2018 REACCH Summer Internship Program
Research Projects Description

University of Idaho

Assessing Soil Health and Microbial Community Function in Agroecosystems

Mentors: Michael Strickland (Soil Science, UI)

Increased demand for food and fiber crops must be met through methods that improve the long-term sustainability of our agricultural systems. Improvement and maintenance of soil health is an important consideration for creating a more resilient food system, especially considering climate change (https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health/). Farmers in the inland Pacific Northwest are interested in adopting new practices to improve soil quality, but are currently struggling to understand how to assess the impact of these practices. In addition, farmers are being encouraged to use relatively new soil tests especially those tests aimed to assess microbiological aspects. In this project, an undergraduate researcher will conduct research aimed at understanding how soil microbiological properties are related to soil health. The results of this research will be communicated to farmers interested in building soil health on their farms. Potential research questions include: How do results of current soil health tests compare to current methods aimed at assessing soil microbial community composition and function? How do soil microbiological assessments respond to changes in management regimes (e.g. cover crops and tillage)? The researcher will learn the basic scientific principles behind the soil health concept, and the methodologies currently used to assess soil microbial communities.

Learning Objectives:

- Field and laboratory assessment of soil health.
- Knowledge of soil microbial community composition and function.
- Management influences on long-term soil productivity.
- Collaboration with stakeholders.

References:

Kibblewhite, M.G., Ritz, K., Swift, M.J. Soil health in agricultural systems. *Philosophical Transactions of the Royal Society – B*. **363**: 685-701.

Biology of an Invasive Aphid

Mentor: Sanford Eigenbrode (Entomology, UI) and Ying Wu (Entomology, UI)

In 2011, a newly invasive aphid species was discovered infesting wheat over much of the inland Pacific Northwest. This species, *Metopolophium festucae cerealium*, which we refer to as the ‘wheat-grass aphid’, continues to be abundant in the region. We have studied its biology to determine some of its host range, the geographic extent of the invasion, the level of injury it can cause to infested plants, its interactions with other aphid species, and its capacity to transmit viruses. Despite this increasing understanding, there is much yet to be learned about the wheat grass aphid that is suitable for study within a summer internship. The intern will work with experienced graduate students and a support scientist to determine economic injury caused by the aphid using a replicated field cage trial. The intern will also compare the abundance and distribution of the aphid within experimental plots of wheat planted in the fall and the spring. The work will contribute to scientific publications and to a web and print-based descriptions of the aphid suitable for use by farmers and other citizens.

Learning objectives:

- Field sampling design and implementation.
- Crop health and yield measurements.
- Insect identification and curation.
- Basic analysis of insect abundance, crop yield and biomass data from different treatments.
- Approaches for web based delivery of information to producers.

References:

Halbert SE, Wu Y, Eigenbrode SD. 2013. *Metopolophium festucae cerealium* (Hemiptera: Aphididae), a new addition to the aphid fauna of North America. *Insecta Mundi* 0301:1-6

Davis TS, Wu Y, Eigenbrode SD. 2014. Host settling behavior, reproductive performance, and effects on plant growth of an exotic cereal aphid, *Metopolophium festucae* subsp. *cerealium* (Hemiptera: Aphididae). *J. Econ. Entomol.* 43:682-8

Sadeghi SE, Bjur J, Ingwell L, Unger L, Bosque-Pérez NA, Eigenbrode SD. 2016. Interactions between *Metopolophium festucae cerealium* (Hemiptera: Aphididae) and *Barley yellow dwarf virus* (BYDV-PAV). *J. Insect Sci.* 16:1–6

Identifying the Impacts of Soil Acidification on Phosphorus Availability and Transport in Surface Runoff

Mentors: Erin Brooks (Hydrologic Modeling, UI) and Daniel Strawn (Soil Science, UI)

Over 60 years of application of inorganic nitrogen fertilizers is leading to widespread acidification in near surface soils in agricultural fields in the inland Pacific Northwest. Coincidently many growers have testified that phosphorus (P) fertilizer application in the region does not seem to be resulting in any crop yield benefit. Recent analysis of soil samples suggests that contrary to information provided in fertility guides, extractable P (i.e. plant available soil P) is increasing as soils are becoming more acidic. This increasing availability of soil P has major agronomic as well as water quality implications. In this project the student can explore the interaction between soil pH and soil P availability from an agronomic and or environmental impact perspective.

Specific questions may include: How will the application of lime effect phosphorus availability? Is the increase in plant available soil P also resulting in increased soluble reactive P and sediment bound P in surface runoff? What are the long term implications of lime application and climate change on P transport in this region?

Learning Objectives:

- Field methods for sampling soils.
- Laboratory methods used to measure different forms of soil P.
- Rainfall simulation/flume students to study P transport by surface water.

Oregon State University

Biochar Impacts on Wheat Germination and Growth

Mentors: Stephen Machado (Agronomy) and Rakesh Awale (Soil Science)
Oregon State University, Columbia Basin Agricultural Research Center, Pendleton, OR

The application of biochar to arable soils is considered one of the most promising strategies to mitigate climate change through long-term sequestration of carbon whilst simultaneously increasing crop yields. Biochar is a carbon rich (60-80% C) product obtained from the pyrolysis of organic materials at elevated temperatures (>250°C) in a low or no oxygen environment. Because of its porous structure, high surface area, and affinity for charged particles, biochar amendment to soil may improve soil porosity, bulk density, infiltration, and water holding capacity. Review of the literature however reveals considerable variation in plant and soil responses to biochar addition, and the mechanisms by which biochar influences soil-water-plant relationships remains unclear (Blanco-Canqui, 2017). Biochar application has shown to reduce both saturated as well as unsaturated hydraulic conductivities and decrease water potential of soils under wide climatic conditions. Low soil water potential limits or prevents seed germination, seedling growth, and plant establishment that are critical to crop yield and productivity (Singh et al., 2013). Such adverse effects of biochar on reduced water potential can be particularly pronounced in the dryland regions, such as the inland Pacific Northwest, where the soil water content is often too dry for rapid germination of seed and remains unsaturated most of the time. In addition, with the high C:N ratio (low N concentration), biochar amendment can immobilize soil N and lead to low N availability to crops (Biederman and Harpole, 2013). Low N availability may affect both seed germination and seedling growth, and therefore additional N fertilization to compensate for the N-immobilization may be required. To this end, understanding the potential influences of biochar on soil water and N availability for seed germination and crop growth is needed before making irreversible biochar application to soils. The objective of this study is to investigate the effects of biochar, applied at various rates in combination with chemical N-fertilizer to silt loam soils, on the relationship between soil water potential and water content, seed germination, and plant growth across a wide range of moisture conditions.

Learning Objectives:

- Field and greenhouse biochar experiments.
- Soil sampling, analytical equipment and techniques to assess soil and plants.
- Data collection, management, and statistical analysis.
- Writing report and result presentation.

References:

Biederman, L.A., and W.S. Harpole. 2013. Biochar and its effects on plant productivity and nutrient cycling: a meta analysis. Glob. Change Biol. 5:202-214.

Blanco-Canqui, H. 2017. Biochar and soil physical properties. Soil Sci. Soc. Am. J. 81:687-711.

Singh, P., H.M. Ibrahim, M. Flury, W.F. Schillinger, and T. Knappenberger. 2013. Critical water potential for germination of wheat cultivars in the dryland Northwest USA. Soil Sci. Res. 23:189-198.

Role of C:N:P:S Stoichiometry on Carbon Sequestration in the Dryland Agroecosystems

Mentors: Stephen Machado (Agronomy) and Rakesh Awale (Soil Science)
Oregon State University, Columbia Basin Agricultural Research Center, Pendleton, OR

Soil organic carbon (SOC) sequestration is crucial for sustaining soil health, increasing agricultural productivity, and mitigating climate change. Identifying management strategies that increase SOC can maximize these benefits in dryland farming in the Inland Pacific Northwest (IPNW). Although it is widely assumed that increasing C inputs, particularly through slowly decomposing crop residues, or reducing C outputs by minimizing soil disturbance will increase SOC levels, long-term studies within IPNW have failed to support this traditional concept. Emerging insights from recent analytical and experimental advances have recognized that microbial conversion of crop residue C into their biomass and byproducts is an important SOC stabilization mechanism. Availability of major nutrients like nitrogen (N), phosphorus (P) and sulfur (S) in soil, and microbial demand of such nutrients relative to C (i.e. C:N:P:S stoichiometry) can largely influence microbial growth and their processing of available resources into SOC. As such, while many studies suggest that substrate decomposition and thereby SOC sequestration will reach maximum rates in the absence of nutrient limitation, others maintain that soil C can accumulate even when under nutrient limitations (Craine et al., 2007; Kirkby et al., 2013). Soil microorganisms can cope with their elemental imbalance by adjusting their use efficiencies of elements (C, N, P, S), by releasing a variety of extracellular enzymes for microbial assimilation of nutrients, or by shifting microbial community structure and concomitant shifts in biomass stoichiometry (Mooshammer et al., 2014). Anthropogenic interventions such as fertilizer application, nutrient removal in harvest, soil disturbance, and changes in plant community in agricultural systems can alter stoichiometric imbalance between microbial communities and their chemical environment. Therefore, this project aims to examine C:N:P:S stoichiometric relationship of microbial biomass and activity with soil to determine potential mechanisms of SOC turnover in long-term agricultural experiments differing in soil types, cropping systems, tillage, and fertility management. Insights from this study will provide basis for designing cropping systems that promote SOC accretion, soil fertility and productivity, and resiliency to climate change in the IPNW.

Learning Objectives:

- Field and laboratory experiments on SOC dynamics.
- Soil sampling, laboratory assessments, analytical equipment.
- Data collection, management, and statistical analysis.
- Writing report and result presentation.

References:

Craine, J.M., C. Morrow, and N. Fierer. 2007. Microbial nitrogen limitation increases decomposition. Ecology 88:2105-2113.

Kirkby, C.A., A.E. Richardson, L.J. Wade, G.D. Batten, C. Blanchard, and J.A. Kirkegaard. 2013. Carbon-nutrient stoichiometry to increase soil carbon sequestration. Soil Biol. Biochem. 60:77-86.

Mooshammer, M., W. Wanek, S. Zechmeister-Boltensten, and A. Richter. 2014. Stoichiometric imbalances between terrestrial decomposer communities and their resources: mechanisms and implications of microbial adaptations to their resources. Front. Microbiol. 5:22.

Exploring Climatic Limitations for Hazelnut Production and Competing Uses of Crop Land

Mentors: Laurie Houston (Applied Economics, OSU); David Rupp (Oregon Climate Change Research Institute) and Nik Wilman (North Willamette Research and Extension Center)

In recent years, hazelnuts have become one of Oregon's fastest-growing crops, with 3000-4000 new acres planted each year, making hazelnuts an increasingly important element of the economy. Hazelnut orchards with the new cultivars resistant to eastern filbert blight are profitable and valued for being a low-input, stable land use that provides a sustainable source of protein and oil as well as ecosystem services such as carbon fixation.

In this project, we will examine the sustainability of Oregon's unique hazelnut industry under climate change projections and evaluate the potential to expand the cultivation of European hazelnuts to other parts of the Pacific Northwest. We will also identify crops and land uses that are being converted (and have the potential to be converted) to hazelnut production in order to examine the tradeoffs that are being made regarding other land uses.

The intern will work jointly with researchers in climate science, agricultural/natural resource economics, and horticulture to identify important weather and climate variables that influence hazelnut production in Oregon (where 99% of commercial hazelnuts produced in the US are grown). These variables will be used to create a suitability index for hazelnut production that will be applied on the landscape to identify how suitable hazelnut growing regions in the area may change under a changing climate, as well as identify desirable traits for future varieties of hazelnuts. The intern will also explore the relative advantages and disadvantages of growing hazelnuts as opposed to other crops that would also be suitable to the same locations, in order to examine the tradeoffs producers will face regarding crop choices. **Specific research questions include:** How might climate change influence hazelnut production in the Willamette Valley? What crops and land uses are being replaced by the recent growth in hazelnut plantings; and how might this change in the future?

Learning Objectives:

- Gain first-hand experience applying basic statistical methods to large datasets
- Gain familiarity in creating visuals using observed and modeled climate data
- Understand the importance of the translation of science for crop management
- Build essential communication skills
- Gain experience working with and integrating diverse disciplines

Qualifications: Introductory classwork or work experience with GIS and R (or other statistical software). Coursework in horticulture, economics, or climatology is a plus.

References:

The effects of climate change on spatiotemporal changes of hazelnut cultivation areas in the Black Sea region, Turkey. http://www.academia.edu/8673758/The_Effects_of_Climate_Change_on_Spatiotemporal_Changes_of_Hazelnut_Corylus_Avellana_Cultivation_Areas_in_the_Black_Sea_Region_Turkey

Hazelnut resurgence. http://projects.registerguard.com/rg/business/34016102-63/hazelnut-boom-showing-up-on-edge-of-eugene.html.csp

'Renaissance' turns around fortunes of Oregon's popular nut. http://www.capitalpress.com/Orchards/20160721/renaissance-turns-around-fortunes-of-oregons-popular-nut

Assessing the sustainability of payments for ecosystem services in Mexico

Mentors: Alix-Garcia (Applied Economics, OSU)

Between 1990 and 2010, Mexico lost 7.8 percent of its forest cover (FAO 2010). Over half of Mexico's forest is classified as primary forest – the most biodiverse and carbon-dense form of forest – thus raising the ecological cost of deforestation far beyond the already important forest functions of carbon sequestration, erosion control, and hydrological regulation. To respond to deforestation and degradation as well as biodiversity losses, in 2003 Mexico's National Forestry Commission introduced its first program of payments for ecosystem services (PES). PES is designed to encourage the conservation of land cover and maintenance of intact ecosystems through payments to owners of environmentally valuable land

A series of evaluations of Mexico's program have shown that it is relatively effective in preventing deforestation. Alix-Garcia et al. (2012, 2015) and Sims and Alix-Garcia (2017) found that the 2004-2010 cohorts of the hydrological services program reduced rates of land cover change by approximately 25-50%, and that the pre-2010 hydrological services program likely had a small positive effect on assets at the household and locality level and may have increased educational opportunities for some households (Alix-Garcia et al. 2015, Sims and Alix-Garcia 2017). More recently, Alix-Garcia et al. (2017) showed positive impacts of the 2011-2014 cohorts on areas of forest at high risk of deforestation.

Despite this evidence, important questions remain. In particular, there is minimal understanding of repeated application to the program. Rejected applicants can reapply every year, and beneficiaries can choose to either apply to continue their contract after 5 years, exit permanently after 5 years, or exit temporarily and then reapply at a later date. Understanding these patterns of behavior is essential for adjusting program design to encourage long-term protection of forests. **Specific research questions include:** What are the characteristics of land that only enrolls in the program once, compared to land submitted repeatedly? What does this imply about the long-term sustainability of the program?

Learning Objectives:

- Gain first-hand experience applying basic statistical methods to large datasets
- Build essential communication skills that utilize graphs and summary statistics to explain geophysical and social characteristics of research data
- Gain experience with public speaking and presenting research in simple easy to understand style.

Qualifications: Introductory classwork or work experience with GIS and statistics

References:

Alix-Garcia, Jennifer M, Elizabeth N Shapiro, and Katharine RE Sims. "Forest Conservation and Slippage: Evidence from Mexico's National Payments for Ecosystem Services Program." *Land Economics* 88, no. 4 (2012): 613-38.

Alix-Garcia, J. M., K.R.E. Sims, et al. (2015). "Only One Tree from Each Seed? Environmental Effectiveness and Poverty Alleviation in Mexico's Payments for Ecosystem Services Program." American Economic Journal: Economic Policy **7**(4): 1-40.

Alix-Garcia, J.M., K.R.E. Sims, and Victor Orozco (2017). "Evaluation of Mexico's Payments for Environmental Services Program: 2011-2014" A Report for CONAFOR-SEMARNAT-CONEVAL.

Samii, Cyrus, Matthew Lisiecki, Parashar Kulkarni, Laura Paler, and Larry Chavis. (2014). "Effects of Payment for Environmental Services (Pes) on Deforestation and Poverty in Low and Middle Income Countries: A Systematic Review." *Campbell Systematic Reviews* 10, no. 11.

Sims, Katharine RE, and Jennifer M Alix-Garcia. (2017). "Parks Versus Pes: Evaluating Direct and Incentive-Based Land Conservation in Mexico." *Journal of Environmental Economics and Management* 86: 8-28.

Washington State University

The 'Hidden Half' of Nutrient Management

Mentors: Dr. Isaac Madsen (Crop and Soil Sciences, WSU) and Dr. Bill Pan (Crop and Soil Sciences, WSU).

Roots are sometimes referred to as the 'hidden half' of plants. Although hidden, roots play a critical role in the plants ability to take up nutrients, stabilize the soil, and keep the plant anchored. Research on roots can be difficult because root process are sensitive in both time and space, but are not easily observed. Research being conducted at WSU is on the leading edge of soil-plant interactions as relates to root-nutrient interactions. Root images taken by office scanner can be used to analyze the growth of roots around fertilizer bands and the response of roots to the fertilizers.

Learning objectives:

- Experience what it is like to work on cutting edge research in the rapidly developing field of root imagery and root-soil interactions

- Research will be contextualized into the broader perspective of efficient resource use and diversifying dryland cropping systems

Washington State University

Soil Health Assessment for improving Crop Productivity

Mentors: Dr. Bill Pan (Crop and Soil Sciences, WSU), Dr. Isaac Madsen (Crop and Soil Sciences, WSU) and Haiying Tao (Crop and Soils Sciences, WSU)

Soil Health is a topic that has received great attention amongst the soil science and agribusiness communities in recent years. It is defined by the US Natural Resource Conservation Service as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. This definition speaks to the importance of managing soils so they are sustainable for future generations. We have recently received funding from NRCS as 1 of 4 national locations to assess soil health across a continuum of two soil series as affected by landscape and management across N. Idaho and E. Washington. Analytical tests have been defined to characterize the physical (e.g. physical impedance, aggregation, water infiltration), biological (e.g. molecular indicators of beneficial and pathogenic microbes), and chemical (e.g. availability of plant essential and toxic elements) status of soils relevant to overall soil health. We will identify key sampling sites where winter wheat is being grown, conduct field visits, take soil samples, plant measurements, and conduct laboratory analyses to identify key soil health indicators that relate to crop root development and productivity. The intern will assist in this project, gaining knowledge and field/lab analytical experience, as well as data summarization, statistical analysis and communication.

Learning objectives:

- Gaining knowledge and field/lab analytical experience
- Data summarization
- Statistical analysis and communication

The 'Hidden Half' of Nutrient Management

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Roots are sometimes referred to as the 'hidden half' of plants. Although hidden, roots play a critical role in the plants ability to take up nutrients, stabilize the soil, and keep the plant anchored. Research on roots can be difficult because root process are sensitive in both time and space, but are not easily observed. Research being conducted at WSU is on the leading edge of soil-plant interactions as relates to root-nutrient interactions. Root images taken by office scanner can be used to analyze the growth of roots around fertilizer bands and the response of roots to the fertilizers. In the research being conducted this summer at WSU interns will get to experience what it is like to work on cutting edge research in the rapidly developing field of root imagery and root-soil interactions. This research will be contextualized into the broader perspective of efficient resource use and diversifying dryland cropping systems.

Learning objectives:

- Work on research in rapidly developing field of root imagery
- Work on research in root-soil interactions

Exploring Plant-Aphid-Virus Interactions in the Palouse

Mentors: David Crowder (Entomology, WSU) and Robert Clark (Postdoc, WSU)

Both natural and agricultural systems in the Palouse host a variety of native legume plant species (clover, vetch, etc). These native plants can affect the dynamics of agricultural legume crops (peas, lentils, and chickpeas) in several ways. For example, native legumes might harbor abundant populations of beneficial insects like lady beetles that feed on crop pests. Native legumes might also act as ecological “sinks” that trap pest insects, preventing them from moving into crop fields. However, native legumes may also negatively affect legume crops by harboring plant pathogens, or providing refuges for pest insects. However, we know relatively little about the potential positive/negative impacts of native legume species on crop production. We are seeking a student intern to conduct research, in both the field, laboratory, and greenhouse, investigating how native legumes might affect crop legumes through these different mechanisms. The student intern will work with faculty Dr. David Crowder and postdoctoral researcher Dr. Robert Clark, as well as graduate students in the Crowder lab, to collect insects and plant samples in the field and run conduct experiments in the greenhouse. Overall the internship will provide training in pest insect identification and plant community survey techniques. Results of the experiments will be analyzed with student involvement, therefore providing valuable training in data management and statistics useful for careers in research and extension. Come join us collect fascinating plants and animals on the Palouse this spring, while helping our team uncover methods to improve the sustainability of legume crop production.

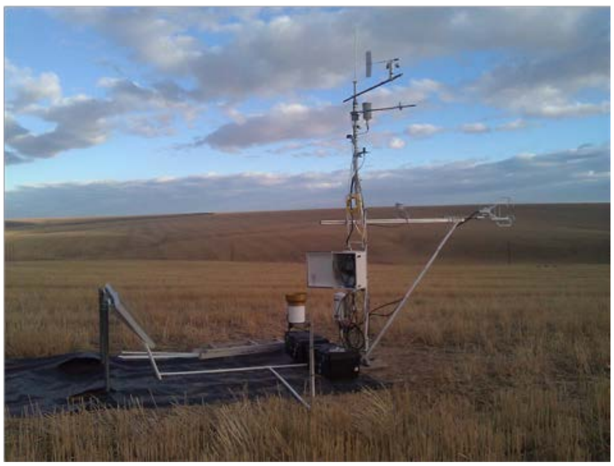
Learning Objectives:

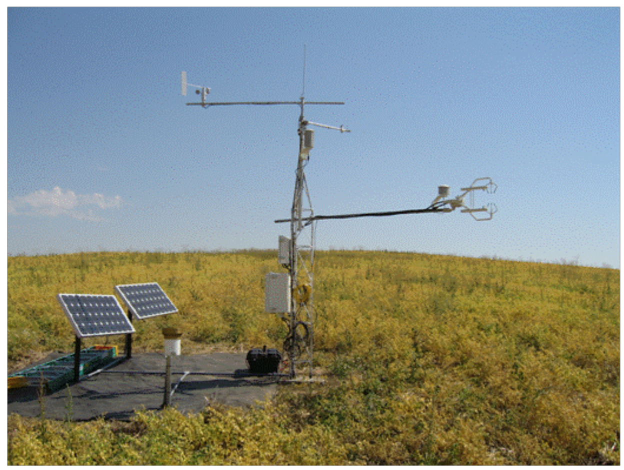
- Gain skills in experimental design and field ecology
- Learn to read and interpret scientific literature
- Gain experience working with plants, insects, and microbes in the field and lab

- Learn how to identify plants and insects in the field
- Develop skills in statistics and data analysis
- Learn how to present data in an academic setting

Greenhouse Gas Flux Measurements of Agricultural Systems

Mentors: Brian Lamb (Atmospheric Science, WSU), Shelley Pressley (Atmospheric Science, WSU) and Zhongming Gao (Atmospheric Science, WSU)





Part of the Regional Approaches to Climate Change in Pacific Northwest Agriculture (REACCH PNA) program involves continuous monitoring of greenhouse gas (GHG) fluxes to establish a baseline for carbon sequestration and N2O emissions for current crop management practices and to investigate how GHG fluxes change for selected management alternatives. The approach is to use micrometeorological methods to directly measure CO2/H2O/N2O fluxes over representative fields within the region. Over the past 5 years, measurements have been made at 5 locations (Chi et al, 2016; Waldo et al., 2016). As a result of the REACCH project, Washington State University (WSU) has established a long term agricultural research station (LTAR) on the WSU Cook Agronomy Farm. Four of the original 5 towers have been relocated to the LTAR site. Figure 1 illustrates two of the sites monitoring GHG fluxes. *Figure 1. Photographs of the Lind (left) and Cook Farm (right) flux tower sites.*

The REACCH summer undergraduate student will work closely with both faculty and a post doc during this project and be involved in all aspects of the study including 1) Site maintenance, 2) instrument calibration, 3) collection of associated biological data, 4) data analysis of GHG fluxes, and 5) interpretation of data to address the scientific objectives of the study. Specifically, data from each of the sites will be analyzed for patterns associated with management events and meteorological conditions including seasonal differences and cross-site variability.

Learning Objectives:

- Experience working with scientific instruments.
- Collection of samples and data for a long-term monitoring program.
- Data analysis following specified standards and protocols.
- Micrometeorological measurement techniques (i.e. eddy covariance).

References:

Chi, J., Waldo, S., Pressley. S., O'Keeffe, P., Huggins, D. R., Stöckle, C., Pan, W. L., Brooks, E., and Lamb, B. K. (2016): Assessing carbon and water dynamics of no-till and conventional tillage cropping systems in the inland Pacific Northwest US using the eddy covariance method, Agriculture and Forest Meteorology 218-219, 37-49, doi.org/10.1016/j.agrformet.2015.11.019.

Waldo, S., Chi, J., Pressley. S., O'Keeffe, P., Pan, W. L., Brooks, E., Huggins, D. R., Stöckle, C., and Lamb, B. K. (2016): Assessing carbon dynamics at high and low rainfall agricultural sites in the inland Pacific Northwest US using the eddy covariance method, Agriculture and Forest Meteorology 218-219, 25-36, doi.org/10.1016/j.agrformet.2015.11.018.

Quantifying Phenotypic Plasticity in Downy Brome

Mentors: Ian Burke (Crop and Soil Sciences, WSU) and Amber Hauvermale (Crop and Soil Sciences, WSU)

A more precise understanding of phenotypic plasticity is essential to understand potential for climate adaptation in downy brome (Bromus tectorum). Phenotypic plasticity is a hallmark of downy brome success, and many distinct phenotypes have been observed from the same genotype. To quantify the phenotypic plasticity, the student will conduct growth chamber experiments to determine various downy brome genotypes norm of reaction The experiment will test extremes of climate representative in the Pacific Northwest. The student will quantify biomass allocation, specific and whole-plant leaf area:biomass ratios, and root specific length. By quantifying these parameters, the student will facilitate an understanding of the diverse ways downy brome adjust functionally to environmental stresses, and help improve short and long term downy brome response to short term severe events now being included in climate models.

Learning Objectives:

- Assist in the design and implementation of a growth chamber and greenhouse project
- Analyze quantitative data

- Develop scientific communication skills

References:

Lawrence, N. C., Hauvermale, A.L., and Burke, I.C. 2018. Downy brome (Bromus tectorum) vernalization: variation and genetic controls. Weed Sci. (In Press)

Lawrence, N.C., Hauvermale, A.L., Dhingra, A. and Burke, I.C., 2017. Population structure and genetic diversity of Bromus tectorum within the small grain production region of the Pacific Northwest. *Ecology and evolution*, *7*(20), pp.8316-8328.