USDA ARS United States Department Of Agriculture Agricultural Research Service

Land Management and Water Conservation Research Unit Pullman, Washington

Report from the

Program Visioning Conference

October 27, 2009

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Executive Summary

On October 27, 2009, a Program Visioning Conference for the USDA, Agricultural Research Service, Land Management and Water Conservation Research Unit (LMWCRU) was held on the Washington State University campus in Pullman, WA. The conference brought together LMWCRU partners, customers and stakeholders to discuss their visions for the future direction of the Unit and express their thoughts concerning high-priority researchable problems associated with agricultural sustainability in the low (<12 inches), intermediate (12-18 inches), and high (>18 inches) precipitation zones of the inland Pacific Northwest. Building upon input from the conference participants, a writing team was charged with recommending a vision and mission for the LMWCRU consistent with the goals and strategic plans of appropriate ARS National Programs, Administration research priorities, and appropriate relationships between LMWCRU, Washington State University, University of Idaho, state and federal agencies, and other ARS laboratories. In addition, the vision and mission should encompass the unique capabilities and resources at the LMWCRU, and maximize the synergy obtained by collaborating with stakeholders and research partners. Lists of priorities and problems were compiled from breakout group discussions and three broadly inclusive and overlapping research themes were identified: 1) Soil and Residue Management, 2) Dryland Cropping Systems, and 3) Water Conservation. General recommendations were developed by the writing team along with suggested focus areas for each of the three research themes. General recommendations included developing strong team research programs to study efficient and cost-effective approaches to adapt to climate change and focusing on a few, highly visible projects. It was suggested that future research be directed at effective soil and residue management practices that reduce soil erosion; improving soil physical, chemical and biological properties; reducing greenhouse gas (GHG) emissions; sequestering carbon; and improving soil water retention. A need was also identified to investigate agronomic feasibility of producing legumes, oilseeds and other potential biofuel crops in rotation with other economically important crops including winter and spring wheat, which currently are agronomically well suited to the inland PNW region.

Vision

Promoting food security and environmental protection through adaptation of dryland cropping systems to climate change.

Mission

Develop dryland cropping systems for climate change and climate variability in a region dominated by winter precipitation, strong climatic gradients, distinctive terrain and unique agroecological zones.

Introduction

The USDA-Agricultural Research Service Land Management & Water Conservation Research Unit (LMWCRU) is located on the campus of Washington State University (WSU) in Pullman, Washington and is eight miles from the University of Idaho in Moscow, Idaho. The Unit has the mission and the collective, demonstrated expertise to study environmental issues and to develop technologies to economically produce dryland crops while protecting the air, soil, and water resources of the multistate region.

The LMWCRU is situated at the northeastern edge of a broad region of wind-blown silt dunes that span northern Idaho, northeast Oregon, and eastern Washington, which is often referred to as the inland Pacific Northwest (PNW). The region includes an area known as the Palouse, one of the premier wheat growing areas in the world. In fact, the region produces 85% of the soft white wheat grown in the United States. Land and water management are integral factors affecting erosion of the steep hill slopes of the inland PNW. Water management is also a concern for agricultural sustainability.

The LMWCRU has a praiseworthy past record of research to develop diversified dryland cropping systems that increase net farm productivity and profitability by maximizing water and nutrient use efficiencies and reducing energy consumption and agricultural chemical use, while enhancing soil, air and water quality in the inland PNW. The unique geographic location of the LMWCRU and its well established, strong relationships with two major land grant universities provides an unparalleled opportunity to address the future dryland crop production research in a region with distinctive agricultural landscapes and highly variable temperature and precipitation.

The LMWCRU conducts research beyond the Palouse region to address problems of the drier regions of the Columbia River Plateau. Research in this drier region addresses the needs for land management practices that reduce wind erosion and particulate emissions, improve air quality, reduce greenhouse gas emissions, and enhance the economic viability and diversity of the region's dryland cropping systems. The outstanding level of expertise and unique physical location strongly positions the LMWCRU for a key leadership role in the adaption of farming systems across this large, important agricultural region to anticipated climate change.

The LMWCRU is currently comprised of a team of six, highly respected and competent senior scientists (Appendix A). The Unit is in a period of transition and is planning for the future. A new Research Leader has been appointed within the past 12 months, and at least one scientist plans to retire within the next couple of years. An exceptionally high percentage of the Unit's funding is allocated toward salaries and benefits, which is limiting the capacity of the unit to fully address issues of concern to stakeholders. The Unit has been successful in obtaining external research support to augment their research program, and will likely continue this practice in the future. The Unit is also working to enhance it's stature in the region and expand its stakeholder base.

Visioning Conference

On October 27, 2009, a Program Visioning Conference was held on the WSU campus in Pullman, WA. The full-day conference (Appendix B) brought together LMWCRU partners, customers and stakeholders to discuss their visions for the future direction of the Unit (see Appendix C). As part of the conference, participants were asked to contribute their thoughts and ideas concerning existing and potential new research activities for the LMWCRU. The participants were also asked to express their thoughts concerning high-priority researchable problems associated with agricultural sustainability in the low (<12 inches), intermediate (12-18 inches), and high (>18 inches) precipitation zones of the inland Pacific Northwest.

A writing team was chosen (see Appendix D) and charged with recommending a vision and mission for the LMWCRU, building upon the substantial input from the conference participants. The recommendations are consistent with the goals and strategic plan of the appropriate ARS National Programs, the President's National Priorities and also take into account appropriate relationships between LMWCRU, Washington State University, University of Idaho, state and federal agencies, and other ARS laboratories. In addition, the team was instructed that the vision and mission should encompass the unique capabilities and resources at the LMWCRU, and maximize the synergy obtained by collaborating with stakeholders and research partners. This document presents the recommendations coming out of the Visioning Conference as summarized by the six members of the diverse writing team.

Overarching Concepts

Unique Location. The LMWCRU is located near the northeastern boundary of a broad gradient of agroecological zones governed by varying climate, soils (sands to silt loams), and topography. Annual precipitation ranges from about 6 in/yr on the western boundary to more than 28 in/yr on the eastern boundary of the Columbia Plateau. This steep gradient of climate and production environments, across the more than 100 mile expanse of the Columbia Plateau, is truly unique in the USA and affords an unmatched opportunity for comparative development, study and modeling of a series of dryland cropping systems tailored to fit each agroclimatic zone. These unusual circumstances also make it practical to test the response of a range of cropping systems to potential climate change within a relatively small area regardless of whether future annual precipitation increases or decreases.

Research Integration. Future anticipated changes in weather and precipitation patterns could have a catastrophic effect on crop production in the inland PNW. The integration of semi-arid dryland cropping systems, soil management and water conservation research into focused team projects will be necessary to ensure our nation's food security. This region provides a unique opportunity to holistically examine dryland, cereal-based production agriculture under the stress from climate change and across a gradient of existing agroecosystems. Successful integration of the research is made possible by the diverse talents of the highly qualified scientists in the LMWCRU, the climatic gradients and potential collaborations with regional universities, ARS laboratories and other partners. These great resources provide a good balance of basic, applied and multi-disciplinary approaches to solving problems that will positively impact agriculture in this large, unique region.

Washington State University-Pullman and the University of Idaho-Moscow have outstanding dryland research programs in the higher rainfall areas (e.g., >16 in/yr) of the region, and the biggest need is for research in the drier areas (<18 in/yr) of the inland PNW. Stronger ties are encouraged with the ARS Laboratory in Pendleton, OR, which is located in the intermediate precipitation zone of the inland PNW, to ensure a complimentary research program fully meets the needs of a diverse group of stakeholders and partners throughout the Columbia Plateau.

Customers, partners and stakeholders expect that this Unit will fully integrate many of the broad issues and concerns discussed later in this document into cropping systems that solve problems of dryland production agriculture in the inland PNW region. Coordinated team research, using existing expertise in air, soil and residue management, cropping systems, and environmental issues provide a solid foundation for maximum impact and effective use of the Unit's resources.

Palouse Conservation Field Station. An important asset of the Unit is the ARS Palouse Conservation Field Station (PCFS), which is located three miles northwest of the main Washington State University campus. The PCFS comprises 200 acres of rolling cropland and a wealth of data has already been collected at this site. All Unit scientists can effectively utilize resources at the PCFS and provides convenient access to landscapes representative of the Palouse. Unit scientists also partner with WSU and University of Idaho researchers and have full access to WSU facilities such as the Cook Agronomy Farm, a unique 140 acre farm designed to conduct integrated, interdisciplinary farm-scale precision farming and landscape ecology experiments. In addition, USDA and WSU crop genetic resource/breeding and plant pathology scientists are spatially and programmatically integrated to address cropping systems issues with holistic approaches.

Outreach. It is important to communicate the results of research to the stakeholders in the region as well as to assist in broad-based efforts to attract and keep young people involved in agriculture. Stakeholders at the LMWCRU Visioning Conference identified field days, student interns, demonstration projects, web-based technology transfer mechanisms, K-12 educational activities, interaction with the tribes, and partnering with universities in the writing of popular press and extension publications as high priorities.

The Inland Pacific Northwest Region

The inland Pacific Northwest region comprises more than 10 million acres of crop and range lands in west-central Idaho, north-eastern Oregon, and eastern Washington. The climate is typified by relatively cold, wet winters and warm to hot, dry summers, making it unique among dryland crop production regions in the USA. There is considerable variation in annual rainfall along a geographical east-west transect in the rain shadow of the Cascade Mountain Range. Annual precipitation ranges from a low of around 6 in/yr near the Columbia River in south central Washington to >28 in/yr near Pullman, WA, a distance of only about 100 miles. Soil types generally range from fine sands to silt loams with very low clay content; nearly 1 million acres in the region are classified as highly erodible. Soils are largely derived from wind-blown glacial deposits and the topography is highly variable, especially in the eastern portions of the region.

About 80% the region's annual precipitation occurs during the winter months and dryland agriculture is based on water stored in the soil profile over winter. This climatic situation is not typical of other major dryland cropping areas in the USA, which are much more dependant on spring and summer rainfall. Thus, research done in others areas is often not applicable to the inland PNW.

The approximately 8 million acres of dryland cropping in the inland Pacific Northwest region can be roughly divided into three climatic zones with some defining characteristics:

- Low precipitation zone - nearly half of the dryland farming area (~3.8 million acres) in the inland PNW (eastern Washington, western Idaho and northeast Oregon) receives less than 12 inches of rainfall annually. Traditional winter wheat-summer fallow monoculture dominates the region with relatively low yields and low biomass making soils highly susceptible to wind and water erosion. Fields in fallow (no crop every other year) are typically tilled during the summers to create "dust mulches" to minimize soil evaporation losses and conserve soil water for the subsequent crop. This region is mainly composed of what is commonly referred to as the Columbia River Plateau in south central Washington State.
- Intermediate precipitation zone - another 2.4 million acres receives an average precipitation of 12-18" annually. While traditional winter wheat-fallow monoculture dominates the region, a three year winter wheat-spring cereal-fallow rotation is also

practiced in the region. No crops are grown during the fallow period and weeds are controlled by cultivation (traditional fallow) or chemicals (chemical fallow) to enhance soil water and nutrients for the subsequent crop. This agroclimatic zone tends to be arbitrarily split between the Columbia River Plateau and the Palouse and includes much of the Walla Walla region.

- High precipitation zone - in the >18” rainfall zone, annual rotations include crops such as wheat, barley and legumes. The primary crop grown is wheat. Steeply sloping hillsides in this region are highly susceptible to erosion of soils by water. This region of about 1.8 million acres is often broadly referred to as the Palouse, but can also include the Camas Prairie area in Idaho.

The importance of crop production in the Palouse and Pacific Northwest (PNW) is indicated by their contribution to food production in the United States. For example, in 2008:

1) The PNW produced approximately 85% of all soft white wheat and 10% of all wheat in the US. The value of all wheat produced in the PNW was over $1.5 billion.
2) The PNW produced approximately 40% of all lentils in the US.
3) The PNW produced approximately 75% of all chickpeas in the US.
4) The PNW produced approximately 70% of all Austrian winter peas in the US.
5) The PNW produced 100% of all wrinkled peas in the US.
6) The PNW produced approximately 25% of all barley in the US.

In the extensive dryland crop production areas in the region, high rates of water and wind erosion and a 50% decrease in soil organic matter (OM) in the last century demonstrate that conventional wheat farming practices are ecologically unsustainable. Conventional wheat-fallow systems in the drier areas of the region have proven to be resource inefficient. However, adoption of proven technologies such as no-till that reduce inputs and conserve natural resources is quite limited across the entire region.

Soil water retention of precipitation during the fallow period of a wheat-fallow rotation is generally only 30% due to evaporation losses despite soil and water conservation practices, but it usually retains sufficient moisture in the seeding zone to establish the fall planted winter wheat crop. The trade-off of tillage for chemical weed control during fallow is excessive wind erosion and soil organic matter oxidation. For chemical fallow systems, the added herbicide use and expense potentially adversely affects the environment and reduces profitability. With limited legume production in the wheat fallow region, the system is heavily reliant on fertilizer N, and N use is dictated by the efficiency of year to year N carryover, which is subject to overwinter losses.

Viable dryland cropping systems in the inland PNW will depend on the crop adaptability to the growing conditions and stresses, and on the ability to identify viable markets for the crops. Therefore, research on agricultural production is urgently needed to ensure the economic and ecological sustainability of the region’s agricultural enterprises and the continued well-being of its rural communities.

Developing Dryland Cropping Systems in Response to Climate Change and Variable Weather Patterns

Predictions for global warming indicate that either positive or negative impacts across large areas of U.S agriculture are possible; largely dependent of the location of interest. Loss of crop production could lead to food shortages, increased food costs or the need to import food from abroad (if available). This has implication for national food security if the Nation's food supply depends on the whims of a foreign government. Furthermore, if the cost of food increases significantly, this will have an adverse impact on the poor and could lead to a portion of the population having inadequate nutrition. Unless global warming leads to increased precipitation, many areas will not be able to economically sustain current levels of agricultural production using existing technologies and cropping systems.

Growers most at risk of yield reductions or even crop failure are those that farm in arid or semi-arid regions, such as the inland PNW. High resolution climate simulations predict that temperatures will increase by 0.5°F per decade and precipitation will change little through the 2050's in the inland PNW. Precipitation is, however, expected to be more plentiful in winter and less plentiful in summer over current levels. If these simulations prove correct, crops grown in the inland PNW will face greater stresses in the short term, which may make current dryland production systems infeasible. This could gravely impact global food security if supplies of wheat and legumes become short due to falling production in this important region because of the large amount of agricultural exports from the dryland inland PNW.

Only those growers that can survive through this predicted period of greater climate stress will be in a position to benefit if climatic conditions improve beyond 2050. Given the potential for significant disturbance to agriculture in this region during the next few decades, research on mitigating the effects of climate change and development of suitable new dryland cropping systems are urgently needed.

In many situations, advanced agricultural technologies may help growers to effectively adapt to effects of climate change. However, for some situations, the added cost of advance technology may not be an option due to expense, which is likely true for the low and intermediate precipitation zones of the PNW where dryland agriculture has very low net margins. In addition, adoption rates of new technologies have been hindered by the wide variability in soil water in time and space and frequent prolonged droughts. Research is needed that demonstrates the agronomic and economic advantages as well as pitfalls of advanced technologies such as no-till and precision agriculture.

Research is needed to develop scientifically-sound, diversified cropping strategies that protect the environment and improve the economic benefits of dryland agriculture through: 1) improved management of soil water, soil, nutrients, and agrochemical applications; 2) diversified, sustainable crop rotations and management systems that include bioenergy crops, employ conservation-based minimum tillage techniques, promote efficient use of rainfall and nutrients, and have either neutral or positive impacts on crop yield and quality; and 3) reduced purchased inputs for growers. Advanced cropping systems include alternative cultural practices for better soil, water and nutrient management, enhanced nutrient cycling and rebuilding soil organic matter levels through sequestration of carbon, reduced commercial pesticide use, increased culturally and biologically based pest management, and reduced environmental risk. Achieving these goals and facilitating their integration into the region's farming enterprises should result in substantial labor, water and energy savings in addition to improved soil quality, reduced soil erosion and greenhouse gas emissions, and lower agrochemical losses to surface and ground waters.

Research should be directed towards reducing the economic risks associated with the integration of new crops and technologies into viable dryland cropping systems over a range of agroecological regions in the inland PNW. New cultural practices and alternative crops are vital for increasing farm efficiency, contributing economic and environmental benefits by breaking up pest and disease cycles, and improving air, soil and water quality. Projected climate change effects will require the development of more efficient methods to store and maintain soil moisture specific to each agroecosystem zone.

Management strategies for multiyear dryland cropping systems that consider their complex interactions with the environment and economic viability are lacking for much of the highly variable agroecological zones of the inland Pacific Northwest region. Strategies that work in higher precipitation areas may not be suitable in areas receiving much less water. The most appropriate and realistic approaches to developing these strategies necessarily require the concentrated efforts of numerous disciplines and full consideration of climate variability and the potential to adapt to future changes in weather patterns.

Research should be conducted to encourage adoption of crop rotations that improve yield and quality of food, feed, bioenergy, and forage crops in a period of changing climate. Crop establishment systems that reduce weed seed germination and emergence, enhance beneficial soil aggregating microbes, and sequester carbon and nitrogen for the benefit of soil structure and crop productivity are urgently needed. Associated research is also needed that will increase producers' understanding and subsequent adoption of sustainable biologically and culturally based disease and weed management strategies and result in improved environmental protection (e.g., reduced use of pesticides) and increased long-term sustainability.

Wind erosion is a significant factor affecting air quality in the region. Combinations of high winds and tillage operations lead to potentially large PM10 particulate emissions, especially in the lower rainfall areas. Soils in the region are also affected by erosion from water. Precipitation (e.g., rain and snowmelt) on frozen and thawing soil leads to soil loss. Due to increased air temperatures projected by many climate change models, much of the region's precipitation will likely occur as rain, which could lead to increased rain-induced erosion. Quantifying the factors affecting erosion is needed. Quantifying the integrated effects of soil, environmental and terrain processes and their interaction with dryland crop management systems is important for controlling erosion and in the development of integrated hydrologic, crop and climate change models. Research directed toward the design of new, multiyear dryland cropping systems that also prevent erosion are needed.

Recommendations:

Due to the unique geographic and climatic setting, the Unit should consider developing strong team research programs to study efficient and cost-effective approaches to adapt to climate change and the creation of a center of excellence for this important research topic. The Unit should focus on a few, highly visible projects where the special talents and skills of its scientists and staff would produce maximum impact. This research program would have significance at both the regional and national levels. A major side benefit of multidisciplinary team projects is that stakeholders quickly see and understand that the Unit is maximizing its resources by concentrating on a few complex systems, and the stakeholders are more likely to support the Unit and the research.

Future research activities should be directed at increasing fundamental understanding of effective soil and residue management practices that reduce soil erosion; improve soil physical, chemical and biological properties; reduce greenhouse gas (GHG) emissions; sequester carbon and improve soil water retention. There is also a need to investigate agronomic feasibility of producing legumes, oilseeds and other potential biofuel crops in rotation with other economically important crops including winter and spring wheat, which currently are agronomically very well suited to the inland PNW region.

The LMWCRU has severely limited financial resources. While Unit staff has decreased in size over the years due to attrition, the number and diversity of major projects have tended to remain the same. The Unit should look for ways to cut back on the number and the diversity of projects given the reduced number of people and inadequate financial resources (even with supporting external grants), and focus on fewer cropping systems projects representing key regional ecosystems.

Specific Research Themes Identified

This section summarizes the discussion and issues that emerged from the partners, collaborators and stakeholders who attended the Visioning Conference. Four breakout groups each identified research priorities, current needs and specific problem areas, which are summarized in Appendix C. In general, the breakout groups expressed great appreciation for the past and current accomplishments of the Unit.

Lists of priorities and problems were compiled from the breakout groups' discussions and three broadly inclusive and overlapping research themes were identified, which are:

- Soil and Residue Management
- Dryland Cropping Systems
- Water Conservation

These are all research themes that the Unit is currently addressing at various levels and this work should generally continue, but these efforts should be directed into a fewer core projects. It was recognized by the attendees that it was probably beyond the capacity of the LMWCRU to address all of the listed research priorities and problems, which are summarized below. However, a common thread was that the Unit should focus on the adaption of dryland agricultural production systems in response to potential climate change, for which this Unit is exceptionally well situated and qualified to address. The exact scope and composition of future Unit research was not specifically addressed, but it should consider the various elements outlined below as much as possible.

It was suggested in the breakout groups that the LMWCRU should develop a research program in a way that assists stakeholders with their immediate needs and is forward looking so that scientifically-based solutions will be available to deal with crop production and environmental problems that will likely occur in the near future. Likewise, the Unit's research program should build on the past successes in the air quality, integrated cropping systems, water erosion management and water conservation programs to develop a holistic approach to managing resources and crop production in dryland agriculture in the inland PNW.

The groups all stated that within the broad areas of agronomy, soil science, atmospheric science, nutrient management, and crop production, the Unit possesses the scientific expertise needed to provide many high-impact contributions to their partners, collaborators, and stakeholders.

It should also be mentioned that a common concern was the need to attract more young people into agriculture including both farming and science. This is beyond the scope of the Unit, but the Unit may be able to encourage high school and college students through its various outreach programs.

1. Soil and Residue Management

a. Background

The adverse impacts of short term and long term droughts on crop production in the region were well documented by the stakeholders, and the effect of potential changes in climate patterns may exacerbate this problem. Maintaining adequate soil water availability during the growing season is a common problem for dryland production throughout much of the region. Wind and water erosion of highly productive soils has numerous social and political implications, and can also adversely affect crop yields. This places pressure on available soil and water resources and dramatically influences resource use and quality considerations.

Practical guidelines are needed on improved agronomic practices, reduced tillage, crop sequences, and management strategies for diverse dryland farming systems across the inland PNW. These systems would have potential to promote efficient water (including precipitation) and crop nutrient use, improve nutrient cycling, pest management, and soil structure maintenance, and enhance economically sustainable productivity. Recommendations are also needed that will provide information on the suitability of various bioenergy and specialty crops for use in existing crop rotations. Increased knowledge is needed of long-term crop responses and crop-weed interactions in dryland cropping systems, including knowledge of cultural methods that will reduce weed seed banks in subsequent crops, improve carbon/nitrogen cycling and reduce GHG emissions.

b. Soil Quality

In order to maintain a profitable cropping system it is necessary to maintain the quality of soil as measured by soil physical and hydrologic parameters as well as microbial community dynamics and soil organic matter levels. Crop residue and cultural practices (e.g., conventional, reduced tillage, or organic) directly influence the composition of the microbial communities within agricultural soils. Microbial populations can differ in their ability to bind soil particles, impacting soil tilth and the propensity to erode by water and wind. These microbial populations also influence the availability of nutrients to the plants and subsequent nutrient cycling. Specific interactions between microbes and plant roots are also critical in enhancing plant growth through fixation of nitrogen (e.g., legumes), uptake of nutrients (e.g., mycorrhizae), production of plant hormones (e.g., plant growth promoting bacteria), and reducing the incidence of pests and diseases. This interplay of tillage, microbial populations, nutrients and plant communities is highly complex and variable. Crop rotation introduces new plant populations, often with new cultivation practices, and changes the soil environment and the microbial population. Ultimately, a balance of carbon, nitrogen, and other nutrients, mediated by organic matter content and the specific microbial communities is very important to overall plant and soil health leading to productive yields.

Soil and crop management also affect carbon storage which may provide a means to reduce global carbon footprints. Research that leads to enhanced, long term carbon storage by dryland cropping systems could help provide growers in the region with another revenue stream, and should be explored where opportunities present themselves.

c. Particulate Matter Emissions and Air Quality

Wind erosion and resultant particulate matter (PM) suspension remains a highly significant issue across the dryland farming areas of the inland Pacific Northwest. Wind erosion also adversely affects soil quality and must be managed to maintain high crop productivity. PM can be transported hundreds of miles from its source and adversely impact population centers and environmental and human health. Suspended PM can also restrict visibility, which has been the cause of highway fatalities in the past. Most of the PM generated from soil erosion is in the so-called coarse fraction (PM10), between 2.5 and 10 micrometers in aerodynamic equivalent diameter size. PM10 is a criteria pollutant regulated by the Environmental Protection Agency (EPA). In the past, some areas of eastern Washington have been in nonattainment for PM10, and presently are in a maintenance mode. Given predicted climate variability and the potential for significant climate changes, agriculture practices must be developed that will not exacerbate PM10 production and affect regional air quality, especially in the next decade with predicted drier conditions.

New regulations being proposed by the US EPA may mandate the control of PM emissions from farming operations. Little is known concerning PM emissions from other agricultural sources in the PNW; although a concerted effort has been made over the past 20 years to quantify emissions from agricultural sources in California, no comparable research has been conducted in the PNW. The large-scale wheat-based agriculture enterprise utilizing unique tillage tools on loess soils make the PNW a unique region as a PM emission source. The need exists to quantify the life-cycle of PM emissions as impacted by tillage tools and operations, residue management, harvest operations, pesticide applications, and sowing implements and operations.

New soil, crop and water management strategies are needed to reduce PM10 emissions from dryland farming operations in the low and intermediate precipitation zones of the PNW as well as similar regions in the southern US. The LMWCRU has been heavily involved in this research for 20 years, but additional research will be required as more new soil and crop systems are sought for a changing climate. Previous research in the region has focused on measurement and quantification of PM10 from agricultural soils and various cropping and soil management regimes; investigating the use of ARS' Wind Erosion Prediction System (WEPS) for estimating erosion and PM10 generation; and the development of a methodology to "tag" suspended soil particles so that PM10 source areas can be more clearly identified. Future research should include development of soil and soil water management strategies within the frame work of dryland cropping systems that fit the various agroecosystems in the region to manage emission sources.

d. Emissions of Greenhouse Gases

Greenhouse gases (GHG) from agricultural and natural landscapes, principally carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), are of great interest because of their relationship to atmospheric changes leading to global warming and potential climatic change. Regional estimates of GHG emissions are needed for more accurate assessments of global GHG budgets, and to help in targeting areas of opportunity for carbon sequestration and GHG emissions management. Agriculture has the opportunity to be a significant contributor to climate change mitigation via GHG emissions reduction and carbon sequestration in soils and biomass. Two of the primary methodologies for accomplishing these objectives is through the conversion from conventional tillage to no-till (reducing CO_2 emissions and enhancing soil carbon sequestration), and through better supplemental nitrogen management (reducing N_2O emissions). The LMWCRU has been actively conducting research on crop system enhancements to improve nitrogen (N) use efficiency, and better determining site-specific N needs to reduce N applications, and thus N_2O emissions. They also have developed a database of N_2O fluxes from various agricultural and grassland systems that will be valuable in future greenhouse gas flux models.

e. Water Erosion Control and Modeling

In the inland PNW, erosion of soil in the hilly terrain is strongly affected by runoff water. There is a significant potential for soil erosion due to the occurrence of several runoff events each winter. Cold temperatures lead to repeated soil freezing and thawing; subsequent precipitation during a thaw event may result in substantial lateral movement of water and sediment over the hilly landscape. Rainfall can lead to soil erosion due to the physical impact of the droplets detaching soil particles, which are transported by the runoff water. Snowfall and sleet also have the potential to produce significant soil erosion by creating runoff water.

This Unit is uniquely located to address soil and water quality research issues relating to the erosion from hilly landscapes common to the region. Research is needed to improve technologies that meet local, state and federal water quality regulations; determine on-site effects and movement of water during natural rainfall events; develop safe and environmentally sound methodologies to reduce erosion; and develop technologies to diagnose, mitigate, and remediate eroded landscapes.

Focus Areas:

- Further studies are needed to identify the impact of emerging crop rotations and cultivation strategies on disease management, crop health, crop productivity, and soil quality.
- Best practices for establishing, nurturing and maintaining ideal soil microbial populations need to be developed in concert with the development of new crop rotation strategies.
- Studies should be designed to ensure that new management options are available to assist growers if the amount of summer precipitation declines in the various agroclimatic zones. The LMWCRU should take advantage of the strong climatic and precipitation gradients that currently exists across the region to address these issues.
- Future PM research should focus, at least in part, on obtaining a better understanding of PM generation in this dryland agricultural region, and the development of new management strategies to control emissions. Logically, this should be closely aligned with soils and cropping systems research in the Unit.
- Scientists at LMWCRU should work with partners and collaborators to transfer the new knowledge and understanding and assist in the incorporation into modeled processes that can be used to improve the predictability of WEPS in this region, as well as other parts of the western US. This research also should be linked with efforts outside ARS to couple model output with meso- and regional-scale meteorological models for better predictions

of PM10 transport and deposition. Finally, dust (PM) biomarking technology should be further explored for application within and outside the region.

- More research is needed to better understand N_2O emissions from the dryland farming systems in the inland PNW. New methods are needed to reduce CO_2 and N_2O emissions to the atmosphere. Research on emissions from a wide variety of soils under various climatic regimes and dryland cropping systems is encouraged. In addition, nutrient management strategies to make most efficient use of N on both traditional (e.g., continuous wheat) and nontraditional (e.g., wheat rotations that include bioenergy and legume crops) cropping systems are needed.
- The Unit is encouraged to continue to participate in national efforts (e.g., GRACEnet program, etc.) to monitor and model greenhouse gas emissions and carbon sequestration.
- Water and wind erosion can occur from the same landscape, particularly in the intermediate precipitation zone of the PNW. Dry-land cropping systems should be developed that are compatible with controlling both wind erosion and/or water erosion on the same landscape. Research should be undertaken to solve interdisciplinary problems related to soil erosion. It is important that this research be coordinated with other ARS laboratories and National Program Leaders as a combined water-wind erosion model is developed by ARS.
- Research should be conducted on the management of biomass or forages with different stubble characteristics as a means to catch or trap sediments.
- Research should be conducted in using perennials along riparian areas to reduce particle movements into streams and waterways.

2. Cropping Systems

a. Background

A major area of research identified by the Visioning Conference attendees was the development and optimization of diverse cropping systems in dryland environments specific to the inland PNW. This research should expand upon the Unit's recognized involvement in research in wheat-fallow cropping systems.

b. Alternative Crops

Monoculture systems do not provide a wealth of ecosystem services. In the low precipitation zone, converting to annual cropping systems (no fallow) that include alternative crops have high economic risk due to yield instability that may be caused by reduced year-to-year soil water availability, new pest problems and climatic fluctuations. Soil quality indicators tend to improve with annual plant production compared to fallow systems. However, diverse cropping systems generally entail more complex management.

Some dryland crop rotation alternatives to wheat-fallow include continuous spring cropping (thus far found to be too resource intensive in the low precipitation zone of the PNW) or increased use of biennial or perennial crops managed with minimal or no-tillage to increase overall crop vegetative cover and to improve the efficiency of crop water use. The integration of more pulse crops into rotations to assist with weed and disease control can be advantageous in the intermediate and high precipitation zones; however, some pulse crops such as chickpea have minimal or even a negative contribution to the nitrogen requirements of next year's crop. Working with other ARS Units in Pullman to identify legumes that are viable for these alternative dryland cropping systems that would decrease overall dependence on synthetic N inputs is a priority.

c. New Crop Rotations

The lack of rotation crops in most inland PNW dryland cropping systems makes the control of pests (weeds, diseases) difficult and costly. Troublesome weeds in the current wheat/summer fallow systems include winter annual grass weeds such as downy brome and jointed goatgrass. Herbicides used to control these winter annual grass weeds provide approximately 80% control. At this level of control, weeds are able to replenish the soil weed seed bank and increase the density of subsequent weed populations. Moreover, these herbicides tend to persist in the environment resulting in restricted crop rotations and possible off-site damage. Herbicide-resistant weeds also threaten the sustainability of the system. Diversification of cropping systems can provide additional tools and cultural tactics to control weeds that have become serious problems in less diverse cropping systems. Other troublesome weeds in the summer fallow phase of the rotation tend to be annual broadleaf species such as Russian thistle and tumble pigweed. Currently, control of these weeds in the summer fallow phase of the rotation is achieved by using spring cultivation followed by repeated rod-weeding operations. Each tillage event requires substantial amounts of fossil fuel to operate the tractor pulling the tillage tool, and increases wind-borne soil particles. In some areas, repeated applications of broad spectrum herbicides (e.g., RoundUp®) are used in place of tillage on fallowed fields, which can lead to herbicide resistance in the target weeds.

d. Input Costs for Improving Profitability and Net Margin

Nutrient costs in dryland grain production following existing standard guidelines have increased to nearly 25% of the gross income in dry land production, which include material costs, and associated transportation and utilization costs. Half of the nutrient cost is associated with application. Energy costs significantly impact grain producer's profits and energy prices can increase much faster than agricultural earnings. Thus, an eroding net margin is becoming problematic for producers in these regions.

Utilizing advanced technology available commercially and or newly-released technology appears to offer solutions to increase net margin. Some of this nutrient-management technology has been developed locally. Certain nutrients have a greater carbon footprint than standard primary nutrients so new methods to handle or apply fertilizers are needed to reduce GHG emissions.

e. Nutrient Input Needs

Emerging research indicates that the old guidelines on applying nutrients are no longer applicable to a growing crop based on new application technologies, new varieties and new tillage methods. Many commercial and university soils laboratories are still using old tillage based, regional, algorithms to determine nutrient needs of dryland crops, and these algorithms are in need of serious updating. No-till techniques have been shown to reduce nutrient requirements as has the inclusion of annual and perennial legume crops into dryland cropping rotations. A major goal for improving profit margins is to reduce nutrient use by timing nutrient applications to more closely match the needs of the growing crop. Working with university collaborators to develop relevant guidelines for today's farming systems in strongly encouraged.

f. Emerging Markets

Emerging new markets (e.g., organically or sustainably produced grains and biodiesel, locally grown feed for a growing animal industry, and cellulosic pulp demand by the PNW pulp and paper industry) will drive interest and opportunities for developing new cropping systems and management practices. This societal trend will require new research to determine agronomic and environmental changes in the cropping systems. For example, Washington State is committed to developing a local feedstock based biofuel industry, which has immediately created a demand for biodiesel and ethanol. The biodiesel demand has sparked interest in local oilseed production, which includes canola and camelina, as new alternative crops that need to be examined and integrated into sustainable cropping systems, while balancing other demands on crop carbon for food, feed and soil. The ethanol and cellulosic pulp demand has sparked interest in crop straw harvesting and in perennial grass production. Again, tradeoffs with other demands on carbon and nutrients for food and production and soil building need to be researched. Ultimately, social and economic impacts on local rural communities need to be co-developed as these cropping systems evolve.

g. Site Specific Management

Site specific management of nutrients, soil water and carbon, and crop residue can be beneficial in today's farming systems, especially for the highly variable soils used to grow winter wheat and spring cereals and legumes in the PNW. However, adoption rates are quite low. Yield and protein monitors provide an opportunity to break down large fields into smaller management zones. Economic performance of each zone can be determined using yield and crop quality monitors, remote sensing, soil sampling and other techniques. Technologies already exist that allow matching varieties or planting densities to specific production zones in a field. Furthermore, improved application techniques and better timing of nutrient applications to match uptake by the crop can enhance nutrient use efficiencies in each zone, and increase profitability. Economic-based methods allow each zone to receive nutrient treatments that meet economic goals.

h. *Energy efficiency*

Energy efficiency improvements are possible by promoting the use of minimum-tillage in the drier region and no-tillage in the wetter region of the PNW. Improvements in energy efficiency can be obtained by combining variable application rate technologies with low cost imported nutrients and the use of stored soil moisture.

Focus Areas:

- Methods are needed to reduce the economic risk of alternative crops.
- Cropping systems research is needed that simultaneously mitigate particulate matter and greenhouse gas emissions.
- Methods of incorporating legumes into existing crop rotations are needed to reduce fertilizer requirements.
- Precision technologies and management systems are needed that promote site specific fertilization, seeding and residue harvesting.
- Research on alternative CRP land management and development of CRP-cropping hybrid systems are needed to achieve multiple production and environmental protection goals for semi-arid lands.
- Up-to-date recommendations are needed on the amount and timing of fertilizer applications for current crops, fertilizer types and tillage methods. Recommendations should also consider the selection of the application equipment.
- There is a need to determine appropriate nutrient application strategies for crops in no-tillage systems.
- Techniques must be developed that define management zones based on stored soil moisture, which is reflected most often by yield.
- Decision support is needed to assist producers in managing complex cropping systems and for utilizing variable rate technologies.

3. Water Conservation and Use Efficiency

Research priorities aligned with soil water conservation included:

a. Life cycle analysis of water budgets of cropping systems, including all phases of the cropping system
b. Sequencing crops in multiyear systems to more efficiently utilize water resources
c. Drought mitigation

Available water and nitrogen, and weed, insect and disease pressure typically are the primary factors limiting productivity in semiarid regions. Diversified and intensified (cropped every year) dryland cropping systems combined with no-till practices that more efficiently utilize soil water have been shown to reduce costs as well as reduce water quality concerns and improve soil quality in the inland PNW region. However, progress toward widespread adoption of diversified rotations using direct seeding techniques has been slow.

The inland PNW region is heavily dependent on winter precipitation to recharge soils for annual crop production, and limited water availability for fall planting of various crops is a large constraint to dryland production. Planting activities in the spring are often limited by excess water and cold soils that delay emergence and can negatively impact soil structure as a result of trafficking. Consequently, crop establishment systems and specific multiyear cropping rotations need to be developed for the widely variable agroecological zones in the inland PNW. These systems need to promote more efficient storage and use of available water (including precipitation) sources throughout the year.

Selecting the best sequence of crops in a multiyear rotation in a particular agroecological zone can determine the success or failure of that rotation. Different crops in a rotation sequence will have different water use amounts and patterns and, as a result, the preceding crop can have a major impact on the productivity and success of the succeeding crop. For example, peas have a much lower water use than winter canola, resulting in more available soil water to germinate a subsequent fall planted crop or improve the yield of the succeeding crop under limited winter precipitation. In addition to field plot and on-farm research, the application of these results can be extended to broad areas in the region by the application of existing crop and soil models that are calibrated using local data sets.

Focus Areas:

- Research should identify techniques that will improve infiltration and store precipitation where it falls upon the soil, thereby maximizing its retention for crop use.
- Development of suitable cropping and integrated management systems are needed that promote efficient use of rainfall and conserve available soil water across the highly diversified agroecological zones in the PNW.
- Water conservation strategies should also optimize soil and air quality, soil aggregation, soil physical properties, soil biological diversity, soil C/N cycling through tillage and residue management, and biologically- and culturally-based cropland pest management strategies.

Appendix A. LMWCRU Scientific Staff

***David Huggins*, Soil Scientist**

David received a BS and MS degree in Forestry from Cornell University and PhD degree in soil fertility and plant nutrition from Washington State University. Prior to joining the Land Management and Water Conservation Research Unit in 1997, David was an Assistant Professor in the Department of Soil, Water, and Climate at the University of Minnesota where he led investigations on crop rotations, N use efficiency and tillage practices for corn and soybean. His current research is directed toward assessing the interactive effects of terrain attributes, soil properties, C and N cycling, crop diversity and tillage on agroecosystem performance. David has authored/co-authored nearly 40 peer-reviewed journal articles, 15 peer-reviewed book chapters, and 50 technical publications and has given 125 oral/poster presentations.

***Ann Kennedy*, Soil Scientist**

Ann received a BA degree from the University of Missouri - St. Louis, MS degree from the University of Missouri – Columbia, and PhD degree from North Carolina State University. She joined the Land Management and Water Conservation Research Unit in 1986 and is a Fellow in the Soil Science Society of America and the American Society of Agronomy. Her area of expertise is in soil microbiology and soil microbial ecology. Her current research focuses on plant-microbe interactions and soil quality in dryland cropping systems. She conducts research to characterize microbial community indicators of soil quality and plant health, to identify soil biomarkers for fingerprinting eroded soils, and to identify soil microbes that suppress weeds. Ann routinely works with K-12 teachers to bring science experiments into the classroom as a means to encourage young students' interest in science.

***Donald McCool*, Agricultural Engineer**

Don received a BS and MS degree in Agricultural engineering from the University of Missouri and PhD degree in Agricultural Engineering from Oklahoma State University. He joined the Land Management and Water Conservation Research Unit in 1971. His current research focus' on the basic processes and interactive effects of climate, topography, and soil and crop management on runoff, erosion, water quality and sedimentation on non-irrigated crop and grazing lands in regions dominated by winter hydrology. Don conducts research on developing and testing mathematical models of the erosion process as influenced by frozen and thawing soils and developing and testing soil, vegetative, topographic, mechanical, structural, or other practices or management systems to control runoff, erosion, and sediment yield.

***Brenton Sharratt*, Research Leader / Soil Scientist**

Brenton received a BS and MS degree in soil science/biometeorology from Utah State University and a PhD degree in soil science from the University of Minnesota. Prior to joining the Land Management and Water Conservation Research Unit in 2002, Brenton was stationed with the USDA-ARS in Fairbanks, Alaska and then in Morris, Minnesota. His current research focus' air quality as impacted by windblown dust. Specifically, he is interested in processes that govern the emission of windblown dust and developing tillage and cropping systems for reducing windblown dust emissions from agricultural soils. Brenton is the co-director of the Columbia Plateau Wind Erosion / Air Quality Project and has authored 4 book chapters, 65 referred journal articles, and over 90 other publications.

***Jeff Smith*, Soil Scientist**

Jeff received a BS degree in soils and plant nutrition from the University of California and MS and PhD degrees in soil chemistry/biochemistry from Washington State University. He joined the Land Management and Water Conservation Research Unit in 1986. His research interests include developing techniques and principles which apply to nutrient cycling and plant nutrient management and developing nutrient budgets for conservation tillage systems for the production of small grain and legume crops. His current research emphasizes carbon and nitrogen cycling, nitrogen transformations in soils, trace gas production from terrestrial ecosystems, groundwater chemistry and hydrology, and the use of radioactive and stable isotopes in plant and soil studies.

***Frank Young*, Agronomist**

Frank received a BS degree from South Dakota State University and MS and PhD degrees in Agronomy from the University of Minnesota. He joined the Land Management and Water Conservation Research Unit in 1997. His research interests include the biology and control of weeds in small grains and the development of integrated systems of pest management for wheat production. His current research focuses examining the agronomics and economics of alternative oil seed crops for biofuel production. Frank was project leader of two large-scale, long-term, multidisciplinary field research studies – the first involved developing economically feasible, environmentally sound, reduced-till spring cropping systems in the winter wheat-fallow region of the PNW and the second involved identifying a stable crop production system for the integrated management of jointed goatgrass.

Appendix B. Agenda

Program Visioning Workshop

Land Management and Water Conservation Research Unit
USDA - Agricultural Research Service
Pullman, Washington

October 27, 2009

Agenda

8:30	Registration
9:00	Welcome and Charge, ***Andrew Hammond***
9:15	ARS unique capabilities and National Programs, ***Charlie Walthall***
9:45	Overview of LMWCRU, ***Brenton Sharratt***
10:15	Break
10:30	Charge to Break-Out groups, ***Robert Matteri***
	Break-Out groups
12:00	Lunch
12:30	Preliminary reports from Break-Out groups, ***Robert Matteri***
1:00	Break-Out groups reconvene
2:30	Break
2:45	Reports from Break-Out groups, ***Robert Matteri***
	Discussion of issues, priorities, and vision for LMWCRU
4:00	Wrap-up, ***Andrew Hammond***
4:30	Optional - tour of PCFS
6:00	Optional - no-host dinner

Appendix C. Breakout Group Priority List

Group #1

The following were future issues of importance to stakeholders that should be addressed by the LMWCRU:

1. Soil erosion, soil quality/health
    a. Microbial communities impact on productivity/nutritional content of plants
    b. Nutrient cycling
    c. Organic matter
2. Alternative crops/markets/price supports
    a. Rotation crops
    b. Companion cropping
3. Water issues
    a. Water budgets for a system
    b. Rotation crop effects
4. Input costs
    a. Current study of nitrogen input needs, how to apply it
    b. Precision agriculture
        i. More information on its most efficient application is needed
        ii. Understand the mechanism needed to define management zones
        iii. Decision support
        iv.

The following were questions or comments raised by the stakeholders that may be important to future research undertaken by the LMWCRU:

1. How can we do more with less energy, fertilizer? (Gap between inputs and income needs to be positive).
2. How do we improve nutritional content of the crops?
3. How do we improve and take advantage of nutrient cycling (shallow and deep soils)?
4. Need to evaluate impacts of factors using a whole systems approach.
5. Information on what it takes to meet "sustainability" requirements is missing.
6. Combine need to diversify crops with market availability.
7. Replacement for conventional drill/ other improvements in equipment.
8. Greater coordination/cooperation with NRCS.

Group #2

The following were future issues of utmost importance to stakeholders that should be addressed by the LMWCRU:

1. Maintain/ enhance long term perspective of ARS research.

2. Developing regionally specific systems to manage cropping and rangeland resources that are economically feasible and environmentally sustainable.

    a. Sustain/improve soil quality: ability of the soil to perform key functions, such as controlling erosion (wind and water), biological activity, carbon storage, water retention and filtration, etc. Develop protocols to quantify soil, air, water quality and carbon sequestration.

    b. Soil microbiological/cultural control of weeds, pests and diseases.

    c. Optimization of soil microbial communities to enhance crop production and sustainability.

    d. Improve nitrogen use efficiency by determining optimal rate, timing, type and form parameters for dryland cropping systems in the PNW.

The following were future issues very important to stakeholders that should be addressed by the LMWCRU:

a. Diversifying the range of crops that can be cultivated in dryland agriculture.

Group #3

The following were future issues identified by stakeholders that should be addressed by the LMWCRU:

Water Conservation, Nitrogen Use Efficiency, Water Use Efficiency, Nutrient Efficiency, Overall Sustainability, Soil Life

- Crop rotation effect on water efficiency? Water use management? Information that NRCS can use
- Alternative cropping systems-are they better or worse for water efficiency? Plant breeding?
- Perennial crops? For <10 inch rainfall area.

Of the six stakeholders in Group #3, five gave the above a high priority, one a medium priority, and zero a low priority.

Addressing Uniqueness of PNW and Areas within PNW
Landscape Patterns, Rainfall, Relevance of Research on Research Farms

- Wants research in all geographical areas of PNW, don't stay in Pullman.
- Research specific to agro-eco zones
- Research partnerships to facilitate

Of the six stakeholders, zero gave the above a high priority, five a medium priority, and zero a low priority.

Rural Sociology, Economic Sustainability, Area Culture

- Advantage of non-regulatory vs. regulatory processes for conservation effectiveness, which is cost effective?
- Food systems for low and intermediate and high rainfall areas that benefit local growers and consumers?
- Address profitability of descending scales

Of the six stakeholders, two gave the above a high priority, four a medium priority, and zero a low priority.

Climate Change, Carbon Sequestration, Gaseous Emissions, Atmospheric N Deposition, N Loading

- Better research to quantify carbon mitigation and verify sequestration benefits (all aspects of production)
- Research in soil building and cropping systems to fit to new climate?
- Research models on effect of climate change on dryland cropping systems? Soil erosion, PM10? (Earlier spring, more spring runoff, shifting rainfall patterns, snow level)

Of the six stakeholders, two gave the above a high priority, four a medium priority, and zero a low priority.

Air Quality, Burning Replacement and Tradeoffs

- PM10, PM2.5   Effect of biodiesel?
- Alternatives to burning and emission reduction techniques for burning- site specific burning.
- Rural roads as a source of PM10
- Sources of PM10

Of the six stakeholders, one gave the above a high priority, five a medium priority, and zero a low priority.

Energy Efficiency, Conservation, Solar,

- Energy budgets for different production systems, energy efficiency
- Energy crops for low rainfall zones
- Farming and food systems that maximize energy efficiency
- Provide tools and data so farmers can figure out how to run analyses for energy efficiency and other cropping inputs (N).

Of the six stakeholders, five gave the above a high priority, one a medium priority, and zero a low priority.

Ag Engineering Feasibility of Nuclear Power Production of NH3

Of the six stakeholders, zero gave the above a high priority, one a medium priority, and five a low priority.

Group #4

The following summarizes future issues of utmost importance to stakeholders that should be addressed by the LMWCRU:

****Develop rotations, alternative crops and crop sequencing for short term and long term economic, and environmental sustainability, and adaptation to potential climate change.**

**** Increase outreach and youth education**

****Quantify and identify Agricultural Management effects on Soil Health, soil quality sustainability, weeds, nutrients in food, soil erosion for specific precipitation, cropping and soil zones using a systems approach.**

The following were future issues identified by stakeholders that should be addressed by the LMWCRU. Issues of utmost importance have a "1" prefix, very important a "2" prefix, ands important a "3" prefix:

-1 Environmentally friendly product to increase water infiltration but reduce capillary action to reduce the need for tillage
-1 Systems approach to reduce Soil erosion e less than 12 inch rainfall zones (wind and water)
-3 Identify methods to recognize and manage spatial variability effects on parameters that affect crop production and soil conservation (spatially recognizing characteristics that affect the above).

Precision agriculture.
-2 peas and lentil production research as an alternative crop and as a source of fixed N.
-2 N fixation interactions with legume production systems (how do we increase N fixation)
-3 Assess short and long term soil quality and economic effects of stubble burning.
-3 Ecological effects of forest and rangeland prescribed burning.
- An important Goal!! : Increase adoption of methods already developed for erosion control and improved land management (demonstration, farm-programs, education outreach)
-Suggested name change "Dryland Climate Change Adaptation Research Unit"
-2 Develop technology and tools to assess the impact to potential climate change on long term crop production, pests and soils.
-1 Develop nutrient management and cropping systems practices to reduce Greenhouse gas emissions especially with N_2O.
-3 Guide research to adapt to future climate change (considering temperature and precipitation, and GG concentrations, crops)

-<u>Important Goal:</u> The need to engage and encourage Young Farmers (the aging farmer demographic) ARS-Outreach to youth via partnering with: FFA, University students, high school and elementary school and through Coop-Extension

-1 Assess economic viability (with or without government program) of cropping systems to encourage adoption and increase an incentive to stay in farming
-Goal: How do we make work in soil and crop sciences more attractive to youth?
- 3 Need to quantify speed and direction of tillage operations on soil aggregate stability. (Need for reflection and long term memory to evaluate GPS-Technology best direction of tillage and speed).
- 1 Rotation effects and crop sequencing effects on soil health and root-zone microbial dynamics nodulation increases with canola pea and lentil rotations, mycorrhizal associations?
-1 develop improved specific **quantitative** measurements of soil quality versus testimonials
-2 Need for long term research with dynamic soil properties in tillage and cropping System studies to improve soil quality.
-Need for more quantitative documentation of "Direct seeding no-till research": why and when it works versus why and when it might not work? Crop rotations and diversification
-Disease management with no-till in monoculture systems versus rotation no-till systems
-2 Develop a Quantitative tool that is region (soil, precipitation and cropping system) specific for C sequestration and greenhouse gas emissions: "Cap and trade" Carbon trading effects on agriculture. "Trading on real numbers" what is going to be the regulation?

Soil Gortex

Research pressing issues and directions:

1. Adoption of sustainable alternative crop rotation systems for < 15-inch rainfall zones (long term and short term).
2. Quantify and Measure Soil Health: Quantify and identify Agricultural Management effects on Soil Health, soil quality sustainability, weeds, nutrients in food, soil erosion for specific precipitation, cropping and soil zones using a systems approach.
3. Soil Gortex (lets water in but not out)
4. Develop rotations, alternative crops and crop sequencing for short term and long term economic, and environmental sustainability, and adaptation to potential climate change.

Appendix D. Writing Team

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