglades Agricultural Area (EAA) originated under seasonally-flooded conditions leading to accumulation of organic matter above the bedrock limestone. These peat soils developed over several thousand years, but with drainage of these soils for water control and crop production in the early 1900s, the flooded conditions that led to organic matter accumulation were removed. Following these changes, soils were drained for most of the year, leading to enhanced organic matter decomposition, soil compaction, promotion of muck fires, and increased wind erosion. These factors have led to decreases in soil depth above the bedrock limestone, a phenomena commonly referred to as soil subsidence.

Draining and farming has also had consequences for the chemistry of these soils. Tillage operations have transported particles of calcium carbonate from the subsurface into the root zone of the surface soil. Additionally, carbonates dissolved in water can move up in the soil profile due to capillary action, and are often deposited at or near the soil surface after water is evaporated. All of these factors have significantly increased soil pH. When these soils were initially drained, pH values were in the range of 4.5 to 5.5. Now the typical range for the shallow muck soils of the EAA is 6.5 to 7.5. In light of the probable continuance of subsidence in the future, soil pH can be expected to increase.

Nutrient availability is closely related to soil pH, where pH increases affect nutrient retention into pools that are considered unavailable to plants. Variations from the optimum nutrients levels required for plant growth can be damaging and stunt growth and reduce yields. This deficiency is readily observed for phosphorus and micronutrients, such as manganese, copper, and zinc. Most micronutrients and phosphorus are readily available to crops at low pH values, but their availability is optimal at pH values below the current pH of most muck soils in the EAA. The problem is not so much that total nutrient concentrations are low, but rather their availability to plants is too low. Although micronutrients differ somewhat in the response to pH, all show decreased availability at pH values commonly observed in most muck soils. Thus, the muck soils are increasingly developing conditions where most applied fertilizer nutrients are being made less and less available to crops.

There are several ways to address the problem of increasing soil pH either through amendments or management. One way is to add an acid-forming amendment, such as elemental sulfur, to reduce the soil pH. Another approach is through fertilizer management strategies to combat nutrient limitation, such as timing, placement, split applications, and use of slow-release forms. Reducing the number and intensity of tillage operations can also be effective to address the vertical movement of calcium carbonate. But perhaps the most direct way of counteracting pH shifts is by slowing the rate of subsidence and soil oxidation by flooding of fields during fallow periods. During crop production, it is likely that stabilizing the water table will slow the movement of solubilized calcium carbonate upward with capillary water movement.

These land management practices need to be optimized to allow for improved soil nutrient management, and to minimize any further changes to muck soils. Thus, it is essential to better understand the underlying mechanisms affecting soil pH and nutrient availability, and to identify land and crop management practices that can be utilized to improve soil sustainability. For additional information, contact Alan Wright at: alwr@ufl.edu

Congratulations! Fall 2014 Graduates

PhD

Jing Hu (Reddy and Sharma Inglett)
Shengsen Wang (Li & Gao)
Sutie Xu (Silveira and Sharma Inglett)

MS

Miurel Bermudez-Herrera (Morgan)
Eva Christensen (Hochmuth)
Amber Daigneault (Mackowiak)
Marcos Lima (Schumann)
David Rossignol (Osborne)

MS

Amy Schroeder (Li)
Jason Seitz (Clark)

BS

Karen Alldridge – SLS-WS (Bonczek)
Brett Birch – SLS-SS (Bonczek)
Martha Risedorf – SLS-WS (Bonczek)
Jennifer Brown – IS-EMANR-UFO (Curry & White)
Danny Wilson – IS-EMANR (Curry)

Stable Isotope Biogeochemistry

Most elements of biological interest (including C, H, O, N, and S) have two or more stable isotopes. The slight difference in isotope masses gives rise to measurable differences in the isotope ratios of elements in various compounds and reactions. This allows stable isotopes to be used as indicators and tracers of these elements in biogeochemical cycles. In biogeochemical studies, carbon and nitrogen are perhaps the most useful stable isotopes as they are found in the earth, the atmosphere, and as major components of all living things. Both C and N have a heavy isotope (^{13}C and ^{15}N) with a natural abundance of ~1% or less, and a light isotope (^{12}C and ^{14}N) that makes up the remainder. Some studies are based on this natural abundance level of the isotopes, while others utilize isotopically enriched compounds as tracers (e.g., fertilizer studies).

Stable isotopes are typically measured using isotope ratio mass spectrometry (IRMS) where ionized compounds are passed through a high magnetic field and separated based on their charge to mass ratio. Data collected are not absolute isotope abundances, but rather the ratio of the heavy:light isotope in the sample relative to the same ratio in an internationally accepted standard. Studies examining stable isotopes at or near natural abundance levels are usually reported in delta (δ) notation in parts per thousand or per mil ("‰"), while studies using enriched levels (e.g., fertilizer based on ^{15}N) use atomic percent values.

The Soil and Water Science Stable Isotope Mass Spectrometry Facility is newly renovated (January 2014) and is located in McCarty-A. The instrumentation was purchased and is maintained as a collaborative research facility by the SWSD and UF Department of Geological Sciences. The centerpiece of the facility is a Thermo Finnigan MAT DeltaPlus^{XL} mass spectrometer configured to measure stable isotope ratios of certain gases (especially CO_2, N_2, and N_2O). An elemental analyzer and a gasbench are presently dedicated to the mass spectrometer for the purpose of delivering gas samples to the mass spectrometer. For additional information, contact Kathryn Curtis at: venz@ufl.edu or Patrick Inglett at: pinglett@ufl.edu

Modeling Biogeochemical Cycles

The cycles of carbon and nitrogen have undergone a huge change since the inception of industrialization. For example, levels of CO_2 has risen by about 40% and the creation of reactive nitrogen from cultivating nitrogen fixing crops, from production of fertilizer and from burning fossil fuel has doubled. These changes have profound impacts on ecosystems. Models are vital tools towards prediction and understanding of the consequences of this large human experiment with the Earth system. Questions whether plants and soils will continue to sequester fossil carbon dioxide as they have done in the past, whether excess nitrogen deposition on natural systems will impact nutrient status of streams, river, and estuaries, are important considering the continuing environmental changes.

Photo credit: Jack Brookshire

Nitrate in streams, carbon dioxide emissions from forests and soils, methane and nitrous oxide bubbling out of wetlands, all these natural processes require mechanistic understanding and there is a need to be able to predict these processes under a changing environment. Stefan Gerber's modeling group is working towards continuous development and application of models that allow such prediction. Moreover, biogeochemical models provide a "sandbox" in which our biogeochemical understanding can be tested. The modeling tools the group is applying and developing range from simple pen-and paper models to complex, Earth-encompassing models of biogeochemical cycles. For example, the group just completed an assessment of global nitrous oxide emissions.

The model evaluation suggests that global change may increase nitrous oxide emissions more than previously thought, because estimates so far relied on measurement mostly restricted to mid-latitudes, thereby underestimating impacts from tropical soils. Overall, the representation of biogeochemical processes in numerical models poses a big challenge, as it requires the characterization of physical, biological and chemical interactions. The challenge is also one of scales: Do interactions that occur on very small scales (from < 1cm to a few meters) manifest themselves at a larger scale, be it a research plot in a forest, a watershed, a pixel in a satellite image or a gridcell of a large climate model? For additional information contact Stefan Gerber at: sgerber@ufl.edu.

Faculty, Staff and Students

Congratulations to the following faculty and students for their outstanding achievements

Jim Jawitz was the recipient of the 2014 UF Water Institute (WI) Faculty Fellow Award. The WI Faculty Fellow Program recognizes faculty who make outstanding contributions to interdisciplinary water research, extension or education programs, and contributes to the goal of the WI.

Peter Nkedi-Kizza, was selected for the Carnegie African Diaspora Fellowship Program. As part of the fellowship Kizza will conduct research and teach a new course at Makerere University, Uganda. The potential students are MS and PhD students in the departments of Chemistry, Environmental Science and Agriculture in Uganda, Kenya, Tanzania, Sudan, Zimbabwe and Ethiopia.

Vimala Nair was the recipient of the 2014 Outstanding Senior Scientist Award by the Association of Agricultural Scientists of Indian Origin (AASIO). The award was presented during the ASA/CSSA/SSSA Annual Meetings in Long Beach, CA, November 2014.

ASA/CSSA/SSSA Awards to Graduate Students

2014 Graduate Student Leadership Conference award: **Biswanath Dari** (Nair & Mylavarapu) and **Debjani Sihi** (P. Inglett)

Biswanath Dari was the recipient of the Best Graduate Student Poster Award by the Biochar Community (Soil and Environmental Quality division). He was also a recipient of the second place award in the Pedology Student Oral competition. **Dari** was recognized by the AASIO as the 2014 Outstanding Graduate Student.

Debjani Sihi was awarded a second place in the SSSA Wetland Soils division and the third place in the Agronomy-Crop-Soil (ACS) Diversity Student Poster Competition.

Soil and Water Science Department Awards

Undergraduate Awards:

Donald A. Graetz Education Award – **John Carroll** (Curry)
Frederick B. Smith Scholarship – **Lacey Hancotte** (Bonczek)
Outstanding Undergraduate Award – **Haley Glaab** (Curry)

Graduate Awards:

Quantitative Environmental Soil Science Pedometrics Award – **Pasicha "Ploy" Chaikaew** (Grunwald)
Ben Skulnick Fellowship – **Sara Mechtensimer** (Toor)
Sam Polston Scholarship – **Christine VanZomeren** (Reddy)
Victor W. Carlisle Scholarship – **Rose Collins** (Mylavarapu)
William K. Robertson Scholarship – **Biswanath Dari**
WBL Fellow Award – **Anna Normand** (Reddy & Clark)
WBL Fellow Award – **Elise Morrison** (Ogram & Turner)

Staff Award:

Bill Reve SWSD Superior Accomplishment Award: **Dawn Lucas** (Hochmuth)

15th Annual Soil and Water Science Department Research Forum Awards

Best Oral Presentation – **Ky Gress** (Ma)
Best Lightning Talk – **Anna Normand**
Best Graduate Student Poster – **Odiney Alvarez- Campos** (Daroub); **Jing Hu** (Reddy & S. Inglett); **Elise Morrison** and **Jian Wu** (Graham)
Best Undergraduate Student Poster – **Brett Nelson** (Wilkie)

Mark your calendars for the 16th Annual Soil and Water Science Research Forum scheduled on September 17, 2015.