

Effects of cropping-system, irrigation method, and soil properties on soil nitrogen and organic matter dynamics in the Big Horn Basin

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Proposal to the University of Wyoming Agricultural Experiment Station Competitive Grants Program

Submitted by:

Jay Norton, Soil Fertility Specialist and Assistant Professor, Department of Renewable Resources, 307-766-5082, jnorton4@uwyo.edu

Abdel Mesbah, Weed Science Specialist, Director, Powell Research & Extension Center, Department of Plant Sciences, 307-754-2223, sabah@uwyo.edu

Dannele Peck, Assistant Professor, Department of Agricultural & Applied Economics, 307-766-6412, dpeck@uwyo.edu

Gary Franc, Plant Pathology Specialist and Professor, Department of Plant Sciences, 307-766-2397, francg@uwyo.edu

Katta Jayaram Reddy, Professor, water quality/aquatic chemistry, Department of Renewable Resources, 307-766-6658, Katta@uwyo.edu

Urszula Norton, Biogeochemistry Research Scientist, Department of Renewable Resources, 307-760-2189, unorton@uwyo.edu

Sandra Frost, Big Horn Basin Agricultural Educator, Cooperative Extension Service, Powell, 307-754-8836, sfrost1@uwyo.edu

James Gill, Big Horn Basin Extension Educator, Cooperative Extension Service, Worland, 307-347-3431, jrgill@uwyo.edu

Study period: Three years: January 1, 2008 to December 31, 2010

Study location: Big Horn Basin irrigated croplands

PROJECT ABSTRACT

We propose to investigate factors that support sustainability in sugar beet production on farms in the Big Horn Basin, Northwestern Wyoming. Increasing costs, changing markets, and off-site environmental concerns interact to create a need for better understanding of production efficiency and ecological impacts of irrigated sugar beet systems. The project will provide data that is lacking for these systems, including soil organic matter (SOM) dynamics, nitrogen (N) cycling, greenhouse gas (GHG) emissions, and tradeoffs between economic performance and soil sustainability. This data will provide decision support in the short term and will leverage funding for future, more in-depth research and extension in the mid to long term.

This interdisciplinary project would build upon past AES-CGP-funded work by analyzing how rotation systems for pathogen control affect soil quality and productivity under different soil and water conditions. Our primary objectives are to describe ecological and economic sustainability and to make results available to growers. The 16 scenarios include four on-farm crop rotations in place for 10 or more years on clayey and sandy soils and under furrow- and sprinkler-applied irrigation. Each production scenario will be replicated three times and will include an unfertilized pair. The four rotations will be defined by a project advisory team of producers and agricultural advisers. The primary pitfall of this study design is the variability of production practices from farm to farm. We plan to minimize variability through the field selection process and by carefully recording practices within each of the 16 scenarios.

The project addresses the first and second priorities of the 2008 RFP by: 1) assessing economic viability and maintenance of the resource base; and 2) evaluating long-term impacts of farming systems on the resource base as on-farm soil quality and off-site contributions to air and water quality. The project addresses the discovery and dissemination focus areas defined in the University of Wyoming College of Agriculture mission. Working closely with a project advisory team of Big Horn Basin producers and ag advisers, along with inclusion of University of Wyoming Cooperative Extension Service (CES) Area Agricultural Educators on the research team, will ensure both the relevance of research questions and the dissemination of results. The instruction mission of the College is also addressed because both graduate students and College faculty with teaching appointments in three departments will participate in the project.

Though this proposed work is broad in scope, it's coincidence with complementary projects managed by the Project Director will facilitate field and laboratory work and sharing of human resources and equipment. It parallels a similar on-farm project funded by the USDA-NRI Soil Processes Program that will investigate soil processes and economic factors in dryland cropping systems of Southeastern Wyoming. A PhD student paid through this proposed project and the dryland wheat NRI project will combine investigations of soil quality and economics.

Total Funds Requested: \$60,000: \$20,000 each in 2008, 2009, and 2010

Previous AES CGP Support for Co-PIs:

FY2002: Microbiological Characteristics of Winter Clouds and Precipitation and the Microphysical Factors that Govern Bacterial Deposition. **G.D. Franc** and R.D. Borys.

FY2006: Development of Rapid PCR-based Tests to Detect Fungicide Resistance Profiles in *Cercospora beticola*. **G.D. Franc**, L.E Hanson, and W.L. Stump.

OBJECTIVES, RATIONALE, AND EXPECTED SIGNIFICANCE

Goals and Objectives:

Our long-term goal is to develop or enhance management approaches that improve profitability and reduce negative environmental impacts of irrigated agriculture. Our immediate goal is to evaluate agricultural sustainability of cropping systems that Big Horn Basin farmers have used for ten or more years. Farmers of the Big Horn Basin use many different production approaches but the relative productivity, sustainability, and environmental impacts are not well documented. Data from this on-farm research will help to identify and refine relevant questions about soil and water management for further research and extension efforts. Specific objectives include:

- 1. Evaluate effects of sugar beet cropping systems used by Wyoming producers on soil properties that support sustainable production.** *Hypothesis: Crop rotations used for pest control have auxiliary benefits to soil health and crop yield that vary with soil type and irrigation system. In particular, rotations that utilize legumes and/or trap crops will contribute to higher SOM content.*
- 2. Analyze N losses to leaching and greenhouse gas emissions from the cropping systems.** *Hypothesis: Sugar beet cropping systems in the Big Horn Basin lose economically significant quantities of N to surface and ground waters, and to the atmosphere as GHG. The magnitude of loss is highest under furrow irrigation on sandy soils.*
- 3. Assess weed and pathogen populations in each cropping system.** *Hypothesis: Effectiveness of long-term implementation of crop rotations for weed and pathogen control varies by type of rotation, soil type, and irrigation method.*
- 4. Link soil processes research to field and farm scale production activities using comparative economic analyses of cropping systems.** *Hypothesis: Profitability will not vary significantly among cropping systems, but will vary by soil and irrigation method.*

To enhance the regional relevance of this work, the objectives will be repeated on four sugar-beet-based cropping systems on both clayey and sandy soils and under both furrow and sprinkler irrigation systems. Nutrient and water management differ markedly with different soil properties, particularly soil texture, which controls the movement and storage of water and nutrients. Producers in the Big Horn Basin and other predominantly furrow-irrigated areas are steadily converting to overhead sprinkler systems because of lower labor and water needs. Questions remain, however, as to how nutrient and water management must change with conversion.

In addition to our four scientific objectives, we believe that our approach utilizing an advisory team of producers and agricultural advisors to guide implementation of the project will enhance technological exchange among researchers, producers, and advisers in the Big Horn Basin. Also, the broad scope of this project will serve to identify issues and farming practices that warrant further study and extension effort. Results will be published via extension bulletins, presentations, and peer-reviewed scientific papers.

Rationale and Significance

The proposed work would investigate soil processes and economic factors defining agricultural sustainability in irrigated cropping systems in the Big Horn Basin. Increasing costs, changing markets, and environmental concerns are creating needs for more efficient management of agricultural inputs. Current research at the Powell REC shows that recommended fertilizer rates based on crop needs do not achieve projected yields. This suggests that a large amount of mineral N is being lost through runoff, leaching, and/or to the atmosphere as GHG emissions. Losses of fertilizer are costly in both agronomic and environmental terms. At the same time, economists predict incentives for intensified production due to demand for biofuels crops (Collins, 2006; Elobeid et al., 2006; Brown, 2007) and increased conservation due to incentives for soil-C sequestration (Lewandowski et al., 2004). Research has shown that sugar beets produce biofuel more efficiently than corn and many other crops (Tzilivakis et al., 2005b; Righelato and Spracklen, 2007). Both intensification and conservation require increased knowledge about interactions among soil physical, chemical, and biological processes. Additionally, glyphosate-resistant varieties, which may become prominent in Big Horn Basin sugar beet production, enable uses of green manure and mulch crops not possible before (Petersen and Rover, 2005). Improved understanding of SOM dynamics in different production scenarios will facilitate adoption of these potentially beneficial practices.

Farmers in the Big Horn Basin of Northwestern Wyoming utilize many different farming systems on two basic soil types and under two different irrigation systems. To better understand interactions among nutrient cycling, nutrient losses, productivity, and economics under the different conditions, we propose a broad-scaled, multidisciplinary evaluation of four irrigated crop rotations under furrow and sprinkler irrigation and on fine soils of lower river terraces and sandy/gravelly soils of higher benches. This work will provide data for extramural proposals for more detailed study of particular processes and practices, both on farms and on the UW RECs. We believe this work will improve researchers' understanding of Northwestern Wyoming farming systems, which will improve channels of communication and opportunities for information transfer.

Research proposed here would generate much-needed information on trace gas emissions from irrigated and fertilized sugar beet fields, which is presently lacking (Draycott and Christenson, 2003, pp. 9 and 31). We anticipate that one product generated from objectives 1 and 2 will be development of comprehensive C inventories that will include estimates of both trace gas emissions and stable and transient soil organic carbon pools across a wide spectrum of management-derived scenarios and across a variety of heterogeneous sites.

The project would coincide with two complementary research/extension projects managed by PI/PD Norton: 1) ongoing work on the Powell Research & Extension Center (REC) evaluating alternative N fertilizer formulations, rates, and application methods and 2) on-farm research investigating soil nutrient and moisture dynamics in dryland wheat farming systems in Southeastern Wyoming funded starting this fall by the USDA-NRI Soil Processes program. These complementary projects will allow for efficient laboratory analyses and resource sharing, and will create a well-rounded Ph.D. research project for a motivated student.

REVIEW OF PREVIOUS WORK

There is an extraordinary amount of literature that speaks to the objectives of this proposal. The following paragraphs represent an attempt to begin to sort through the long history of sugar beet research, to apply it to production practices in the Big Horn Basin, and to identify areas where we could contribute on regional, national, and global scales.

Nitrogen and soil organic matter dynamics in sugar beet cropping systems

The tradeoff between sugar beet yield and quality is the subject of a long-running debate. Sugar refiners and agronomists tend to urge lower rates for increased quality and lower refining costs (personal communication, Cal Jones, CEO, Wyoming Sugar Company), while producers tend to prefer higher N rates that sacrifice some quality for larger yields. The long and rich body of literature on nutrient management in sugar beet production is dominated by studies seeking balance between high N needs early in the season for rapid leaf development, and lower needs late in the season for better root quality (e.g., Deming and Brewbaker, 1934; Halvorson and Hartman, 1975; Whitmore et al., 1987; Malnou et al., 2006). Crop rotation and tillage effects on N dynamics have also received a great deal of attention. Halvorson and Hartman (1988) found that sugar beets grown under reduced tillage in Eastern Montana have nearly the same N needs as those grown with conventional tillage, but Moraghan et al. (2003) found that N needs in North Dakota are reduced if straw is removed following a wheat crop. Generally, organic sources of N such as manures or crop residues reduce the predictability of N availability, but if carefully managed can boost productivity and reduce N loss without hurting sugar quality (Draycott and Christenson, 2003).

In the Big Horn Basin, producers have responded to a long history of University of Wyoming research and extension on the use of rotations and trap crops for pest control (e.g., Brewer, 1995; Franc et al., 1997; Gray and Koch, 1997; Koch et al., 2005) by implementing a number of different crop rotation systems. The rich body of scientific literature on effects of rotation and tillage on soil organic matter and N dynamics in sugar beet and other crops suggests that rotations used by Big Horn Basin producers for pathogen control also impact SOM and N dynamics. It is known from long-term rotation studies in Nebraska, for instance, that beet yields increase with longer rotations up to one sugar beet crop in six years, especially if alfalfa is included (Wilson, 2001). Differences among the various shorter-term rotations common in the Big Horn Basin are not well documented, however, especially as affected by soil type and irrigation method.

Interactions among soil texture and soil water characteristics have controlling influence on SOM dynamics and N mineralization (Paul and Clark, 1996). Conversion from furrow to sprinkler irrigation can reduce N losses through leaching (Canter, 1997) and runoff as it conserves water. But water and nutrient management change significantly and producers report problems with both following conversion (personal communication, Powell REC farm manager Mike Killen, August 13, 2007). On some soils it can be difficult to apply enough water for optimal growth under sprinklers. Water shortage inhibits plant uptake but may stimulate N mineralization through the effects of rewetting dry soils. Less loss of N under sprinklers through leaching and GHG emissions may mean more N is available late in the season when it can negatively impact

sugar beet quality. These factors mean changes in nutrient management approaches are necessary, but more information is needed.

Nitrogen losses and trace gas emissions from sugar beet cropping systems

Current research at the Powell REC along with other analyses of nutrient cycling under furrow irrigation suggest that as much as half of the N applied as fertilizer can be lost from soils without being taken up by crops (Skinner et al., 1999; Draycott and Christenson, 2003). Such losses are detrimental to both profitability and environmental sustainability of farm enterprises. Costs of N fertilizer are increasing rapidly along with energy costs; minimizing loss has significant positive impacts on economic sustainability (Whitmore et al., 1987). Pathways of N loss include loss of nitrate through leaching, loss of both fertilizer and organic N in runoff, and losses in GHG emissions to the atmosphere.

Nitrogen-rich effluent from agricultural lands is a serious pollution threat to both ground and surface waters, and sugar beets are known to lose significant N through leaching and runoff (Draycott and Christenson, 2003). Leaching of excess N late in the growing season can actually be an unintended part of the management system with benefits to sugar beet quality at harvest (Martin-Olmedo et al., 1999). Different irrigation application methods significantly impact leaching and runoff losses (Canter, 1997) and require altered management approaches to optimize N utilization by crops (Skinner et al., 1999).

Measurements of trace GHG emissions from sugar beet cropping systems in different soil and water management scenarios will provide much needed information that can vary greatly during the year and across land use practices. Trace gas measurements are not only sensitive to management, but can also change depending on specific attributes of different soils. One of the most variable terms in global trace gas budgets is flux from natural and agricultural systems (Holland et al., 1999). Agricultural sources are thought to constitute as much as 40 to 80 percent of the global inventory of these gases and are known to be dynamic. The three gases carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) are of particular interest because of their overall content in the atmosphere, their ability to stay radiatively active for extended periods of time and therefore, influence the radiation balance in the atmosphere (Holland et al., 1999).

There are many factors influencing trace gas emissions to the atmosphere. Carbon dioxide is emitted from soils during soil respiration. This CO₂ derives from the metabolic activity of soil microbes decomposing SOM and from plant root activity. Most of the plant debris entering the soil is quickly turned over to CO₂, with a small fraction sequestered in the soil (Schlesinger, 1990). Decomposition of SOM and microbial respiration is therefore a major source of CO₂ flux in the global C cycle. Factors affecting the activity of microorganisms will in turn, affect rates of CO₂ flux. These factors include the abiotic environment (temperature, water, aeration, pH, mineral nutrients), plant residue quality, soil texture and mineralogy, and soil disturbance (Paustian and Babcock, 2004). Soil texture and mineralogy are well recognized as influencing SOM levels. Soil C tends to increase with higher clay content and therefore CO₂ flux rates also increase (Burke et al., 1989).

Nitrous oxide is produced in soil primarily by denitrification and nitrification, both microbially mediated processes carried out by anaerobic heterotrophs or chemoautotrophs, which are ubiquitous in most soils. The process of nitrous oxide production is not limited to water-saturated environments as was previously thought, but occurs in any soil in which oxygen-depleted microsites are formed (Sextone et al., 1985) or as an end product of nitrification in dry soils. SOM and nitrate (NO_3^-) are critical to denitrification. Nitrous oxide production is especially high after irrigations and rainfall events when increased soil moisture stimulates microbial CO_2 production, restricts O_2 diffusion, and creates temporary anaerobic sites. Temporal variability is equally important as N_2O flux tends to be affected when environmental conditions change. The correlation of N_2O production with soil C abundance has been observed in a wide scope of field and laboratory measurements. For example, Ambus and Christensen (1995) observed that dissolved organic carbon, which is a direct source of energy for denitrifiers, is one of the major limiting factors for N_2O production. Land use practices can significantly impact rates of N_2O production. Soil texture also plays a significant role on N_2O flux rates, especially soils of heavy texture, which can seasonally create the right conditions for temporary anaerobic microsites.

Methane emissions are produced mainly from saturated soils by a process called methanogenesis. In non-flooded soils CH_4 consumption by methanotrophs dominates over CH_4 production. Methane consumption in aerobic soils is considered to be one of the globally important sinks for C, as measurable rates of CH_4 oxidation have been documented in a variety of environments (Mosier et al., 1991). Factors affecting methane consumption include soil NH_4^+ -N concentrations (high enzymatic similarity and preferential substrate use), soil structure (ability to impede or promote oxygen diffusion), texture, and soil water content.

In general, information on trace gas emissions from irrigated sugar beet is lacking (Draycott and Christenson, 2003). For these reasons, the accurate accounting of trace gas emissions is required for the determination of trace gas inventories in irrigated sugar beet and to assess impacts of management and rotations.

Economics of sugar beet cropping systems

A cropping system that achieves resource sustainability must also be economically viable to remain a part of a farm management plan. This study will examine sugar beet cropping systems that Big Horn Basin producers have implemented for ten or more years. The persistence of these systems in the study area for a decade (or more) immediately suggests that they are economically viable; otherwise, producers would have abandoned them for more successful enterprises. It does not indicate, however, whether these systems are equivalently sustainable from a natural resource perspective. Two systems with identical profit distributions could have different degrees of resource-sustainability. Alternatively, two systems with equivalent degrees of resource sustainability could generate different profit distributions. This suggests that producers might have the opportunity to choose from a set of agronomically-similar cropping systems that generate alternative combinations of economic performance and resource sustainability. The goal of the economic analysis proposed for this study is to characterize the combinations of economic performance and resource sustainability (as measured by soil SOM content, nitrogen

losses, and the prevalence of weeds and pathogens) available to sugar beet producers in the Big Horn Basin.

A growing body of literature examines the relationships between resource sustainability and the profitability (or other measures of economic performance) of agriculture. Several studies, for example, compare the profitability of conventional versus reduced tillage, the latter of which can decrease soil erosion and weeds, and increase water-use efficiency. Conclusions have been mixed, with some studies showing that reduced tillage is equally profitable as conventional tillage (DeVuyst and Halvorson, 2004), and others concluding that reduced tillage is less profitable (Epplin et al., 1994). The profitability of organic farming, which can reduce chemical residues in soil and water, has also been a widely studied topic. Conclusions in this debate also vary across case studies (Offermann and Nieberg, 2000). It is not clear, a priori, whether the natural resource sustainability of sugar beet production in the Big Horn Basin can be enhanced without a reduction in economic performance. Tzilivakis et al. (2005a) report that of thirteen sugar beet systems observed in the UK, the system with the best overall environmental performance score (which considers the environmental effects of nutrients, pesticides and energy) also generates a net return per ton of sugar beet that is comparable to many systems, and better than several. Despite the system's socially-appealing balance of environmental and economic performance, it represents only 18% of the UK's sugar beet acreage (Tzilivakis et al., 2005a). Possible explanations for this relatively small percentage are that only a small proportion of the UK's production environments can support this sugar beet system, or that small profit gains are sufficient to attract producers to other, less environmentally-friendly sugar-beet systems. Regardless, Tzilivakis et al.'s (2005a) findings provide evidence that some sugar beet producers can achieve relatively high levels of environmental performance without giving up much or any economic performance. Tzilivakis et al.'s (2005a) results are not likely to be directly transferable to the Big Horn Basin, however, because there are several clear differences between the production-setting in the UK versus the Big Horn Basin. A similar study for the Big Horn Basin is therefore needed.

METHODS

Overall Study Design

The study will take place on farms in two irrigation districts in the Big Horn Basin that have distinctly different soil types (clayey & sandy/gravelly). Within each area, four common sugar-beet-based crop rotations (e.g., sugar beet-barley-bean, sugar beet-barley, sugar beet-bean, sugar beet-barley with trap crop) under two different irrigation methods (sprinkler & furrow) will be evaluated. Study plots will be located in a sugar beet phase of each cropping system in 2008 and will stay in the same field for three growing seasons (selected rotations may change based on input from advisory team). Companion plots with no added N fertilizer will be located adjacent to each cropping system plot as controls. Three replications of each system and the no-added-N controls will be evaluated. This will amount to a total of 96 plots within 16 different systems:

4 systems x 2 soils x 2 irrigation methods = (16 fields + 16 controls) x 3 replications = 96 plots

In addition to input from a project advisory team of Big Horn Basin-area producers and agricultural advisers, the unpublished Park County soil survey will be used to help locate farms on similar soil types within each irrigation district. Location of plots within farms will be based partially on hand texturing to assure similar soil types among the cropping systems and irrigation methods. Management practices, including fertilization, irrigation, crop varieties, pesticides, and others will be carefully recorded based on information from cooperating producers. To the extent possible, we will select farms that use similar fertilizer rates, formulations, and application methods and similar pesticide applications. For the no-added N control plots, we will work with producers to assure amounts of N applied with sulfur and phosphorus fertilizers are equivalent among the different systems. The no-added N plots will be relatively small (e.g., approximately 11 x 35 feet depending on the size of planting equipment) and will be protected from broadcast N fertilization by placing tarps over the plots.

Objective 1: Evaluate effects of sugar beet cropping systems used by Wyoming producers on soil properties that support sustainable production

Hypothesis: Crop rotations used for pest control have auxiliary benefits to soil health and crop yield that vary with soil type and irrigation system. In particular, rotations that utilize legumes and/or trap crops contribute higher SOM content.

Though it has been well-established that tillage and crop rotation systems reduce pathogen concentrations (e.g., Franc et al., 1997; Gray and Koch, 1997; Wilson, 2001; Draycott and Christenson, 2003), harmful insects (Brewer, 1995), and weed populations (Cousens and Mortimer, 1995), the effects of those management variables on soil organic matter and N dynamics are not well documented for sugar beets, especially in the unique environmental conditions of the Big Horn Basin.

Soil Physical and Chemical Properties. Basic soil properties that impact crop production will be quantified by standard soil analysis methods. Analyses include particle-size distribution by the hydrometer method (Gee and Bauder, 1986), bulk density by the core method (Blake and Hartge,

1986), pH and EC by electrode (Thomas, 1996), inorganic C by gravimetric analysis (Loeppert and Suarez, 1996), and gravimetric moisture. These analyses will be done one time for the study fields, including one soil profile core sampled by horizon for each of the 16 study fields (96 surface samples and approximately 64 profile samples = 160 one-time samples).

Soil Organic Matter Dynamics.

Labile-pool SOM: To quantify available and readily mineralizable C and N, field-extracted samples will be analyzed for nitrate (NO_3^-) and ammonium (NH_4^+) using the Technicon TRAACS flow injection system (Technicon, Tarrytown, NY). Dissolved organic C will be measured using a UV-persulfate TOC Analyzer (Phoenix 8000, Tekman-Dorhmann, Cincinnati, OH). Dissolved organic N will be measured as NO_3^- generated upon N persulfate oxidation of 0.5M K_2SO_4 extracts (Cabrera and Beare, 1993). Microbial biomass will be analyzed on fresh, refrigerated soil samples within 72 hours of collection by fumigation-extraction (Horwath and Paul, 1994). Mineralizable C and N will be analyzed by aerobic incubation (Zibilske, 1994). These dynamic, temperature-, moisture-, and substrate-dependent SOM constituents will be measured three times seasonally over 2008, 2009, and 2010 (288 samples per year).

Physical fractionation of SOM: To quantify SOM fractions known to respond to changes in soil C processes affected by management, physical fractionation of the soil will be done by separating the light, intra-aggregate (protected), and mineral-associated SOM fractions following the density fractionation method of Sohi et al. (2001). The light, protected, and mineral-associated fractions separated by this method are chemically distinct and correspond to the active, slow, and passive SOM pools, respectively (Sohi et al., 2005). Total C and N in fractions and whole soils will be measured by Carlo Erba combustion on an EA1100 Soil C/N analyzer (Carlo Erba Instruments, Milan, Italy). Inorganic C (described under physical and chemical properties) will be subtracted from total C to determine total organic C. These relatively stable SOM pools will be analyzed in one set of samples from the study fields (96 total samples).

Crop yield and quality. The yield and quality of harvested sugar beets is the ultimate test of long-term sustainability of cropping systems. We will count the number of crop plants per 10 feet of row in each treatment before harvesting subplots by hand and measuring crop yield, and quality (quality analyses by Western Sugar and other qualified labs for other crops). Residue left after harvest will be analyzed for biomass and N content (96 plant samples per year for total C and N analysis).

Objective 2: Analyze N losses to leaching and greenhouse gas emissions from the cropping systems.

Hypothesis: *Sugar beet cropping systems in the Big Horn Basin lose economically significant quantities of N to surface and ground waters, and to the atmosphere as GHG. The magnitude of loss is highest under furrow irrigation on sandy soils.*

For this initial study, we propose to evaluate pathways of N loss **only in the sugar beet-barley rotation** (or as determined by the project advisory team) under the two soils and two irrigation systems.

Plant uptake: Petiole N content (Ulrich and Johnson, 1959) for sugar beet crops will be analyzed in one bulk sample from each study plot three times per year (72 petiole analyses per year). Whole-plant N content will be analyzed at harvest;

Surface runoff: Surface water samples will be collected during irrigation three times in each season from the inflow and tail water of three furrows (bulked) in each furrow-irrigated plot (total of 24 water samples per sampling; 72 water samples per year). Any runoff observed from sprinkler-irrigated plots will be noted and samples collected if possible. Samples will be frozen immediately after collection and then analyzed for nitrate concentration as described above for soil extracts within 48 hours of thawing.

Deep leaching: Porous-cup lysimeters will be installed within and below the root zone (one-foot and four-foot depths, respectively) in the upper, middle, and lower reaches of one furrow in each furrow-irrigated plot and in three random locations (bulked) in each sprinkler-irrigated plot. Samples will be drawn three times each season during the study period [((6 water samples per furrow plot x 12 plots) + (2 samples per sprinkler plot x 12 plots)) x 3 samplings = 288 samples analyzed for nitrate content per year of the study].

Trace gas emissions: Trace gas monitoring will be performed six times during the irrigation season during summer for three years. An enclosure technique for measuring CO₂, CH₄ and N₂O fluxes will be used for this experiment (Mosier and Mack, 1980). Specifically, we will install PCV rings 25-cm diameter and 10 cm high inserted in the ground (2 to 5 cm deep) for the duration of each irrigation season. These rings will serve as bases for chambers periodically installed on plots for monitoring trace gas evolution. Area within the bases will be left undisturbed for the duration of each season. Trace gas flux measurements will be taken by using static chambers deployed on the soil surface for a period of 30 minutes (Hutchinson and Mosier, 1981). Sampling will be performed by drawing a single air sample from chamber headspace using 30-ml syringe secured with a stopcock at 0, 15 and 30 minutes after the chamber is sealed. Twenty-five ml aliquots of these gas samples will then be injected into previously evacuated 12-ml tubes sealed with butyl rubber septa (24 plots x 3 samples x 6 times = 432 gas samples per year). The tubes will be transported to University of Wyoming for analysis by on an Automated Gas Chromatograph (Varian 38001) equipped with thermoconductivity, flame ionization and electron capture detectors to capture CO₂, CH₄ and N₂O respectively (Mosier and Mack, 1980). Best fluxes will be estimated from the rate of change of the gas concentration in the chamber headspace. Soil water content will be monitored daily using a TDR probe. Soil samples (0- to 10-cm depth) will be collected at the end of the last day of monitoring from randomly selected locations adjacent to the trace gas chambers. Composite soil samples will be homogenized in the field, all visible coarse fragments (greater than 4 mm) removed, and subsamples drawn for immediate field extraction in 2M KCl and analysis for available N as described above. The remainder of the composite samples will be bagged and stored on ice for transportation to the lab and further analyses.

Objective 3: Assess weed and pathogen populations in each cropping system

Hypothesis: Effectiveness of long-term implementation of crop rotations for weed and pathogen control varies by type of rotation, soil type, and irrigation method.

The effectiveness of crop rotations for weed and pathogen control in sugar beet production is well documented (e.g., Franc et al., 1997; Wilson, 2001). We intend to perform scouting-level assessments of weed and disease populations (e.g., Clay and Johnson, 2002) twice each season to evaluate and compare cropping systems under different soil and irrigations situations. If time allows, we will do cyst counts in soil samples for sugar beet cyst nematodes (Byrd et al., 1976). Presence of crop diseases will be visually assessed at harvest for sugar beet, dry beans, and barley.

Objective 4: Link soil processes research to field- and farm-scale production activities using comparative economic analyses of cropping systems

Hypothesis: Profitability will not vary significantly among cropping systems, but measures of soil sustainability will.

Standard enterprise budgeting techniques will be combined with net present value analysis to estimate total revenue, and total fixed and variable costs of production for each cropping system*soil type*irrigation method considered (Westra and Boyle, 1991; Kay and Edwards, 1999). Production costs will be determined using information provided by participating producers and other experts. Historical price data will be combined with the study's yield data to calculate total revenue. Net revenue will be the primary measure of economic performance.

Each system's measure of economic performance will be paired with its measures of soil sustainability (e.g. SOM content, nitrogen loss, and weed/pathogen prevalence). Each cropping system's vector of performance measures will then be compared to other cropping system's to determine whether any system achieves both the highest level of economic performance and the highest level of soil sustainability. Tzilivakis et al. (2005a) provides an example of the analytical framework, but applies it to sugar beet systems in the United Kingdom. The proposed study will build upon Tzilivakis et al. (2005) by focusing on soil sustainability as a measure of environmental performance; by using actual field measurements of performance, rather than results from simulation models, and by investigating sugar beet systems in an environment that differs significantly from the UK.

COOPERATION

Roles and Responsibilities

Jay Norton, Soil Fertility Specialist and Assistant Professor, Department of Renewable Resources, 307-766-5082, jnorton4@uwyo.edu.

Projector Director: Project oversight and management, site selection, fieldwork and analyses for Objective 1, co-advisor for graduate student.

Abdel Mesbah, Weed Science Specialist and Director, Powell Research & Extension Center, Department of Plant Sciences, 307-754-2223, sabah@uwyo.edu

Co-PI: Project liaison to Powell-area producers, oversight of weed studies in Objective 3.

Dannele Peck, Assistant Professor, Department of Agricultural & Applied Economics, 307-766-6412, dpeck@uwyo.edu

Co-PI: Oversight of analyses in Objective 4; co-advisor for graduate student.

Gary Franc, Plant Pathology Specialist and Professor, Department of Plant Sciences, 307-766-2397, francg@uwyo.edu

Co-PI: Oversight of data collection and analyses of pathogen populations in Objective 3.

Katta Jayaram Reddy, Professor, water quality/aquatic chemistry, Department of Renewable Resources, 307-766-6658, katta@uwyo.edu

Co-PI: Oversight of data collection and analyses of N loss to ground and surface waters in Objective 2.

Urszula Norton, Biogeochemistry Research Scientist, Department of Renewable Resources, 307-760-2189, unorton@uwyo.edu

Co-PI: Will carry out study of trace gas emissions in Objective 2.

Sandra Frost, Big Horn Basin Agricultural Educator, Cooperative Extension Service, 307-754-8836, sfrost1@uwyo.edu

Co-PI: Liaison to Big Horn Basin producers, extension programs/tours on results, coordination of and assistance with field work.

James Gill, Big Horn Basin Extension Educator, Cooperative Extension Service, 307-347-3431, jrgill@uwyo.edu

Co-PI: Liaison to southern Big Horn Basin producers, extension programs/tours on results, coordination of and assistance with field work.

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