SOIL PHYSICS PRACTICUM 5110

Validation of Parameters of the Energy Balance Equation for the Bioenergy Feedstock Switchgrass

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Statement of critical need:

Finding strategies to reduce evaporation rates is essential in Oklahoma where, due to the semiarid climate, evaporative losses from the soil surface can reach approximately 50% of available water (ex. rainfall, irrigation). However, the widely used micro-lysimetry method to directly measure evaporation is difficult, tedious and time consuming. An accurate estimate of evaporation under the potential bioenergy feedstock, switchgrass (*Panicum virgatum*), is needed to improve land management practices in Oklahoma. Evaporation can be considered a loss from the soil water balance as yield is not dependant on it, whereas water loss from transpiration is necessary for plant growth. As cultivation of switchgrass expands due to the increasing demand for bioenergy feedstock, in depth knowledge of its relationship to soil moisture is needed to make informed decisions regarding valuable water resources. Municipal consumption and irrigation demands are increasing, causing water resources to dwindle (stat). Modeling techniques are widely used to accurately estimate evaporative losses from soil moisture; however their accuracy for use under switchgrass has yet to be determined. Therefore, validation of the parameters used in calculating the energy balance equation needs to be determined through comparison with direct measurements of evaporation losses in an active switchgrass stand. Lysimeters enable direct measurement of evaporative losses from the soil surface. Verifying the accuracy of the various parameters of the energy balance equation for switchgrass will remove the need for direct measurement in field.

Nature, scope and objective:

The long term goal for the team of collaborators representing various disciplines within the Department of Plant and Soil Sciences is to provide unique learning opportunities to the project participants in order to further knowledge and experience in methods relevant to the study of Soil Physics in general and the surface energy balance in particular. The objective of this proposal is to determine the accuracy of the parameters estimated for the energy balance equation for use in modeling water loss due to evaporation under switchgrass by comparison with direct measurement by microlysimeters. The central hypothesis of the proposed research is that the parameters of the energy balance equation will provide a satisfactory estimate of water loss due to evaporation within a stand of switchgrass, eliminating the need for microlysimeters. The rationale for the proposed research is that accurate estimation of evaporative losses will improve land management practices and crop selection in semi-arid climates utilized for bioenergy feedstock production thereby increasing sustainability. The proposal team is well prepared to succeed with this project due to success in modeling portions of the energy balance equation for regions of Oklahoma utilizing the resources available from the Oklahoma Mesonet as well as installation and monitoring of microlysimeters in field research.

The specific aims of this project are as follows:

Specific aim #1: Increase proficiency in application of the energy balance equation to model evaporation from the soil surface. Information will be gathered from the Oklahoma Mesonet website and in-field instruments which will provide data needed to calculate the various parameters needed for the energy balance equation.

Specific aim #2: Determine the accuracy of estimated parameters used in the energy balance equation to model evaporative losses from the soil in switchgrass plots. Direct

measurements of evaporation beneath the canopy will be compared to the results garnered by the energy balance equation.

Statement of Results or Benefits:

The proposed research project is unique as the amount of water lost to the atmosphere due to evaporation from the soil surface has yet to be determined for switchgrass. At the completion of this project is expected that participants will have an in depth understanding of the energy balance equation and its broad applications. Participants will also have gained experience in performing field techniques pertinent to Soil Physics research. This project will verify the accuracy of the energy balance equation when estimating evaporative losses from the soil surface beneath switchgrass. An accurate model of water losses due to soil evaporation will improve water resource management for producers of switchgrass for bioenergy feedstock.

Related research and significance:

The proposed project will increase knowledge of calculation and direct measurement of key parameters of the energy balance equation for the project participants, and will lead to improved management decisions and water conservation strategies in Oklahoma. In addition, participants will gain knowledge and experience in procedures common to the Soil Physics discipline including but not limited to soil texture analysis, soil moisture content and soil sampling.

The critical need to determine and accurately model evaporative losses in agricultural lands is widely recognized. As outlined by Koplow (2006), bioenergy feedstocks are increasing in popularity, with potentially substantial implications for land and water use. Furthermore, accounting for the variability in evaporation when using micro-lysimeters may become one of the most important considerations in direct measurements of evaporation therefore replications in the field to determine accuracy are required (Daamen, 1993).

Factors that contribute to high evaporation include minimal rainfall, abundant sunshine, low humidity, and periodic strong winds, all of which are characteristics of Oklahoma's semi-arid climate (Guru et. al, 2000). These characteristics, along with increased irrigation in the high plains have led to regions of the Ogallala aquifer, a vital water source for majority of the region, running dry (Guru et. al, 2000). Therefore, it is increasingly important that land managers and crop producers make informed decisions regarding crop selection to reduce evaporative losses and limit the water required for irrigation of land. Switchgrass has already been determined to have positive influences on water conservation due to the important attributes of high yield, efficient use of water and nutrients, low agrochemical inputs, and positive influences on soil and water conservation, additional knowledge of its effect on soil evaporative losses will enable further improvements in cultivation techniques (Sanderson et. al, 1996).

Therefore, the proposed project is significant because it will lead to valuable experience for the project participants as well as verifying the accuracy of the energy balance equation when estimating evaporative losses from the soil surface beneath switchgrass.

Methods, procedures and facilities:

Specific aim #1

Validation of parameters for the energy balance equation for the bioenergy feedstock switchgrass

The soil energy balance equation will be used to estimate evaporation:

0=Rn + G + Lx E +H

Where, *Rn,* is net radiation; *G,* is soil heat flux; *L,* is latent heat of vaporization; *E,* is evaporative flux and *H,* is sensible heat flux.

Net radiation will be determined by calculating the net short wave radiation (Rns) and the net long wave radiation (Rnl). A pyranometrer and a pyrgeometer will allow the team to measure the Rns and Rnl respectively. Both sensors are expected to be placed in clear spots under the switchgrass canopy by using metal arms and connected to a data logger (Decagon Devices, Inc.).

Soil heat flux will be calculated by using the following one dimensional soil heat flux equation:

G= —

The thermal conductivity is denoted by (J s^{-1} m^{-1} K^{-1}) and vertical distance by z and temperature by T. Thermal conductivity will be measured by using a heat pulse sensors for soil thermal properties (KD2, Decagon Devices, Inc.). Temperatures are going to be measured at 2 and 4cm depths with thermocouples.

The **latent heat of evaporation** (L) is 2.44 x 10^6 J kg^{-1} at 25 °C. The value of L is temperature dependent (T, in °C):

L = 2.501 - 2.370 × 10^{-3} x T

Sensible heat flux is the transfer of heat away from or to the surface by conduction or convection and is described by using the following formula:

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Where, *Rn,* is net radiation; *G,* is the soil heat flux and β, is the Bowen ratio. The Bowen ratio will be measured by using two Psychrometers placed at different heights. One instrument will be located at *0.64h,* where h is canopy height, and the other one will be at 1 meter above the first one.

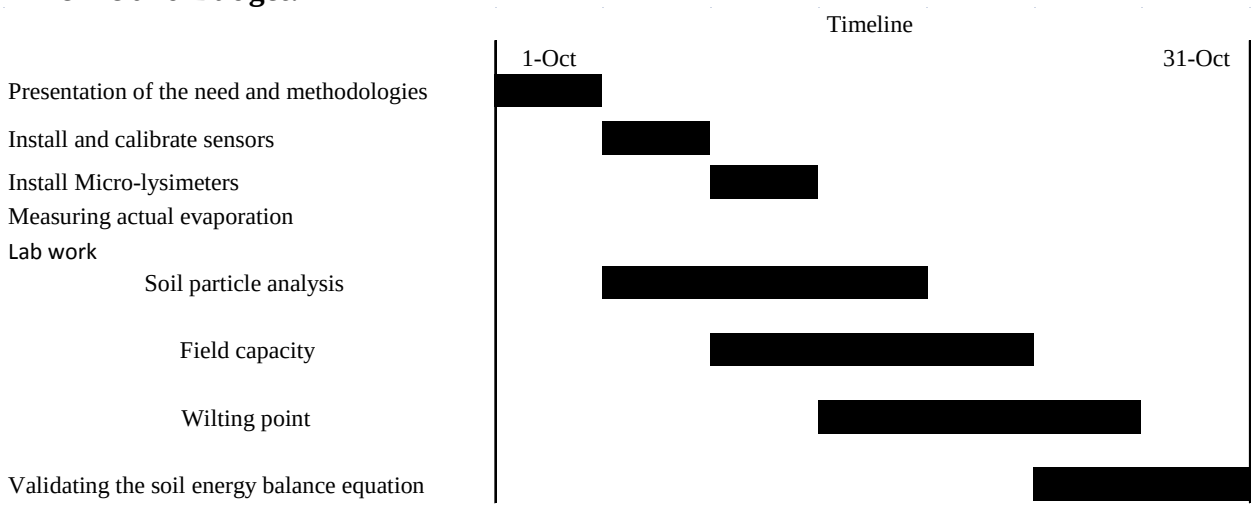
Soil texture will be measured according to the standard procedures of the hydrometer method, field capacity will measured according to tempe cell standard method and wilting point according to pressure plates standard method.

Specific aim #2

Micro-lysimeters are small tubes of Polyvinyl chloride (PVC) with a length of 15 cm, an internal diameter of 7.47 cm and sharpened at one end. A high number of replications need to be done to obtain reliable results. For this reason the team considers appropriate eight replications in representative spots. Micro-lysimeters will be installed in the ground during wet conditions by using a rubber mallet. Measuring actual evaporation will start 24 hours after a rainfall event. This

is due to soil shearing when installing micro-lysimeters, and a rainfall event will remove these effects. Micro-lysimeters will be sealed at the bottom and weighed at 24, 48 and 72 hours after a rainfall event. These weights will allow the proposal team to calculate actual evaporation. Micro-lysimeters will be returned to the same location after being weighed.

Timeline and Budget:



Item	Quantity	Cost/unit	Total
Pyranometer (Apogee)	1	180	180
Pyrgeometer (Apogee)	1	600	600
Psychrometer	2	50	100
Total			**$880**

References:

Daamen, C.C., Simmonds, L.P., Wallace, J.S., Laryea, K.B., Sivakumar, M.V.K., 1993. Use of microlysimeters to measure evaporation from sandy soils. Agric. For. Meteorol. 65, 159 –173.

Guru, M.V., & Horne, J.E. (2000). *The Ogallala Aquifer*. Retrieved September 29, 2002, from: http://kerrcenter.com/RDPP/Ogallala2.htm

Koplow, Douglas N. *Biofuels, at What Cost?: Government Support for Ethanol and Biodiesel in the United States : 2007 Update*. Winnipeg: International Institute for Sustainable Development, 2007.

Sanderson MA ,Adler PR , Boateng AA , Casler MD , Sarath G. *(2006) Switchgrass as a biofuels feedstock in the USA Can J Plant Sci 86:1315–1325.*

Curriculum Vitae

1. Personal Information

- *Name:* **Patrignani, Andres**
- *Birthdate:* April 8th, 1984
- *Birthplace:* Venado Tuerto, Argentina
- *Personal Address:* 27 N University Place Apt #2, Stillwater, OK
- *Cell Phone:* (405) 747-6808
- *E-mail:* andres.patrignani@okstate.edu

2. Education and Degrees
   - Current Master Student at Oklahoma State University. GPA: 4.0
   - Agronomy Engineer: National University of Rosario. 2008. GPA: 3.34

3. Background as Researcher
   - Undergraduate Teaching Assistant (Faculty Staff*).* Biology Professorship. 2005-2008
   - Undergraduate Teaching Assistant (*ad honorem).* Crop Management Professorship. April-August 2007
   - Undergraduate Teaching Assistant (*ad honorem).* Biology Professorship. 2004-2005

4. Research Papers
   - **Patrignani, A.**; Godsey, C.; Ochsner, T. Water use of double crops in no-till cropping systems in central Oklahoma. Will be presented at ASA-CSSA-SSSA International Meeting. Long Beach, CA. 2010.
   - **Patrignani, A**.; Mondino, M.C.; Ferratto, J.; Ortiz Mackinson, M.; Longo, A. The effect of a new alternative in the Netherland pruning system in greenhouse *Capsicum annum* productivity. Argentinean Association of Horticulture. 2007.
   - **Patrignani, A**; Feldman, S.R.; Petenello, M.C.; Cabello, M. Isolation of Mycorrhizas in contaminated soils with Hydrocarbon. Rosario Society of Biology. Argentina. 2006.
   - Feldman, S.R**.; Patrignani, A.**; Cabello, M. Preliminary Description of associated mycorrhizas in *Spartina argentinensis* Parodi. Rosario Society of Biology. Argentina. 2005.
   - Feldman, S. R.; Cabello, M.; **Patrignani, A.**; Barberis, I. 2005. Arbuscular Mycorrhizas in *Bromeliaceae* in the *Schinopsis balansae* Woodland. Argentinean Botany Symposia. 2005.

5. Internships
   - One year internship as Visitor Research Scholar at South Dakota State University. (Sponsored by Monsanto-SDSU-Aapresid). 2009. Activities developed at Monsanto Company, and Soil Fertility and Soil testing lab at SDSU.
   - One year internship at Agronomy division of Aapresid (Argentinean No-Till Farmers Association). 2008
   - Internship in Soybean Eco-Physiology Programe. National University of Rosario. 2007.

6. Distinctions
   - Selected at the 37th Symposium "Wings of Excellence Award 2007" as one of the 200 leaders of the future by St. Gallen University, Switzerland. Essay presented: ¨Human Beings: a suicide plague? ¨ http://www.stgallen-symposium.org/
   - First Place in Undergraduate Research Grants sponsored by New Bank of Santa Fe. Investigation Project: "*in vitro* Meristem Culture *of Spartina argentinensis*, for the propagation to regenerated plants". U$S 3,000.
   - First Mention at the Competition: 'The Agricultural Sector and the Government Support'. Essay presented: 'From the same that shouted Eureka!' Argentina. 2007.

Bethany Layne Scott

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EDUCATION

Oklahoma State University, Stillwater, OK — May 2012
Graduate Research Assistant
Major: Plant and Soil Sciences
Concentration: Soil Science

Oklahoma State University, Stillwater, OK — May 2010
Bachelor of Science in Natural Resources, *Cum Laude* — ***GPA 3.7***
Major: Environmental Science
Option: Water and Natural Resources

Tulsa Community College, Tulsa, OK — December 2005
Associates of Arts
Major: Liberal Arts

QUALIFICATIONS

Water Testing

- Became a certified Water Watch volunteer for the Oklahoma Water Resource Board
- Training included concept training, water quality testing, and final site testing
- Able to test for water and air temperature, water color, water transparency, pH, dissolved oxygen, and nutrients
- Gained valuable knowledge of the equipment and procedures

Soil Testing

- Capable of testing soil pH, identifying soil characteristics, and determining nutrient requirements
- Able to collect proper soil samples in the field as well as interpret a soil survey

ORGANIZATIONS AND ACHIEVEMENTS

Environmental Science Club-OSU

- Club Secretary
    - Schedule meetings, recruit new members, assist in meeting setup, make guest speaker arrangements

Phi Theta Kappa Honor Society

- For three consecutive years participated in fund raising for cancer research with the American Cancer Society's Relay for Life

Scholarships and Honors

- Presidents Honors Roll
- OSU Regents Scholarship
- AT&T Presidential Scholarship
- J. Fleming Memorial Scholarship

Tracy M Wilson

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Education

Oklahoma State University, Stillwater, OK
Fall 2009-present

- Master of Science, 2011
- Major: Plant and Soil Science, concentration in Soil Science
- Cumulative GPA 3.25
- Recipient of the George Christie Memorial Graduate Scholarship, 2010

University of Tennessee, Knoxville, TN
2002-2006

- Bachelor's of Science, December 2006
- Major: Animal Science conc. Production/Business
- Minor: Business
- Cumulative GPA 3.19

Experience

Graduate Research Assistant
June 2009-present Oklahoma State University, Stillwater, OK

- Thesis project studies the effects of harvest frequency of perennial grasses for biofuel feedstocks on soil organic carbon stocks, also effects of high shrink/swell soils on carbon stock estimates
- Responsibilities include managing field, greenhouse, and laboratory experiments, collecting and analyzing data
- Assisting in field experiments evaluating soil carbon stocks under No-Till management compared to conventional tillage, effects of raised beds on bulk density and soil moisture
- Assisted in greenhouse study to evaluate of leaching potential of Nfusion in combination with Urea Ammonium Nitrate in soils of three textural classes

Reports

Warren, J.G, and T. Wilson. 2010. Evaluation of leaching potential of Nfusion in combination with Urea Ammonium Nitrate in soils of three textural classes, Final Report. Submitted to Georgia-Pacific. 15pp.

Professional Associations and Leadership Activities

- Assisted in the 2010 Regional Land Judging Competition for 4-H and FFA of Oklahoma
- Member of the Department of Plant and Soil Sciences Code of Conduct committee.
- Representative of Plant and Soils Sciences Graduate Student Organization to the Graduate and Professional Student Government Association
- Assisted in Research Week activities for Oklahoma State University Graduate College
- Member of:

  Soil Science Society of America, 2010-present

  Agronomy Society of America, 2010-present

  Crop Science Society of America, 2010- present