ACCOMPLISHMENTS REPORT
Northwest Regional Biomass Research Center
May 2014 – October 2015
Submitted by: Dan S. Long, Coordinator

This report summarizes the accomplishments of the Agricultural Research Service's Northwestern Region Biomass Research Center focusing on (1) Feedstock Development, (2) Feedstock Production, and (3) Conversion and Co-product Utilization. The purpose of this report is to provide information for an external assessment of the NWRBRC's performance for the period May 2014-October 2015 (18 months).

Research Units Reporting:
Small Grains and Potato Germplasm Research Unit – Aberdeen, ID
Northwest Watershed Management Research Unit – Boise, ID
Forage Seed and Cereal Research Unit – Corvallis, OR
Soil and Water Conservation Research Unit – Pendleton, OR
Northwest Sustainable Agroecosystems Research Unit – Pullman, WA
Agricultural Systems Research Unit – Sidney, MT
Physiology and Pathology of Tree Fruits Research Unit – Wenatchee, WA

Accomplishments:

I. **Feedstock Development:** Feedstock development mainly involves species and cultivar testing and selection for suitability of production, but also identifying current and potential resources available for bioenergy production, determining chemical composition of feedstocks that influence thermo-chemical conversion and ethanol yield, and assessing the relative energy benefits and environmental impacts that are associated with growing bioenergy crops.

Ongoing Evaluation of Environmental Impacts of Juniper Removal. Juniper encroachment into shrub steppe rangelands in the Great Basin reduces understory vegetation, promotes extensive bare ground, and increases runoff and erosion. ARS scientists in Boise, ID completed a multi-site field campaign to re-measure the impacts of juniper removal on sagebrush steppe vegetation, infiltration, runoff, and erosion. The re-measurement field campaign is part of a long-term study to assess ecohydrologic impacts of juniper removal and potential use as a biomass feedstock. Burning effectively stimulated herbaceous vegetation, but reduced the limited pre-fire shrub component. Tree cutting and mastication stimulated herbaceous vegetation, retained shrub cover, and resulted in substantial downed woody fuels and residual juvenile juniper. Herbaceous cover and tree debris across treatments tended to disburse overland flow and reduce flow energy and sediment transport relative to untreated controls. Results are available in recent publications by Pierson et al. (2014, 2015) and were used to evaluate the role of process connectivity and sediment availability on runoff and erosion from disturbed rangelands (Williams et al. 2015). Data acquired from the research was also used in two recent studies to enhance application of the Rangeland Hydrology and Erosion Model (RHEM) for quantification of environmental benefits of various conservation practices, including juniper removal (Al-Hamdan et al. 2015a, 2015b). A synopsis of the ongoing juniper study is included in a recent overview paper on the greater Sagebrush Steppe Treatment Evaluation Project (McIver et al. 2014). CRIS Project 2052-13610-011-00

Biomass contribution from conservation buffers estimated in dryland PNW. Meeting the goals set by the Energy Security and Security Act for production of lignocellulosic biofuels requires the evaluation of all potential feedstock sources. The most productive areas of the arid and semiarid west are those near to rivers and streams. In the dryland cropping region of the interior Pacific Northwest, much of the land adjacent to streams has been taken out of crop production to create conservation buffers. Scientists in

Pendleton, OR evaluated the productivity and extent of these areas using a perennial grass, tall wheatgrass, commonly used in conservation buffers. Though annual productivity within our research sites was similar to that found in the Midwest and southeastern U.S., the area suitable for this level of productivity is insufficient to contribute substantially to lignocellulosic biofuel production (Williams et al. in review). CRIS Project 2074-21610-001-00D

Collaborations expand crop diversity in the northwestern U.S. and boost rural economic development. A major agronomic concern in the northern Great Plains region is the limited diversity of crops grown by producers, especially in dryland areas. That limited diversity increases risk to producers, contributes to disease and pest problems and impedes rural economic growth by limiting options to producers and small businesses. Consequently, ARS scientists at Sidney, MT are participating in a large, 10-state collaborative research initiative with the intention of increasing dryland cropping diversity for the region's producers and promoting rural economic development in these areas. Partners include major universities, seed companies, biofuel refiners, and various major end users of biofuels including airports and transportation providers. The initiative evaluates sustainable cropping systems incorporating various oilseed crops produced across a range of dryland environments to ensure continuity of jet fuel supplies for commercial and defense aviation and other uses. These initiatives also address cropping diversity and economic development issues raised by stakeholders in several local focus group meetings in eastern Montana and western North Dakota, where the vast majority of the nation's crucifer oilseed crops are grown. CRIS Project 3032-13210-006-00

Plant biomass and greenhouse gas emissions vary with grass species and nitrogen fertilization. Perennial grasses diversify the traditional wheat-fallow rotation of the northern Great Plains and can be successfully grown for biofuel feedstock or as forage for beef cattle, the leading producer of agricultural receipts in Montana. ARS scientists in Sidney, MT continue to evaluate above- and below-ground biomass, soil C and N, greenhouse gas emissions, and water use in smooth brome and intermediate wheatgrass (cool-season grasses) and switchgrass (warm-season grass) applied with 0 to 84 kg N ha^{-1}. Prairie sandreed and little bluestem (warm-season grasses) establishment was unsuccessful during two consecutive growing seasons suggesting a need to carefully consider species selection for biomass production in the cool-season climate of the northern Great Plains. Preliminary results suggest that above and belowground biomass increased with increased N rate and that intermediate wheatgrass production was greater during above-average precipitation than other grasses from 2010-2013, but that switchgrass biomass production was superior in 2014-2015. In 2012-2013, CO_2 and CH_4 emissions did not vary with treatments, but N_2O emissions were higher in switchgrass with 56 kg N ha^{-1} than the other treatments. Further research is continuing to determine an appropriate grass species with adequate N fertilization rate that can sustain biomass yield, increase soil C and N sequestration, and mitigate greenhouse gas emissions in the semiarid region of the northern Great Plains. CRIS Project 3032-13210-006-00

Renewable jet fuel feedstocks and cover crops to replace fallow. Ethiopian mustard and camelina are two leading candidates for biofuel feedstocks. ARS researchers in Sidney, MT initiated a 6-yr study in 2014 to investigate the seed yield, water and N use, C and N pools, insects, and soil microbiology of the these two non-food crops. A ten-species cover crop mix in place of fallow will also be evaluated as a source of biomass and to increase ecosystem services. Planting bioenergy feedstocks in place of fallow would decrease soil erosion, soil C loss, saline seep formation, and evaporative soil water loss while increasing overall land productivity, regional economics, and ecosystem services. CRIS Project 3032-13210-006-00

II. **Feedstock Production:** Feedstock production includes aspects of cultivation to determine best management practices for producing bioenergy crops.

Weeds found to devalue biomass production in dryland Pacific Northwest. Stream side buffers increase capacity of agro-ecosystems to provide wildlife habitat, sediment and nutrient sinks to improve water quality, and cellulosic feedstock for biofuels. The establishment of stream side buffers can be difficult, with weeds competing with desired species and contaminating feedstocks. Scientists in Pendleton, OR evaluated these problems while quantifying the productivity of tall wheatgrass, alfalfa, and a mix of alfalfa and tall wheatgrass in conservation buffers. Tall wheatgrass, planted either alone or mixed with alfalfa, was the most successful at out-competing weeds. Establishment and maintenance of weed-free buffer strips, however, requires substantial inputs of time and labor, and use of herbicides, which is likely to substantially reduce net gains expected from cellulosic feedstocks (Williams et al. 2015). CRIS Project 2074-21610-001-00

On-combine sensing for post-harvest assessment of environmental stress in farm fields. Scientists in Pendleton, OR developed a method for simultaneously mapping the grain yield, grain protein, and straw yield in farm fields from a combine harvester. The mapping system consists of three different sensors: mass-flow yield monitor to measure grain yield, in-line near infrared (NIR) sensor to measure grain protein, and light detection and ranging (LiDAR) sensor to measure crop height. Straw yield was estimated from crop height as derived from LiDAR. The resulting data can be used to map various indicators of environmental stress. One indicator is the harvest index (HI), or ratio of grain yield to total above ground crop biomass (e.g., grain yield + straw yield). Using HI, one can identify areas within a field where the crop experienced stress during vegetative growth, stress during grain filling, stress during both periods, or no stress. Farmers can better interpret yield maps of grain and straw with regard to environmental stress factors that limit biological productivity (Long and McCallum, 2015). CRIS Project 2074-21610-001-00

Flower yellowness used to estimate canola biomass and flower number. Flowers interfere with ability to use light that is reflected from green leaves to determine the condition of growing plants. Scientists at Pendleton, OR determined how flowers influence reflectance of light from plants and what bands of light are useful for estimating flower number and plant biomass. The effects of flower number and biomass on the amount of blue, green, red, and near infrared light reflected from spring canola were investigated in a field study consisting of three water regimes and three fertilizer nitrogen levels. The result of dividing blue light by green light was strongly related to the number of yellow flowers per unit area. Dividing near-infrared light by blue light was most suitable for estimating biomass during flowering. Information on the quality and quantity of light reflected from plants during flowering may improve how remote sensing is used to describe plant development and reproductive capacity during the growing season (Sulik and Long, 2015). CRIS Project 2074-21610-002-01

Novel spectral index developed for predicting yield of Brassica oilseed crops. Scientists at Pendleton, OR developed the normalized difference yellowness index (NDYI) to model variability in within-field relative yield potential and overcome limitations of the normalized difference vegetation index (NDVI) during flowering. NDYI only requires wavebands in the visible region of the spectrum and can be applied to any satellite or aerial sensor that has blue and green channels. The derivation of the NDYI is based on the absorption feature of carotenoids present in the floral tissue of Brassica oilseeds such as canola. Empirical measurements and theoretical analyses suggest that NDYI is better correlated with final yield than other commonly used indices such as NDVI. Overall, NDYI is found to have a more linear relationship with final yield than NDVI, with NDVI saturating at high yield values. In addition, NDVI is confounded by variation in flowering whereas NDYI directly exploits variation in flowering. This highlights the benefit of using a spectral index that is sensitive to reproductive growth of vegetation instead of vegetative growth for crops with spectrally prominent reproductive canopy elements. Our results indicate that NDYI is a better indicator of yield potential than NDVI during mid-season development stages (Sulik and Long, in review). CRIS Project 2074-21610-002-01

Recommendations for sustainable bioenergy feedstock production. Rapid expansion in biomass production for biofuels and bioenergy in the Americas is increasing demands on the ecosystem resources required to sustain soil and site productivity. Scientists at Pendleton, OR and colleagues reviewed the current state of knowledge on biogeochemical processes and ecosystem sustainability related to biomass production. Biomass production systems incrementally remove greater quantities of organic matter, which in turn affects soil organic matter and associated carbon and nutrient storage, and off-site impacts. While these consequences have been extensively studied for some crops and sites, the ongoing and impending impacts of biomass removal require management strategies for ensuring that soil properties and functions are sustained for all combinations of crops, soils, sites, climates and management systems, and that impacts of biomass management are environmentally acceptable. In a changing global environment, knowledge of cumulative impacts will also become increasingly important. Long-term experiments are essential for key crops, soils and management systems because short-term results do not necessarily reflect long-term impacts, although improved modeling capability may help to predict these impacts. Identification and validation of soil sustainability indicators for both site prescriptions and spatial applications would better inform commercial and policy decisions. In an increasingly inter-related but constrained global context, researchers should engage across inter-disciplinary, inter-agency, and international lines to better ensure long-term soil productivity across a range of scales, from site to landscape (Gollany et al. 2015). CRIS Project 2074-11120-003-00

Research needs identified in Columbia Plateau and Northern Glaciated Plains. ARS scientists at Pendleton, Pullman, and Sidney and their university colleagues reported on the development of dryland oilseed crops to provide feedstock for production of biofuels in semiarid portions of the northwestern United States. Bioenergy feedstocks derived from Brassica oilseed crops have been considered for production of hydrotreated renewable jet fuel, but crop growth and yields in the Northwestern region are limited by a lack of plant available water. Based on a review of the scientific literature, several areas were identified where research could be directed to provide improvements. The current agronomic limitations for oilseed production are mainly due to seedling establishment under extreme heat, dry seedbeds at optimum planting times, survival under extreme cold, and interspecific competition with weeds. To improve emergence and stand establishment, future work should focus on developing soil management and seeding techniques that optimize plant available water, reduce heat stress, and provide a competitive advantage against weeds that are customized for specific crops, soil types, and soil and environmental conditions. Spring and winter cultivars are needed that offer increased seedling vigor, drought resistance, and cold tolerance (Long et al., in review). CRIS Projects 2074-21610-001-00 and 2074-21610-002-01

Harvest of tall cereal varieties with a stripper header increased residual biomass in a no-till fallow system. ARS scientists and their university colleagues in Pullman, WA found that winter triticale and tall winter wheat can produce 40% more residue than a semi dwarf winter wheat in the same system. Harvesting with a stripper header leaves standing stubble in the field that is nearly as tall as the unharvested crop. In the winter wheat fallow area, which is plagued by high winds that cause soil erosion, no-till management can greatly reduce soil erosion during the fallow period. Producing greater amounts of residue by growing tall varieties of cereal and leaving tall residues by harvesting with the stripper header and maintaining a no-till (chemical) fallow has been able to reduce wind gust speeds to 1/3 of what is experienced in tilled fallow. Reduction of wind speeds leads to a reduction in evaporation of soil water, which has allowed our research plots to maintain more uniform soil moisture under managed stripper header residues. Greater uniformity of soil moisture led to more uniform establishment of winter canola crops planted in the late summer when compared to their short-stubble, tilled-fallow counterparts. Using a stripper header for management of the microclimate at the soil surface may allow farmers to reduce the amount of tillage that is used in the winter wheat-fallow region. CRIS Project 2090-21610-002-00

Feral rye control in winter canola. Feral rye is a winter annual grass weed that reduces winter wheat yield >30% and costs U.S. wheat growers $27 million per year. An ARS agronomist at Pullman, WA conducted a study from 2010 to 2014 to evaluate the efficacy of three herbicides on feral rye control and winter canola yield. Canola yield and weed control varied with environmental conditions and feral rye density, but in general, fall plus spring applications of quizalofop and glyphosate effectively and consistently increased yield and controlled feral rye. With the integration of winter canola into this region, an opportunity exists to manage feral rye while improving cropping system diversity and economic sustainability (Young et al., 2015). CRIS Project 2090-21610-002-00

Biodiesel crops such as Juncea canola are promising replacements for fallow in dryland durum rotations. Identifying suitable cropping alternatives to fallow can increase acreage for crops that can be used as biodiesel and jet fuel feedstock. These potential cropping systems need to efficiently use water and nitrogen (N) fertilizer, which is a major input expenditure. USDA researchers at Sidney, MT investigated yield, weeds, insects, and water and N use of three oilseeds (camelina, crambe, and juncea canola) as replacement for fallow in 2-year durum rotations. Results from the 5-yr study suggested that in semi-arid areas, juncea canola could be a suitable alternative to fallow in 2 year durum rotations. Researchers found that juncea canola had significantly superior seed and oil yield compared to the other oilseeds tested and appears to be a promising candidate for biofuel production in semi-arid areas of eastern Montana and western North Dakota. Furthermore, growing juncea canola in place of fallow did not affect the following year's durum yield meaning producers can expect to maintain existing profits from their wheat production while adding additional profit from a new cash crop. Because several million acres of fallowed fields are available in semi-arid regions, the nation could also benefit through an increased supply of oilseed feedstocks for biodiesel production which could help reduce our dependence on imported oil, without impacting existing food production. (Allen et al., 2014a). CRIS Project 3032-13210-006-00

Camelina seeding depth and germination temperature requirements determined. Camelina offers a new cropping alternative to fallow in the northern Great Plains. However, little agronomic information is available for this non-food oilseed feedstock intended for jet fuel or biodiesel markets. Consistent and timely establishment of very small seeded crops, like camelina, is critical for stand density, evenness of emergence and ripening, and to suppress weed competition. Consequently, ARS researchers in Sidney, MT determined that seeding camelina to a depth deeper than ¼ inch decreased plant density and crop competiveness with weeds. Also, researchers found that camelina emerged at temperatures below 0°C, suggesting that early planting in the spring would probably be limited by field access due to wet soil rather than the base temperature requirement. Uneven emergence and ripening of camelina was a persistent problem in various USDA-ARS trials conducted near Sidney, MT in spite of efforts to modify seeding depths, rates, and species selection, suggesting a need for further crop development and breeding selection. (Allen et al., 2014b) CRIS Project 3032-13210-006-00

Crop diversification, management level, and tillage influence spring wheat yield, water use and soil carbon and nitrogen levels. Lack of cropping diversity and limited soil water availability constrain spring wheat production in the northern Great Plains. To improve cropping system performance, ARS researchers in Sidney, MT conducted a 9-yr experiment to compare productivity, soil water and N use, and soil C and N pools, in four crop rotations with increasing levels of diversity (continuous spring wheat (SW); pea-SW; barley hay-pea-SW; barley hay-corn-pea-SW), two tillage systems (no-till and minimum till), and two management systems (Conventional management included standard seed rates and plant spacing, early planting date, broadcast N fertilizer, and short stubble height; Ecological management included variable seed rates and plant spacing, delayed planting date, banded N fertilizer, and tall stubble height). Spring wheat in diversified rotations (including those with bioenergy crops) had greater yield and water use efficiency than continuous wheat. Including bioenergy crops in diversified rotations not only offset the demand for nonrenewable resources, but also improved the productivity of subsequent rotational crops as well as the production potential of the overall cropping system. No-tillage with conventional management increased surface residue, soil C and N storage, and microbial biomass and activity, while minimum till with conventional management increased soil N availability (Lenssen et al., 2014). CRIS Project 3032-13210-006-00

Optimal grass species with adequate nitrogen fertilization and cover crop can increase carbon and nitrogen sequestration. Removal of aboveground biomass of perennial grasses can reduce soil C and N sequestration, but grass species with adequate N fertilization and cover crop may restore soil C and N levels. A 5-yr study on the effects of perennial grass species, cover crop, and nitrogen fertilization rates were studied by ARS scientist in Sidney MT in collaboration with Fort Valley State University, GA. Preliminary results suggest that elephant grass with clover cover crop and 100 kg N ha^{-1} increased aboveground biomass and can sequester more soil C and N than the other treatments and increased N fertilization rate can increase the potential for N leaching. CRIS Project 3032-13210-006-00

Cover crop mixture can increase sweet sorghum biomass yield and soil carbon and nitrogen storage. Sweet sorghum is an important feedstock for biofuel production but little is known about the effects of cover crops on sweet sorghum production and soil C and N levels. ARS scientist from Sidney, MT collaborated a 5-yr study with Fort Valley State University to determine the suitability of marginal land for the production of sweet sorghum and to evaluate the benefits of incorporating winter cover crops on sorghum biomass yield, quality, and soil C and N in Fort Valley, GA. Treatments included hairy vetch, rye, rye/hairy vetch mixture and a no cover crop control. Preliminary results showed that hairy vetch/rye mixture cover crops can increase sweet sorghum brix and sugar contents and soil C and N storage compared to other cover crops. CRIS Project 3032-13210-006-00

III. Conversion and Co-product Utilization: Conversion and co-product utilization revolves around evaluating the breakdown and conversion of biological feedstocks, developing systems for converting crop residue to energy, and determining the usefulness of co-products of conversion for non-energy purposes.

On-farm Gasification Simultaneously Produces On-farm Energy, Process Heat, and Biochar. Coupling on-farm gasification to energy-intensive equipment lowers energy costs, diverts waste, and delivers a soil amendment that has the potential to increase soil moisture retention, improve agricultural yields, and sequester carbon. ARS researchers in Corvallis, OR evaluated the agronomic potential of biochar derived from the gasification of seed screenings, a regionally abundant agricultural residue. Increased soil moisture was one of several positive effects that biochar had on wheat plant growth in on-farm trials. Additionally, biochar acted as a liming agent, and alleviated soil acidity and related aluminum toxicity (Trippe et al., 2015). In the field, biochar out-performed a liming treatment that raised soil pH by the same amount, which may be related to increased soil permeability, promotion of root growth, and potentially improved spring frost tolerance. These effects collectively contributed to a 250% increase in wheat yield. This research provides important guidance to growers that may be considering coupling on-farm energy generation to biochar production and amendment to ameliorate acidic soils and to increase soil moisture retention. CRIS Project 2072-21410-004-00

On-farm Residues Can Reduce Energy Costs When Used to Generate On-farm Energy. The gasification of residues simultaneously produces heat and biochar as potentially valuable by-products. ARS researchers previously determined that biochar sourced from seed screenings is an effective amendment to acidic cropland soils (Trippe et al. 2015). However, other, more lucrative markets for this biochar have also been identified. The observed liming qualities of this biochar led ARS scientists in Corvallis, OR to predict that it could facilitate the remediation of acid mine soils to a state that enables plant establishment. ARS researchers evaluated the potential of biochar to simultaneously increase soil pH and decrease metal solubility in soils from two abandoned mines. Mine soils amended with 4% (w/w) biochar promoted the germination and growth of wheat in these highly weathered soils (Phillips et al., 2015). A complimentary experiment that measured leached metals indicated that biochar amendment rates ≥4% were sufficient to simultaneously neutralize the pH and reduce concentrations of potentially toxic elements (zinc, copper, nickel, and aluminum) in mine drainage. These findings support the use of gasified biochar amendments to revegetate acid mine soils and provide foundational data that support alternative niche applications for biochar-based amendments. CRIS Project 2072-21410-004-00

Soil-borne Disease Management without Chemical Fumigants. Soil fumigation has been the primary means used for the control apple replant disease, but impending modifications to existing regulations are likely to increase the cost of soil fumigation and/or restrict use of this disease control measure on certain sites. Brassicaceae seed meal amendments have been effective in controlling apple replant disease, but require post-plant application of the fungicide mefenoxam. Scientists in Wenatchee, WA devised a composite seed meal formulation and examined it for disease control in organic orchard systems. The composite seed meal formulation was as effective as soil fumigation in controlling replant disease and resulted in tree growth and yield that was equivalent to or greater than that attained in fumigated soils. The pre-plant seed meal amendment suppressed lesion nematode populations and root infection by Pythium spp. relative to the no-treatment control through three growing seasons while lesion nematode populations typically recovered in fumigated soil. Long-term suppression of plant pathogens in response to pre-plant SM amendment was associated with the persistence of a distinctive microbial community associated with apple roots. In contrast, the rapid re-colonization of fumigated soil by root pathogens was associated with the reversion of the rhizosphere soil microbial community to one that was indistinguishable from that of the no-treatment control. This difference in pathogen re-establishment typically corresponded with enhanced tree growth and yield in seed meal amended soils. Thus, it is plausible that the beneficial effects of Brassicaceae SM amendment in terms of overall growth and yield will be persistent leading to enhanced orchard economic viability (Mazzola and Strauss, 2014). CRIS Project 2094-21220-001-00

Chemical and Physical Methods for Fractionalizing Condensed Distillers Solids. Fuel ethanol production in the U.S. and elsewhere is an important and growing industry. In the U.S, about 40% of annual corn production is now converted into fuel ethanol. During co-product recovery, condensed distillers solubles (CDS) has to be mixed with distillers wet grains before drying due to CDS's recalcitrance to drying. This results in distillers dried grains with solubles, a major co-product of dry-grind ethanol processing. Scientists at Aberdeen, ID developed chemical, physical, and physicochemical methods for fractionating CDS. The effort not only results in several new co-products with value-added uses but also addresses the dewatering problem of CDS and makes it possible to dry each component alone. When convectively dried at 60°C, all the new fractions showed faster drying rates than CDS, except for the glycerol-rich fraction. To further demonstrate the improved drying performance of the new fractions, we used a drum dryer to dry a protein-rich fraction and CDS (the control). Results show that while both materials could be dried to a range of endpoint moisture contents, the dried protein-rich fraction exhibited a broader range of water activity and lighter color than CDS and that the new fraction can be readily drum-dried into a shelf-stable, flaked product (Liu et al., 2014). CRIS Project 2050-21310-005-00

Biochar Increases Available Nitrogen from Manure Amendments. Amending soils with biochar, a byproduct of bio-oil production, potentially could remove excess atmospheric carbon dioxide while improving soil quality. ARS researchers at Kimberly, ID and St. Paul, MN measured plant-available nitrogen and greenhouse gas emissions from plots treated with biochar and/or manure. Although biochar decreased carbon dioxide emissions from soil, it also decreased corn yields under particular soil conditions. Combining biochar with manure eliminated potential yield reductions from biochar while increasing nitrogen availability from manure. This demonstrated the synergy of applying biochar and manure to soil (Lentz et al., 2014). CRIS Project 2054-13000-008-00

Publications:

Allen, B., A. Lenssen, U. Sainju, T. Caesar-TonThat, and R. Evans. 2014a. Nitrogen Use in Durum and Selected Brassicaceae Oilseeds in Two-year Rotations. Agronomy Journal 106:821-830.

Allen, B., M. Vigil, and J. Jabro. 2014b. Camelina Growing Degree Hour and Base Temperature Requirements. Agronomy Journal. 106:940-944.

Al-Hamdan, O., M. Hernandez, F. Pierson, M. Nearing, C. Williams, J. Stone, J. Boll, and M. Weltz. 2015a. Rangeland Hydrology and Erosion Model (RHEM) Enhancements for Applications on Disturbed Rangelands. Water Resources Research *DOI: 10.1002/hyp.10167*.

Lentz, R., J. Ippolito, and K. Spokas. 2014. Biochar and Manure Effects on Net Nitrogen Mineralization and Greenhouse Gas Emissions from Calcareous Soil Under Corn. Soil Science Society of America Journal. 78:1641-1655.

Liu, K., R. Milczarek, and F. Barrows. 2014. New Co-products from Grain-based Fuel Ethanol Production and Their Drying Performance. Proceedings of American Oil Chemists' Society Meeting. PCP 5 Symposium.

Long, D., and J. McCallum. 2015. On-combine, Multi-sensor Data Collection for Post-harvest Assessment of Environmental Stress in Wheat. Precision Agriculture 16:492-504.

Mazzola, M., and S. Strauss. 2014. Replant Disease Control and System Resilience to Pathogen Re-infestation in Response to Brassica Seed Meal Amendment. Acta Horticulturae. 1044:105-112.

McIver, J., M. Brunson, S. Bunting, J. Chambers, P. Doescher, J. Grace, A. Hulet, D. Johnson, S. Knick, R. Miller, M. Pellant, F. Pierson, D. Pyke, B. Rau, K. Rollins, B. Roundy, E. Schupp, R. Tausch, and J. Williams. 2014. A synopsis of short-term response to alternative restoration treatments in sagebrush-steppe: The SageSTEP project. Rangeland Ecology and Management 67:584-598.

Pierson, F., C. Williams, P. Kormos, and O. Al-Hamdan. 2014. Short-term Effects of Tree Removal on Infiltration, Runoff, and Erosion in Woodland-encroached Sagebrush Steppe. Rangeland Ecology and Management 67:522-538.

Pierson, F., C. Williams, P. Kormos, O. Al-Hamdan, S. Hardegree, and P. Clark. 2015. Short-term Impacts of Tree Removal on Runoff and Erosion from Pinyon- and Juniper-dominated Sagebrush Hillslopes. Rangeland Ecology and Management 68:408-422.

Williams, C., F. Pierson, P. Robichaud, O. Al-Hamdan, J. Boll, and E. Strand. 2015. Structural and Functional Connectivity as a Driver of Hillslope Erosion Following Disturbance. International Journal of Wildland Fire DOI:10.1071/WF14114.

Williams, J., D. Robertson, and S. Wuest. 2015. Biofuel Feedstock Production Potential in Stream Buffers of the Inland Pacific Northwest: Productivity and Management Issues with Invasive Plants. Journal of Soil and Water Conservation. 70:156-169.

Sulik, J., and D. Long. 2015. Spectral indices for Yellow Canola Flowers. International Journal of Remote Sensing 36:2751-2756.

Trippe, K., S. Griffith, G. Banowetz, and G. Whitaker. 2015. Changes in Soil Chemistry following Wood and Grass Biochar Amendments to an Acidic Agricultural Production Soil. Agronomy Journal 107:1440-1446.

Trippe, K. , S. Griffith, G. Banowetz, and G. Whitaker. 2015. Biochars Derived from Gasified Feedstocks Increase the Growth and Improve Nutrient Acquisition of Triticum aestivum (L.) Grown in Agricultural Alfisols. Agriculture, 5:668-681.

Young, F., D. Whaley, N. Lawrence, I. Burke. 2015. Feral Rye (*Secale cereale*) Control in Winter Canola in the Pacific Northwest. Weed Technology (In press).

Manuscripts in Review:

Al-Hamdan, O., F. Pierson, M. Nearing, C. Williams, M. Hernandez, J. Boll, S. Nouwakpo, M. Weltz, and K. Spaeth. 2015b. Developing a Parameterization Approach of Soil Erodibility for the Rangeland Hydrology and Erosion Model (RHEM). Transactions of the ASABE *In review*.

Gollany, H., R. Kenton, J. Hilbert, M. Galdos, M. Cisz, B. Titus, A. Scott, H. Asbjornsen, S. Resh, and R. Chimmer. Biogeochemical Research Priorities for Sustainable Biofuel and Bioenergy Feedstock Production in the Americas. Environmental Management.

Lenssen, A., U. Sainju, W. Iversen, B. Allen, and R. Evans. 2014. Crop Diversification, Tillage, and Management Influences on Spring Wheat Yield and Soil Water Use. Agronomy Journal (in press).

Long, D., F. Young, W. Schillinger, C. Reardon, W. Williams, W. Pan, and D. Wysocki. Ongoing Development of Dryland Oilseed Production Systems in the Northwestern Region of the U.S. Bioenergy Research.

Phillips, C., K. Trippe, S. Griffith, G. Whittaker, and G. Banowetz. Biochar From Gasified Grass and Wood Facilitates Plant Establishment in Acid Mine Soils. Journal of Environmental Quality (in revision).

Sulik, J., and D. Long. A Normalized Difference Vegetation Index for Modeling Yield of Brassica Oilseeds. Remote Sensing of Environment.

Williams, J., D. Robertson, D. Long, S. Wuest, D. Kumar, A. Ankita, and G. Murthy. Conservation buffer Biofuel Feedstock Production Potential in the Inland Pacific Northwest: Ethanol Production. Journal of Soil and Water Conservation.