PROJECT SUMMARY

Title: Economic and environmental sustainability of conventional, reduced-input, and organic approaches on western crop-range-livestock farms

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We propose to investigate economic and environmental sustainability of conventional, reduced-input, and organic approaches in cash-crop and beef-calf production on small and medium-sized crop-range-livestock farms. Producers seeking alternative practices to decrease costs or increase value need region-specific information for the cold, dry, irrigated cropping and livestock production systems of the western U.S.

We will establish a continuum of small plots for mechanistic research, large plots for systems research, and on-farm studies. For the intensive plot studies, six production systems (3 approaches x 2 systems) on four replicated plots will be established at James C. Hageman Sustainable Agriculture Research & Extension Center in Lingle, WY. Cow-calf pairs will graze on rangelands in summer and be fed grain and forage from plots during fall and winter. Parameters to be measured over the four-year study period include 1) weed, pathogen, arthropod and nematode populations; 2) soil biological, physical, and chemical properties; 3) water use efficiency and soil moisture dynamics; 4) crop and forage growth, yield and quality; 5) livestock performance; and 6) economic viability. For the extensive, on-farm studies, five farms operating under each production system will be selected for on-farm monitoring of stable indicators of soil productivity, economics, and marketing potential for products from the three approaches.

Agricultural systems conferences, extension bulletins, training workshops, and other programs aimed at a variety of learning styles will be developed to disseminate results. Research will be presented to Wyoming science teachers and incorporated into the Agroecology curriculum and other University of Wyoming agriculture courses.

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Introduction

Rising costs of fuel, fertilizer, and related inputs threaten the economic viability of agriculture in the semiarid Western High Plains and Intermountain regions (e.g., Huang, 2007). According to the 2002 Census of Agriculture, 97 percent of Wyoming farms had annual sales of less than $500,000. Small and medium-sized farms are critical to small towns and rural communities and are especially vulnerable to rapid changes in agriculture. In response to pressures that squeeze profit margins, producers are seeking production alternatives that decrease costs, increase yields, or increase value. Reduced-input and organic production approaches may achieve these goals, but success in either requires learning new techniques, exploring new markets, and risking short-run profit losses. **Our goal is to provide scientifically tested information on economic and environmental sustainability of conventional, reduced-input, and organic agricultural approaches on small- and medium-sized farms in the Western High Plains and Intermountain regions**. This four-year project assembles diverse investigators, educators, and producers to establish much-needed region-specific agricultural systems research at the University of Wyoming James C. Hageman Sustainable Agriculture Research and Extension Center (SAREC). SAREC has state-of-the-art livestock research and handling facilities, irrigated pastures and cropland, dryland wheat strips, and native rangeland, plus new laboratory, education, and dormitory facilities for research and education on agricultural systems.

Several cropping system studies across North America compare conventional, reduced-input, and organic production (Aref and Wander, 1998; Brandt and Zentner, 1995; Clark et al., 1998; Delate and Cambardella, 2004; Mueller et al., 2002). However, sound, region-specific information on production approaches is not available for integrated crop-range-livestock agroecosystems prevalent across the Western High Plains and Intermountain regions. Producers lack information on approaches that could enhance the long-term viability, competitiveness, and efficiency of small and medium-sized farms. Research that compares whole systems on-farm and at research stations is needed because many principles developed from reductionistic research fail when applied to complex whole-farm systems (Drinkwater, 2002). Systems projects on research stations can keep external factors (soils, climate, landscape) constant in randomized, factorial designs to analyze whole suites of practices (e.g. crop rotations, alternative inputs, reduced tillage, and integration of livestock) that mimic real agricultural philosophies in ways not possible in either small-scale reductionistic or farm- or larger-scale research. In this manner, whole-system impacts on crop yield and quality, soil quality, pest populations, water relationships, animal performance, and economic viability can be determined. This approach generates hypotheses that scale up to whole farm, whole watershed, or regional projects or scale down to specific cause-effect relationships explored in complementary mechanistic research (Drinkwater, 2002). This proposed project would establish a continuum of small-plot mechanistic research to large plot systems research to on-farm monitoring that would foster multidirectional inquiry, discovery, and dialog among producers, researchers, and educators.

Compared to conventional production practices, reduced-input and organic approaches rely on higher levels of soil organic matter (SOM), healthy populations of beneficial organisms, and price premiums from value-added products, such as organic-certified food or feed, all of which take time to establish. Profits may decrease during the transition due to confounding effects of reduced yield (e.g. as soil microbial, weed, arthropod, and pathogen communities adjust to altered types of inputs and management practices), and in the case of organic production, the three-year waiting period during which organic price premiums cannot be realized. Initially, this research project will provide information on the magnitude and timeframe of yield and profit reduction during transition. Results of transition studies in other regions indicate that meaningful results will be obtained with four years (e.g., Delate and Cambardella, 2004; Liebhardt et al., 1989; Tu et al., 2006). Although an understanding of transition period is critical, meaningful systems research is, by necessity, long-term (Stanhill, 1990). Differences among production methods change over time as SOM quantity and composition, soil-water characteristics, and populations of soil microbes, weeds, pathogens, and harmful and beneficial insects tend toward new steady-state conditions. As a result, long-term studies become increasingly valuable and productive with time (Aref and Wander, 1998; Riley, 2000). Initial support will build broad citizen engagement and foster locally based long-term funding to establish permanent monitoring of economic and environmental implications of conventional, reduced-input, and organic production approaches in Western High Plains and Intermountain regions.

Production Approaches

Three production approaches will be compared: conventional, reduced-input, and organic.

The **conventional production approach** uses inputs as needed to maximize production, namely commercial synthetic pesticides and fertilizers, livestock growth enhancers, fed antibiotics, and other chemical technologies used by conventional feeder calf producers. It will use conventional tillage practices that leave less than 15 percent of crop residues on the soil surface.

The **reduced-input production approach** uses inputs to supplement more intensive management. Integrated management of pests, nutrients, and conservation tillage are used to reduce reliance on inputs. Our reduced-input approach will utilize “natural” livestock production methods without growth enhancers or fed antibiotics. Crop rotations, manure, and precision management tools such as satellite and fixed-wing aerial imagery, GPS and variable-rate application, and other technologies will be used to maximize profits by balancing yields with input costs. The University of Wyoming is a member of the Upper Midwest Aerospace Consortium (UMAC), which provides false-color aerial imagery for precision agriculture.

In the **organic production approach**, pest control and nutrient management are based on practices allowed by the USDA National Organic Program standards. Plots identified for organic production will be USDA certified through International Certification Services, Inc. of Medina, ND. USDA rules allow for certification of research plots but may limit certification of products produced if adequate buffers cannot be maintained. Transition from conventional agronomic farming acreage to USDA-certified organic acreage takes a minimum of three years following the last application of inorganic fertilizers and/or pesticides.

Production Approach Impacts on Pests, Soil Processes, and Economic Viability

Soils under conventional farming approaches have lost at least 60 percent of their original SOM during the last century (Aguilar et al., 1988; Bowman et al., 1990). Depleted SOM contents from long-term conventional farming create systems that require ever-increasing inputs to supply water and nutrients (Grant et al., 2002; Shaver et al., 2002) and control weeds (Kirchmann et al., 2007) and diseases (van Bruggen et al., 2006). Though this system can work economically for large farms that require only narrow profit margins and have high purchasing power, environmental sustainability is compromised. Recent increases in fuel and fertilizer prices threaten economic sustainability of small and medium-sized farms.

Reduced-input management has both conventional and organic tools at its disposal and can therefore be the most knowledge/management intensive approach. Maintaining or increasing yield relies on increasing SOM contents to increase moisture- and nutrient-supplying potential, as does the organic approach. Reduce-input management relies largely on reduced disturbance (tillage) to build SOM, while organic management relies more on inputs of manure, green manure, and N-fixing legumes because intensive tillage is often required for control of weeds and pathogens. Transition to either reduced-input or organic management can have similar pitfalls for producers, including increased fertilizer needs as rebounding microbial communities immobilize available nutrients (Grant et al., 2002; Liebhardt et al., 1989; Norton, 2007) and increased expenses as equipment is purchased or modified. Organic production has the added economic pitfall of the three-year transition period when yield may be lower but premiums are not available (Martini et al., 2004).

Goals and Objectives

Our goal is to scientifically compare economic and environmental sustainability of three approaches in the Western High Plains and Intermountain regions. Specific objectives include:

1. Quantify parameters that underlie long-term viability, competitiveness, and efficiency of conventional, reduced-input, and organic cow-calf and cash-crop production;
2. Extend results of the research to producers, agricultural educators, consultants, and others;
3. Incorporate research component into K-12, undergraduate, and graduate education.

Rationale and Significance

The proposed work would investigate integrated economic, social, and agroecological parameters of production options available to small and medium-sized crop-range-livestock farms at a time when farm profits are threatened by high fuel and fertilizer costs (Huang, 2007) and economists predict both increased production due to incentives for biofuels crops (Brown, 2007; Collins, 2006; Elobeid et al., 2006) and increased conservation due to incentives for soil carbon (C) sequestration (Lewandrowski et al., 2004). Addressing these issues requires knowledge about costs, benefits, and sustainability of available approaches. SAREC, located in the Northwestern High Plains of Eastern Wyoming, provides a unique opportunity to investigate a semiarid crop-range-livestock agroecosystem that covers a huge section of the western U.S., and to extend decision-making knowledge to producers, educators, and students (priorities 1 and 2 of the FY 2008 priorities for integrated projects).

Approach

Objective 1: Quantify parameters that underlie long-term viability, competitiveness, and efficiency of conventional, reduced-input, and organic cow-calf and cash-crop production.

General Hypothesis: *Alternative production approaches support ecological and economic sustainability of small and medium-sized crop-range-livestock systems in the semiarid West.*

Summary

This work will establish linked *intensive* and *extensive* research for comparison of parameters that support agronomic, ecological, and economic sustainability among three production approaches. Our goal is to establish a continuum of short-term small-plot (~40 m^2) mechanistic research to long-term, large-plot (0.4 to 0.8 ha) systems research to on-farm field-scale studies that provide two-way lines of inquiry and discovery. The extensive study will allow scaling from newly established research plots to long-term farms in both spatial and temporal parameters. Parameters to be measured include: 1) soil biological, physical, and chemical properties; 2) soil hydraulic properties, soil moisture, and soil temperature; 3) weed, pathogen, arthropod, and nematode populations; 4) crop and forage growth, yield, and quality; 5) livestock performance; 6) economic viability, and 7) marketing potential for products from all three approaches.

Study Area

Agroecosystems of Wyoming's ecoregions (USEPA, 2007) represent a broad swath of the semiarid Western U.S. that is generally too dry for non-irrigated agriculture. But abundant water from snow-melt-driven rivers supports irrigated agriculture, with much of the irrigated land producing forage for stock-cow herds that produce calves for sale in the fall and utilize rangelands for grazing. Irrigated cash crops are important in areas with longer growing seasons and deep, fertile soils. Wyoming agroecosystems are characterized by cool temperatures and short growing seasons. The average frost-free period at SAREC is about 125 days. Average annual precipitation is 300 to 400 mm, over 75 percent of which comes during summer thunderstorms that can be extremely heavy. Strong winds in winter and spring dry out soils and can damage crops. Soils are typically deep loams and sandy loams with native SOM content of about one percent. The farm is in Goshen County, Wyoming, on 1570 ha, with 154 ha irrigated croplands, 617 ha non-irrigated croplands, and 775 ha native rangelands.

Procedures for Research Station Plots (Intensive Studies)

Farming Systems Selection

Crop rotations (Table 1) were designed by our management/advisory committee (one organic crop/livestock producer, one reduced-input crop/livestock producer, one conventional crop/livestock producer), and the SAREC director, farm manager, and operations manager (see project management plan). Rotations are based on current cropping systems proven for this region and in common use within each production approach (no novel practices will be included in the base production systems, but may be tested with supplemental funding by splitting base plots, which this study design accommodates).

Cash-crop production system

Major cash crops grown in this region include corn (*Zea mays* L.), dry beans, and sugar beets (*Beta vulgaris*) in rotation. Prices of corn for both organic and non-organic production are at unprecedented levels because of organic feed prices and biofuel production, so our advisory team recommended two years of corn in each rotation.

Beef-calf production system

Maintenance of stock-cow herds for annual production of beef feeder calves for sale to feed lots is the most prevalent crop/range/livestock system in the high plains and intermountain regions (Padbury et al., 2002). "Backgrounding," or feeding grain plus corn silage and/or alfalfa (*Medicago sativa* L.) hay for several weeks after weaning is a common practice on farms with irrigated grain/forage crop rotations. Cattle typically utilize cover crops in spring before turnout on rangelands, and forage and grain stubble in the fall and early winter. They are fed hay and/or silage grown on the farm for the balance of winter. Our model beef-calf production system is based on this type of operation (Figure 1).

Research Design

Six model, four-year rotations (beef-calf production and cash-crop production under conventional, reduced-input, and organic approaches) will be established on 15 ha of sprinkler-irrigated land at SAREC (see Table 1). Each of the six approach*production-system treatment combinations will be replicated four times in a two-factor factorial set in a randomized complete block design. There will be four blocks. Space and logistical constraints predict that each of the six approach*system treatments will be replicated in space but not in time, meaning that only one phase of each crop rotation will be represented each year. The ideal design would replicate treatments in both space and time and would require four replications of each of four rotation phases each year, or 16 plots per treatment x 6 treatments = 96 plots, which is not feasible for the resources available, especially when measurements of livestock performance (a key component of this proposal) are included.

Table 1. Cropping system descriptions. Plot size accommodates split plot design that will facilitate evaluation of alternative strategies and complementary mechanistic research based on hypotheses developed from base systems research. Crop varieties most suitable for each production approach will be utilized.

Approach	System	Crop rotation	Description
Conventional	beef-calf	alfalfa alfalfa alfalfa corn/triticale	**Beef-calf production focus**: Four-year, three-crop rotation using synthetic fertilizer and pesticides at conventionally recommended rates. Livestock component would integrate rangeland and would focus on producing conventional feeder calves.
Conventional	cash-crop	dry bean corn sugar beet corn	**Cash-crop production focus** with no livestock component: Four-year, three-crop rotation using synthetic fertilizer and pesticides at conventionally recommended rates.
Reduced-input	beef-calf	alfalfa alfalfa alfalfa corn/triticale	**Beef-calf production focus:** Four-year, three-crop rotation using manure and compost, conservation tillage, precision agriculture, and integrated pest management combined with synthetic fertilizer and pesticides to optimize profit. Livestock component would integrate rangeland and would focus on producing conventional or “natural” feeder calves.
Reduced -input	cash-crop	dry bean/cover crop corn sugar beet corn	**Cash-crop production focus** with no livestock production component: Four-year, four-crop rotation using conservation tillage, precision agriculture, and integrated pest management combined with synthetic fertilizer and pesticides to optimize profit (no animal manure).
Organic	beef-calf	alfalfa alfalfa alfalfa corn/triticale	**Beef-calf production focus:** Four-year, three-crop rotation using organic-approved inputs and procedures. Livestock component would integrate rangeland and would focus on producing organic certified feeder calves.
Organic	cash-crop	corn corn barley/alfalfa alfalfa	**Cash-crop production focus** with no livestock component: Four-year, four-crop rotation using organic-approved inputs and procedures and using lentil as a green manure crop, altered row spacing for weed control, cultivation, etc.

From the perspective of crop-soil-pest parameters, the experimental unit is an approach*system plot (i.e., organic*cash-crop, conventional*beef-calf, etc.). Each of the 12 cash-crop-system plots will be 0.4 ha in size (4.8 ha total) and the 12 beef-calf-system plots will be 0.8 ha in size (9.6 ha total). The 15-ha study area has been under a conventionally managed, two-year corn-alfalfa rotation since the University of Wyoming acquired the SAREC farm in 2001. The entire area will be mold-board plowed and disked prior to establishing the experiment.

From the perspective of livestock performance measurements, the experimental unit is three cow-calf pairs that would utilize hay, grain, and stubble from the irrigated 0.8-ha plots for feed and forage during fall, winter, and spring and 75 ha of SAREC rangeland for grazing during summer. The three-pair experimental unit would be duplicated within each of the three beef-calf production approaches (see Table 2) (3 pairs x 2 reps x 3 approaches = 18 pairs total from the base herd maintained at SAREC). In years when no corn is produced in the beef-calf plots, feed grain needed for calves will be supplied by cash-crop plots under the appropriate approach.

For summer grazing, twenty-five ha of native rangeland will be used for each production approach (75 ha total rangeland). The native range areas will be treated the same under each treatment and will not be monitored for this study, though the organic certification process will be carried out for 25 ha associated with the organic production system.

Based on average yields for SAREC fields, this design provides space to continuously operate baseline systems described in Figure 1 on half of each plot for long-term systems evaluation as well as mechanistic research on subplots on half of each plot for reductionist hypothesis testing. The six base systems will be established and monitored under this request.

While the ideal research design would include the same crops under each approach, realities of organic production call for a different crop rotation from the non-organic approaches. Sugar beet is the highest profit crop available to Wyoming producers but cannot be feasibly grown or marketed organically. Also, renewing soil fertility without synthetic fertilizers requires inclusion of a legume with high nitrogen (N) fixation potential (most commonly alfalfa) in rotation.

Figure 1. Schematic feed and forage cycle for crop/range/beef-calf production system.

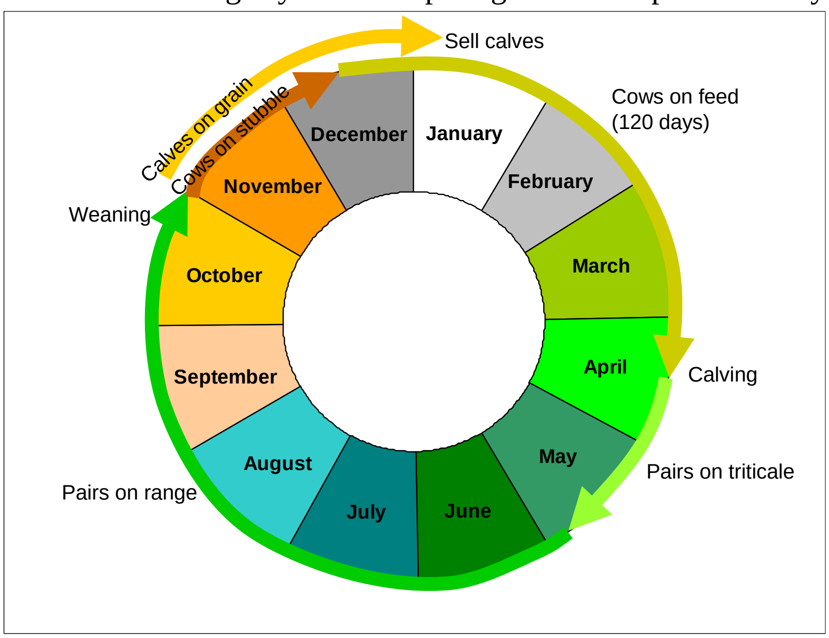

Table 2: Schematic layout of beef-calf production plots. Agronomic parameters (plant, soil, water, insects, weeds, pathogens) would be monitored on four replicated plots in each treatment (heavy and dashed lines). Livestock performance parameters (gain) would be monitored on three-cow-calf-pair experimental units duplicated within each approach and fed from hay, grain, and stubble grown within that approach (delineated by heavy lines).

Plant/soil rep	1	2	3	4
Livestock rep	1		2	
Conventional				
Reduced-input				
Organic				

Soil Sampling Procedure for Soil and Soil-Borne Pathogen Parameters

Fifteen sampling points will be located at random distances from even intervals along a transect across each of the twenty-four plots, but laying wholly within the diagnostic soil type Mitchell silt loam (Stephens et al., 1971). Each point will be recorded with a Trimble GPS unit and used throughout the study. Sampling frequency for each parameter is shown on Table 3. Unless noted under specific procedures, soil sampling(>48 hours after irrigation) will include:

1. Soil cores (0 to 15 cm) collected from 15 points and composited for each plot. Composite samples will be thoroughly homogenized and subsamples immediately drawn, placed in sterile "Whirlpak" sample bags and placed on ice for analyses of weed seed bank, soil-borne pathogens, nematodes, and soil physical, chemical, and biological parameters;
2. At the beginning and end of the study 2-m soil cores will be collected from each of the 15 points and composited by six depth increments based on the typical pedon description for Mitchell silt loam: 0-15, 15-30, 30-50, 50-75, 75-150, and 120-200 (or by observed soil horizons). These samples will be treated the same as the 0- to 15-cm samples for analysis of basic soil quality and SOM dynamics parameters.

Table 3. Sampling frequency of soil and pest parameters. See text for sampling designs.

	Year 1			Year 2			Year 3			Year 4		
Sample Time:†	1	2	3	1	2	3	1	2	3	1	2	3
Weed seedbank assessment			■			■			■			■
Pathogen assessment		■			■			■			■	
Nematode assessment		■	■		■	■		■	■		■	■
Arthropod assessment§		■	■		■	■		■	■		■	■
Basic soil quality	■											■
Labile-pool SOM	■	■	■	■	■	■	■	■	■	■	■	■
Physical fractionation of SOM	■											■
Soil microbial community	■	■	■	■	■	■	■	■	■	■	■	■
Soil N fixation	■	■	■	■	■	■	■	■	■	■	■	■
Soil hydraulic properties	■											■
Soil unsaturated infiltration		■									■	
Soil temperature and water content	■	■	■	■	■	■	■	■	■	■	■	■

† 1 = plant/preplant; soil temperatures begin to accommodate biological activity; 2 = mid growing season when organisms are most active; 3 = harvest/killing frost.

§ Assessed monthly during each growing season.

Soil biological, physical, and chemical properties: Jay Norton, Naomi Ward, & Pete Stahl

Studies of cropping systems in the Central and Northern Great Plains show distinct impacts of tillage, rotation, and soil amendments on SOM dynamics and on recovery of SOM lost during long-term conventional cropping (Grant et al., 2002; Sherrod et al., 2005; Six et al., 1998) and suggest that SOM dynamics change with altered management. There is a well-documented time lapse between the initiation of organic inputs and enhancement of soil quality (e.g., Delate and Cambardella, 2004; Drinkwater, 2002; Tu et al., 2006). At first, as organic materials are added to the depleted soils, rapidly growing microbial communities immobilize nutrients and can suppress yields, or, in reduced-input systems, increase needs for fertilizer over the previous conventional approach (Drinkwater, 2002; Sherrod et al., 2003). As SOM content stabilizes at higher levels, nutrient-supplying capacity increases and the SOM pool forms a season-long nutrient supply. We expect to see similar trends to those reported from investigations of transition to organic and reduced-input approaches in the midwest, but the relatively low SOM contents, along with extreme wet-dry cycles from irrigation in a dry climate, may affect these dynamics in ways that call for altered management approaches. **Hypothesis: Labile nutrient pools will decrease in size as soil microbial communities grow following implementation of reduced tillage and incorporation of organic materials, but will recover as microbial populations stabilize within the timeframe of the project. Stable, long-residence-time SOM pools will increase in size over the course of the study.**

Basic soil quality (Jay Norton). Basic soil properties will be quantified by standard analysis methods once at the beginning and at the end of the study on the 0- to 15-cm depth and soil profile samples and in the extensive study samples. Analyses include particle-size distribution by the hydrometer method (Gee and Bauder, 1986) (once in year 1 only), bulk density by the core method (Blake and Hartge, 1986), pH and electrical conductivity (EC) by electrode (Thomas, 1996), cation exchange capacity (CEC) (Sumner and Miller, 1996), total C and N by Carlo Erba combustion on an EA1100 Soil C/N analyzer (Carlo Erba Instruments, Milan, Italy), inorganic C by modified pressure-calcimeter (Sherrod et al., 2002), total phosphorus (P) by alkaline oxidation (Dick and Tabatabai, 1977), available P (Olsen and Sommers, 1982), exchangeable Ca, Mg, and K by NH_4OAc extraction (Knudsen et al., 1982) and gravimetric moisture.

Labile-pool SOM (Jay Norton). To quantify available and readily mineralizable C and N, 10-g subsamples will be extracted with 0.5M K_2SO_4 and analyzed for nitrate (NO_3^-) and ammonium (NH_4^+) by TRAACS flow injection (Technicon, Tarrytown, NY). Dissolved organic C will be measured using a UV-persulfate TOC Analyzer (Phoenix 8000, Tekman-Dorhmann, Cincinnati, OH). 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 temperature-, moisture-, and substrate-dependent properties will be measured in the 0- to 15-cm depth three times seasonally each year of the study, and on soil profile samples at mid growing season in years one and four.

Physical fractionation of SOM (Jay Norton). SOM fractions known to respond to changes in management will be quantified by separating light, intra-aggregate (protected), and mineral-associated SOM fractions via density fractionation (Sohi et al., 2001). The fractions separated by this method are chemically distinct and correspond to active, slow, and passive SOM pools (Sohi et al., 2005). Total C and N in fractions and whole soils will be measured by Carlo Erba combustion and inorganic C will be subtracted from total C to determine total organic C. These relatively stable SOM pools will be analyzed in 0- to 15-cm depth and the soil profiles at the beginning and end of the study and also in the extensive study samples.

Soil Microbial Community Structure and Function (Naomi Ward & Peter Stahl). Crop rotation, organic matter inputs, and tillage methods influence soil temperature and moisture as well as the spatial and temporal availability of energy sources and nutrients to microbes (Doran and Linn, 1994a; Doran and Linn, 1994b; Stahl et al., 1999). It follows that such practices affect microbial community composition and activity (Bossio, 2005; Cookson et al., 2008; Lundquist, 1999; Powlson, 1987; Stahl et al., 1999; Tu et al., 2006; Wakelin et al., 2007; Zablotowicz, 2007). Some studies (Frey et al., 1999; King, 2002) find no consistent effect of agronomic practices on bacterial communities, these appear to be in the minority. **Hypothesis: Greater diversity of crops in rotation and inputs of organic materials such as manure and green manure will lead to greater structural and functional diversity of soil microbes as microbial communities recover from annual disturbance associated with tillage and inorganic fertilization within the timeframe of the project.**

Soil microbial community structure will be characterized by analysis of soil phospholipid fatty acid (PLFA) content for productivity of larger taxa of soil microorganisms (Buyer and

Drinkwater, 1997; Mummey et al., 2002) in the soil ecology laboratory of Co-PI Dr. Peter Stahl and complemented by 16S ribosomal (r) RNA gene sequence-based techniques for analysis of fine-scale microbial diversity in the molecular biology laboratory of Co-PI Dr. Naomi Ward. 16S rRNA genes can be retrieved directly from environmental samples and analyzed by sequencing or by profiling methods such as DGGE (Muzyer and Smalla, 1998) or T-RFLP (Liu et al., 1997). Quantitative monitoring of functions such as N fixation (Widmer, 1999), nitrification (Stephen, 1999), and denitrification (Flanagan et al., 1999) can be achieved using quantitative PCR (qPCR). Genomic DNA will be extracted (MoBio PowerSoil kit), 16S rRNA genes PCR-amplified, and PCR product composition determined by T-RFLP (Liu et al., 1997). Nitrogen cycling potential will be determined by qPCR of *nifH* (N fixation), *napA* (denitrification), and *amoA* (nitrification) genes (Wakelin et al., 2007). These potentially dynamic microbial populations will be measured in the 0- to 15-cm depth three times seasonally each year of the study.

Soil hydraulic properties, soil moisture, and soil temperature: Ginger Paige & Thijs Kelleners

Changes in agricultural production impact SOM and soil structure, affecting infiltration processes, soil hydraulic properties and soil moisture and temperature regimes. Hydraulic properties of soils play important roles in plant water uptake, plant growth dynamics, and soil microbial activity. Information on soil hydraulic properties will help extrapolate findings to other regions, possibly through modeling. **Hypothesis: Soil water holding capacity, infiltration rates, and temperatures will change in response to different management approaches during the time-frame of the study.**

Soil hydraulic properties and infiltration processes (Ginger Paige). We will measure soil moisture retention curves (standard pressure plate methods) and saturated hydraulic conductivity (constant head permeameter) from intact soil cores at the beginning and end of the study period. Infiltration rates (and unsaturated hydraulic conductivity) will be measured using a tension infiltrometer. Steady-state infiltration rates will be measured at three different negative pressure heads (tensions) and at zero tension at a minimum of three locations per plot. By measuring infiltration at known tensions we can determine pore-size distributions of the soils. Hydraulic conductivity parameters will be determined using the steady-state infiltration rates from tension infiltrometer measurements (Reynolds and Elrick, 1991) and by inverse modeling using the Hydrus-2D numerical soil water flow code in axi-symmetrical mode (Simunek et al., 1999).

Soil water content and soil temperature (Thijs Kelleners). We will monitor these dynamic soil parameters continuously with hydra probe sensors (Stevens Water Monitoring Systems Inc., Portland, OR), which measure real permittivity, imaginary permittivity, and temperature in the same volume of soil (measurement volume ~40 cm^3). The real permittivity can be related to the soil water content through a soil-specific calibration curve. The imaginary permittivity can be converted directly to a bulk electrical conductivity value. One site will be installed at a representative plot in each of the six treatments. At each of the six sites, sensors will be installed at three depths below the surface (15, 45, and 75 cm). The sensors will be connected to dataloggers for hourly data recording.

Weeds, pathogens, nematodes, arthropods: Andrew Kniss, Gary Franc, & Alex Latchininsky

Hypothesis: *Pest populations will increase with initial transition to reduced-input and, especially, organic production approaches but will stabilize at acceptable levels within the four-year timeframe of the study.*

Weed Seed Bank (Andrew Kniss). Liebhardt et al. (1989) found that increased weed populations limited yield during transition to reduced-input corn production. Delate and

Cambardella (2004) found increased weed populations after transition to organic corn-soybean [*Glycine max* (L.) Merr.] cropping systems, but not enough to impact yields. **Hypothesis: Weed populations will increase in reduced-input and organic systems, but management such as row-spacing, well-planned rotations, and residue management will offset economic impacts.**

The weed seed bank is an appropriate method of quantifying weed flora when comparing crop rotations (Ball and Miller, 1993; Buhler et al., 2001; Roberts and Rickettes, 1979). Soil subsamples (0- to 15-cm depth) will be collected from each plot following corn harvest as described above and refrigerated at 5º C until processing (< 6 wk after collection). Seeds will then be extracted from soil using a semi-automatic N.C. Elutriator (NC-E1) on 300-µ mesh screens. All seeds will be identified by species and counted. Seed viability will be determined by applying gentle pressure to each seed with tweezers, and seed resisting pressure recorded as potentially viable (Sbatella et al., 2007).

Pathogens and nematodes populations (Gary Franc). Cook (2006) shows that, even though yield potential increases with higher SOM levels in reduced-input cropping systems, abundant residue- and soil-inhabiting pathogens can suppress yields. Tillage operations disrupt pathogen niches and bury infested crop debris (Schumann and D'Arcy, 2006). Conversely, van Bruggen et al. (2006) found that "healthy" soil, with high levels of biological diversity and activity, internal nutrient cycling, and resilience to disturbance, suppressed occurrence of soil-borne diseases. They hypothesize that with a greater diversity of soil microbes of different trophic groups, pathogens face more competitors and antagonists, which improves biological suppression of pathogens compared to systems with reduced biological diversity.

The cold, semiarid environment of Wyoming could have confounding effects on pathogen populations during transition to higher SOM systems. Cold winters can limit survival of some pathogens while the dry environment naturally suppresses disease spread. But build-up of SOM from additions occurs slowly, and water pulses from irrigation during hot summer months speed mineralization, so that the scenario described by van Bruggen et al. (2006) may take a very longer to develop. **Hypothesis: Conventional cropping systems will experience fewer or reduced disease problems relative to organic cropping systems (Hickey, 1986). But components of a healthier soil described by van Bruggen et al. (2006) will begin to suppress soil-borne pathogens within the timeframe of the research.**

Disease assessment will be accomplished by relative comparison of disease reaction among treatment plots (Mathre, 1997; Schumann and D'Arcy, 2006; Schwartz et al., 2004; Stuteville and Erwin, 1990; White, 1997). Disease incidence (frequency) and severity (amount of disease present) will be assessed by utilizing appropriate assessment scales for each host-pathogen interaction (Horsfall and Barratt, 1945; Horsfall and Cowling, 1978; James, 1971). Relative disease ratings integrate the numerous factors affecting disease development, including environmental effects, host-plant effects, and pathogen abundance and virulence (Hickey, 1986).

Soil-borne pathogen populations will be assessed by direct measurement as appropriate to the particular cropping system and the pathogen. Ectoparasitic nematodes are mobile and will be assessed when host plants are actively growing at mid growing season. Cyst nematode populations will be assessed in the fall following harvest. Standardized methods will be used for nematode population assessment (Wilson et al., 2001).

Arthropod populations (Alex Latchininsky). Studies comparing arthropod populations among conventional, reduced-input, and organic production approaches typically show that species diversity is higher in organic fields partly due to lack of spraying (Delate and Cambardella, 2004) and partly to increased landscape variability from crop rotations (Clough et al., 2007).

Greater diversity often means insect pests can be kept in check by thriving natural enemies (Altieri, 1995; Letourneau, 1997). Alternative management practices can also impact pest populations through either bottom-up approaches, such as soil nutrient impacts on plant health (Letourneau et al., 1996), or top-down approaches that encourage bird or arthropod predators (Costamagna and Landis, 2006; Jones and Sieving, 2006). **Hypothesis: Crops under reduced-input and organic approaches will have higher abundance and diversity of insects but pest damage will not be higher because reduced insecticide pressure will contribute to conserving natural enemy populations.**

Sweep net sampling will be used to assess arthropod densities and diversity (Lockwood et al., 2000; Pfadt, 2002; Smith et al., 2006). This method is particularly effective in tall crops such as corn. Among the insect orders most frequently captured by sweep nets in Wyoming are Coleoptera, Diptera, Hemiptera, Homoptera, and Orthoptera (Smith et al., 2006). Sampling will be conducted using a standard 37-cm entomological sweep net. Fifty low slow sweeps to capture young, less mobile arthropods will be followed by 50 high fast sweeps to capture swifter mature arthropods in each plot. Low slow sweeps will be conducted near the ground surface at a rate of ca. 50 sweeps/min. High fast sweeps will be conducted at or near the top of vegetation canopy at a rate of ca. 150 sweeps/min. The samples will be taken once a month in June, July, and August of each study year.

Crop and forage growth, yield, and quality: Jim Krall & Rik Smith.

There is little research on irrigated organic production in semiarid regions, but recent long-term studies comparing yields and grain quality in non-irrigated systems suggest that organic practices can be as productive as conventional ones. Many studies show that after initial depression of yields, organic production outcompetes conventional production with lower input costs (reviewed by Badgley et al., 2007; Delate and Cambardella, 2004). Particular challenges under organic approaches include N supply for corn and weed control for corn and beans (Cavigelli, 2008), but in most cases evaluated in a Wisconsin study, weed control was effective and yields were equal among organically grown and conventionally grown corn, soybeans, and winter wheat (Posner et al., 2008). In Montana winter wheat cropping systems, Miller et al. (2008) found that organic production yielded as much or more than reduced-input no-till systems and that economic returns were equal after four years. These long-term studies do not include livestock as a component of production systems.

Reduced-input techniques, especially those that emphasize reduced tillage and judicious use of inputs, mostly follow similar trends to organic production, with initial depression in yields as SOM systems recover, followed by yields equal to or greater than conventional approaches (e.g., Halvorson et al., 2002). Both organic and reduced-input approaches often yield higher grain protein than conventional approaches because, as crops rely increasingly on mineralization of SOM for N, they acquire more N later in the growing season when grain is maturing (Grant et al., 2002; Miller et al., 2008). **Hypotheses: Though organic and reduced-input systems will undergo initial depression in yields as observed in other studies, improved control over available moisture and nutrients in our irrigated semiarid, low SOM system will improve weed control and speed recovery to equal or above conventional systems. Integration of livestock will provide additional N and other nutrients that will further increase organic and reduced-input yields. Grain quality from organic and reduced-input corn will be higher than that from conventionally produced corn.**

Grain will be harvested using SAREC's small-plot combine in four 1.5- x 6-m sampling subplots corresponding to the soil/pest transects. Hay will be harvested from the subplots using a research swather. Hay and grain will be analyzed for yield, test weight, and grain protein. The balance of hay and grain will be harvested with standard farm equipment.

Livestock performance: Bret Hess & Steve Paisley.

Limited data published thus far indicate that compared with conventional production systems organic beef production systems have lower output per unit area (Younie, 1992), produce lighter carcasses (Woodward and Fernández, 1999), require 39% more in feed costs to finish steers (Fernández and Woodward, 1999), and need to garner a 16% premium to be economically competitive with cattle finished conventionally (Berthiaume et al., 2006). Thus, small- to medium-sized beef operations must be able to make knowledge decisions about resources required and potential economic consequences associated with transitioning from conventional to organic or reduced inputs/natural beef production systems. **Hypothesis: Beef cattle production efficiency will be less for reduced-input and organic approaches, which will necessitate receiving premiums for beef produced under these alternative systems.**

Feeder-calf performance in each beef-calf production approach (conventional, reduced-input, and organic) will be monitored each year as weight at weaning and at sales in calves from six cow-calf pairs (two three-calf replicates in each treatment). For grazing and grain harvest, the 0.8-ha alfalfa and corn/triticale plots will be split by electric fence with feed for three pairs on each half of each plot. Each experimental unit (three cow-calf pairs) will be fed from hay and grain from the corresponding approach/system during November through May and on corresponding rangeland from June through October (see Figure 1). Livestock feeding facilities at SAREC will allow precise tracking of individual animal rations and performance. Hard data from the livestock experiment will be used by economists to estimate premiums required to ensure that the alternative systems are economically viable.

Economic returns: Dannele Peck, Ben Rashford, & John Hewlett.

The relative profitability of conventional versus organic or reduced-input cropping practices has been consistently established for several commodities. A meta-analysis of organic versus conventional crop studies conducted before the year 2000 reveals that organic corn and sorghum typically outperform conventional counterparts, while the opposite is true for many small grains and oilseeds (Marra and Kaval, 2000). This and other more recent studies (e.g., Delate et al., 2003) suggest likely economic outcomes for corn grown under alternative practices; results are more difficult to predict for other components of the cash-crop system: sugar beets, alfalfa and dry bean. Liebman et al. (1993) find that dry beans produced under a reduced-input system are less profitable than conventionally-grown dry beans. Tzilivakis et al. (2005) find that sugar beets produced under organic practices are more profitable than conventionally-grown sugar beets. However, no study has analyzed the profitability of reduced-input sugar beets. Delate et al. (2003) and Archer et al. (2007) found that organic corn-soybean rotations that include two years of alfalfa are more profitable than a conventional corn-soybean rotation when organic premiums are received. Delate et al.'s conclusions remain the same whether organic premiums are received or not, but Archer et al. conclude that organic rotations are less profitable than conventional during the transition period, before crops qualify for organic premiums. Neither study addresses the rotation systems proposed here or the unique climatic challenges of the proposed study area.

Though livestock manure is commonly considered in comparative economic analyses of conventional versus alternative production practices (e.g., Lu et al., 2000), studies that directly include livestock as a component of an integrated crop-livestock system are far less common (e.g., Brusko et al., 1985; Franzluebbers and Stuedemann, 2007). Frost et al. (2007) conclude that organic cow-calf operations in Wales are no more or less profitable than conventional operations. **Hypothesis: Cash crop and cow-calf systems under reduced-input and organic practices will generate lower economic net returns than conventional practices if organic premiums are not received, but will generate higher net returns than conventional if organic premiums are received.**

Partial budgeting will be used to analyze, for each cropping system (i.e. cash crops and cow-calf), differences in revenue and cost between the conventional, reduced-input, and organic approaches. The analysis will be repeated each year of the study to determine whether the flow of net revenue across years differs between approaches. Of specific interest is whether revenue is sufficient to cover variable costs during the period of transition from conventional to alternative approaches. Results of this analysis will indicate whether producers interested in adopting one of the alternative approaches should expect and prepare for short-run losses. The discounted stream of net revenue will also be calculated for each approach and then compared to evaluate relative economic performance over the entire study period. Partial budgeting is a technique used to evaluate changes in revenue and cost associated with a modification of a baseline farming system (Boehlje and Eidman, 1984). Inputs will be regularly recorded by the project manager (Table 3). We will use these primary data, augmented with secondary data (e.g. regional crop output prices, fuel prices and wage rates), to perform the partial budgeting analysis.

Table 3. Description of economic data requirements.

Primary Data[1]	Description
Labor	Hours of labor per plot, by activity
Machinery	Hours of machinery use per plot, by type of machinery
Fertilizer	Fertilizer application rates per plot, and fertilizer price per unit by type of fertilizer
Seed	Seed application rates per plot, and seed price per unit, by type of seed
Water	Water applied to each plot
Veterinary	Veterinary costs for each approach's herd
Livestock Forage	Quantity and nutritive value of each type of forage (crop and rangeland) fed to each approach's herd
Yield	Crop yield per plot, and calf weight gain per herd

[1]Primary data represent actual inputs applied to each study plot; they will be collected on a routine basis by on-site staff. Input data will be collected for operations that contribute to crop and livestock production, but not for operations that contribute to the collection of data (e.g. labor hours for the collection of study samples will not be included as a labor input).

Procedures for On-farm sampling (Extensive Studies)

Five farms operated under each production approach will be identified via information from the Wyoming Department of Agriculture and agriculture marketing information. On these 15 farms we will sample stable indicators of environmental and economic sustainability described above for intensive studies, plus marketing parameters described below, on a one-time basis. Soil samples will be collected along transects (as for intensive plots, including deep cores) in crop rotations similar to our intensive plots and analyzed for stable SOM and nutrient parameters (i.e., basic soil quality parameters, SOM fractionation). Livestock management and all inputs and costs will be determined via interviews from set survey questions.

Examine potential marketing for value-added natural and organic farm products.

There is evidence that small and medium-sized farms are not benefiting from increases in sales of organic and naturally produced products, (http://www.ers.usda.gov/Data/Organic/). Challenges for developing alternative value chains for farms include 1) long-term contractual relationships under prevailing commodity production regimes and that restrict ability to create or look for new opportunities; 2) location far from major processing and consuming markets, which poses unique transportation and marketing issues, and 3) lack of tools and technology for sensing market demand signals in innovative or emerging markets. These issues will be explored by collecting primary and secondary data. Secondary sources will include local USDA, Wyoming Business Council, producer organizations, and other publications. Primary data will be collected by surveying the "extensive" sample of farmers so that comparisons can be made across approaches. We expect this research to give us a clear analysis of the strengths, weaknesses, opportunities, and constraints that farmers in Wyoming and the region face in investigating alternative cropping systems, crops, value chains, and markets for their products.

Objective 2: Extend results to producers, agricultural educators, consultants, and others.

We will develop extension and outreach activities and materials for many learning styles. Extension educators on the project team will collaborate with Dr. Karen Williams, Ph.D., Curriculum & Instruction, an expert in curriculum development for adult and distance learning.

The newly-established SAREC was created to "serve the citizens of Wyoming, the region and nation by facilitating innovative discovery, dissemination, and engagement of integrated agricultural systems that are ecologically sound, economically viable, and socially acceptable." SAREC has the strategic goal to "facilitate dialogue among stakeholders with diverse roles and backgrounds to advance understanding and implementation of sustainable agriculture practices" through *engagement*. This project has already created a forum for rich engagement as producers, researchers, and educators have worked together to design this proposal. Leaders of similar projects, in other agroecosystems (e.g., University of California, Davis, Sustainable Agriculture Farming Systems project, http://safs.ucdavis.edu, and the North Carolina State Center for Environmental Farming Systems, http://www.cefs.ncsu.edu/farmingsys.htm) report that engagement fostered by the long-term projects is consistently richer than anticipated.

Agricultural Systems Extension Bulletin series (Project team).

Beginning in year one, researchers, extension specialists, and extension educators on the team will work with the Cooperative Extension publications office at the University of Wyoming to create a branded series of bulletins reporting research results. Delate et al. (2006) provide an example of a bulletin series, though ours will cover all three production approaches.

Agricultural Systems Conferences (Project team).

In each mid-growing season of years two, three, and four the project team will hold a conference at SAREC featuring the research plots, design, goals, and results. Members of the research team as well as regional and national experts on agricultural systems and production approaches will be invited to speak. The conferences will be advertised across Wyoming and the High Plains and Intermountain agroecosystems.

Decision-support tool CD (Ginger Paige).

An electronic, web-based decision-support tool parameterized with agronomic, ecological, and economic data from the research will be developed in year four utilizing the Facilitator open source multiobjective decision support system (http://facilitator.sourceforge.net/) developed by USDA-ARS for assessing agricultural management practices (Paige et al., 1996).

Targeted training workshops (Extension educators and specialists).

In project years three and four, team members with extension appointments will develop training workshops targeted at extension educators, producers, and consultants. The workshops will utilize bulletins and other materials from the project, will offer continuing education credits, and will be presented at meetings of target groups, such as the Wyoming Crop Improvement Association, Wyoming Stock Growers, and the Wyoming Ag Business Association.

Interactive project web site (Project team collaborating with UW Dept of Ag webmaster).

Beginning upon funding, the team will develop a project website describing goals, objectives, design, and results, and featuring links to related information.

Evaluation.

Built-in evaluation mechanisms will be developed for each extension/outreach product that will enable constant improvement of materials in response to target audience comments.

Objective 3: Incorporate research into K-12, undergraduate, and graduate education.

K-12 education

Participatory field trips (Dallas Mount). Cooperative Extension Service Area Agricultural Educator Dallas Mount has developed working relationships with instructors of agriculture and natural resources courses at Wyoming Community College and southeastern Wyoming high schools. Dallas will coordinate hands-on field trips for these classes that feature members of the research team guiding students and instructors in the research process and results.

Science/agriculture teacher education (Robert Mayes, Jay Norton). With assistance from collaborator Dr. Robert Mayes, Director of the University of Wyoming Science and Math Teaching Center (SCMT) (see letter of support), the PD will facilitate teacher workshops in years 2, 3, and 4 at the Wyoming Science Teachers Association annual meetings. Workshops will present not only research results, but will strive to involve teachers in the scientific processes and to forge relationships that lead to field trips and student involvement in the project. Dr. Mayes will also help disseminate research results via SCMT's teacher listserv and webpage.

Undergraduate/graduate education

We will integrate research activities and results into the interdepartmental Agroecology degree program and other courses taught by Co-PI's in the University of Wyoming College of Agriculture by developing experiential learning opportunities. Since its creation in 1991, the Agroecology degree program at the University of Wyoming has consistently drawn excellent rural and urban students that come to study local agroecological issues, but the program lacks locally relevant case studies, recent research examples, and system comparisons. The integrated research proposed here will elegantly address this problem. Co-PI Dr. David Wilson, coordinator of the Agroecology Program, will develop guidelines for integration throughout the degree program. Dr. Karen Williams, Ph.D. Science Curriculum and Instruction, will collaborate to develop effective learning tools. Delate (2006) provides an example of incorporation of an agricultural systems project into curriculum.

Laboratory Course Integration.

Students in College of Agriculture courses with laboratory sessions will be active participants in the systems research. Courses include: Weed Science & Technology (Andrew Kniss), Soil Microbiology (Peter Stahl), Plant Pathology (Gary Franc), Ecology of Plant Protection (Gary Franc), and Livestock Feeds & Feeding (Bret Hess).

Example: Weed Science & Technology – Andrew Kniss. A unit on reduced input and organic weed management practices, in which students take a field trip to SAREC in mid-September (an ideal time of year to see differences in weed communities and densities), will be developed. Students will see management practices required to make each system work, learn how each practice influences weed management, and observe differences between study treatments. During laboratory lessons in weed science experimental methods and weed seed identification, students will elutriate samples to separate seeds from soil, and separate, identify, and count the weed seeds. A course database will be constructed from data collected by students from one replicate of the study each year. Data collected by students (with additional project data) will facilitate discussions of mechanisms that control changes in the weed community as a result of management practices.

Lecture/Seminar Course Integration

Capstone Agroecology Seminar – Jay Norton. The Agroecology Senior Seminar is a required course in the interdepartmental Agroecology major at the University of Wyoming. Students take the course during their last semester and the research activities and results will provide an excellent framework for an activity that promotes group collaboration and critical thinking skills. In a semester-long side-study activity, three groups will each concentrate on one production approach. Each group will write a projection of what will happen in their plots. The class will visit the plots in mid-semester after reporting on their projections. Co-PI's will discuss their research activities and results in the field and in guest lectures. In the last part of the semester the groups will further research the production approaches to address: How does our group's production approach impact: 1)Agricultural sustainability? 2) Global environmental change as soil, air, and water quality? 3) Global food issues?

Organic Food Production – David Wilson. The Organic Food Production course, developed in 1996, has the highest enrollment in the Agroecology curriculum. Case studies and system comparisons are critical to the course format and this research project will allow interjection of information that is local, recent and relevant. A group discussion format will be used for integration of this research into the Organic Food Production course with one group assigned to each of the six proposed systems. Each group will have one week to review the yearly progress of each system individually, then will summarize progress in specific areas of sustainability and economic viability. Once each group has analyzed their assigned system, they will participate in a classroom comparison and discussion. noting strengths and weaknesses of the systems.

Economics of Rangeland Resources (40 students per year) – Dannele Peck. Topics covered in the course for which research results could serve as examples: 1) Using net present value to compare projects with different timeframes and flows of costs and benefits. Compare the net present value of alternative approaches to a particular farm system; and 2) Choosing the optimal combination of outputs, given a technical relationship between two outputs (i.e. their physical tradeoff), and the relative output prices. Identify the optimal combination of crop production and soil quality (or related ecosystem services), given complementarities and competitiveness over various portions of the production possibilities curve, and alternative ratios of output prices.

Sustainable Agriculture; Crop & Weed Ecology – Rik Smith. The research program and results will be used as a case study of long-term research in these Plant Sciences courses. Students will use the study design and results to form hypotheses and design complementary investigations on differences among the six systems. The graduate course Crop and Weed Ecology will analyze long-term data , for the benefit of the research project and to help the students learn to analyze integrated, multidisciplinary systems data.

Course Evaluation & Improvement.

All laboratory and classroom activities will be evaluated and improved each year by including specific questions in the class evaluation for student input and then using student responses to change and improve the section.

Statistical Analysis

Means for fixed terms that are deemed significant ($P < 0.10$) in the analysis will be separated using Fisher's protected LSD. Statistical calculations will be facilitated by use of the MIXED procedure of the Statistical Analysis System (SAS Institute, Version 9.1.3, Cary, NC). For dependent variables not affected by the timeframe of this proposed work (e.g., soil texture) data will be analyzed using the GLM procedure, Statistical Analysis System, in a one-way analysis of variance set in a randomized complete block design. If the F test for system indicates differences, means will be separated using Fisher's protected LSD.

Database Management & Sample Archiving

All raw data collected during the project will be filed and stored in hard and electronic formats utilizing the database management systems developed by the SAREC research committee for long-term management of their base cow herd and crop production systems. An intranet database management system for data input, sorting, and retrieval of data collected and initially analyzed by authorized PI's and others will be developed and set up for long-term compilation of data from the project. Air-dried soil samples remaining after analyses will be stored in the University of Wyoming greenhouse sample storage facility. Soil genomic DNA will be archived by storage at -80ºC , to allow future in-depth characterization of microbial community and function. Gene sequences obtained in this study will be made publicly available through deposition in GenBank.

Limitations and Potential Pitfalls

Statistical power is limited because replication in time is sacrificed to facilitate logistical feasibility of an operable livestock component. Careful site selection for sampling will minimize variability by utilizing a diagnostic soil type common to all plots. Collection of soils data as covariates will improve statistical analyses. By running the investigation for four growing seasons we will minimize limitations of short-term research, though we recognize that some parameters we measure may not stabilize within four years of transition. The extensive component is subject to the limitations of on-farm research, including lack of control and variable soil, climate, and other parameters. But the component is invaluable as a continuum linking findings from research station plots to real-world situations. We will use soil survey information and hand texturing to assure equivalent sampling areas to the extent possible. We plan to continue the research as a long-term study if funding is available.

Potential Hazards

All personnel will be required to attend laboratory and field work safety training provided by the University of Wyoming Department of Environmental Health and Safety. They will be trained in field and laboratory procedures by experienced research technicians.

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Key Personnel Roles & Project Management Plan

Key Personnel Roles

Principle Investigators

Jay B. Norton, PI/PD, Assist. Prof, Soil Fertility; project and budget management, soil studies;
Eric J. Arnould, Disguished Professor of Sustainable Business Practice; marketing studies;
Gary Franc, Professor, Plant Pathology, pathogen and nematode studies;
Bret Hess, Assoc. Professor, Animal Science, livestock management and performance;
John Hewlett, Farm & Ranch Management Specialist, economics studies, extension programs;
Thijs Kelleners, Assist. Professor, Soil Physics, soil moisture and temperature monitoring;
Andrew Kniss, Assist. Professor, Weed Ecology, weed population and seed bank studies;
James Krall, Professor, Crop Production, Director, SAREC, crop yield and quality studies;
Alex Latchininsky, Assist. Professor, Entomology, arthropod population studies;
Dallas Mount, Area Agriculture Educator, livestock mgmt., extension and education programs;
Ginger Paige, Assist. Prof., Water Resources, water holding capacity and infiltration studies;
Steve Paisley, Beef Cattle Exten. Specialist, livestock management & performance, extension;
Dannele Peck, Assist. Professor, Agricultural & Applied Economics, economics studies;
Melea Press, Assist. Professor, Marketing and Sustainable Business, marketing studies;
Ben Rashford, Assist. Professor, Agricultural & Applied Economics, economics studies;
Rik Smith, Assist. Professor, Agroecology, crop ecology and nitrogen fixation studies;
Peter Stahl, Assoc. Professor, Soil Microbiology, soil microbial ecology studies;
Naomi Ward, Assist. Professor, Molecular Biology, soil microbial ecology studies;
David Wilson, Academic Professional, Agroecology Degree Program, education coordinator.

Collaborators

Karen Williams, Professor, extension programs, curriculum development, evaluation;
Robert Mayes, Director, Science & Math Teaching Center, Univ. Wyo., K-12 teacher outreach;
David Legg, Professor, Statistics Laboratory, data management and analysis.

Growers

Tim Bartel, Spear 7 Farms, organic dairy, beef, & cash crops, 307-837-2133, tcb@actcom.net;
David Hinman, reduced-input beef & crop production, 307-331-0410, hardrock@dishmail.net;
Byron Yeik, irrigated/dry cash crops & beef production, 307-837-2566, dyeik@prairieweb.com.

Research Manager

(Search will initiate search upon notification of funding)

Graduate Students

(Search will initiate search upon notification of funding)
Ph.D. Soil organic matter and microbiology, yrs 1-3, supervised by Co-PD/PI Norton and Ward;
M.S. Agricultural economics, yrs 3-4, supervised by Co-PD/PIs Peck, Rashford, and Hewlett.

Project Management Plan

We plan to hire a full-time project manager with crop, livestock, data collection, extension education skills and experience to be stationed at the SAREC field station and under the direct supervision of Co-PI/PDs Jay Norton and James Krall. The project manager will oversee field management and data collection activities as well as playing an active role in developing and presenting extension and education programs. The following committees will develop and manage separate components of the research.

Oversight Committee

General project management will be guided by an oversight committee responsible for personnel decisions, major purchases, and general project expedition and integrity:
Jay Norton, PI/PD;
James Krall, Co-PI/PD, SAREC Field Station Director;
Bret Hess, Co-PI/PD, Associate Agricultural Research Station Director;
John Hewlett, Co-PI/PD, Farm & Ranch Management Extension Specialist.

Field Management Committee

On-the-ground direction for the project manager in management of livestock, crop production, irrigation, fencing, etc. will be provided by our Field Management Committee:
James Krall, Co-PI/PD
Jay Norton, PI/PD, Extension Soil Fertility Specialist;
Bob Baumgartner, SAREC Farm Manager;
Steve Paisley, Co-PI/PD
Dallas Mount, Co-PI/PD
Tim Bartel, organic grower;
David Hinman, reduced-input grower;
Byron Yeik, conventional grower.

Extension Programs Committee

Development and delivery of extension materials will be overseen by:
Dallas Mount, Co-PI/PD, Extension Southeast Wyoming Area Agriculture Educator;
John Hewlett, Co-PI/PD, Senior Extension Farm & Ranch Management Specialist;
Karen Williams, collaborator, Curriculum development & adult education expert.

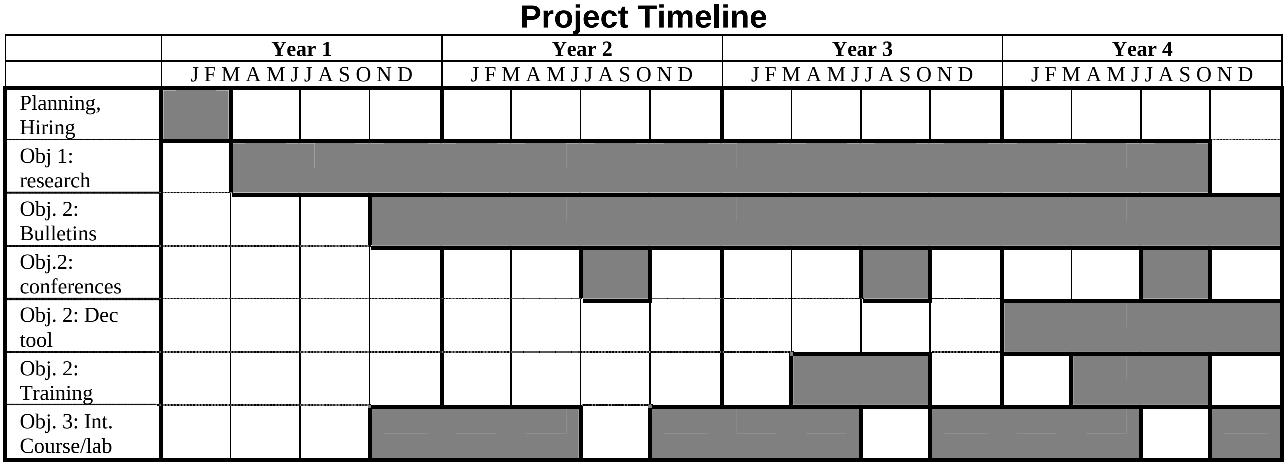
Graduate & Undergraduate Education Committee

Coordination of research-coursework integration will be provided by:
David Wilson Co-PI/PD, Agroecology Degree Program Curriculum Coordinator;
Dallas Mount, Co-PI/PD, Coordination of community college & high school involvement;
Karen Williams, collaborator, Curriculum development & adult education expert.

Database Management & Sample Archive Committee

Development and management of long-term database management and sample storage systems:
Jay Norton, PI/PD, Extension Soil Fertility Specialist;
Andrew Kniss, Co-PI/PD Assist. Professor, Weed Ecology;
David Legg, Professor, Statistics Laboratory.

Project Timeline



Project Logic Model: Economic and environmental sustainability of conventional, reduced-input, and organic approaches on western crop-range-livestock farms

Situation: Producers are challenged to remain profitable/sustainable due to rising input costs.

Assumptions: Producers can achieve reduce costs by implementing practices that include reduced input volumes or organic certification.

INPUTS	ACTIVITIES	OUTPUTS*	SHORT TERM KNOWLEDGE	MEDIUM TERM ACTIONS	LONG TERM CONDITIONS
In order to accomplish our goals will need the following resources	Accomplishing the following activities will result in the following measurable deliverables	Accomplishing these activities will result in the following evidence of progress	We expect the following measurable changes within the life of the grant	We expect the following measurable changes within the next one to three years	We expect the following impacts/trends within the next three to seven years or more
• SAREC land, equipment, staff • College of AG faculty/resources • Extension educators • Graduate Students • Producers	• Design and conduct research of organic certification and reduced inputs • Publish scientific articles • Conduct workshops and trainings for students and producers • Conduct educational conference for producers • Develop case studies • Conduct regular meetings with researchers, extension educators, and producers	• Scientific publications • Printed (educational) materials • Bulletin series • Curriculum materials • Workshop and conference materials • University level case studies/units • Decision making tool for producers (CD) • Interactive website • Teacher workshops • Marketing study	• Producers will increase knowledge of cost to transition to new methods • Increase in knowledge transfer/communication between researchers, extension educators, and producers • Increased knowledge of soils and ecosystem impacts • Increased knowledge of pest cycles, nutrition cycles, and moisture dynamics • Increased knowledge of organic certification requirements and how to achieve them • Increased knowledge of yields • Increase in "locally based" instruction/data	• Producers will use knowledge gained to evaluate implementation of new practices • Producers change practices based on strategies developed • Researchers and extension educators will adopt and use holistic research practices	• Agriculture businesses in the Western High Plains increased their ability to remain profitable and sustainable • Maintain or improve the contribution of the rural economy to the Western High Plains economic base

Economic and environmental sustainability of conventional, reduced-input, and organic approaches on western crop-range-livestock farms

November 24, 2008

Proposed committees

The following are proposed committees and major tasks for the ag systems project.

Project Oversight

General project management will be guided by an oversight committee responsible for personnel decisions, major purchases, and general project expedition and integrity:
Jay Norton, PI/PD;
James Krall, Co-PI/PD, SAREC Field Station Director;
Bret Hess, Co-PI/PD, Associate Agricultural Research Station Director;
John Hewlett, Co-PI/PD, Agricultural & Applied Economics.

SAREC Field Management

On-the-ground cropping system and livestock management decisions. Decisions will draw on the expertise of the whole research team.
James Krall, Co-PI/PD
Jay Norton, PI/PD, Extension Soil Fertility Specialist;
Bob Baumgartner, SAREC Farm Manager;
Bret Hess, Co-PI/PD
Dallas Mount, Co-PI/PD
Tim Bartel, organic grower;
David Hinman, reduced-input grower;
Byron Yeik, conventional grower.

Intensive Research Data Collection & Management

Integrated design of data collection and management for six parameters to be measured on replicated plots (six subcommittees), in consultation with Dr. David Legg:

Weed, pathogen, arthropod and nematode populations;

Gary D Franc, plant pathogen and nematode populations;
Andrew Kniss, weed populations;
Alex Latchininsky, arthropod populations;

Soil biological, physical, and chemical properties;

Jay Norton
Peter D. Stahl
Naomi L. Ward

Water use efficiency and soil moisture dynamics;

Thijs J. Kelleners
Ginger Paige

Crop and forage growth, yield and quality;

James M. Krall

Rik Smith

Livestock performance;

Bret W. Hess
Steven Paisley

Economic viability

John Hewlett
Dannele Peck
Ben Rashford

Extensive Research Data Collection & Management

Study plan, sight selection, and collaborative design and management for one-time on-farm data collection; in consultation with the whole team.
Jay Norton, PD, soil fertility extension specialist;
Dallas Mount (plus Jeff Edwards), extension educators;
Dannele Peck, ag & applied economics;
Eric Arnould, sustainable business management;
Melea Press, sustainable business management.

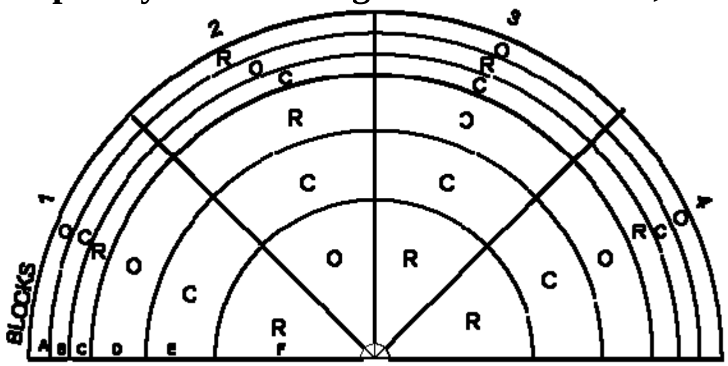
Extension Programs

Development and delivery of extension materials will be overseen by:
Dallas Mount, Co-PI/PD, Extension Southeast Wyoming Area Agriculture Educator;
John Hewlett, Co-PI/PD, Senior Extension Farm & Ranch Management Specialist;
Karen Williams, collaborator, Curriculum development & adult education expert.

Graduate & Undergraduate Education

Coordination of research-coursework integration will be provided by:
David Wilson Co-PI/PD, Agroecology Degree Program Curriculum Coordinator;
Dallas Mount, Co-PI/PD, Coordination of community college & high school involvement;
Karen Williams, collaborator, Curriculum development & adult education expert.
Robert Mayes, Director, Science & Math Teaching Center, Univ. Wyo., K-12 teacher outreach;

Plot Layout and planting plan, SAREC Ag Systems Project.
Developed by Field Management Committee, 2/20/09



Plot layout under 36-acre, half-pivot irrigation system. Tiers A, B, & C are one-acre cash-crop plots; tiers D, E, & F are two-acre beef-calf plots. Entire area has been in conventionally grown continuous corn for six years. Stalks are grazed in winter.

YEAR 1: 2009[4]

Sys.	CROP	Tillage	Fertility	Weed Mgmt	Insect/disease
cash crop	**Organic** Oats + alfalfa[3] oats cut & baled	disk moldboard roller harrow drill	None, unless soil test indicates need for P	Adjust cutting times depending on weed issues	Monitor & respond
	Conventional Pinto beans	disk moldboard roller harrow drill	30 lbs N 50 lbs P	Preplant: Eptam/sonalan Post emerg.: raptor/basagran, “Select” for grass	Seed-treat for wireworms; Spray for bean beetle as needed
	Reduced-input Pinto beans followed by ann. grain cover crop	Landstar + drill (direct harvest to avoid trash issues)	Soil test recommendation	Preplant: Eptam/sonalan Post emerg.: raptor/basagran, “Select” for grass	Seed-treat for wireworms; Spray for bean beetle as needed
beef calf	**Organic** Oats + alfalfa/grass[1,3]; oats green-chopped & ensiled	disk moldboard roller harrow drill[2]	None, unless soil test indicates need for P	Adjust cutting times depending on weed issues	Monitor & respond
	Conventional Oats + alfalfa/grass; oats green-chopped & ensiled	disk moldboard roller harrow drill	200 lbs of 11-52-0	Bucktril as needed	leaf-hopper resistant variety
	Reduced-input Oats + alfalfa/grass; oats green-chopped & ensiled	Landstar roller harrow drill	Soil test recommendation	Bucktril as needed (min-till may increase weeds)	Monitor & respond

1. Nontreated or organic seed for organic alfalfa & oats;
2. Max tillage necessary for organic to bury weed seed bank;
3. Alfalfa-regar brome-orchard grass mix increases yield for beef production systems; straight alfalfa increases value for organic cash-crop system.
4. Field prep and planting will begin in late March and be completed by late April, 2009. Plot layout will be done by mid March (so schedule baseline sampling for late March).

Four-year rotation plan, SAREC Ag Systems Project. Revised on 2/20/09 by Field Management Committee.

Approach	System	Yr	Crop rotation	Description
Conventional	beef-calf	1 2 3 4	alfalfa+oats alfalfa alfalfa corn silage/triticale	**Beef-calf production focus**: Four-year, three-crop rotation using synthetic fertilizer and pesticides at conventionally recommended rates. Livestock component would integrate rangeland and would focus on producing conventional feeder calves.
Conventional	cash-crop	1 2 3 4	dry bean corn grain sugar beet corn grain	**Cash-crop production focus** with no livestock component: Four-year, three-crop rotation using synthetic fertilizer and pesticides at conventionally recommended rates.
Reduced-input	beef-calf	1 2 3 4	alfalfa+oats alfalfa alfalfa corn silage/triticale	**Beef-calf production focus:** Four-year, three-crop rotation using manure and compost, conservation tillage, precision agriculture, and integrated pest management combined with synthetic fertilizer and pesticides to optimize profit. Livestock component would integrate rangeland and would focus on producing conventional or "natural" feeder calves.
Reduced -input	cash-crop	1 2 3 4	dry bean/cover crop corn grain sugar beet corn grain	**Cash-crop production focus** with no livestock production component: Four-year, four-crop rotation using conservation tillage, precision agriculture, and integrated pest management combined with synthetic fertilizer and pesticides to optimize profit (no animal manure).
Organic	beef-calf	1 2 3 4	alfalfa+oats alfalfa alfalfa corn silage/triticale	**Beef-calf production focus:** Four-year, three-crop rotation using organic-approved inputs and procedures. Livestock component would integrate rangeland and would focus on producing organic certified feeder calves.
Organic	cash-crop	1 2 3 4	oats+alfalfa alfalfa corn grain beans (soy or dry)	**Cash-crop production focus** with no livestock component: Four-year, four-crop rotation using organic-approved inputs and procedures and using lentil as a green manure crop, altered row spacing for weed control, cultivation, etc.