Project Duration: February 2011 – February 2016

REACCH
Regional Approaches to Climate Change – PACIFIC NORTHWEST AGRICULTURE

YEAR 1 ANNUAL REPORT

FEB 2011 – FEB 2012

February 14, 2012

USDA | University of Idaho | Washington State University | Oregon State University

Regional Approaches to Climate Change for Pacific Northwest Agriculture

Funded through Award #2011-68002-30191 from USDA National Institute for Food and Agriculture

Not everything that counts can be counted,
and not everything that can be counted counts.

Albert Einstein

Cover photo by AlisonMeyerPhotography.com

Climate Science Northwest Farmers Can Use

An overview: who we are, why we're funded and what we are doing

Managing agricultural systems efficiently, profitably and sustainably is a tremendous challenge. In the US we have addressed this challenge for generations through partnerships between farmers, agricultural industries, researchers at land grant universities and the USDA Agricultural Research Service. The evidence is clear that climates are changing globally and in the US. Climate change will … "add another layer of complexity and uncertainty onto …[an agricultural] system that is already exceedingly difficult to manage on a sustainable basis" (Coakley et al. 1999). To address anticipated effects of climate change on US agricultural systems, the National Institute for Food and Agriculture (NIFA) has funded more than 30 projects nationally within its the Climate Variability and Change Program within the past two years. The broad goals of NIFA's programs are to work with producers to assist them in adapting to projected climate variability and change ("adaptation"), and to minimize agriculture's emission of greenhouse gasses (GHG) that contribute to climate change ("mitigation").

REACCH is a $20 million, five-year NIFA project that aims to ensure the long-term viability of cereal-based farming in the Inland Pacific Northwest (IPNW) amid a changing climate and to identify farming practices that can help reduce agricultural greenhouse gas emissions. Our project is a partnership involving scientists and educators from three land-grant institutions (Oregon State University, the University of Idaho and Washington State University) and the USDA's Agricultural Research Service in the Pacific Northwest. REACCH will build upon the legacy of research and extension to improve soil conservation and the efficiency and profitability of the region's production systems, but differs in the breadth and depth of its integration. Research, extension and education efforts will integrate diverse elements such as climate modeling, cropping systems modeling, economics, agronomy, crop protection and others in a transdisciplinary manner. Critical to the success of this effort is ensuring that our project communicates effectively with farmers, industry personnel and other stakeholders and partners with them to achieve the adaptation and mitigation goals of REACCH.

Adaptation

For the Inland Pacific Northwest, climate models are consistent in projecting warmer temperatures, especially in the summer months and many project trends for drier summers. Within REACCH we aim to use the best available models to project conditions for farming and to test alternative production practices suitable for those conditions. The alternatives we will consider include intensification of cropping systems, greater cropping system diversity and use of biofuels, amendments that promote greater nutrient cycling and use efficiencies, and reduced tillage that enhances soil C sequestration. Climate will also change pressures from some pests, weeds and diseases. REACCH is working to anticipate these change and their implications for management.

Mitigation

GHG (carbon dioxide, nitrous oxide and methane) trap heat in the atmosphere, contributing to increasing global temperatures and associated shifts in climates. Direct GHG emissions from agriculture account for at least 6% of total US emissions from all sources (US Environmental Protection Agency (EPA)) and 12% worldwide (Intergovernmental Panel on Climate Change). Farming practices that store more soil carbon and reduce nitrous oxide and methane emissions could reduce overall GHG emissions by 5 to 14% according to some estimates. Examples include adoption of precision nitrogen management that increases nitrogen use efficiency thereby reducing nitrous oxide emissions, and conservation tillage practices that sequester more soil C and improve soil productivity and sustainability. REACCH will assess the potential of these approaches to reducing emissions and assist with adoption.

Opportunities

Fortunately, efforts to achieve adaptation and mitigation are coupled, presenting the potential for win-win scenarios for agriculture. Farming practices that improve nitrogen use efficiency, carbon storage and resilience to changing climates can be more profitable while they address GHG mitigation goals. REACCH activities will seek to identify these win-win opportunities and help industry realize them. The work of REACCH will provide the tools and decision support to meet effectively and profitably any proposed agricultural emission standard in our region and to ensure that any standards are reasonable and science-based.

Partnerships

REACCH is benefiting from close cooperation with other regional projects to make the best use of our resources and the legacy of research, education and extension in the region. We are working closely with the two other large coordinated agricultural projects (CAPs) funded by NIFA to address climate variability and change: the Sustainable Corn project led by Iowa State University and PINEMAP, the southern pine project, led by the University of Florida.

REACCH and the Future

A successful REACCH will not only help our region's agricultural systems respond to climate variability and change, but will also establish integrated approaches that can address other emerging challenges as they arise for the region's agriculture such as changing commodity prices, costs of inputs, emerging pests and diseases and others. Our project aims to establish the networks and infrastructure that will prepare us to meet these challenges.

This Report

REACCH has been funded for one year, with many activities commencing after our Launch Meeting (May 9-11, 2011). In this report, we provide a summary of our activities during this first year for stakeholders and other citizens, and for our funding agency, NIFA. Our aim is to inform and to provide sufficient information for feedback from all affected parties.

The report includes an overall executive summary and summaries of each of our project's objective team and integrating efforts. For those interested in more detail, we provide longer technical reports for each of these areas, and appendices with more information about project activities.

United States Department of Agriculture
National Institute of Food and Agriculture

Oregon State University | University of Idaho | Washington State University | USDA ARS Agricultural Research Service www.ars.usda.gov

Weather, Climate and Agriculture

Given the central importance of climate and weather for REACCH, it is important to clearly define our terms. Both weather and climate concern varying conditions of the atmosphere, but they differ in temporal scale. Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time. Weather is important for agriculture, as it can be both beneficial and detrimental to crop production. On a year-to-year basis, weather influences the number of growing-degree days, length of the growing season, timing and amount of precipitation and evapotranspiration from crops. These factors can combine in advantageous ways for optimal growing conditions; however, a late spring freeze or lack of moisture in the growing season can severely limit yields and create a host of concerns for growers. Weather also determines the conditions under which pests appear in crops and how they might migrate. Over longer time periods, weather patterns shift, resulting in climate change or variability. Our ability to forecast how weather changes day-to-day (weather), year-to-year, and decade-to-decade (climate), plays a vital role in keeping agriculture production flexible, adaptable and cost effective. Research allows us to use models of the Earth system to examine how weather variables may vary several decades into the future. Information from these models is “downscaled” to fine spatial resolution that can then be used by agricultural researchers. Climate changes will differ among locations, just like weather, so our downscaling approach is similar to that used for shorter term weather forecasting. We can test these models by using them to project past climates and examine them for accuracy. Our best estimate is for increases in temperature across the Inland Northwest by about 3-4 ºF by the mid-21st century and between 4-6.5ºF by the late-21st century, with a bit more warming during the summer months. Our best estimates suggest that annual precipitation will increase by about 5-15% by the middle and latter half of the 21st century. However, summertime precipitation is expected to decrease significantly and along with warmer summer temperatures, result in a decrease in soil moisture during the late summer months.

So, in summary, our best estimates are that future conditions in the Inland Pacific Northwest will be warmer throughout the year, with larger temperature increases in summer. These changes are likely to increase the number of growing-degree days and the length of the growing season. While models estimate an increase in annual precipitation, overall decreases in summer precipitation and increased evapotranspiration are likely to decrease water availability during the summer months.

Source of temperature and precipitation estimates:
http://www.webpages.uidaho.edu/jabatzoglou/inw/

Executive Summary

The *overarching goal* of Regional Approaches to Climate Change for Pacific Northwest Agriculture (REACCH, in this report) is to *enhance the sustainability of cereal production systems of northern Idaho, north central Oregon, and eastern Washington under ongoing and projected climate change while contributing to climate change mitigation by reducing emissions of greenhouse gasses.* Scientists, educators and students from diverse disciplines and four institutions are working together in a transdisciplinary effort with stakeholders to ensure results are innovative, useful and impactful. The context of this project is global, but the focus is regional because of the unique climatic conditions, agricultural systems, social and economic conditions that pertain in the Inland Pacific Northwest.

RESEARCH ACTIVITIES (OBJECTIVES 1-5 AND INTEGRATING THEMES)

A modeling framework (Objective 1): REACCH requires a conceptual and operational framework that captures the linkages amongst human, biological and climatic systems relevant to agriculture. This is achieved by integrating several modeling approaches: Agro-ecozone modeling, climate projections, cropping systems simulations, and economic and environmental impact assessment modeling. YR 1 activities focused on team organization and clarifying the structure and approaches for model integration.

Monitoring carbon, nitrogen and emissions (Objective 2): Monitoring is necessary to optimize soil carbon levels and nitrogen use efficiency and reducing greenhouse gas (GHG) emissions. In YR 1, a bi-modal GHG monitoring system was initiated at a subset of sites for baseline assessment of GHG fluxes at field and treatment levels. Two field-scale catchments were instrumented to quantify sediment, carbon, and inorganic nitrogen loading in run-off water.

Alternative cropping systems (Objective 3): During YR 1, a network of existing and new field cropping system experiments has been identified or established over the study region for comparative assessment of baseline and alternative agronomic adaptation and GHG mitigation practices in wheat-based systems. Fifteen experiments at 11 locations are distributed amongst the major agroecological zones across the tri-state region.

Social and economic factors (Objective 4): The adoption of agricultural management practices and technology is determined by social and economic considerations that can be influenced by public policy. In YR 1, a longitudinal survey of wheat growers in the REACCH area was initiated to establish a baseline of social and economic considerations. Planning focused on ensuring integration of these data, existing data from the USDA National Agricultural Statistics Service (NASS) Ag Census and Agricultural Resource Management Survey and the modeling framework established by *Objective 1.*

Pests, weeds, diseases and beneficial organisms (Objective 5): Baseline surveys across the region were conducted for important insect pests, weeds, pathogens and nematodes that affect wheat production in the region. Earthworms were sampled because they influence soil quality and soil carbon. A climate-based model of one invasive pest, cereal leaf beetle, was completed and plans for similar models of other organisms were developed.

Additional integrating themes: In addition to the integration achieved in *Objective 1,* two cross-cutting themes will support project-wide integration. One is delineating AgroEcological Zones (AEZ) of the region empirically using multiple years of the NASS Crop Data Layer. Dynamic AEZs were developed in YR1. Another is formulating the Life Cycle Analysis (LCA) for different production systems within REACCH.

EDUCATION AND EXTENSION ACTIVITIES (OBJECTIVES 6-7)

K-12 education (Objective 6): Survey results of teachers in ID, WA and OR were used to guide product development for teacher education. A brief overview of the REACCH project was given at teacher workshops within each state, and a brochure with this information was also distributed. A partnership with a NASA-sponsored climate education project was established in YR 1. Workshops are planned for summer 2012.

Undergraduate and graduate education (Objective 6): A summer research experience for undergraduates program was developed and advertised for summer of 2012, with placements in all three states. Graduate student recruitment materials were developed and disseminated. Currently 8 of the 14 positions are filled and all positions will be filled by Sept. 2012. Three postdocs are or have been employed within the project and two are being recruited.

Extension (Objective 7): A Stakeholder Advisory Committee representing farmer, industry, government and environmental interests was expanded in YR 1 and used to inform design of the REACCH Extension program, including a communication plan, grower activities, technology-enabled education, and impact assessment. A search for the faculty extension coordinator position was initiated with hiring targeted for early in YR 2.

CAPACITY BUILDING AND PROJECT-WIDE MANAGEMENT

Cyberinfrastructure and data management (Objective 8): The REACCH Environmental Data Manager position was filled and an initial data management strategy and framework were developed. The initial framework for the project web site for interactive access by researchers, stakeholders and educators was created. Partnerships were established with the University of Idaho's Northwest Knowledge Network for data storage and access.

Project-wide management: A Project Manager and assistant were hired. Project leadership met 24 times and objective teams met frequently. A PI retreat in Feb. 2011 and a project-wide Launch Meeting in May 2011 were held. An on-line collaborative tool, Central Desktop, was adopted to coordinate project-wide activities. A survey assessed participant's perceptions of project process to guide improvements for YR 2. Six scientific advisory panelists were enlisted. The first project-wide annual meeting will take place Feb. 29-March 2, 2012 in Pendleton, Oregon.

OUTPUTS

As described in the following sections, REACCH personnel have made 17 presentations to professional and scientific meetings and 47 presentations at producer meetings and field days. The project has contributed to 14 refereed scientific articles, 9 extension reports or bulletins, 2 webinars and extension 1 video.

OUTCOMES AND IMPACTS

Our publications and presentations have improved knowledge of climate change and agriculture among professionals and producers.

This annual report covers the period from 15 Feb. 2011 to 14 Feb. 2012.

TABLE OF CONTENTS

OBJECTIVE OVERVIEWS[1]

TECHNICAL REPORTS

APPENDICES

[1]*Most objective overviews contain the following sections: Executive Summary, Outcomes/Impacts YR 1, Outputs YR 1, Milestones and Deliverables, Broad Impacts, Training, Collaborators and "Integrated Knowledge", and Plan of Work YR 2.*

Project Management

Leads: Sanford Eigenbrode, sanforde@uidaho.edu   Dianne Daley Laursen, diannedl@uidaho.edu

REACCH-PNA is a large complex project spanning three states, four institutions, more than 12 academic departments and engaging the efforts of more than 50 scientists, staff, and students. Program management is designed to facilitate communication, ensure transdisciplinary integration and thematic focus, and allow the effective integration of the research, extension and education components of the project. Management also coordinates communication with the producers of our region, our stakeholders in production agriculture, agricultural industries, local, state and federal government, and more than 40 cooperator farmers. Our goal is to coordinate these activities seamlessly to allow participants to focus on the research, extension and education activities essential for the success of REACCH.

Achievements

1. Key project personnel were hired including the Project Manager and Environmental Data Base Manager.
2. Central Desktop (CD, www.centraldesktop.com) was adopted as the project-wide online collaborative tool for communication, document storage and authoring, discussion, and calendaring.
3. Protocols were adopted for authorship, citations, presentations, and data management.
4. The Stakeholder Advisory Committee (SAC) and Scientific Advisory Panel (SAP) were recruited and are engaged in the project.
5. A project-wide Planning Meeting and a Launch Meeting were held for all PI's and stakeholders.
6. Planning is complete for our first annual meeting in late February, 2012.
7. Administrative and budget procedures were established across and within institutions.
8. A first-year project-wide assessment survey was completed by PI's, professional and technical staff, and the SAC.
9. Cross-project coordination and communication was established with Sustainable Corn (sustainablecorn.org) the corn climate CAP led by Iowa State University and with PINEMAP (pinemap.org), the southern pine climate CAP, led by the University of Florida.
10. Twelve popular press articles were written regarding the REACCH project for wide ranging lay audiences.
11. Regular and extensive internal team and project-wide meetings were formalized
12. Partnerships were established with other regional projects addressing agricultural sustainability and climate change.

YR 2 Planned Activities

Project management activities will continue, adjusted based on feedback from all PIs. The REACCH director will participate in coordinated activities with other the other climate CAPs and related projects. An assessment survey will be completed for YR2. Efforts will continue to partner with related projects regionally and nationally.

Outcomes/Impacts YR 1

Outcomes and Impacts, defined as changes in knowledge, actions or conditions**,** have been limited in YR 1 because our project is just beginning. Through the use of Central Desktop and our regular team meetings we are seeing improved levels of communication, increasing the trust and collaboration among our team, thus enabling new approaches to research questions.

REACCH has been a potential partner on numerous grant proposals across the region (Appendix A) and thus has the potential impact for increasing the research capacity of the region. REACCH has enhanced the capabilities of numerous ongoing and newly initiated agriculture and climate change programs such as the Pacific Northwest Climate Center, the Northwest Knowledge Network, Climate Friendly Farming and Bio-Earth among others.

Outputs YR 1

Product: *Scientific Advisory Panel*
The SAP is comprised of senior professionals representing key dimensions of the REACCH Project. Six SAP members (Appendix B) have been recruited and will be reviewing project activities based on our annual report (February 2012) and annual meeting (February 2012).

Product: *Stakeholder Advisory Committee*
The SAC includes representatives of growers, agricultural industry, commodities, citizen groups, state, and federal agencies (Appendix C). This group is dynamic and growing. Communication with this committee is coordinated by PI's Steve Petrie and Chad Kruger and our Project Manager Dianne Daley Laursen. Representatives of the SAC were instrumental in our February, 2011 Planning Meeting and attended our May, 2011 Launch Meeting. Objective teams have drafted responses to SAC questions and concerns. These are incorporated into a SAC program panel at our upcoming annual meeting Feb.29-Mar. 2, 2012 in Pendleton, OR.

Events: *Project-wide presentations*

- ✓ Walden, V. C. Kruger and J. Adam, Carbon Nation panel discussion, Pullman, WA November 9, 2011
- ✓ Eigenbrode, S.D. REACCH Project Overview, Sustainable Corn, Iowa Corn CAP Annual Meeting, Chicago, IL, Nov. 9, 2011
- ✓ Eigenbrode, S.D. Vigilant management strategies to guard against insect pests as climate and weather patterns shift. Spokane County Crop Improvement Association, Spokane, WA, Nov. 19, 2011

- ✓ Eigenbrode, S. D., Abatzoglou, J. T., Antle, J., Burke, I. C., Capalbo, S., Gessler, Pl, Huggins, D. R., Johnson-Maynard, J., Kruger, C., Lamb, B. K., Machado, S., Mote, P., Painter, K., Pan, W., Petrie, S., Paulitz, T. C., Stöckle, C., Walden, V. P., Wulfhorst, J. D., Wolf, K. Regional Approaches to Climate Change for Inland Pacific Northwest Cereal Production Systems American Geophysical Union Meeting, Dec. 2011, San Francisco, CA. (This poster was also presented in Chicago November 2011)
- ✓ Eigenbrode, S. D. Notes from a basically applied scientist, University of Idaho Humanities Series, Jan 24, 2012, Moscow, ID
- ✓ Eigenbrode, S. D. The REACCH project gets moving. Pacific Northwest Direct Seed Conference, Feb. 9, 2012, Spokane, WA
- ✓ Eigenbrode, S. D. Climate change and PNW agriculture. Department of Geography, University of Idaho, Feb. 14, 2012 , Moscow, ID

Events: *Meetings*

- ✓ Planning Meeting, Tri-Cities, WA, Feb. 23-25, 2011
- ✓ Launch Meeting May 10-11, 2011 Moscow, ID, sixty climate related posters were presented.
- ✓ First Annual Meeting, Pendleton, OR, Feb 29-March 2, 2012, planning completed
- ✓ Twenty-five bi-weekly Project Leadership meetings
- ✓ Eight annual meeting planning committee meetings
- ✓ Bi-weekly assessment/evaluation conference calls between Project Evaluator, Director and Manager since November 2011
- ✓ Executive Committee (4 institution leads) conference calls as needed
- ✓ Objective and cross objective team meetings bi-weekly and/or as needed
- ✓ Monthly meetings with NKN and REACCH staff on CI and personnel resource needs

Activities*: Personnel*

- ✓ Hired Project Manager, September, 2012
- ✓ Hired Environmental Data Manager, November, 2012
- ✓ Extension Educator position in the UI Human Resources process, will be announced in February 2012
- ✓ Part-time Education Educator position description drafted, in process with UI Human Resources.

Events: *Policy Maker Briefings*

- ✓ Briefings for Idaho Representatives Simpson and Labrador and Idaho Senators Crapo and Risch, February 2011
- ✓ Briefing to Representative Simpson to describe regional climate projects, including REACCH, August 2011
- ✓ Sanford Eigenbrode briefing with John P. Revier, staffer for ID Congressman Simpson, October 2011
- ✓ REACCH included in UI briefings to all four Idaho Congressional members to encourage sustained funding, October 2011

Events: *Institutional Coordination*

- ✓ Sanford Eigenbrode meets periodically with University of Idaho VPR McIver
- ✓ REACCH personnel were part of a team of scientists convened by the Vice Presidents for Research for WSU, UI and OSU to promote cross-institutional partnerships in thematic research areas, including climate change.
- ✓ UI VPR staff met with Vice Presidents for Research at Oregon State University and University of Washington to explore regional cooperation in data management in support of NW regional climate science (including REACCH). November-December, 2011

Activities: *Underrepresented Audiences*

- ✓ Tribal farms are involved with our research experiments and with successful adoption of best farming practices. In YR 1 we interacted with Kevin Hudson, Tribal Farming Manager for the Confederated Tribes of the Umatilla Indian Reservation, Pendleton, OR. Kevin is on our SAC and will attend our annual meeting.
- ✓ Our Project Manager hired this year is a member of the Chickasaw Nation.
- ✓ In Oct., 2011, we engaged with Dr. Dr. Daniel R. Wildcat, Haskell Indian Nations University, exploring common scientific interests and summer REU's.
- ✓ We have initiated a partnership with Columbia Basin College, a minority serving (primarily Hispanic) institution to engage students in project research and education.
- ✓ Teachers from minority serving K-12 schools participated in our teacher's survey (Objective 6).
- ✓ Recruitment outreach targeting students in underrepresented groups for our graduate level assistantships and undergraduate research experiences.

Activities: *Central Desktop*

The REACCH project uses Central Desktop (http://www.centraldesktop.com), and on-line collaboration tool for all elements of internal project coordination within and between project management and the objective and science team leads. Central Desktop provides us mechanisms to:

1. Monitor, document, and track accountability of the overall project milestones and deliverables
2. Maintain communication among all researchers, research facilities, students, and institutions throughout the project
3. Develop a repository for all activities, processes, outputs, and discussions within objective teams
4. Enhance cross project integration as all members of the team can visit workspaces in any area and keep current on all the aspects of the project
5. Facilitate scheduling and calendar coordination across the project
6. Can provide an instantaneous real-time snap shot of the project status
7. Allows NIFA program manager Michael Bowers access to project activities

Activities: *Standardized Operating Procedures*

- ✓ Authorship guidelines were adopted
- ✓ A Citation Style Guide was adopted
- ✓ Protocols were developed for categorizing and filing data on CD
- ✓ REACCH was instituted as a sub-department in the UI College of Agricultural and Life Sciences with its own administrative and budgeting functions
- ✓ Templates were developed for poster and PowerPoint presentations
- ✓ Printed and electronic materials and a new REACCH logo were created
- ✓ Meeting calendars were adopted with agenda and participant standards
- ✓ Cross-project sampling protocols were identified

Products: *Popular Press*

- ✓ REACCH has been featured in 12 popular press media stories in local newspapers, Alaska Airlines magazine, and other publications. (Appendix D).

Milestones and Deliverables

There are no milestones and deliverables assigned specifically to project management in YR 1. The organizational structure and procedures outlined in the grant proposal have been accomplished as outlined in this report section.

During our annual meeting Feb. 29-Mar. 2, 2012, we will solicit input from our team to develop milestones and deliverables for YR 2 for project management.

Broad Impacts

Outcomes and impacts, defined as changes in knowledge, actions or conditions, have been limited in YR I because our project is just beginning. REACCH has been an essential potential partner on numerous grant proposals across the region (Appendix A) and thus has the potential impact for increasing the research capacity of the region. REACCH has enhanced the capabilities, collaborations, and cross disciplinary of work of numerous ongoing and newly initiated agriculture and climate change programs such as the Northwest Climate Center, the Northwest Knowledge Network, Climate Friendly Farming and Bio-Earth among others. In partnership with Sustainable Corn, the climate CAP led by Iowa State University, and PINEMAP, the southern pine CAP, led by the University of Florida, REACCH is pioneering new large grant delivery mechanisms within USDA NIFA.

Training

Internal Training

- ✓ At our launch meeting several internal workshops were held for REACCH Project members and stakeholders including: **(1)** Modeling Climate Change Impact and Adaptation using Minimum-Data Tradeoff Analysis, organizers John Antle and Susan Capalbo; **(2)** Successfully Dealing with the Media, organizer Steve Petrie.
- ✓ Three internal training sessions have been held on Central Desktop, one each at UI, WSU and OSU. Training focused on organizing data on CD according to our Logic Model: activities, inputs, output outcomes, impacts, and integration.
- ✓ The Environmental Data Manager has met with all objective team leads and conducted one workshop to assess data management needs and inform participants of capabilities.
- ✓ Undergraduate and graduate students are invited to give presentation during our bi-monthly Project Leadership calls.

External Training

- ✓ In Sept., 2011 REACCH personnel participated in the Opportunities and Challenges for Scientists in a Changing World: A Communications Workshop held at the University of Idaho and organized by Nancy Baron and her team from Compass On Line.
- ✓ In October, 2011 REACCH participated in The 11th Annual Distinguished American Indian Speakers Series at the University of Idaho, welcoming Dr. Daniel R. Wildcat. Wildcat's presentation, "After Progress: Enacting Systems of Life Enhancement," looked at how people impact the planet and drew upon ancient Native American wisdom and nature-centered beliefs to advocate a modern strategy to combat global warming. Dr. Wildcat met privately with several REACCH members during his visit.
- ✓ On Nov.9, 2011 REACCH PI's and collaborators participated in a panel discussion following the screening of "Carbon Nation" at WSU with a crowd of over 500 (which is the second largest turnout for a "Carbon Nation" screening, according to Peter Byck, the director of the film and special guest speaker.
- ✓ REACCH is a co-sponsor of the *Interdisciplinary Climate Change Spring 2012 Seminar Series* at the University of Idaho, Spring, 2012. The seminar series consists of 15 regional, nationally, and internationally renowned speakers, including several REACCH PI's. Seminars are free and open to the University of Idaho community and the public.
  https://sites.google.com/site/interdisciplinaryclimatechange

Collaboration and "Integrated" Knowledge

Integrated collaborations within our project are just beginning. The REACCH Project regularly meets with the Project Directors, Managers, Evaluators, and Environmental Data Managers from PineMap (led by the University of Florida) and Sustainable Corn CAP (led by Iowa State University). These interactions facilitate improved project management and communication on the national level to the funding agency, USDA NIFA. Collaborating partners are regularly invited to Project Leader bi-monthly telephone calls, including Bio-Earth (http://www.cereo.wsu.edu/bioearth/) and Climate Friendly Farming (http://www.cereo.wsu.edu/bioearth/).

The Toolbox Project (http://www.cals.uidaho.edu/toolbox/) contributed to the REACCH Launch Meeting in two ways: first, Michael O'Rourke (UI, Philosophy) gave a presentation to the meeting as a whole describing the Toolbox workshops and their role in the center, and second, O'Rourke and two members of the Toolbox Project conducted parallel, introductory workshops during the project Launch Meeting. These workshops included participation from those in attendance at the launch meeting, who spent 90 minutes discussing their research worldviews in collaborative dialogue.

Plan of Work for YR 2

- ☐ Project Management will utilize Gantt charting to track interdisciplinary project milestones and deliverables
- ☐ We will respond to assessment/evaluation feedback from our team members from YR 1. We believe we will implement changes to our Project Leader calls and other management functions. See Assessment section.
- ☐ We will host some of our SAP in the summer of 2012 for field and research site visits
- ☐ The Project Director, along with others, will conduct visits to Capitol Hill in Washington DC to raise awareness of the REACCH project.
- ☐ A service level agreement with NKN will be implemented to enhance our cyberinfrastructure.
- ☐ The reacchpna.org website will be launched and targeted at stakeholder audiences.
- ☐ Additional personnel will be hired to complete the staffing organization chart of REACCH.
- ☐ REACCH is co-hosting the NW Climate Center annual conference to be held in Boise, ID in October, 2012

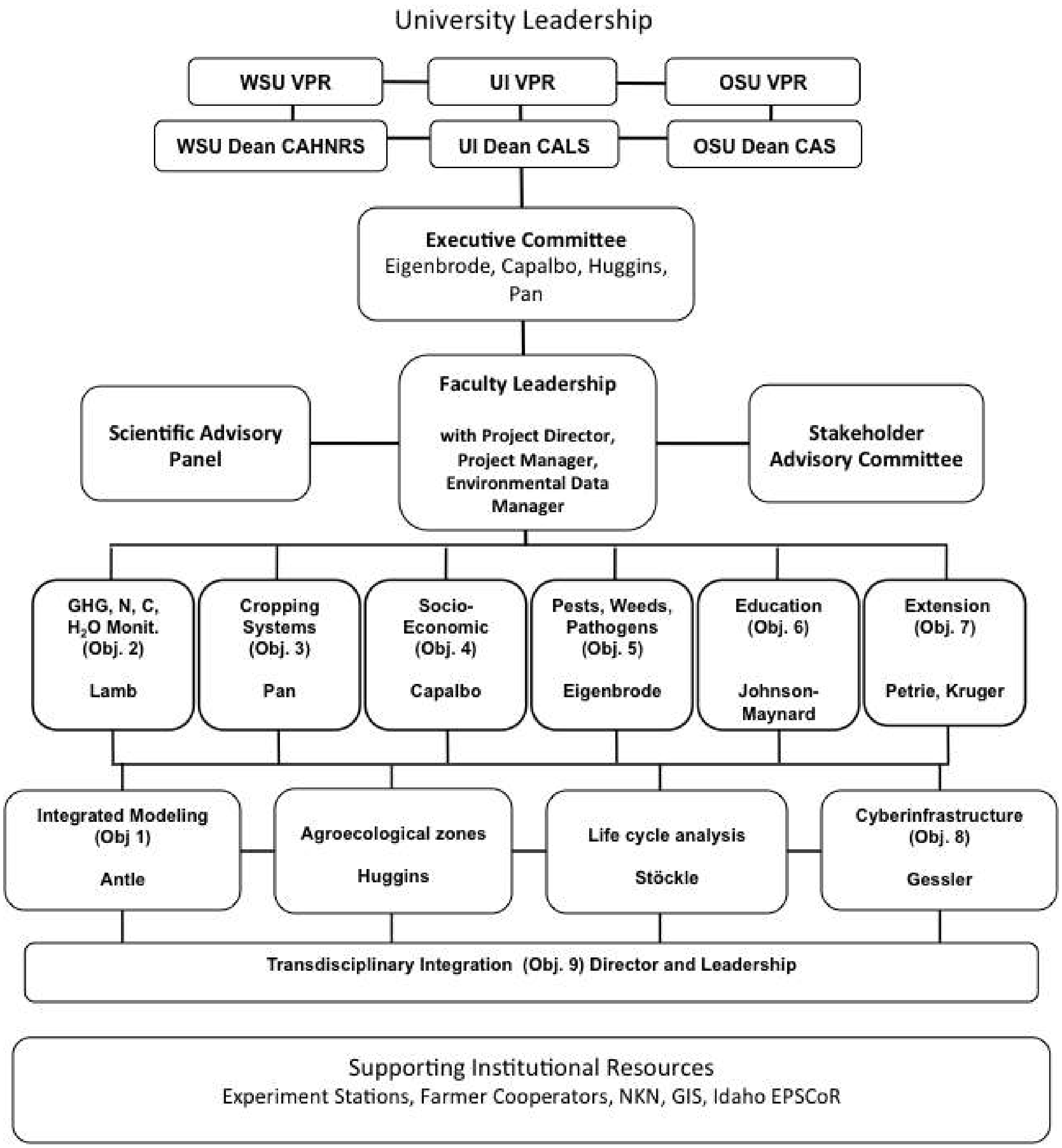

Figure 1. The REACCH organizational structure is designed to provide oversight and coordination of project activities, to ensure accountability for project deliverables, to maintain open communication with institutional administrators and to incorporate input from stakeholders throughout project implementation.

Executive Summary

Lead: John Antle, john.antle@oregonstate.edu

The goal of the Objective 1 team (Team 1) is to develop a conceptual and operational framework for carrying out coordinated climate, crop and economic modeling of the climates.

Achievements

Activities for YR 1 focused on team organization, and developing the building blocks of the CM approach (Figure 2), involving groups represented on our team: Agro-ecozone (AEZ) modeling (AE), climate data and modeling (CM), the CropSyst model for crop system simulations (CS), and the TOA-MD economic model for economic and environmental impact assessment (TOA).

Team 1 participated in regular Project Leadership meetings. Walden also represented the cyber-infrastructure team for Objective 8. Our work involved preparation of historical climate data, downscaled climate modeling, cyber-infrastructure, and education. These data were made available to the project and for the implementation of a preliminary crop and economic model analysis of the wheat-fallow system.

The CS group focused on preparing the climate data from the CM group, and land use and soil data, to implement the CropSyst model for the REACCH region, designing a model output format for use by TOA, and implementing model runs for wheat-fallow systems.

The TOA group's work involved acquiring access to agricultural census and ARMS data, data analysis, conceptual model development, and development of technology and socio-economic scenarios, and graduate student training. Accomplishments included: preparation of census data and documentation; parameterization of the TOA-MD model for the wheat system using the census data; preparation of a draft manuscript on RAPs (scenarios for simulation modeling).

Team 1 also was involved in coordination with the Objective 4 team for simulation modeling technology scenario design. Major accomplishments were preparation of a preliminary simulation analysis of the impacts of climate on the wheat-fallow system in the REACCH region, and design of technology scenarios.

YR 2 Planned Activities

The climate team will work towards M1.2a, the selection of GCMs and scenarios important to the REACCH project, to devise a representative set of climate scenarios. The team will also work toward a publication that addresses observed and projected changes in physical climate pertinent to Pacific Northwest agriculture. Observed and projected climate scenarios will be incorporated into the cross-project AEZ related activity. CS group will continue to setup and run CROPSYST to meet deliverables 1.2b, 1.3a, 1.3.b. The TOA group will continue to prepare census data and establish socio-economic scenarios for deliverables 1.2 and 1.3. Antle will finalize publication on scenarios, and will begin to develop publications on using census data with TOA model to analyze climate impacts.

Outcomes/Impacts YR 1

No outcomes/impacts to report for YR1, because this objective is producing integrated modeling with outputs coming later in the project.

Outputs YR 1

Products: *Publications completed and in preparation*
- ✓ Abatzoglou, JT, Development of gridded surface meteorological data for ecological applications and modeling, International Journal of Climatology, in press
- ✓ Antle, J.M. 2011. Representative Agricultural Pathways for Agricultural Model Inter-comparison and Impact Assessment. In preparation.

Events: *Presentations*
- ✓ Antle, J.M. Representative Agricultural Pathways. Presentation at a workshop, The Nature and Use of New Socioeconomic Pathways for Climate Change Research, National Center for Atmospheric Research, Nov 2-4 2011, Boulder, CO
- ✓ Antle, J.M. Workshop on TOA-MD Modeling for Climate Impact Assessment. June 15-17, 2011, Oregon State University. Participants were 12 faculty and graduate students at OSU, including PhD student Hongliang Zhang working for REACCH, Penny Diebel, OSU professor and REACCH collaborator, Susan Capalbo, REACCH co-PI.

Events: *Meetings*
- ✓ Objective team conference call, July 22, 2011
- ✓ Objective team meeting, August 19, 2011, Columbia Basin Research Center, Pendleton, OR (meeting report on CD)
- ✓ Objective team meeting, February 10, 2012, Columbia Basin Research Center, Pendleton, OR, with Objective team 4

Milestones and Deliverables

Milestone added: 1.1c: Develop Socio-economic scenarios, due Nov 2012.
All other milestones achieved on schedule (1.1a and 1.1b).

M1.1a *Downscaled climate scenario incorporated into transdisciplinary framework*
- ✓ Created one model/scenario of downscaled meteorological data for integrating into Objective 1 transdisciplinary framework. Abatzoglou communicated in detail with members of the CM team to ensure data produced by the climate modeling group could be incorporated across the Objective 1 framework.
- ✓ The downscaled data from the CMIP3 models are currently available at INSIDE Idaho via various different access protocols.
- ✓ Both the MACA and BCSD downscaling codes were ported to the High Performance Computing (HPC) Center at the Idaho National Lab (INL).

M1.1b *Ag census and other data identified and prepared*

- ✓ Access to agricultural census data was obtained at NASS office in Portland by Antle and grad student Zhang. Data were reviewed and SAS programs written to compute statistics needed to parameterize the TOA-MD model for wheat systems. Documentation and summary statistics prepared and uploaded to Central Desktop.

M1.2b *Cropping systems characterized for economic modeling*

- ✓ A proof-of-concept analysis was designed and is being implemented for the wheat-fallow system (WF-1). Preliminary results are being prepared for presentation at the 2012 annual meeting. An Objective 1 meeting was held in August 2011 and report produced.
- ✓ Antle attended a meeting organized by the National Center for Atmospheric Sciences in Boulder, CO, in November 2011 on socioeconomic scenarios, and made a presentation on RAPs and their linkage to SSPs. A draft manuscript on this topic was prepared. A meeting of Objective teams 1 and 4 members was planned for Feb 10, 2012 to discuss technology and socioeconomic scenarios for the REACCH project.

D1.2a *GCM outputs translated to scale needed for agroecological models*

- ✓ Abatzoglou developed a historical gridded surface meteorological data at scales needed for agroecological modeling, and has used this dataset as the basis to translate GCM data to scales needed for climate change modeling efforts.

Broad Impacts

This objective is working to conduct simulation modeling of climate impacts and adaptation. Therefore, most of the impacts of this work will come later in the project when most of the milestones and deliverables occur.

Training

- ✓ Walden conducted a half-day workshop for IGERT students (plus some interested faculty) on how to access downscaled climate model data using the OPeNDAP protocol and our new ArcGIS toolbox via INSIDE Idaho. This was in collaboration with Rick Rupp from WSU, a member of the CI team in Objective 8.
- ✓ OSU Ag& Res Econ PhD student Hongliang Zhang joined the project in June 2011. He is developing programs to analyze agricultural census data, and he has been trained to use the TOA-MD model.
- ✓ YR 1 graduate student Sihan Li (supported in part by REACCH) is examining results of the new super ensemble of 25-km regional climate model simulations for western US using volunteer computers.
- ✓ Training for graduate students and faculty collaborators in use of the TOA-MD model was provided in a 2-day workshop at OSU in June 2011.

Collaborations and "Integrated" Knowledge

- ✓ Collaboration among members of Objective Team 1 to link climate data, crop model simulation, and economic model simulations.
- ✓ Collaboration between members of Objective Teams 1 and 4 to develop climate, technology, policy and socio-economic scenarios for the integrated modeling.
- ✓ J. Antle is co-leader of the economics team of the Agricultural Model Inter-Comparison and Improvement Project AgMIP. AgMIP is conducting global agricultural economic model inter-comparisons, and Antle will acquire data from that exercise to design price scenarios for the REACCH regional scenarios.

Plan of Work for YR 2

- ☐ The climate team will work towards M1.2a, the selection of GCMs and scenarios important to the REACCH project, to devise a representative set of climate scenarios.
- ☐ We will continue to create downscaled climate scenarios from the models deemed representative for the study area (M1.1a, D1.2). These scenarios will be based on the new CMIP5 model output, which we are currently assembling.
- ☐ We will also work toward a publication that addresses observed and projected changes in physical climate pertinent to Pacific Northwest agriculture.
- ☐ Observed and projected climate scenarios will be incorporated into the cross-project AEZ related activity.
- ☐ CS group will continue to setup and run CROPSYST to meet deliverables 1.2b, 1.3a, 1.3.b.
- ☐ OA group will continue to prepare census data and establish socio-economic scenarios for deliverables 1.2 and 1.3.
- ☐ Antle will finalize publication on scenarios, and with Zhang will begin to develop publications on using census data with TOA model to analyze climate impacts.

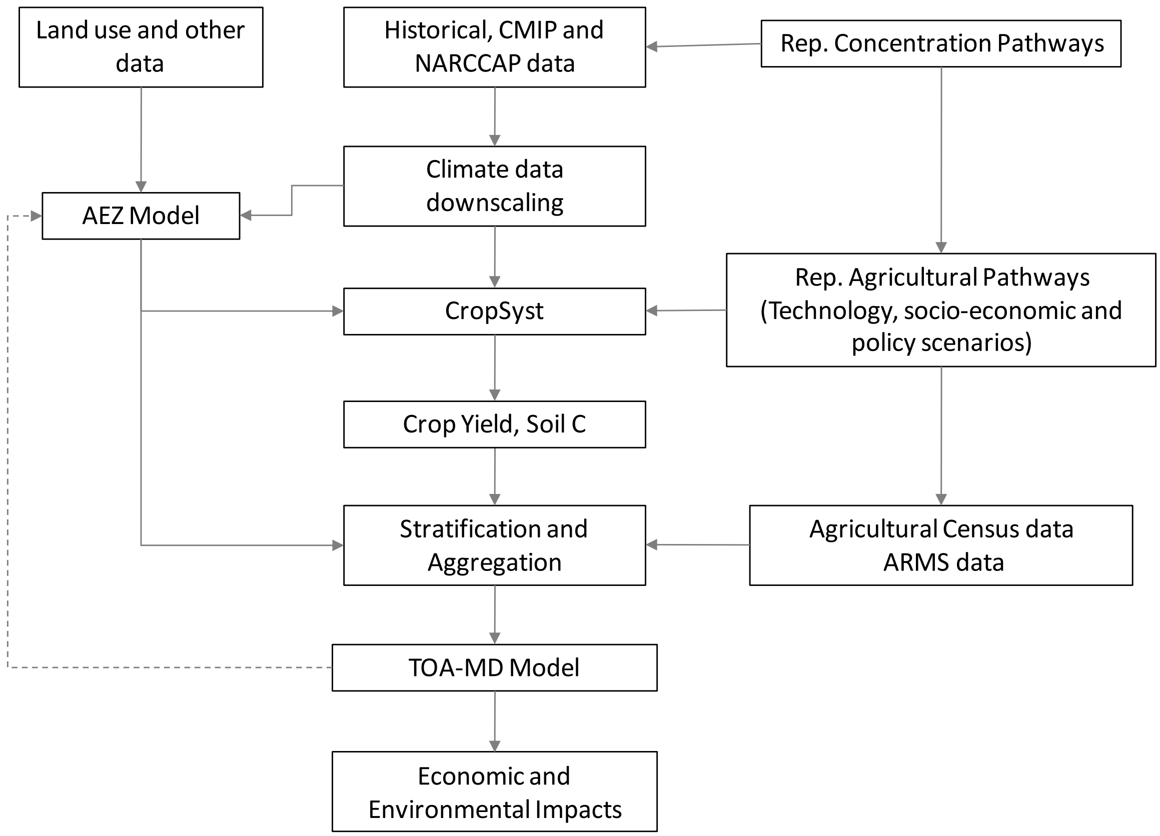

Figure 2. Framework for coupling of the AEZ Model, Climate Data, the CropSyst model, and the TOA-MD economic model

Executive Summary

Lead: Brian Lamb, blamb@wsu.edu

The goal of Objective team 2 is to establish a baseline and monitor changes in soil carbon, nitrogen levels and GHG emissions related to mitigation of and adaptation to climate change in the region's agriculture.

Achievements

Objective 2 is focused on monitoring greenhouse gas (GHG) fluxes to establish a baseline for carbon sequestration and N_2O emissions for current crop management practices and to investigate how GHG fluxes change for selected management alternatives. The approach is to use micrometeorological and chamber-based methods to directly measure $CO_2/H_2O/N_2O$ fluxes over representative fields within the region and to also measure, at selected sites, the loss of C and N due to wind and water erosion. During the first year of the program we developed specifications and plans for deployment of flux tower systems at six proposed locations, static chambers at one location, installation of water erosion instruments at two sites and wind erosion samplers at one site. In August 2011, we installed the first flux tower system at the WSU Cook Agronomy Farm (CAF) no-till site near Pullman, WA. In November 2011 we installed a second flux tower system near the WSU Lind Experimental Research Farm over a wheat/fallow field. Coupled with the flux tower system at CAF, we installed 64 static chambers on a micro-plot study with N, glucose and water treatments. We began development of data reduction and analysis methods for these flux data streams, and we compiled preliminary flux results from the two flux tower sites and the chamber site. We conducted initial N_2O and CH_4 flux measurements at the CAF site during a 10-day period in late October, 2011. We recruited a post-doctorate, Dr. Kirill Kostyanovsky, to conduct chamber-based gas flux studies. We purchased additional hardware and instrumentation for the remaining four flux tower systems.

Two field-scale (1 km^2) catchments, the CAF and a field managed under conventional tillage practices, were selected and instrumented with event-based water sampling capabilities to quantify sediment, and inorganic N loading. Both a tile line and surface runoff monitoring station was installed at the CAF to compare surface and subsurface transport of C and N. Event-based water sampling was also initiated at the outlet of a 40 km^2 watershed located downstream of the field-scale conventional tillage site. Initial sediment and nitrate-N loading estimates were calculated at the watershed-scale site using existing data. Plans were developed for installation of wind erosion samplers at the Lind site during the spring 2012. We recruited a student to conduct C and N analyses of archived wind erosion samples as a basis for developing a longer term record of C and N losses due to wind erosion.

YR 2 Planned Activities

The major focus for YR 2 is to complete the deployment of the flux tower systems. The team will continue the chamber-based microplot study and initiate wind erosion measurements at the Lind site. The team will also continue the water erosion deployment and measurements. The team will develop data processing and analysis procedures for the flux and related data and initiate a real-time web site that displays flux data.

Outcome/Impacts YR 1

There are no outcomes/impacts to report at this time since it is early in the project and we have spent this year getting instruments installed and running.

Outputs YR 1

Products: *Publications submitted*

- ✓ Manuscript submitted: Stöckle, C., Higgins, A., Kemanian, R., Nelson, D., Huggins, J., Marcos, H., Collins. Carbon storage and nitrous oxide emissions of cropping systems in Eastern Washington: A simulation study. Submitted to Journal of Soil and Water Conservation, Dec. 2011.

Events: *Meetings*

- ✓ Participation on bi-weekly Leadership Meeting
- ✓ Objective 2 Monitoring team meetings (every two weeks)
- ✓ Sub-team meetings for students and faculty in the Laboratory for Atmospheric Research for detailed discussions of monitoring plans and progress

Milestones and Deliverables

- ✓ A draft Standard Operating Procedures (SOP) document for the flux tower systems was written.
- ✓ For the CAF no-till site, CO_2 and H_2O fluxes and related meteorological data were measured and the data sets compiled for the period from August 15, 2011 through December 31, 2011. Preliminary results were presented at Project Leadership meetings and uploaded to Central Desktop.
- ✓ For the Lind wheat/fallow site, CO_2 and H_2O fluxes and related meteorological data were measured and the data set compiled from November 1, 2011 through December 31, 2011. Preliminary results were presented at Leadership meetings and uploaded to Central Desktop.
- ✓ Preliminary flux data using fast N_2O and CH_4 instruments were obtained at the CAF no-till site during 10 days in November, 2011. Analysis of these data is ongoing.
- ✓ A microplot experiment with four N levels, two glucose levels, two water levels replicated four times in a split-plot design was field-deployed following winter wheat planting in November, 2011 at CAF with 64 automated gas-flux chambers and supportive environmental monitoring equipment. Analyses of these data are ongoing.
- ✓ Carbon and nitrogen sampling was initiated at field-scale and watershed-scale sites. Nitrogen and sediment load estimates were calculated at the Paradise Creek stream gauge station using existing data sets. Analysis of these data is ongoing.

Objective 2: Monitoring

Following the development of monitoring plans for the flux tower, chamber-based and erosion systems, the milestones/tasks and deliverables were updated and uploaded to Central Desktop.

M2.1 *Tower flux site and chamber-based operations and analysis*

2.1.1 Obtain instrumentation, identify sites and deploy flux systems

- ✓ Purchased 6 flux systems and 64 automated chamber-based systems
- ✓ Identified sites: CAF no-till, CAF conventional till, high rainfall Idaho site, and Lind dry fallow sites
- ✓ Prepared Standard Operating Procedures document for tower deployment and operations (in draft form)
- ✓ Tested and deployed 2 flux systems and 64 chamber-based systems
- ✓ Purchased one N_2O instrument

2.1.2 Operate systems, maintain QA systems, and archive raw and initial processed data

- ✓ CAF no-till site flux tower operated continuously and data compiled from August through December 2011
- ✓ Preliminary tests for measuring N_2O and CH_4 fluxes were conducted at the CAF site
- ✓ Lind wheat/fallow site flux tower operated continuously and data compiled from November through December 2011
- ✓ CAF chamber study deployed and operating from December, 2011 through present and coordinated with the USDA-NIFA Site-Specific Climate-Friendly Farming project

2.1.3 Data analysis and presentation (final QA, web presentation, final data archival, post-processing for data products)

- ✓ Monthly, routine data processing completed for the two flux tower sites and one chamber site.
- ✓ Analysis of the N_2O tests for flux tower results was initiated

M2.2 *Wind erosion measurements and analysis*

2.2.1 Obtain instrumentation, identify sites and deploy systems

- ✓ Obtained six soil erosion profile samplers and wind speed profile system; prepare for deployment
- ✓ Identified historic wind erosion events having sufficient soil for N determination
- ✓ Prepared to conduct N analysis on current and historic samples

M2.3 *Water erosion measurements and analysis*

2.3.1 Field-scale monitoring

- ✓ Identified two field-scale (~1 km^2) catchments: WSU CAF and a privately owned conventional tillage site north of Moscow, ID separated by roughly 10 km.
- ✓ Installed flumes for continuous measurement of surface runoff (December 2011) and tile line flow (July 2011) from the CAF.
- ✓ Automated water samplers were installed at each site to allow for event-based water sampling.

- ✓ As a collaborative effort with the USDA-NIFA Site-Specific Climate-Friendly Farming project, suction-cup Lysimeters and shallow wells were installed at the CAF to track nitrate movement throughout the catchment.
- ✓ Water samples were analyzed from dissolved organic C, total N, nitrate, and ammonia.
- ✓ Installed a flume and automated water sampler at the Idaho conventional tillage site (January 2012).

2.3.2 Watershed-scale Monitoring

- ✓ Identified the Paradise Creek stream gauge station as the primary watershed-scale site for monitoring C and nitrate loading.
- ✓ Water samples from a paired stream gauge station located downstream of the city of Moscow were also analyzed for dissolved organic C which allows for a comparison between C loading from rural and urban sources
- ✓ Carbon analysis of event-based water samples at the Paradise station was initiated in July 2011.
- ✓ The Palouse River stream gauge station at Hooper was selected as a regional-scale sampling location
- ✓ Monthly sampling was initiated at this location in August 2011.

2.3.3 Field data analysis

- ✓ Data collection did not start until late summer and therefore C load could not be calculated.
- ✓ Existing event-based water sample and flow data at the Paradise Creek stream gauge data indicated that 700 Tonnes of suspended sediment and 24 Tonnes of nitrate-N were delivered during the 2011 water year.
- ✓ Preliminary data indicate that the tile lines likely provide a relatively constant source of dissolved organic C to regional streams.
- ✓ Preliminary data also indicate increasing C loading from the city of Moscow.
- ✓ Historic data collected at the Palouse River gauge at Hooper suggest a slight decreasing trend in total organic C load from 1992-2003.

M2.3.4 *Soil erosion modeling across spatial scales*

- ✓ Historic data collected at the Palouse River gauge at Hooper suggest particulate organic C can be linearly related to suspended sediment concentration during peak flow events
- ✓ No significant modeling results to report at this time.

Broad Impacts

Preliminary results from the CAF flux measurements were used in lectures to the Nitrogen Cycling and Nitrogen Methods graduate courses at WSU that are part of the WSU IGERT program, entitled Nitrogen Systems: Policy-oriented Integrated Research and Education (NSPIRE). The REACCH program was used as a foundation for development and submission of a pre-proposal to the NSF Sustainability Research Network (SRN) program. REACCH was also described as leverage for a NSF Research Experience for Undergraduates (REU) site proposal submitted by WSU.

Training

Two PhD Students, Sarah Waldo and Jinshu (Jackie) Chi, were recruited to work on the Monitoring team. They are being trained in the deployment, operation, and data reduction steps for the flux tower systems. An undergraduate researcher, Laurel Graves, was recruited, and she is beginning to work on analyses of archived wind erosion samples for N and C losses. A MS student, Ryan Boylan, was recruited to assist in collection and analysis of carbon loading from the field-scale and watershed-scale catchments. A post-doctorate, Dr. Kirill Kostyanovsky, was recruited for the chamber-monitoring study, starting employment on Feb. 1, 2012.

Collaborations and "Integrated" Knowledge

The primary activity in terms of integration and collaboration was close cooperation between the Objective 2 Monitoring team and the Objective 3 Cropping Systems team. In particular, the deployment of the 64 automated static chamber experiments at the CAF no-till site was closely coordinated to be near the flux tower, but to avoid interference from the generator exhaust.

Plan of Work YR 2

- ☐ The major focus for YR 2 is to complete the deployment of the flux tower systems
- ☐ Continue the chamber-based microplot study
- ☐ Initiate wind erosion measurements at the Lind site
- ☐ Continue the water erosion deployment and measurements
- ☐ Ongoing development of routine data processing and analysis procedures for the flux and related data
- ☐ Work has been initiated to create a real-time web site where the flux data will be displayed.
- ☐ We plan to present initial flux data at the Biogeochemical Cycling Symposium sponsored by the American Meteorological Society in Boston in May 2012.

Executive Summary

Lead: Bill Pan, wlpan@wsu.edu

REACCH cropping systems (CS) Objective 3 is focused on quantifying and projecting the effects of current and potential alternative cropping systems and innovative technologies on carbon, nitrogen, water, and energy flows and budgets. Research is being coordinated directed at refining and implementing best management practices related to these cropping system management tools, identifying management impacts on carbon and nitrogen flows and GHG emissions, developing win-win scenarios by identifying short and long term benefits of shifting C, N flows through these systems, and improving cropping system flexibility for adapting to climate change.

Achievements

A network of existing and new field CS experiments has been identified and/or established over the study region for comparative assessment of alternative agronomic adaptation and GHG mitigation practices in wheat-based systems. Production system alternatives for specific AEZs are related to residue management, crop diversification and intensification, N fertilizer management, and recycling C, N byproducts. Fifteen experiments at 11 locations are distributed amongst the major AEZs across the tri-state region. Nitrogen management will focus on best management practices and site-specific approaches, tailored to the most appropriate wheat class and variety for the AEZ. Reduced tillage or direct seeding will be emphasized in all systems. Finally, opportunities and benefits of manure and biosolids will be explored throughout the region. All of these approaches have potential long-term implications for climate change mitigation and adaptation, as well as yielding short-term economic, environmental and agronomic benefits.

Local CS site leaders/scientists for each experiment were identified and/or integrated into the Objective 3 team. A CS coordinator, Jolene Mwangi, collected/organized plot plans, experiment operation details, pictures, past publications, oversaw establishment and execution of fall soil and plant sampling, storage for C, N, and biomass analysis. Lauren Young joined the team in April. Additional cross-disciplinary PI's include Claudio Stöckle, Dave Huggins (AEZ), Steve Petrie (Objective 7, Extension) and Kate Painter (Objective 4, Economic and Social). Suggestions for survey questions concerning cropping systems management were provided to Dr. Painter and incorporated into the survey that is ongoing. The CS team drafted potential short term and long-term win-win scenarios for providing a basis for hypothesis testing and for future outreach discussions with farming and environmental communities.

YR 2 Planned Activities

The team will identify experiments that are amenable to chamber gas monitoring of management variables, process, analyze soil and plant samples from 2011 experiments, establish protocol for soil C fractionation on spring soil samples, continue field experiments, collect samples and conduct soil and plant analyses necessary for constructing C, N budgets, and analyze systems for water and N use efficiency and carbon, energy flows, and other agroecological indictors. The team will also gather existing wheat-N response data, establish new site-specific N experiment at Wilke Farm and integrate closely with AEZ mapping and modeling research on regional C, N flows.

Outcomes/Impacts YR 1

At this early stage, impacts are mainly centered on increased grower, agency and student knowledge of crop management alternatives and their potential beneficial impacts on system productivity and reduced environmental impacts.

Outputs YR 1

The key Cropping Systems team extension presentation outputs and outcomes for the first year of the program include the following, organized by the four CS variables/technologies:

Products: *Technology: No-till agriculture, residue management*

- ✓ Esser, A. D. and A. Kennedy. Presentation on changes in the soil on long-term direct seeded systems. Northern Lincoln County Field Day, June 21, 2011, Wilbur, WA
- ✓ Esser, A.D. J. Brown, and D. Robertson. Incorporating canola into no-till and conventional cropping systems. Variety Test Plot Tour, June 22, 2011, Davenport, WA
- ✓ Huggins, D. No-till agriculture: equipment, soil and pest issues, Jan. 3-4, 2011, Choteau, Shelby and Great Falls MT
  - *Consumer/user:* 200 growers, researchers, agency and agribusiness people
- ✓ Huggins, D. Wheat residue harvesting or burning impacts on crop yield, soil nutrient removal and availability and soil C storage, Jan. 20, 2011, Richland, WA
  - *Consumer/user:* 30 STEEP researchers and grower/industry advisory group
- ✓ Huggins, D. Field burning effects on nutrient losses and crop productivity, Feb. 8, 2011, Spokane WA
  - *Consumer/user:* WA Dept. of Ecology Field Burning Task Force
- ✓ Huggins, D. Surface residue management effects on soil water storage, March 2, 2011, Reno, NV
  - *Consumer/user:* 300 growers, agribusiness, educators, consultants
- ✓ Huggins, D. Field burning effects on nutrient losses and crop productivity, June 16, 2011, Spokane WA
  - *Consumer/user:* WA Dept. of Ecology Field Burning Task Force
- ✓ Huggins, D. Presentation on field burning and residue harvest effects on nutrient losses and crop productivity, June 23, 2011, Pullman WA
  - *Consumer/user: 100 growers, educators, agribusiness and agency people*

Products: *Technology: Crop diversification and intensification*

- ✓ Burke, I. C. CRP Transition to Crop Production. Colfax Direct Seeders Meeting, December 15, 2010 and Whitman County Growers, January 3, 2011, Lewiston, ID
  - *Consumer/User:* 77 Growers, agency, agriculture industry advisors.
  - *Impact/outcome: Education on CRP transition past and future research, BMPs and issues*
- ✓ Esser, A.D. The WSU Wilke Research and Extension Farm Production and Economic Report. Wilke Farm Grower Meeting, December 15, 2011, Davenport, WA
- ✓ Huggins, D.H. Long-term no-till cropping system impacts on economics, weed and disease management, soil C sequestration and precision N management, STEEP Annual Review, Jan. 20, 2011, Richland, WA
  - *Consumer/user:* 30 STEEP researchers and grower/industry advisory group
- ✓ Pan, W., K. Sowers, D. Roe, organizers. Oilseed production workshops. Presentations on canola, camelina agronomics, economics, end uses by W. Pan, D. Huggins, B. Schillinger, A. Esser, A. Hammac, and several others. Jan 25, Okanogan, WA; Jan 26 Reardan, WA; Jan 27, 2011, Colfax, WA
  - *Consumer/user:* 250 growers, researchers, agency and agribusiness people
- ✓ Pan, W. Sustainable Aviation Fuel Northwest Planning Meeting. April 7, 2011. SEATAC, Seattle WA
  - *Consumer/user:* 50 aviation industry, military, biofuel industry, agency members of SAFN that drafted the May 25, 2011 SAFN report on recommended pathways towards sustainable aviation fuel
  - *Impact/Outcome:* The report is now available to the public from SAFN web site.
- ✓ Pan, W. 2011. Pan, W.L. Oil, Soil and the Big Boil: Agricultural systems, biofuels and climate change. Electrical and Mechanical Engineering Graduate Seminar, Chemical Engineering 401, Climate Change; April 5, WSU Pullman, WA
  - *Consumer/user:* 20 chemical engineering students
- ✓ Pan, W. and S. Ha. Growing a clean energy future. The power of renewable biofuels takes flight. WSU Innovators Luncheon, April 27, 28, 2011, Seattle, WA
  - *Consumer/user:* 60 biofuel industry, investors, agency, WSU supporters.
- ✓ Pan, W., S. Hulbert, H. Grimes. 2011. Networking with biodiesel industry. Jun 14, Pullman, WA.
  - *Consumer/user:* Wally Tempe and Joel Edmonds, owner and manager of Inland Empire Oilseeds, largest oilseed crusher and biodiesel production facility in eastern WA.
- ✓ Young, F. North central WA winter canola research field tours. Two farm fields, May 17 and Jun 15, 2011,Okanogan, WA
  - *Consumer/user:* 62 growers, oilseed industry, Colville tribal members, agency people

- ✓ Schillinger, W. Camelina varieties, N management, seeding date research review. Jun 15, 2011,WSU Dryland Research Station, Lind Field Day, Lind WA
  Consumer/user: 250 growers, researchers, agency and agribusiness people
- ✓ Hughes, M., Hulbert, S., Hammac, A. Oilseed research update. Jun 23, 2011,WSU Cook Agronomy Farm, Pullman, WA
  Consumer/user: 106 growers, researchers, agency people
- ✓ Hulbert, S., Young, F., H. Collins, W. Pan (organizing committee). Bioenergy crops. The future is now. Future Energy Conference and Bioenergy Research Symposium. Oct 18,2011, Seattle, WA
  Consumer/user: 60 biofuel industry, investors, agency personnel

Products: *Technology: Recycled C, N nutrients*

- ✓ Huggins, D. Conservation tillage and cropping systems for organic crop production in the Palouse, Feb 2,2011, Pullman, WA
  Consumer/user: 50 growers, agribusiness and agency personnel
  Impact/outcome: Education and increased awareness of conservation organic production systems suitable for the Palouse region

Products: *Technology: Nitrogen management systems*

- ✓ Hammac, A., R. Koenig, W. Pan. Nitrogen management and cycling in canola. Jan 25, 2011,Okanogan, WA; Jan 26, 2011 Reardan, WA; Jan 27, 2011, Colfax, WA
  Consumer/user: 250 growers, agribusiness and agency, Colville tribal personnel
- ✓ Huggins, D. Conservation farming impacts on soil quality and the application of precision technologies in the Palouse, Feb. 1, 2011, Pullman, WA
  Consumer/user: growers, agribusiness and agency personnel
- ✓ Huggins, D. N products used to reduce N losses and increase N use efficiency, Feb. 9, 2011, Pomeroy, WA
  Consumer/user: 60 growers, agribusiness and agency personnel
- ✓ Huggins, D. Strategies to improve N use efficiency in wheat, March 3, 2011, Reno, NV
  Consumer/user: 300 growers, agribusiness, educators, consultants
- ✓ Huggins, D. Evaluating N use efficiency, March 4, 2011, Pullman, WA.
  Consumer/user: 40 graduate students, educators
- ✓ Huggins, D. Precision farming: variable wheat density and N rates for increasing wheat yield. Presentation on precision farming technology research, June 23, 2011, WSU Cook Agronomy Farm, Pullman WA
  Consumer/user: 100 growers, educators, agribusiness and agency people
- ✓ Hammac, A. Nitrogen cycling in canola: implications for N management. June 23, 2011, WSU Cook Agronomy Farm, Pullman WA
  Consumer/user: 100 growers, educators, agribusiness and agency people

Product: *Presentation: Comprehensive:*

- ✓ Huggins, D. Agricultural mitigation of global climate change transfer: Presentation on how growers can help mitigate global climate change, March 16, 2011, Grangeville, ID

  Consumer/user: IASCD Division II meeting, 50 growers, agency people

Products: *Publications: Refereed extension bulletins, fact sheets, manuals*

- ✓ Kincaid, R., K. Johnson, J. Michal, S. Hulbert, W. Pan, J. Barbano, and A. Huisman. 2012. Intercropped biennial canola for silage. WSU Dairy Newsletter. 21:1.
- ✓ Koenig, R. T., W. A. Hammac, W. L. Pan. 2011. Canola growth, development and fertility. WSU Extension Fact Sheet FS045E.
- ✓ Sowers, K.E., R.D. Roe, and W.L. Pan. 2011. Oilseed Production Case Studies in the Eastern Washington High Rainfall Zone. WSU Extension Manual EM037E.
- ✓ Sowers, K.E., R.D. Roe, and W.L. Pan. 2011. Oilseed Production Case Studies in the Eastern Washington Low to Intermediate High Rainfall Zone. WSU Extension Manual EM (in press)
- ✓ Hulbert, S., S. Guy, B. Pan, T. Paulitz, B. Schillinger, D. Wysocki, K. Sowers. 2011. Camelina production in the dryland Pacific Northwest. WSU Extension Fact Sheet (in press)

Product: *Popular press*

- ✓ Young F.L. Building a lasting partnership – Small-scale canola biodiesel experiment may go big. 2011. U.S. Canola Digest. Vol. 3:18-19.

Products: *Presentations/abstracts: given at scientific conferences*

- ✓ Chastain, T.G., S.O. Guy, W.F. Schillinger, D.J. Wysocki, and R.S. Karow. 2011. Camelina: Genotype and environment impacts on seed yield in Washington, Oregon, and Idaho. [CDROM]. American Society of Agronomy annual meeting, ASA, CSSA, and SSSA Abstracts, 16-20 Oct. 201, San Antonio,TX
- ✓ Hammac, W.A., W.L. Pan, and R.T. Koenig. 2011. Impact of Nitrogen Use Efficiency on Greenhouse Gas Emission in Canola Biodiesel Feedstock Production. Soil and Water Conservation Society International Conference. Washington, DC
- ✓ Hammac, Ashley, William Pan, Richard Koenig and Ian Burke. Nitrogen and Sulfur Fertility Effect on Canola (Brassica napus) Protein Content and Fatty Acid Profile. American Society of Agronomy annual meeting, ASA, CSSA, and SSSA Abstracts. 16-20 Oct.,2011, San Antonio, TX
- ✓ Pan, W., D. Huggins, A. Esser, S. Eigenbrode, C. Kruger, S. Machado, A. Mcguire, S. Petrie, W. Schillinger, C. Stöckle, F. Young. Cropping systems management for mitigating and adapting to climate change. REACCH Launch Meeting, May 9-11, 2011Moscow, ID

- Sowers, Karen, Dennis Roe and William Pan. Tailoring Extension Education Efforts to Region-Specific Oilseed Production Zones in Washington State. American Society of Agronomy annual meeting, .ASA, CSSA, and SSSA Abstracts, 16-20 Oct.,2011, San Antonio, TX
- Schillinger, W.F., D.J. Wysocki, T.G. Chastain, S.O. Guy, and R.S. Karow. Camelina: Planting date and method impacts on stands and seed yield in Oregon, Washington, and Idaho [CD-ROM]. American Society of Agronomy annual meeting, ASA, CSSA, and SSSA Abstracts,16-20 Oct.,2011, San Antonio, TX.
- Waldo, S., T. McClellan, C. Kelley, and A. Hammac. 2011. Interdisciplinary Approach to Nitrogen Management in the Eastern PNW: Integrating the NSPIRE IGERT. REACCH Launch Meeting, May 9-11, Moscow, ID
- Wysocki, D.J., W.F. Schillinger, S.O. Guy, T.G. Chastain, and R.S. Karow. Camelina: Grain yield and protein response to applied nitrogen in Oregon, Washington, and Idaho. CD-ROM]. American Society of Agronomy annual meeting, ASA, CSSA, and SSSA Abstracts, 16-20 Oct., 2011,San Antonio, TX
-

Products: *Publications: Refereed scientific journal publications and book chapters*

- Brown, T.T. and D.R. Huggins. 2012. Dryland Agriculture's Impact on Soil Carbon in the Pacific Northwest. Journal of Soil and Water Conservation (accepted).
- Collins, H.P., M.M. Mikha, T.T. Brown; J.L. Smith, D.R. Huggins, U.M. Sainju. 2012. Increasing the Sink: Agricultural Management and Soil Carbon Dynamics: Western U.S. Croplands. In: Follet et al. (eds). Book Chapter, available in 2012.
- Kincaid, R., K. Johnson, J. Michal, S. Hulbert, W. Pan, J. Barbano, and A. Huisman. 2011. Biennial canola for forage and ecosystem improvement in dryland cropping systems. 2011. Advances in Animal Biosciences 2(2):457.
- Hammac, A., W.L.Pan, R.P.Bolton, R.T.Koenig. 2011. *In-Situ* Imaging to Assess Oilseed Species' Root Hair Responses to Water Stress. Plant Soil 339: 125-135.
- Huggins, D.R., Karow, R.S., Collins, H.P., Ransom, J.K. 2011. Introduction: Evaluating long-term impacts of harvesting crop residues on soil quality. Agron. J. 103:230–233.
- Ibrahim, H.M., Huggins, D.R. 2011. Spatio-temporal patterns of soil water storage under dryland agriculture at the watershed scale. Journal of Hydrology. 404:186-197.
- Qiu, H., D.R. Huggins, J.Q. Wu, M.E. Barber, D.K. McCool, S. Dun. 2011. Residue management impacts on field-scale snow distribution and water storage. Transactions of the ASABE, Vol. 54(5): 1639-1647.
- Singh, P., Flury, M., and W.F. Schillinger. 2011. Predicting seed-zone water content for summer fallow in the Inland Pacific Northwest, USA. *Soil & Tillage Research* 115-116:94-104.
- Schillinger, W.F. 2011. Rainfall impacts winter wheat seedling emergence from deep planting depths. *Agronomy Journal* 103:730-734.
- Schillinger, W.F. 2011. Practical lessons for successful long-term cropping systems experiments. *Renewable Agriculture and Food Systems* 26:1-3.

- ✓ Schillinger, W.F., R.H. McKenzie, and D.L. Tanaka. 2011. Barley production in North America. p. 241-251. *In* S.E. Ullrich (ed.) Barley: Improvement, Production, and Uses. Blackwell Publishing Ltd., Ames, IA
- ✓ Wuest, S.B., and W.F. Schillinger. 2011. Evaporation from high residue no-till versus tilled fallow in a dry summer climate. *Soil Science Society of America Journal* 75:1513-1519.
- ✓ Young, F.L., Long, D.S., and Alldredge, J.R. "Effect of Planting Methods on Spring Canola (*Brassica napus* L.) Establishment and Yield in the Low-Rainfall Region of the Pacific Northwest. *Crop Management.* Accepted with revisions December 2011.

Product: *Student Work: Theses/Dissertations*

- ✓ Hughes, M. 2011. Plant Nutritional Influence on Cold Hardiness of Canola. MS Thesis. Washington State University, Pullman, WA.

Milestones and Deliverables

M3.1 *Cropping alternatives and associated C, N, water measurements initiated, YR 1-4*

Establish infrastructure and identify resources for existing and new cropping system experiments

- ✓ Inventory and collect information on existing REACCH related CS experiments, pictures, publications, students and collaborators. Site information organized and posted by site on CD.
- ✓ A three state site tour was conducted in August 2011 with site leaders and other objective PIs to familiarize REACCH investigators with field sites and experiments.
- ✓ Design and establish new experiments at Davenport, WA (transition zone), Ralston and Okanogan, WA (fallow zone) and Prosser, WA (irrigated zone).
- ✓ Write-up overview summary of existing experiments that include history, objectives, previous findings/conclusions and future directions

Establish fall sampling protocol

- ✓ Create and communicate unified fall sampling protocol to site managers.

Fall sample collection, storage and analysis

- ✓ By plot biomass sampling: 1 square meter; whole plot grain harvest
- ✓ By plot soil sampling: 1 foot increments to 5 ft. (as conditions allow)
- ✓ Store, process and analyze grain and straw samples for determination of biomass, C, N concentration.

Fall data reporting

- ✓ Post site pictures of experiments
- ✓ Post timeline of field operations
- ✓ Report post-harvest grain and straw biomass
- ✓ Report post-harvest grain and straw C/N
- ✓ Report soil gravimetric moisture, nitrate, ammonium
- ✓ Report total soil C and N

Establish spring sampling protocol

- ✓ Create and communicate unified spring sampling protocol to site managers

Spring sample collection, storage and analysis
- ✓ By plot soil sampling: 1 foot increments to 5 ft (as conditions allow)
- ✓ Store, process and analyze grain and straw samples for determination of biomass, C, N concentration.

Spring data reporting
- ✓ Post site pictures of experiments
- ✓ Post timeline of field operations
- ✓ Report soil gravimetric moisture, nitrate, ammonium

Carbon fractionation
- ✓ Report total soil C and N and their fractionation

Undergraduate and graduate student recruitment
- ✓ Recruit undergraduate and graduate students that focus on Obj. 3 goals

M3.2 *Analyses of NUE, WUE, C, energy and delivery of initial inputs for modeling YR2-5*
Component analysis of water and N use efficiency, carbon and energy flows and other agroecological indicators of cropping systems
- ✓ Select appropriate models and analyses
- ✓ Analyze systems for water and N use efficiency and carbon, energy flows, and other agroecological indictors
- ✓ Completed initial assessment of NUE, WUE, C and energy balances as affected by zone, climate and treatment
- ✓ Presentation of initial CS experiments and results at regional workshops and ASA
- ✓ Review paper on CS NUE
- ✓ Systems ranked for NUE, WUE, C, and energy balance

D3.4 *Alternatives assessed, linked to biophysical and socio-economic modeling, YR4-5*
- ✓ Agronomic, crop and socioeconomic modelers develop alternative approaches for making integrated assessments in developing win-win scenarios
- ✓ Best approaches for integrated assessments identified
- ✓ Cropping system indicators incorporated into integrated assessment (see other deliverables)
- ✓ Win-win cropping system scenarios are identified for achieving economic, sociological, and environmental goals.
- ✓ Evidence of stakeholder response to recommendations

Tasks *Not completed YR 1*
- ☐ Establish better coordination and communication amongst our site leader teams. We have yet to have a meeting in which all site leaders are in attendance at the same time. We will attempt to do so at our REACCH Annual Meeting in Pendleton. Key issues such as progress reporting, assurances of uniform sampling and analysis protocol, and data sharing need to be discussed.
- ☐ Few of the site leaders were able to attend the CD training, and may still require training.

- ☐ A plan for soil C fractionation will need to be decided upon before spring 2012 field sampling.
- ☐ Discussions with C. Stöckle, John Antle, Susan Catalpo, and Kate Painter have yet to take place on what specific field data they require to complete their modeling tasks. This will be accomplished at an upcoming meeting at Hood River, OR.

Broad Impacts

Washington Biofuels Cropping Systems (WBCS) project and REACCH research and extension programs have supported increased oilseed adoption in wheat rotations in 2011, also spurred by increased worldwide oilseed prices and regional demand for biodiesel. In WA, canola production increased by 40% in 2011 compared to 2008-2010, due to: **(1)** increased canola prices; **(2)** favorable environmental growing conditions for winter canola; (**3)** improved grower awareness and knowledge of canola production opportunities and best management practices disseminated by our WBCS and REACCH programs.

Training

Undergraduate students:

- ✓ Brandon Hasart completed an undergraduate research project and REACCH internship in December, 2011 prior to his graduation with a B.S. in Crop Science. Brandon was mentored by PhD candidate Tai McClellan and Drs. Pan and Smith on measuring NH_3 and N_2O emitted from soil applied crop residues.
- ✓ An announcement was developed for recruiting CS interns during summer 2012.

Graduate students:

- ✓ Current NSF IGERT NSPIRE students W. Ashley Hammac and Tai McClellan are cross-linked with REACCH, researching fertilizer and crop residue impacts on C, N cycling and budgets of wheat based cropping systems. Together with Obj. 2 students Sarah Waldo and Chris Kelley, they presented a poster of the NSPIRE/REACCH integration at the first REACCH annual meeting. Mr. Hammac is also cross-linked on an EPA project to assess LCA of oilseed production in the PNW.
- ✓ Meagan Hughes completed her M.S. degree in soil science in December 2012, contributing research on the physiology and plant nutritional management of winter hardiness in canola, a key to broader winter canola adaptation in the PNW.
- ✓ Discussions were initiated to adapt an NSPIRE core graduate course, Global Nitrogen Systems, to serve as a core course for future REACCH students beginning in 2012
- ✓ REACCH graduate assistantships in CS were announced at 2011 National ASA meetings in San Antonio, TX. Applicants are being reviewed.

- ✓ A new PhD Soil Science student, Isaac Madsen, was recruited to begin in spring 2012. He has interests in working on the irrigated CS experiment at Prosser, WA.
- ✓

Collaboration and "Integrated" Knowledge

- ✓ Provided CS related questions to Kate Painter for gathering specifics on current CS management practices in the REACCH grower surveys.
- ✓ Developed win-win short term and long term best management scenarios for improving wheat system economic and environmental sustainability while mitigating and adapting to climate change. These scenarios will be helpful in outreach communications of the short and long term benefits of the project to the agricultural industry and environmental communities alike.
- ✓ Discussions and plans were initiated for conducting gas emissions monitoring on experimental plots of CS experiments.
- ✓ Discussed with modeling team the acquisition of regional N fertilizer usage, and crop yield data for generating regional C, N input/output budgets
- ✓ Piloted undergraduate internship program in fall 2011, drafted announcement for additional internships for summer 2012.

Plan of Work YR 2

- ☐ Identify experiments that are amenable to chamber gas monitoring of management variables
- ☐ Pilot gas emissions measurements at selected sites
- ☐ Process, analyze soil and plant samples from 2011 experiments
- ☐ Summarize and report data
- ☐ Establish protocol for soil C fractionation on spring soil samples
- ☐ Finalize draft field sampling protocols that will be used across the research sites.
- ☐ Continue field experiments, collect samples and conduct soil and plant analyses necessary for constructing C, N budgets
- ☐ Analyze systems for water and N use efficiency and carbon, energy flows, and other agroecological indictors
- ☐ Gather existing wheat-N response data and assess the need for updated N fertility recommendations on inland PNW wheat
- ☐ Establish new site-specific N experiment at WSU Wilke Farm
- ☐ Work towards integrated AEZ mapping research on regional C, N flows with AEZ and modeling teams

Executive Summary

Lead: Susan Capalbo, susan.capalbo@oregonstate.edu

The goal of the Objective 4 team (Team 4) is to determine the social and economic factors influencing agricultural management, on-farm adaptation with technology and practice implementation, and policy development that will improve production efficiency while mitigating greenhouse gas emissions. In YR 1, Team 4 focused on research design and background components necessary to achieve this goal. A longitudinal survey (LS) of wheat growers in the REACCH area is underway, after recruitment, survey design, and a pre-test of the survey. Another accomplishment has been the integration of Objective 1 economic information, simulation modeling, and technology scenario development with grower-level information from the longitudinal survey as well as Ag Census and USDA Agricultural Resource Management Survey data.

Achievements

1. Outputs related to the longitudinal survey include a list of 42 growers who have agreed to participate in the LS participants, a GIS map of the farm locations, development and pretesting of the survey instruments, and creation of a logbook for participants.
2. Other outputs include development of the sociological framework and research methodology to guide data collection for YR 2-YR 5, including: ongoing literature review of key emerging areas not previously addressed, theoretical model for adaptation likelihood scenarios, and fieldwork protocols.
3. Working with Objective 1, a compilation of the summary statistics from the Agricultural Census data for 37 counties in Oregon, Washington, Idaho was developed (Tables 1-6).
4. Team members made presentations at 2 grower meetings.

YR 2 Planned Activities

YR 2 activities prepared the way for ongoing activities through YR 2, including: **(1)** Expanded levels of key informant interviews among stakeholders and growers targeting the non-market factors related to adaptation; **(2)** Survey design & implementation for the general population survey to be administered in the region; **(3)** survey design / review of the grower survey to be administered in YR 3; **(4)** further development of the economic model to be applied for Objective 1 integration.

Outcomes/Impacts YR 1

Outcomes and impacts, defined as changes in knowledge, actions, or conditions, have been limited in YR 1 because our project is just beginning. The research design and sociological framework for the study assimilates a new intersection of knowledge relating to: **(1)** emerging data on climate variability in the Pacific Northwest region; **(2)** farm structure and production behavior related to climate gauging; **(3)** public shifts in sentiment about climate effects and food security. The method for integrating methodologies for outcomes from Objectives 1 and 4 was established and exemplifies transdisciplinary work. The conceptual approach, data needed, link to modeling, and Objective 1 linkages to larger regional and global impact assessments have been established.

Outputs YR 1

Events: *Meetings*

- ✓ A day-long project meeting was held at a central location (Hood River, OR) in order to coordinate activities for this objective, including developing survey instruments and other research details for this objective. In addition, the team conducted several conference calls for the same purposes.
- ✓ A meeting was held in October to develop and coordinate integration of the methodology outcomes from Objective 1 and 4.

Events: *Presentations*

- ✓ This project was described to area growers during presentations made at local farmer breakfasts and at the annual tri-state grain convention. A list of 60+ growers was developed as potential contacts for the longitudinal survey. All of these growers were contacted via telephone. Their participation in the survey was requested as well as permission to sample for pests and count earthworms. Due to FOI concerns, this contact list is not kept on Central Desktop. A map of growers who have agreed to participate is superimposed upon a map of AEZ within the study area (Figure 3).

Product: *Stakeholder Tools*

- ✓ A logbook or scrapbook was developed to track relevant data for participants in the longitudinal survey, including dates of crop emergence by year, harvest and planting dates by crop and year, average yields, changes in input usage, tillage practices, etc.

Products: *Pending written materials*

- ☐ A white paper will be produced to explain conceptual approach, data needed, link to modeling, and Objective 1 linkage to larger regional and global impact assessments.

Milestones & Deliverables

M4.1a *Longitudinal interviews (and instrument development) following AEZ strata conducted, YR 1-5.*

- ✓ A list of 42 potential collaborators for the longitudinal survey was chosen from a list of growers who frequently collaborate with university Extension and USDA-NRCS personnel as well as leaders in grower groups. These growers cross 6 agroecological zones representing a variety of farm practices (no-till vs. conventional tillage). They tend to be farm families who have been farming for several generations. Many of them use direct seeding techniques. They do not represent a random sample but rather should be considered collaborators who can inform the scientists working on this project and provide expert opinion on matters of interest to the project.
- ✓ Survey instruments were designed and reviewed by the rest of the teams for additional desired content or suggestions. The survey was pretested on two sets of growers and then modified, which basically entailed shortening the original survey length. Growers were originally contacted by phone, requesting their participation in the survey as well as permission to sample pests and earthworms on their farms. A follow-up mailing was sent along with samples and blank forms for the machinery complement and schedule of operation.
- ✓ Eight grower surveys have been completed.
- ✓ Survey forms were developed that will be used before and during the interview process to gather sufficient data to develop costs for producing wheat for each grower. These costs will be used to develop typical cost scenarios by AEZ for growers. These costs may be further stratified by tillage choice, size of operation, and other criteria. See activities and outputs.
- ✓ Instrument outlines, designs, and rationales are provided for the three core components: key informant interviews (YR 2-4), general population survey
- ✓ (YR 2), and producer population survey (YR 2-3).

M4.1b *Development of sociological framework to assimilate climate variability data, general population sentiments in the region, and on-farm climate gauging*

- ✓ We are in the process of hiring a post-doc to do essential intensive background work, ongoing bibliographic annotation, and continued refinement of the theoretical model for project integration.

- ✓ A sociological framework and research methodology to guide data collection for YRS 2-5 on the project was developed, including: ongoing literature review of key emerging areas not previously addressed, theoretical model for adaptation likelihood scenarios, and fieldwork protocols.

M4.1c *Conduct pilot fieldwork to investigate core themes and member check instrument categories within overall design*

- ✓ A series of 6 pilot interviews were conducted in YR 1 to investigate general saliency of categories pertinent to each primary component of the methodological plan for general population and producer population surveys.

M4.1d *Outline field instrumentation for pilot testing*

- ✓ Outlines for each of the three core data collection instruments were developed in order to gain insights from project collaborators, stakeholders, interviewees, and policy constituents.

Tasksh *Not completed in YR 1*

- ☐ We are in the process of interviewing growers for their 2011 crop year activities, they are not all complete. We were not able to begin the interviewing process until the survey instruments had been finalized and pretested in December. An experienced interviewer was hired to assist with this purpose but was unable to start working until January 1. These first-year interviews will continue until completed as some point during YR 2. The initial interviews are time-consuming, and many of the growers are located in remote areas that are time-consuming to visit.

Broad Impacts

The Economic and Social Objective has increased the awareness of climate change effects on agriculture in the region. Producers are very interested in anything that affects their economic bottom line. The REACCH project and its goals have been disseminated in the following ways:

- ✓ Educating the larger population of Extension educators on climate change issues related to agriculture and how to talk about these issues with their clientele (Kolden and J.T. Abatzoglou, 2012).
- ✓ Educating area growers regarding this project, its goals, and the potential impacts of climate change on agriculture in general. The project has been discussed at meetings such as the Direct Seed Breakfasts, the annual Tri-State Grain Growers Convention in December 2011 and the oilseed production workshops held in January 2012.
- ✓ Educating stakeholder advisory member participants on the range and character of perspectives that continue to evolve and relate to farm adaptation and our project approaches (2 project meetings in YR 1 that convened stakeholders).

Training

- ✓ A Research Associate (Hilary Donlon) with a BS in Agricultural Economics and professional experience interviewing growers has been trained in budget methods used for this study and has been integral to developing the in-person grower interview that we are using for the longitudinal survey.
- ✓ Paperwork is in place with the OSU Department of Human Resources Development in order to hire a post-doctoral candidate to work on the sociological component of this project.

Collaborations and "Integrated" Knowledge

- ✓ Questions were added to the longitudinal survey based on input from other scientists on the project. These questions solicit input from growers on specific pest observations, fertilizer practices, access and usage of web-based materials, and on how Extension and university research in general can help growers with problems related to weather variability and climate change.
- ✓ Collaboration developed with Abatzoglou and Walden to inform the intersection of general population and producer surveys that will allow respondents to envision geographically-displayed scenarios about future climate changes based on scenario modeling.
- ✓ Growers that agreed to participate in the longitudinal survey were asked for permission to conduct insect sweeps and earthworm counts on their wheat fields. These activities were conducted on a subset of growers (see Objective 5).
- ✓ Worked with Objective 1 on data coordination and summary from USDA agricultural census and ARMS data
- ✓ Worked with, Objective 1 on preliminary wheat-fallow simulations being modeled based on USDA data and survey
- ✓ Coordination of modeling scenarios from the Intergovernmental Panel on Climate Change (IPCC) activities and with national and international research on "representative pathways." Expect to link to global and regional economic modeling.
- ✓ The REACCH project has input into the economic components of the National Climate Assessment; Dr. Susan Capalbo and Dr. John Antle are the project leads.
- ✓ Issue to address: technology scenarios need to be identified jointly by Objective 1 and 4 by the start of YR 2, or at the Feb. 10 meeting in Hood River, OR.

Plan of Work YR 2

- ☐ Grower interviews will continue until completed in early 2012.
- ☐ Data from the interviews will be used to determine costs of production for each grower. Growers will receive this information and will be encouraged to provide feedback.

- ☐ A calendar will be produced for tracking relevant data. These calendars will be given to growers during the interview. These calendars will help provide data for each grower's logbook (scrapbook).
- ☐ We will also continue to compile the Ag census information and the ARMS data and modify the framework and data needs for adoption likelihood analysis.
- ☐ In addition to the initial phase of key-informant interviews, in YR 2 the sociological component will consist of development and fielding of the general population survey and design / pilot testing for the producer population survey. YR 2 scope will also include updates and refinement of the annotated bibliography and theoretical model applicable to project integration needs.

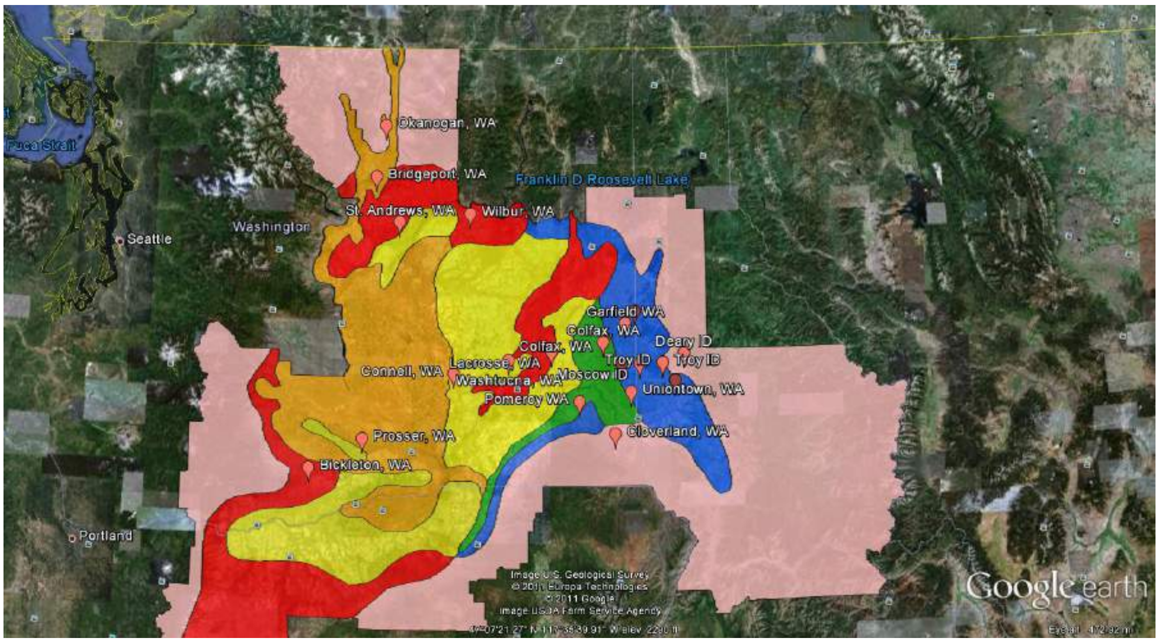

Figure 3. Location of grower collaborators for the longitudinal survey superimposed on AEZ regions (Douglas et al., 1992) in study area

Table 1. Farm Population Characteristics of Wheat Farms in the REACCH Region

Variable	Description	Unit	Mean	Std
HH	Number of persons living the household in farm for principle operator	number	2.7	1.3
TCL	Farm size	acre/farm	1680.2	1537.3
CLHA	Cropland used for harvesting in farm	acre/farm	1033.5	868.7
HHSNR	Household numbers that share in net farm income	number	1.6	1.0
HHINC*	Household income for principle operator	classification	4.4	1.2
PINC	percentage of income from the operation for principle operator	number	60.9	34.1
CROI	Total cropland irrigated acres in farm	acre/farm	97.3	252.5
TLSI	Total livestock inventory in farm	number	19.8	71.6

** HHINC is a classification. 1- Less than $20,000; 2- $20,000 to $29,999; 3- $30,000 to $39,999; 4- $40,000 to $49,999; 5- $50,000 or more*

Table 2. Wheat Production of Wheat Farms

Variable	Description	Unit	Mean	Std
WHAC	Wheat acres in farm	acre/farm	770.5	748.6
WHPR	Wheat production in farm	bushel/farm	41864.4	40207.0
WHIAC	Wheat irrigated acres in farm	acre/farm	30.0	103.2
CLFALLOW	Summer fallow size in farm	acre/farm	414.5	682.1
WINWHAC	Winter wheat acres in farm	acre/farm	629.2	669.4
WINWHPR	Winter wheat production in farm	bushel/farm	35959.5	37038.4
WINIAC	Winter wheat irrigated acres in farm	acre/farm	20.7	82.9
SPRWHAC	Spring wheat acres in farm	acre/farm	140.8	264.3
SPRWHPR	Spring wheat production in farm	acre/farm	5859.6	10852.7
SPRWHIAC	Spring wheat irrigated acres in farm	acre/farm	9.2	46.8
WHY	Wheat yield	bushel/acre	61.1	26.6
WINWHY	Winter wheat yield	bushel/acre	57.7	31.2
SPRWHY	Spring wheat yield	bushel/acre	22.2	29.6

Table 3. Revenue of Wheat Farms

Variable	Description	Unit	Mean	Std
TVWH	Total value of wheat in farm	$/farm	239499.2	236189.7
WHRE	Wheat revenue per acre	$/acre	362.3	196.1
TVOC	Total value of other crops in farm	$/farm	108154.3	207145.7
OCRE	Other crops revenue per acre	$/acre	290.2	814.1
TGP	Total government payments in farm	$/farm	30476.2	33249.2
VCRP	Government payments received from CRP and WRP in farm	$/farm	8641.2	19017.4
TSL	Total value of livestock in farm	$/farm	6740.3	27349.4

Table 4. Costs for Wheat Farms

Variable	Description	Unit	Mean	Std
TEXP	Total expenditure per farm	$/farm	237140.5	208985.6
EXPSEED	Total expenditure for seeds, bulbs, etc. per farm	$/farm	16066.9	18800.2
EXPCF	Total expenditure for commercial fertilizer per farm	$/farm	50094.6	53067.0
EXPCHEM	Total expenditure for agricultural chemicals per farm	$/farm	25186.9	30750.4
EXPHL	Total expenditure for hired labor per farm	$/farm	21512.2	39837.3
EXPCL	Total expenditure for contract labor per farm	$/farm	1672.2	11676.8
EXPCR	Total cash rent paid for land and buildings per farm	$/farm	20085.4	51468.5
EXPPT	Total property tax paid per farm	$/farm	5781.9	9102.5
EXPFO	Total expenditure for fuels and oils per farm	$/farm	22091.1	21093.9
EXPUT	Total expenditure for utilities per farm	$/farm	7126.8	14760.8
EXPSPM	Total expenditure for suppliers, repairs and maintenance cost per farm	$/farm	24898.8	25640.1
EXPCW	Total expenditure for customer work per farm	$/farm	5323.6	15246.6
EXPER	Total expenditure for equipment rental per farm	$/farm	2961.2	10436.9
PCOST	Production cost per acre	$/farm	313.5	425.8

Table 5. Statistical Cost Decomposition for Wheat Farms

Crop	Description	Unit	Mean	Std
WHCOST	Total expenditure for the wheat production per farm	$/farm	129609	128263
OCCOST	Total expenditure for other crops production per farm	$/farm	39686	88844

Table 6. Wheat Farm Net Returns

Crop	Description	Unit	Mean	Std
	Net returns for the whole farm	$/far m	167590	23329.9
	Net returns for the wheat production per farm	$/far m	145000	150212. 3
	Net returns for other crops per farm	$/far m	41264.2	86174.5
	Net returns for livestock per farm	$/far m	5013	23329.9

Executive Summary

Lead: Sanford Eigenbrode sanforde@uidaho.edu

Climate change can affect the biology and distribution of pests such as insects, fungi, weeds, and beneficial organisms. Understanding how changes in temperature and precipitation affect these organisms will help farmers adapt as climates change. The "biotic team" (Obj. 5) is employing monitoring, modeling, and experiments to understand the impacts of climate and practices to adapt to climate on key pests, weeds, pathogens and beneficial organisms across the REACCH study region. The team will integrate with Objectives 1, 3, 4 and the AEZ theme to produce synthetic analyses.

Achievements

1. We conducted baseline surveys across the region for aphids, Hessian fly *Mayetiola destructor*), cereal leaf beetle (CLB) (*Oulema melanopus*), fungal pathogens (*Fusarium culmorum* and *F. pseudograminearum*), plant-pathogenic nematodes, and downy brome (*Bromus tectorum*), all of which are constraints in cereal systems. We also sampled earthworms, which are beneficial for soil properties. The insect sampling included the seven experimental farms that are part of the REACCH project and commercial fields, totaling 23 sites for earthworms 44 sites for insects. **2.** We established 7 sites with traps to monitor flying aphids and sampled these biweekly in spring and fall of 2011. **3.** We completed a climate-based model of CLB that projects its potential severity and phenology across the region currently and in the decades through 2050. **4.** We used weather data to find relationships between prevalence of certain fungi and nematodes, and as a basis for developing regional models for these fungi. **5.** Team members made presentations at 7 grower meetings and 2 professional meetings.

YR 2 Planned Activities

All organisms will be sampled on each of approximately 40 grower/cooperator farms. Aphid flight traps will be monitored weekly from Apr. to Nov. The approach used to develop the CLB model will be employed to create similar models for earthworms, downy brome, Mayweed chamomile (*Anthemis cotula)*, and other weed species. These models will be synthesized to provide an estimate overall pest, disease, and weed severity of index of projected change. Collaboration with the AEZ team (see AEZ) will incorporate cropping system variables to refine these models. A 10-year record of aphid suction trap data and historical downscaled climate records will be used to determine how weather influences aphid flights as a basis for projecting aphid flights in the future, and their overlap with winter wheat planting in the fall with implication for risk of plant virus transmission. One postdoc and three students will be recruited. Three undergraduate researchers will work on the project during the summer. Two publications and 7 professional presentations are planned.

Outcomes/Impacts YR 1

Outcomes and Impacts, defined as changes in knowledge, actions or conditions, have been limited in YR 1 because our project is just beginning. Grower cooperators and participants in grower meetings have better knowledge of organisms on or affecting their operations based on our sampling data and presentations. We do not think our work has yet changed actions or conditions appreciably in YR 1.

Events: *Presentations*
Seven presentations were made at grower meetings** or professional meetings*.
(As listed below, milestones are specifically annotated.)

- ✓ Paulitz, T. Grower seminar on nematodes, included the results of surveys conducted under REACCH, Dec. 8, 2011 Clarkston WA (M5.1)**
- ✓ Kandel, S.L., Elling, A.A. Smiley, R.W., Garland-Campbell, K.A. Nicol, J.M. and Paulitz, T.C. A survey of root lesion nematode (*Pratylenchus* spp.) in the dryland wheat production areas of eastern Washington, Society of Nematology, July, 2011, Corvallis, OR (M5.1)*
- ✓ Eigenbrode, S.D. Vigilant management strategies to guard against insect pests as climate and weather patterns shift. Spokane County Crop Improvement Association, Nov. 19, 2011, Spokane WA (M5.1 and M5.2)**
- ✓ Johnson-Maynard, J.L. 2012. Earthworms in agroecosystems. Direct Seed Grower Workshop, January 12, 2012, Colfax, WA (M5.1)**
- ✓ Eigenbrode, S. D., Abatzoglou, J. Projected range of cereal leaf beetle with climate change scenarios for the Pacific Northwest, Annual Meeting of the Entomological Society of America, Nov. 15, 2011, Reno, NV (M5.2)*
- ✓ Eigenbrode, S. D., Abatzoglou, J. Projected range of cereal leaf beetle with climate change scenarios for the Pacific Northwest, Sustainable Corn, Nov. 9 2011, Chicago, IL (M5.2)*
- ✓ Eigenbrode, S. D. The REACCH project gets moving. Pacific Northwest Direct Seed Conference, Feb. 9, 2012, Spokane, WA (M5, and other project objectives)**
- ✓ Eigenbrode, S. D. Climate change and PNW agriculture. Department of Geography, University of Idaho, Feb. 14, 2012, Moscow, ID (M5.1, M5.2)*.

Activities: *Planning Meetings*

- ✓ The team convened 6 times in 2011 and 2 times so far in 2012 to plan activities.

Activities: *Sampling*

- ✓ Sites across the region were sampled for weeds, insects, pathogens and earthworms. Sampling included cooperator farmers and other commercial farms. At several of the farms, REACCH personnel interacted with cooperators and provided informal explanations of project activities.

Activities: *Modeling*

- ✓ A model was constructed of cereal leaf beetle potential severity across the region and based on climatic and soil parameters and was presented as a poster at two meetings and as part of an oral presentation to producers.

Milestones and Deliverables

M5.1 *Assess climate related vulnerabilities to pests and beneficial organisms*

- ✓ Data from controls recorded
- ✓ Earthworm density and biomass measured at research stations
- ✓ Earthworm density and biomass measured at cooperator farms
- ✓ Presentation of earthworm data was given to producers
- ✓ Monitoring insects on cooperator farms initiated
- ✓ Insect abundance from cooperator farms measured and summarized
- ✓ Monitoring for insects on experimental farms initiated
- ✓ Monitoring for pathogens and nematodes on experimental farms initiated
- ✓ Poster on nematodes was presented
- ✓ Earthworm sampling directly supported M5.1: preliminary data have been tabulated and are being utilized to design an efficient sampling scheme for YR 2
- ✓ Graduate student recruited to work on earthworm portion of the project
- ✓ Preliminary work and future project efforts have been presented to growers
- ✓ Data from controls analyzed
- ✓ Annual earthworm sampling at cooperator farms analyzed
- ✓ Initial earthworm data used to design sampling plan for YR 2

M5.2 *Predictions of climate related changes in pests, diseases, beneficial organisms and weeds*

(Note: this is a YR 2 milestone but we have made progress on it in YR 1.)

- ✓ Created weather and climate layer for cereal leaf beetle
- ✓ Model presented at two professional meetings

M5.5 *Comparative analysis of pressure from key insects, pathogens and weeds in alternative systems*

- ✓ Baseline sampling for insects, weeds, and earthworms completed this year will be part of the comparative analyses to be completed during YR 5

Broad Impacts

Our monitoring provides the first comprehensive region-wide monitoring of the deleterious organisms (pests, diseases, and weeds); to our knowledge it is also the first effort to characterize earthworm populations across a climatic gradient. These data could be useful for other researchers outside of REACCH. There is significant interest expressed in earthworms, especially by direct seed farmers. Growers at a recent direct seed meeting indicate that earthworm numbers have increased significantly in their fields due to conservation tillage. They are curious about how to continue to manage for these earthworms and in quantifying their impact on soil processes such as infiltration and reduction of erosion.

Our interactions with other research groups are expected to open opportunities for collaborative synergy. These include: **(1)** Climate-based models of insect predator communities being created within the potato RAMP project led by Washington State

University; **(2)** collaborative potential between our team and entomologist Matt O'Neal who is part of the Sustainable Corn CAP at Iowa State University; **(3)** Eigenbrode is co-organizing a symposium at the Entomological Society of America Annual Meeting in 2012 (Nov. 14, Knoxville TN) on climate change and insect pests.

Training

Table 7. Students, postdocs, and support persons receiving training in YR 1

Ying Wu	Support Scientist, Entomology	University of Idaho
Karl Umiker	Support Scientist, Earthworm Ecology	University of Idaho
Steven Odubiyi	Technical Support, Entomology	University of Idaho
Angela Aragon	Undergraduate, Entomology	University of Idaho
Aaron Weed	Postdoctoral Associate, Entomology	University of Idaho
Shyam Kandel	MSc Student, Plant Pathology	Washington State University
Kurt Schroeder	Postdoctoral Associate, Plant Pathology	Washington State University
Sean Wetterau	PhD Student, Weed Science	Washington State University
Nevin Lawrence	PhD Student, Weed Science	Washington State University

Collaborations and "Integrated" Knowledge

Integrated collaborations within our project are just beginning. We plan to work closely with the Objective 3, Cropping Systems and AEZ teams. As mentioned above, some external collaboration is also emerging. Several educational activities based on earthworm ecology were developed and carried out with a local (Moscow, ID) elementary school class. Interest, involvement, and education regarding these organisms can involve generational spans and appears to be an excellent avenue to teach basic soil conservation principles as well.

Plan of Work YR 2

- ☐ Cross integration: We will work with the AEZ team to attempt synthetic models incorporating cropping system patterns with current and projected insect, pathogen, nematode, weed and earthworm distributions.
- ☐ Cross Integration: We will work with Objective 3 team to design and execute appropriate baseline sampling protocols for current and alternative production systems on project experimental farms.
- ☐ Recruitment: At least two new PhD students and one postdoc will be recruited. At least three undergraduate (REU) will be recruited to work during the summer on objective projects related to monitoring and modeling pests.

- ☐ Presentations: Upcoming presentations are planned for at least 5 professional meetings including the tri-societies meeting (SSA, CSA, AAS); the annual meetings of the Entomological Society of America; the American Phytopathological Society; the Weed Science Society of America; and 8 grower meetings including: regional cereal schools in Idaho, Washington and Oregon; the Pacific Northwest Direct Seed Association and others.
- ☐ Publications: At least one publication describing the cereal leaf beetle model will be submitted for publication. Manuscripts on climate based models for weeds and pathogens will be prepared, but may not be submitted by the end of YR 2.

M5.1 *Assess climate related vulnerabilities to pests and beneficial organisms*

- ☐ Continue to monitor insects, weeds, earthworms, and pathogens on grower cooperator farms and stations. (This will be more closely coordinated to identify a specific subset of sites to be shared by all team members for comparative purposes.)
- ☐ Insect sampling will take place 3 times
- ☐ Aphid pan traps will be deployed and monitored weekly
- ☐ Historical aphid trap data will be uploaded with weather data into the data repositories for REACCH and used to examine weather related patterns in aphid flights.

M5.2 *Predictions of climate related changes in pests, diseases, beneficial organisms and weeds*

- ☐ The CLB model will be refined to a more complete niche based model, and similar models will be constructed for at least 1 weed, earthworms, and at least 1 pathogen.
- ☐ To aid in tracking, milestones have been added, so the revised list reads: generate climate based projections for, M5.2a. Cereal leaf beetle, M5.2b. Downy brome, M5.2c. Aphid species, M5.2d. Mayweed, M5.2e. Earthworm species.

M5.3 *Earthworm survival and reproduction*

- ☐ Experiments testing how soil moisture and temperature interact to influence earthworm survival and reproduction will be designed and implemented.

M5.5 *Comparative analysis of pressure from key insects, pathogens and weeds in alternative systems*

- ☐ Monitoring will be done on the experimental farms and on the newly added alternative cropping systems at the start of the year.

Executive Summary

Lead: Jodi Johnson-Maynard jmaynard@uidaho.edu

The overall goal of the REACCH education component is to introduce innovative agricultural approaches to climate change mitigation and adaptation into K-12 and undergraduate and graduate curricula to prepare citizens and professionals for climate related challenges and defining agriculture's role in providing food, energy and ecosystem services.

Achievements

During YR 1, faculty working on the education objective (Johnson-Maynard, Wolf, Velez and Eigenbrode) started building the foundation for an educational network needed to reach this goal. Results of a survey of over 4000 teachers in ID, WA and OR were used to determine the products that will be developed during the project. We gained valuable information regarding the perceived benefits and challenges of integrating climate change and agricultural topics into K-12 curriculums. A brief overview of the REACCH project was given at summer teacher meetings within each state. A brochure that included the project goals and expected deliverables and outcomes along with contact information was distributed. We started to build relationships with teachers in Idaho and conducted two activities for a local kindergarten class. We initiated collaborations with another K-12 climate change education program (NASA-funded ICE-Net). ICE-Net focuses on minority populations and works with schools located outside of the REACCH project area. Through this collaboration, therefore, we will increase the diversity of our audience, expand the geographic influence of our program and have a larger influence on agricultural literacy.

At the undergraduate level we have had two interns working on components of REACCH research. We have also drafted guidelines for the summer research experience for undergraduate (REU) program. A total of 15 positions are available across the three institutions for summer 2012. We will work with collaborators from Columbia Basin College (minority serving institution) to ensure that we recruit a diverse group of interns. Learning objectives were drafted for the undergraduate course on agriculture and climate change and the course is currently being piloted (11 students enrolled) at the University of Idaho.

Graduate student recruitment materials were developed and disseminated. Currently 8 of the 14 positions have been filled.

YR 2 Planned Activities

Teacher workshops will be held during the summer. We will continue to explore collaborations with other climate change education projects. Our first REU cohort will be mentored. All grad positions will be filled by Sept. 2012. Discussions have taken place regarding the development of two graduate level courses (one on spatial statistics and the agroecological zone concept and one on integrated carbon and nitrogen cycling). These courses will be developed in YR 2 and offered no later than YR 3 of the project.

Outcomes/Impacts YR 1

Long-term impacts are limited at this early stage of the project. Our outcomes include: **(1)** improved knowledge of climate change/agricultural programs and opportunities among teachers; **(2)** improved knowledge of organisms in relation to plant growth and soil quality; **(3)** development of graduate student guidelines for the project; **(4)** Development and dissemination of graduate student recruitment materials; **(5)** recruitment of 8 graduated students and 1 post-doctoral researcher; **(6)** collaborations developed that will increase the impact and allow us to reach a more diverse audience.

Outputs YR 1

Product: *Printed material: Brochure*

- ✓ REACCH Education brochure delivered to ID, WA and OR agriculture teachers at each State's summer conference. This brochure includes the project goals, expected deliverables and contact information.

Activities: *School programs*

- ✓ Field activity with local school on earthworm sampling (9/29/11)
- ✓ Laboratory activity (earthworm characteristics, identification and ecology) with local school, Moscow, ID (10/27/11)

Activities: *Collaborators*

- ✓ List of ID, WA and OR teachers interested in participating in the project

Papers: *Proceedings paper summarizing K-6 teacher responses to survey*

- ✓ Wolf, Kattlyn J., Velez, Jonathan J., Johnson-Maynard, J., Eigenbrode, S., Swan, B. G., Blickenstaff, S. M. (in review). *Elementary Teachers Perceptions of Agriculture and their Integration of Agricultural Topics.* Paper submitted to the National Meeting of the American Association for Agricultural Education. Asheville, NC.

Milestones and Deliverables

K-12 Milestones and Deliverables

D1.6a *K-12 survey analyzed and professional materials developed*

- ✓ Completed analysis of the teacher survey (D6.1K-12) and the results are being used to develop K-12 materials for use in YRS 2-5.
- ✓ Results from the teacher survey (K-6) have been submitted for publication (see outputs).
- ✓ Data from the survey sent to secondary teachers has been analyzed and will be submitted for publication in YR 2 of the project.
- ✓ This survey resulted in a list of K-12 teachers that indicated interest in further participating in the study.

- ✓ Met with PIs of a related climate change K-12 education project (NASA-funded, Intermountain Climate Education Network, or ICE-Net) to discuss possible collaboration.
- ✓ Developed a REACCH-education brochure (enclosed) that was presented to teachers following a short oral overview of the project at ID, WA and OR summer teacher meetings.

D6.3 *Classroom activities developed from project results*

We do not expect to widely disseminate classroom activities and lesson plans until YR 3 of the project.

- ✓ Conducted a few initial activities with a local school (Palouse Prairie School of Expeditionary Learning, Moscow, ID). These included both a field and laboratory activity.

Tasks *Not completed in YR 1*

- ☐ The objective team realized that we had to have basic climate change/agriculture materials developed prior to hosting teacher workshops. This milestone was postponed until YR 2.
- ☐ We did not start the process of hiring our half time education coordinator until January 2012. It was determined hiring in YR 2, after our initial list of teachers has been established and we have determined outputs, would be more efficient.

Undergraduate/Graduate Milestones and Deliverables

D.6.2 *Multi-institutional course materials developed on agriculture and climate change*

- ✓ Soil 404/504 (Sustainable Management of Natural Systems) has been developed and is currently being taught at the University of Idaho. This newly developed course will teach students how to analyze food and agricultural systems using a systems approach.
- ✓ Learning objectives were drafted and will be utilized in the assessment of this course.

D6.2b *Formation of interdisciplinary teams based on research themes*

- ✓ A joint graduate student recruitment announcement was developed and disseminated.
- ✓ Eight of the 14 expected graduate students have been recruited and several have started work.
- ✓ Students currently on the project have been attending objective team meetings.
- ✓ Current and recruited graduate students that are geographically close will attend the project annual meeting.
- ✓ We intend to have all graduate students start by fall 2012 as planned.

D6.3 *Undergraduate summer research experiences*

- ✓ Hired a temporary person to help organize the 2012 summer research experience for undergraduate program.
- ✓ While we planned on offering our summer Research Experience for Undergraduate program (D6.3) in YR 3 (after experiments were all up and running), we felt that we were far enough along to offer it in YR 2.
- ✓ REU recruitment materials are currently under development and will be advertised by Feb. 1, 2012.
- ✓ We have made contact with current REUs at all three institutions and are working on integration among REU programs.
- ✓ Personnel at Columbia Basin College (minority serving institution) will assist with student recruitment to ensure a diverse group of undergraduate researchers is recruited in each year of the project.
- ✓ In addition to the REU program, two undergraduates worked as research interns in the laboratories of Drs. Pan and Lamb. These students have been working on small components of larger REACCH studies.

D6.4 *Graduate level course on spatial statistics that covers AEZ concept*

- ✓ Initial conversations regarding a graduate level course on spatial statistics that covers the AEZ concept

D6.5 *Graduate level course on agriculture and climate change adaptation/mitigation*

- ✓ Initial conversations regarding a course that will cover carbon and nitrogen cycles in a comprehensive manner while integrating policy considerations.
- ✓ Developed an initial list of existing courses that may be able to incorporate these concepts.

Broad Impacts

It is difficult to assess outcomes in the early stages of this project. It does appear, however, that REACCH will play a vital role in creating a strong educational network across the region by working directly with teachers and partnering with programs such as ICE-Net. Providing hands-on research opportunities for undergraduates will likely improve interest in agriculture and lead to graduates that are better prepared to work on current and future agricultural problems. In early planning meetings for the summer 2012 teacher workshop in collaboration with ICE-Net we have discussed recruiting teacher teams to attend. Pairing agriculture and science teachers, for example, will enhance integration of agriculture topics across the curriculum. The project will result in a better understanding of the role of agriculture in climate change mitigation/adaptation and improved agricultural literacy among future agricultural professionals and consumers.

Training

Table 8. The names, areas of study, advisors and start dates of undergraduates and graduate students

UNDERGRADUATES		
Brandon Hasart	Crop Residue Effects on $N_2 0$ Emissions	*Pan, Aug. – Dec. 2011*
Laurel Graves	Nitrogen and Erosion	*Lamb, Jan. 2012-Present*
GRADUATE STUDENTS		
Chealsea Walsh	Earthworms Soil Processes	*Johnson-Maynard Summer 2012*
Ashley Hammac	Crop Intensification/Diversification (N Fertility, Canola, Life Cycle Analysis)	*Pan, Aug. – Present*
Tai McClellan	Crop Diversification (Legumes, Canola, and N Cycling	*Pan, Aug – Present*
Taylor Beard	Carbon Sequestration and Management	*Pan, Fall 2012*
Sarah Waldo	GHG Fluxes	*Lamb, Summer 2012*
Jackie Jinshu	GHG Flux Monitoring	*Pressley, Aug – Present*
Hongliang Zhang	Economic Modeling	*Antle, Aug – Present*
Sihan Li	Climate Modeling	*Mote, Aug - Present*

Collaborations and "Integrated" Knowledge

Collaboration with ICE-Net will broaden the geographical scope and increase the number of teachers reached by each project. The focus of ICE-Net is on climate change education among minority groups. Collaboration, therefore, will help extend REACCH impacts to these groups which make up a smaller proportion of the REACCH study area. New ideas on teacher resources are being developed through collaboration of the research, education and cyber-infrastructure objective teams. Through collaboration we will develop new resources for teachers and students to download actual research data for educational purposes. Educational materials and courses will be developed with collaboration of all the REACCH objective teams.

Plan of Work YR 2

In YR 2 we will continue to build a comprehensive climate change/agriculture education network across the region.

K-12 education

- ☐ Development and dissemination of introductory climate change and agricultural classroom activities
- ☐ K-12 summer teacher workshops: **(1)** We will co-host a teacher workshop on climate change in summer 2012 at the University of Idaho with ICE-Net; **(2)** We will work with the Summer Ag Institute at OSU to integrate materials on climate change and agriculture.
- ☐ Hire education coordinator to enhance communication between REACCH and teachers
- ☐ Assessment of teacher workshop

Undergraduate and graduate education

- ☐ Complete graduate student recruitment by fall 2012
- ☐ Assess and revise undergraduate ag/climate change course based on student feedback
- ☐ submit paperwork to cross-list undergraduate course among institutions
- ☐ continue development of graduate level courses (spatial statistics/AEZ and carbon and nitrogen cycling)
- ☐ Completion of the first REU summer program

Executive Summary

Leads: Chad Kruger cekruger@wsu.edu Steve Petrie steven.petrie@oregonstate.edu

Objective 7 contains the Extension components of the REACCH Project, including overall project guidance by and communication with a Stakeholder Advisory Committee (SAC), establishment and training of a network of Extension professionals capable of delivering agricultural climate science to stakeholders, development and dissemination of research results from REACCH to a diversity of stakeholder interests, and evaluation of implementation of practices and policies by REACCH stakeholders.

Achievements

YR 1 project activities included a combination of planning and development of REACCH specific Extension programs, coordination of input and communication with the REACCH SAC, and development and dissemination of relevant research to REACCH stakeholders based on prior efforts. Objective 7 was designed intentionally to increase Extension activity over the duration of the project as new REACCH research results are developed and become available, however relevant prior research has enabled the Objective 7 team to respond to numerous stakeholder inquiries regarding climate change and agricultural research in the region even in YR 1.

YR 2 Planned Activities

Activities for YR 2 include: **(1)** hiring an REACCH Extension Faculty Coordinator; **(2)** coordinating SAC communication; **(3)** establishment of electronic communication mechanisms (in coordination with Objective 8); **(4)** development of additional Extension products.

Outcomes/Impacts YR 1

Outcome 1: Climate change remains controversial among many within the agricultural stakeholder community and associated industry. In spite of the controversy, we created and populated a Stakeholders Advisory Committee (SAC) with representation from a wide range of interest groups. The names and professional affiliations of SAC members are shown in Appendix C. The SAC met at the Planning Meeting and provided valuable input to our proposal. They met again at the Launch Meeting and interacted with the Objective Team leads both formally and informally.

Outcome 2: Pacific Northwest Environmental Organizations have established the Northwest Regional Biocarbon Initiative (NW RBI) as a mechanism for advancing practices and policies that mitigate climate change in terrestrial ecosystems in the PNW. With REACCH guidance, NW RBI has adopted a policy position statement inclusive of agricultural practices researched and validated by the REACCH project.

There are no Impacts to Report for YR 1. Extension impacts will be measured later in the project based on survey of changes implemented against a baseline established early in the project.

Outputs YR 1

Products: *Extension Publications (lay/popular/ industry trade journals):*

- ✓ Kruger, C.E., Yorgey, G.G., & Stöckle, C.O., 2011. Climate change and agriculture in the Pacific Northwest. Rural Connections: Climate Change Adaptations in the Rural West, 5:51-54.
  An invited article on the status of the science of climate change impacts and adaptations in the PNW for a special issue of the news magazine of the Western Rural Development Center
- ✓ Petrie, S, C.E. Kruger, 2011. Helping Ensure Changes are Implemented. REACCH Project One-Page Summaries: Objectives 1- 8.
  One-page summaries of the Objectives for the REACCH Project for lay audiences

Events: *Presentations / Posters*

- ✓ Eigenbrode, S.D., J.T. Abatzoglou, J. Antle, I.C. Burke, S. Capalbo, P. Gessler, D.R. Huggins, J. Johnson-Maynard, C. Kruger, B.K. Lamb, S. Machado, P. Mote, K. Painter, W.L. Pan, S.E. Petrie, T.C. Paulitz, C. Stöckle, V. Walden, J.D. Wulfhorst, K.J. Wolf. Regional Approaches to Climate Change for Inland Pacific Northwest Cereal Production Systems. Tri-State Grain Growers Meeting. Nov. 16-18, 2011, Spokane, WA (poster).
  A poster presentation provided at the WA, OR, and ID wheat producers annual meeting. Attendees included growers, state and federal agency personnel and cereal industry personnel.

- ✓ Kruger, C.E., Yorgey, G.G., Chen, S., Collins, H.P., Feise, C.F., Frear, C.S., Granatstein, D.M., Higgins, S., Huggins, D.R., MacConnell, C.B., Painter, K.M., & Stöckle, C.O. Climate Friendly Farming: Improving the carbon footprint of agriculture in the Pacific Northwest. *Regional Approaches to Climate Change Annual Meeting.* Regional Approaches to Climate Change, Annual Meeting, May, 9-11, 2011, Moscow, ID (poster).

  A poster presentation of prior research on PNW climate change and agriculture research presented at the REACCH Project Launch meeting
- ✓ Kruger, C.E. Climate Friendly Farming: Improving the Carbon Footprint of Agriculture in the PNW. WSU CAHNRS / Extension All Faculty Conference, Oct. 5, 2011, Pullman, WA (invited presentation).

  A presentation on prior research on PNW climate change and agriculture research to the Extension Faculty of the WSU Extension Agriculture Program Unit
- ✓ Kruger, C.E. Thinking about organics recycling in the context of Global Change. Washington Organics Recycling Council, Dec. 8, 2011, Ellensburg, WA (invited keynote presentation).

  A presentation to the organics recycling industry on the importance of recycling organic materials as an agricultural carbon sequestration / GHG emissions mitigation strategy in the PNW
- ✓ Kruger, C.E. Sustainable Pathways to Bioenergy. Washington Future Energy Conference, Oct. 19, 2011, Seattle, WA (invited presentation).

  A presentation to the emerging Bioenergy industry on the trade-offs caused by utilizing agricultural residues as a feedstock for bioenergy rather than for soil carbon sequestration
- ✓ Kruger, C.E. Agriculture and Climate Change in the Pacific Northwest: Impacts and Adaptation. Ag Link Farmer Workshop, Jan. 5, 2011, Dayton, WA (invited presentation).

  A presentation to a producer meeting regarding prior research on the impacts of climate change on PNW agriculture
- ✓ Kruger, C.E. Climate Change and Agriculture in Washington. Othello Sandhill Crane Festival, Mar 26, 2011, Othello, WA (invited presentation).

  A presentation to the public and producers on prior research on agriculture and climate change in the PNW
- ✓ Kruger, C.E. Climate Friendly Farming: Opportunities and Challenges for Whatcom County Agriculture. Time to Act: Adapting to Climate Change in Whatcom County, April 8, 2011, Bellingham, WA (invited presentation).

  A presentation to the public and producers on prior research on agriculture and climate change in the PNW
- ✓ Kruger, C.E. Carbon Footprints in PNW Agriculture and Food Systems. WSU Carbon Master's Program. Whatcom County Extension, Nov. 17, 2011, Bellingham, WA (invited seminar).

  A seminar to a cadre of WSU Carbon Master's students on the issues related to carbon footprints in PNW agriculture and food systems

- ✓ Petrie, S.E. and S. Eigenbrode. Regional Approaches to Climate Change for Pacific Northwest Agriculture - REACCH-PNA Launch Meeting, May 9-11, 2011, Moscow, ID (poster).
  An overall REACCH Project poster presented at the REACCH Launch Meeting

Product: *Video/Multi-media*

- ✓ Raphael, K., Kruger, C.E., Aeschliman, J., Brown, T., & Henry, A., 2011. The Second Solution: Agriculture's Role. Northwest Regional Biocarbon Initiative: http://climatesolutions.org/programs/NBI/soil-stories-and-resources.
  An educational video project co-produced with the Northwest Regional Biocarbon Initiative targeted at improving public and policy-maker understanding of the role that agriculture can play in reducing greenhouse gas emissions

Products: *Webinars/Extension Curriculum*

- ✓ Cogger, C. and T. Zimmerman, 2011. Understanding the Science of Climate Change. WSU CSANR Sustainable Agriculture Webinar Series.
  Part 1: What does the science really tell us about past and current climate trends?
  Part 2: Climate models, skepticism, and our response to climate disruption.
  A two-part web-based seminar hosted by the Project Team designed to equip Extension Educators and other stakeholders with the latest information on climate change science
- ✓ Kruger, C.E., G. Yorgey, S. Kantor and T. Zimmerman. (In progress). What do we know about Climate Change and Agriculture in the PNW? WSU CSANR Sustainable Agriculture Webinar Series.
  Part 1: Greenhouse Gas Emissions, Carbon Sequestration and Mitigation Opportunities
  Part 2: Climate Change Impacts and Adaptation
  A two-part web-based seminar under development designed to provide regional Extension Educators and other stakeholders with a "state of the science" of climate change and agriculture research in the PNW.

Product: *Other*

- ✓ REACCH Stakeholder Advisory Committee list (Appendix C).
- ✓ Response to REACCH Stakeholder Advisory Committee input

Events: *Meetings*

- ✓ Objective 7 bi-monthly committee meeting: Kruger, Petrie, Yorgey, Kantor, and others as appropriate/invited
- ✓ Objective 7 Faculty Coordinator Hiring Committee (3 meetings): Petrie, Kruger, Eigenbrode, Pan

- ✓ REACCH Project Leadership bi-monthly committee meeting: Kruger, Petrie
- ✓ REACCH Website committee meeting (3 meetings): Kruger, w/ Obj. 8
- ✓ REACCH Meeting planning committee (8 meetings): Kruger, w/ Project Management
- ✓ Collaborative Project Coordination with BioEarth Project (monthly meeting): Kruger

Milestones and Deliverables

The Milestones and Deliverables for Objective 7 were reorganized and expanded to provide additional detail that could not be accommodated within the space constraints of the original proposal task lists and specific tasks necessary to achieve deliverables were added with annual due dates to improve effectiveness of reporting each project year through the REACCH Project's "Central Desktop" system. Adjustments in the nomenclature for each Milestone were made to accommodate a broader interpretation of activities, tasks and deliverables for each milestone.

M7.1 *Stakeholder Communication*

- ✓ Coordinated two SAC meetings in 2011, both of which had sub-optimal participation due to timing (initial meeting scheduled on short notice, launch meeting scheduled during height of spring farming activities).
- ✓ Input solicitation (to compensate for participation), was duplicated at these meetings and combined with informal consultation through other means including personal meetings, telephone contacts and email.
- ✓ To alleviate future scheduling challenges, suggestions of optimal timing and notice of annual meetings were provided to the meeting planning committee.
- ✓ Formal input from the SAC was recorded and a "Response to Stakeholder Advisory Committee Input" was prepared, provided to SAC members, and will be reviewed at the 2012 Annual Meeting.
- ✓ Based on SAC input, the Objective 7 team facilitated the development of REACCH Project "Objective 1-Pagers" to provide introductory information to stakeholders about the project. Planning for the SAC session of the 2012 Annual Meeting was initiated in August of 2011.
- ✓ Coordinating with the tri-state climate change Extension Specialist, John Stevenson, in providing leadership for agricultural climate change extension in the Pacific Northwest.

M7.2 *Develop Extension Products for Dissemination to Stakeholders*

This milestone now includes both product development and web-based delivery mechanisms (merges a former milestone and deliverable statement).

- ✓ A project-wide decision was made in YR 1 to collaborate on website development between Project Management, Education (Obj. 6), Extension (Obj. 7), and Cyber-Infrastructure (Obj. 8). Collaboration will optimize management and development of content project-wide and improve efficiencies between research data infrastructure and anticipated extension products developed later in the project.

- ✓ A committee was established to plan web development capabilities (described by Obj. 8). A number of Extension products were developed and delivered upon stakeholder request based on extensive prior research on agriculture and climate change in the PNW.

M7.3 *Develop REACCH Extension Educator Network*

- ✓ The highest priority goal of M.73 for YR 1 was to complete preparations to hire the Extension Faculty Coordinator position (funding budgeted beginning in YR 2). All preliminary decisions and preparations are complete and the package has been submitted to HR at the University of Idaho pending approval to initiate the search.
- ✓ A variety of activities (presentations, webinars, planning meetings) were completed to initiate engagement of Extension Faculty / Professionals and other stakeholder educators in the region regarding climate change and agricultural extension program support.
- ✓ We are early in coordination efforts with the Sustainable Corn CAP (led by Iowa State University) on developing a cereal grain and climate change eXtension Community of Practice.

M7.4 *Stakeholder evaluation –*

- ✓ A decision has been made for partial coordination with Objective 4 (Social and Economic Objective) to add questions to surveys they are also providing to improve efficiency and reduce redundancy and confusion in data gathering from REACCH stakeholders.

M.7.4 Tasks *Not completed in YR 1*

- ☐ Developments for M7.4 have been delayed due to sub-contractual budgeting issues and the late budgetary decision to hold funding for the faculty coordinator position until YR 2.

D7.2.2 *Develop Extension publications, presentations and tools for stakeholders*

- ✓ Tabitha Brown, WSU PhD. student, participated in the development of the Extension video project: “Agriculture’s Role”.

D7.3.3 *Develop and train a virtual community of stakeholders*

- ✓ Approximately 40 WSU Faculty members, including both scientists with Research Appointments and Extension Faculty members from the WSU Agriculture Extension Program Unit (including most Extension faculty with wheat-based programming responsibilities) participated in a seminar on the state of the science of agriculture and climate change in the PNW at the WSU CAHNRS / Extension All Faculty Conference.
- ✓ Approximately 15 Extension “volunteers” in the WSU Whatcom County Carbon Master’s Program participated in a seminar on the state of science regarding agriculture and food systems carbon footprints.

Broad Impacts

Objective 7 was designed to provide upstream and downstream information exchange between project scientists and both traditional (farmers and allied agriculture industry/ representatives) and less traditionally engaged (environmental organizations and policy/ regulatory agencies) stakeholders. REACCH will provide relevant research results to answer both production questions and larger policy questions. The relationship between farmer/industry – regulatory agency – environmental organizations and the REACCH team is essential for ensuring that both technical and policy obstacles are removed for promising management practices to be implemented. While this relationship was designed and anticipated, there are early indications that the prior foundational relationships that have been built in the region could improve the likelihood of accelerating adoption of technically viable climate change mitigation and adaptation activities in the region.

Training

See D.7.2.2 and D.7.3.3 listed above.
Tabitha Brown, WSU PhD. student, is partially funded by REACCH.

Collaborations and "Integrated" Knowledge

The primary "integrated" knowledge development effort of REACCH in YR 1 with mature implications for the Extension Objective was the Agro-Ecological Zone (AEZ) cross-project theme. Early outputs from that effort were particularly instructive for Extension audiences in "visualizing" potential impacts of climate change on regional agriculture – and were useful in generating stakeholder interest in the project.

Objective 7 personnel have been involved in planning activities for the REACCH website and have interacted with stakeholders regarding the development of advanced electronic communication tools to serve information exchange needs between scientists and stakeholders.

Early discussions with members of Objectives 1, 2, 3, 4 and 8 were held in YR 1 regarding collaborative efforts to build advanced communication platforms and tools for stakeholder education when REACCH datasets and tools are sufficiently developed.

External, ongoing Grant collaborations relevant to REACCH:

- BioEarth: Understanding Biogeochemical Cycling in the Context of Climate Variability Using a Regional Earth System Modeling. USDA. Kruger, co-PI and Extension Lead
- Columbia River Supply and Demand Forecast. Washington Department of Ecology. Kruger, co-PI and Extension Lead
- Life-cycle Analysis of Pacific Northwest Feedstocks for Biofuel Production. US EPA. Kruger, PI
- Organic Waste to Fuels. Washington Department of Ecology. Kruger, PI

- Needs Assessment: What is the state of knowledge of private forest landowners regarding global climate change and the impacts to western forests? US Forest Service. Kruger, PI
- PNW Climate Impacts Research Consortium. NOAH RISA. Kruger coordination with John Stevenson.
- Organic Footprints Project. USDA. Kruger coordination with Project Leader Lynne Carpenter-Boggs

Grant proposal submitted relevant to REACCH:

- ✓ Preparing PNW Agricultural Educators to Respond to Climate Change: Needs Assessment and Professional Development for Sustainable Agriculture. Submitted to Western SARE. Kruger, PI

Plan of Work for YR 2

- ☐ D7.1.1 Coordinate SAC meeting at the Annual Meeting
- ☐ D7.2.1 Establish interactive REACCH project website
- ☐ D7.2.2 Complete and deliver "climate change and agriculture webinar series"
- ☐ D7.3.1 Hire Extension Faculty Coordinator
- ☐ D7.3.2 Coordinate with other regional CAP projects on establishing eXtension CoP
- ☐ D7.3.4. Initiate funding solicitation for Extension educators products/ demonstrations
- ☐ D7.4.1 Complete initial stakeholder survey
- ☐ We are planning a newsletter that will be widely distributed to the SAC members, as well as state and federal elected officials (their staffs), executive directors of state wheat growers groups, executive director of Direct Seed Association, directors of state departments of agriculture and environmental quality, our Deans and appropriate VPs including Extension directors, regional EPA administrator and ARS administrator.
- ☐ Knowledge Change outcomes will be assessed during the delivery of the "climate change and agriculture webinar series" and during other Extension activities based on prior research and early REACCH results.
- ☐ Survey data will be collected and evaluated as a baseline for future impact assessment of management practice and policy changes.
- ☐ For YR 2 we expect to provide a technical report regarding input from the Stakeholder Advisory Committee regarding desired outcomes of the REACCH project.
- ☐ We expect to provide a completed baseline evaluation of regional adoption of "climate friendly" management practices for future evaluation of REACCH impact.

Executive Summary

Lead: Paul Gessler paulg@uidaho.edu

The REACCH Objective 8 team is charged with broad oversight of planning and implementation of all elements of cyberinfrastructure and data management for support of all elements of the project. It is critical that these elements be coordinated within and between institutions and with other regional and national efforts that are developing and using common core datasets and computing infrastructure as well as the next generation of Internet capabilities intended to support cutting edge science throughout the Pacific Northwest and nation.

Achievements

Data management will be a critical component to the REACCH cyberinfrastructure efforts. Investigators and staff have contributed extensively in YR 1 to lay a strong foundation for data management that will ensure success as it relates to the project goals and objectives. Over the course of YR 1, several core accomplishments have been completed, including: **(1)** The REACCH initial data management policy framework has been developed; **(2)** The REACCH Environmental Data Manager position was filled; **(3)** An initial data management strategy and framework was developed; **(4)** REACCH uses Central Desktop project management system software (http://www.centraldesktop.com) for all elements of internal project coordination within and between project management and the objective and science team leads.

YR 1 efforts have laid a good foundation for REACCH to begin more operational data management efforts in YR 2 and YR 3: **(1)** The REACCH operational data management plan will be completed in YR 2; **(2)** Implementation of the REACCH data management plan will begin in YR 2; **(3)** Initial systems for REACCH data collection and analysis, under a preliminary projection, should be up and running by January 2013.

Year 2 Planned Activities

The YR 2 core REACCH functional data management goals are: **(1)** build consensus and structure around metadata entry, collection, and management of REACCH scientific data; **(2)** implement a limited number of metadata models for REACCH's multi-disciplinary data needs with metadata tools for researchers to appropriately tag and upload essential scientific data**; (3)** begin prototype application development around data sharing, visualization, and analysis of REACCH data; **(4)** lay the technical and architectural foundation for how REACCH will distribute, disseminate, and institutionally manage REACCH data over the life and beyond of the project;
(5) develop and/or acquire the support services necessary for appropriately managing REACCH data systems; **(6)** overall implementation of the REACCH data management operational plan.

Outcomes/Impacts YR 1

Objective 8 team outcomes and impacts overall have been minimal during YR 1 as most of our effort has been focused on establishing personnel and a data management framework to provide long term support to the REACCH project and to plan for data flow, archiving, and data exploration tools in support of both short and long term objectives. Data management efforts ramped up considerably at the end of YR 1: **(1)** hired the Environmental Data Manager, Erich Seamon; **(2)** completed the REACCH data policy framework; **(3**) important collaborative connections established with other large regional projects (NSF EPSCOR, USGS NW Climate Center, NSF DataONE, LTER, CUAHSI HIS) to complement and leverage resources from these efforts to provide a more sustainable data management strategy for the long term. The diversity of datasets and data streams generated by REACCH researchers has led us to move towards an overall architecture that will take advantage of multiple data repositories when appropriate but also allow REACCH specific data management components to be implemented.

Planning, design, and project build-out have been the focus of data management efforts over the last six months, with the data management strategy, as outlined in the REACCH proposal, being matched up to operational tasks to be completed in YR 2 and YR 3 of the overall project plan. In addition, the data management architecture and design have been initially developed.

Outputs YR 1

Products:

- ✓ A draft REACCH Data Policy document has been developed and distributed amongst the REACCH management team for review and adoption.
- ✓ A draft overall data architecture model for flow and archiving of REACCH data has been established.
- ✓ A draft MOU has been developed for adoption at the Vice President for Research level of the collaborating institutions to formalize our desire to collaborate and share a common vision of cyberinfrastructure and data management within the project region.

Events:

- ✓ Regular cyberinfrastructure meetings are being held both within the REACCH project (weekly) and between other projects that will share data and analysis requirements (monthly and as required).
- ✓ A REACCH web team has been established, regular web team meetings are occurring and a web implementation plan is in place with a preliminary web mock-up developed.
- ✓ Two meetings have been conducted with the Idaho Regional Optical Network (IRON) to help plan and implement data movement and analysis between collaborating institutions and experimental sites.

Activities:

- ✓ Hired REACCH Environmental Data Manager to oversee all elements of cyberinfrastructure and data management for the REACCH project.
- ✓ REACCH programming funds are being used to support personnel for climate model downscaling as a critical element for the science teams

Services:

- ✓ Environmental Data Manager has interviewed team leads to understand project requirements
- ✓ Metadata standards have been identified to serve the needs of the diversity of REACCH Data Sets
- ✓ Northwest Knowledge Network has provided server space, content management software and web portal programming expertise to assist the REACCH web team.

Milestones and Deliverables

M8.1 *Cyberinfrastructure Personnel*

- ✓ Hired REACCH Environmental Data Manager

Tasks *Not Completed in YR 1*

- ☐ We have not yet achieved the milestone and deliverable of completing an overall cyberinfrastructure plan for the project due to delays in completing the hire of our Environmental Data Manager. We expect completion of this deliverable in early 2012.

☐ Our initial proposal included funds for a Web Designer; however, we are considering using these resources in a more flexible manner through contractual services from the Northwest Knowledge Network, a research support service which is part of the University of Idaho. This approach would enable multiple hires with complementary skills so that we can implement web development and other efforts in a more task oriented manner. This approach better meets our changing needs as the web site is implemented and sequentially maintained by the Project Manager and objective leads.

☐

D8.1 *Interface for researchers and stakeholders created*

- ✓ Central Desktop adopted as intra-net portal for all REACCH project members

D 8.3 *Investigate, improve, and maintain cybercollaborative support*

- ✓ Build-out of an intranet portal for shared document and content access by researchers and staff
- ✓ Calendaring and meeting coordination through technology efforts are in place
- ✓ Video conferencing and other multi-media data sharing are occurring.

Broad Impacts

As a result of previously funded large research projects (National Science Foundation's EPSCOR), investments in the development of the Northwest Knowledge Network, as well as other new large regional projects (USGS NW Climate Center, NSF DataOne) the REACCH project has the opportunity to contribute resources to a critical mass of data management efforts that can serve our needs and provide a better long term plan for sustaining our data archives and access. Likewise, it provides an environment of skilled individuals and resources that our Environmental Data Manager can interact with and draw on to meet needs that will evolve and change as the REACCH project progresses.

In addition to the above, our data management emphasis on modularity, extensibility, and decentralization, we believe, has far-reaching implications in terms of large-scale data management collaborative efforts – particularly those that involve scientific discovery and peer reviewed research.

Training

- ✓ Data management training efforts in YR 1 have focused on content management and web site development training and education.
- ✓ With the development of REACCH's web site, http://reacchpna.uidaho.edu, training was attended on site maintenance and content input.

Collaborations and "Integrated" Knowledge

YR 1 efforts have had a significant focus on identifying and building collaborative partnerships so that REACCH data management resources can be utilized as efficiently as possible. Numerous meetings and discussions have occurred with a broad range of projects, programs and institutions related to data management. A brief list includes: **(1)** NSF Long Term Ecological Research (LTER) Network (nationwide); **(2)** NSF Data Observation Network for Earth (DataONE); **(3)** NSF funded EPSCOR Water Resources in a Changing Climate project (Idaho, New Mexico, Nevada); **(4)** NSF supported CUAHSI Hydrologic Information System (nationwide); **(5)** USGS funded Northwest Climate Center (Idaho, Washington, Oregon); **(6)** University of Idaho's Northwest Knowledge Network and UI Library; **(7)** DOE's Idaho National Laboratory (high performance computing and data visualization facilities); **(8)** Idaho Regional Optical Network (IRON)

The collaborations described above have identified many common needs and contributed to the initial conceptual development of the University of Idaho's Northwest Knowledge Network (NKN). The NKN concept builds on the idea that many research projects have similar needs for data management resources, web portal development expertise and capacity as well as the need for complementary research in data management.The NKN design is composed of three complementary elements: **(1)** a data management service center; **(2)** a data management repository and gateway to a variety of repositories and metadata resources; **(3)** a data management and cyberinfrastructure research program.

REACCH investigators have contributed to the conceptual development of NKN. Likewise, the UI's Library is an integral element for data management standards for citation and referencing of research datasets, such as those under development with REACCH funding. These integrated ideas and knowledge are all being supported by our REACCH project as we will be one of the first pilots of this collaborative aimed at developing and preserving datasets not only for ongoing project but to also serve as key data for integration and development of new science and opportunities to conduct regional analyses of importance to our agricultural stakeholders, educators, and researchers throughout the region.

Plan of Work YR 2

Work efforts will ramp up considerably for 2012, with the data management plan to begin in March 2012. The data management plan will describe in detail the strategic and operational steps to be taken for implementation. Some key areas of effort are outlined below.

- ☐ *Overall data management plan implementation*

  With the development of the REACCH data management plan, a strong foundation will be laid for moving forward with data management build-out efforts. This plan not only includes the tasks and milestones for completion, but support services, project control, and quality control and assurance components. This plan will also detail how REACCH will interact with and utilize collaborative resources as discussed above.
- ☐ *Metadata structure build-out*

  Metadata is a very important aspect to the REACCH data management efforts and key to interactive exploration and citation. Given the large and diverse amounts of data, laying a strong structure for metadata collection, storage, and mining, will ensure success later with regards to data analysis and information exposure. YR 2 efforts in this area will involve development of a metadata tool for investigator data tagging, as well as extensible web-browser based tools that will allow for the review and compilation of REACCH data thru these metadata tags.
- ☐ *Application development and integration*

  A core component of the REACCH data management strategy is to provide modular and extensible methods for accessing REACCH data. As part of this strategy, the cyberinfrastructure team will be working to develop both web-enabled and compiled applications to allow investigators, stakeholders, educators, and the public, access and interactive analysis of REACCH data via differing levels of access.

- ☐ *Data Access and Organizational Management*

  Organizational structure and management of REACCH data will be a key component in 2012. In order to effectively manage such a diverse and heterogeneous data system a strong organizational functional structure is necessary, and will be developed.
- ☐ *Training*

  YR 2 plans to be very active in terms of training activities, particularly in the areas of data content transfer for researchers; metadata tagging and uploading; as well as overall technology and knowledge training efforts for researchers, educators, and other stakeholders. The first two areas of training efforts, (data content transfer and metadata tagging), are more focused on training for core researchers and investigators who will be contributing and/or analyzing REACCH data. The third area provides for more broad knowledge transfer of REACCH's efforts, including; presentations; web site content; interactive media; and social media distribution.

Executive Summary

Lead: Dave Huggins dhuggins@wsu.edu

The AEZ concept is used to assess the spatial distribution of crop-relevant resources, their capabilities, and the potential for future land uses. Characterizing AEZs is critical to the development of sustainable prescriptions for land management given climate change, including the capacity to anticipate and develop mitigation and adaptation strategies. Furthermore, AEZs provide a transdisciplinary framework that enables researchers, stakeholders, students, the public, and policymakers to acquire a more holistic understanding of the interrelationships of agriculture and climate change. Our cyberinfrastructure (CI) enabled, geospecific data visualization that incorporates information from climate models, economic models, pest disease and weed vulnerabilities, and other data sources will aid our pursuit of a transdisciplinary examination of climate-driven AEZ futures.

Achievements

1. Detailed boundaries of the REACCH study area were defined using the Major Land Use Areas (MLRA) comprising MLRA 7 (Columbia Basin), 8 (Columbia Plateau) and 9 (Palouse and Nez Perce Prairies) and a small portion of 43A (Northern Rocky Mountains) (Figure 4). **2.** The concept of dynamic AEZs was developed and four major AEZs were defined for the REACCH study area (Annual Crop; Annual Crop-Fallow Transition; Grain-Fallow; and Irrigated) based on the NASS Cropland data layer (Figure 5). **3.** The dynamic AEZ concept was presented at three conferences: Huggins et al., 2011. Dynamic Agroecological Zones for the Inland Pacific Northwest. REACCH Launch Meeting, Feb. 24-25, 2011 (display). **(a)** Huggins et al., 2011. Dynamic Agroecological Zones for the Inland Pacific Northwest. Annual Meeting of the Sustainable Corn CAP, Nov. 7-9, 2011 (display); **(b)** Huggins et al., 2011. Dynamic Agroecological Zones for the Inland Pacific Northwest, USA. American Geophysical Union Annual Meeting, Dec. 4-9, San Francisco, CA (oral). **4.** The proportions of major crops and fallow were characterized for each of the four AEZs (Table 9). A comparison of cropland use between the new AEZ delineations and the agroclimatic zones of Douglas et al. (1992) was developed (Table 10). **5.** A draft white paper describing AEZ delineations as well as an outline of an AEZ paper series were developed and discussed.

YR 2 Planned Activities

1. Complete assembly of REACCH study area characterization data layers including down-scaled climate data and economic data from Objective 1 activities. **2.** Publish one manuscript on the concept and development of dynamic AEZs including AEZ characterization themes for the inland Pacific Northwest. **3.** Work with Objective 1 team to develop spatial data layers of biophysical and socioeconomic variables. **4.** Assess how well biophysical and socioeconomic variables explain the spatial distribution of AEZs using multivariate analysis. **5.** Submit manuscript on prediction of current AEZs using biophysical and socioeconomic variables. **6.** Explore use of predictor variables for representing future agroecological conditions including biophysical and socioeconomic responses to climate change.

"The universe is full of magical things patiently waiting for our wits to grow sharper." Eden Phillpotts

Outcomes/ Impacts YR 1

Outcomes and Impacts, defined as changes in knowledge, actions or conditions, have been limited in YR 1 because our project is just beginning. Project principle investigators and collaborators have a greater understanding of AEZ concepts as a result of presentations and discussions regarding the AEZ concept. We do not think our work has yet changed actions or conditions appreciably in YR 1.

Outputs YR 1

Events: *Presentations*

- ✓ Huggins et al., 2011. Dynamic Agroecological Zones for the Inland Pacific Northwest. REACCH Launch Meeting, Feb. 24-25, 2011 (display).
- ✓ Huggins et al., 2011. Dynamic Agroecological Zones for the Inland Pacific Northwest. Annual Meeting of the Sustainable Corn CAP, Nov. 7-9, 2011 (display).
- ✓ Huggins et al., 2011. Dynamic Agroecological Zones for the Inland Pacific Northwest, USA. American Geophysical Union Annual Meeting, Dec. 4-9, San Francisco, CA (oral).

Events: *Planned Meetings*

- ✓ AEZ concepts were presented and discussed at one meeting with all project collaborators and stake-holders
- ✓ Two meetings of REACCH Objective leaders and one meeting of Objective 1 team members.
- ✓ Numerous discussions on AEZ concepts were held among team members.

Products: *AEZ Development*

- ✓ A draft white paper describing AEZ delineation as well as an outline of an AEZ paper series were developed, posted on REACCH Central Desktop and discussed during team meetings.
- ✓ Huggins, D.R.2011.Defining Agroecological Zones for the Inland Pacific Northwest. Posted to REACCH Central Desktop, April 21, 2011.
- ✓ Huggins, D.R.2011 Ideas for series of AEZ related manuscripts (1-3). Posted to REACCH Central Desktop, Dec. 1, 2011.

Milestones and Deliverables

M9.2 *Cross-cutting themes*

- ✓ The Major Land Use Areas (MLRA) comprising MLRA 7 (Columbia Basin), 8 (Columbia Plateau) and 9 (Palouse and Nez Perce Prairies) and a small portion of 43A (Northern Rocky Mountains) were used to define the REACCH study region in the inland Pacific Northwest (Figure 6). The REACCH study area boundaries were presented to the overall REACCH project team: Huggins, D.R. 2011. AEZ Hierarchy.pdf. Posted to REACCH Central Desktop, May 18, 2011.
- ✓ The National Agricultural Statistical Service (NASS) Cropland Data layer for the years 2007, 2009 and 2010 were accessed. These data layers classify cropland use at a 57m or 30m resolution and provide annual spatial coverage of cropland use for the REACCH study area (Figure 6).
- ✓ The soil classification data layer at the suborder level was identified and used in characterization of the REACCH study area (Figure 7a).
- ✓ Climate data layers (annual precipitation and temperature) for characterization of the REACCH study area were obtained courtesy of the Parameter-elevation Regressions on Independent Slopes Model (PRISM) Climate Group, Oregon State University (Figures 7b and 7c).
- ✓ Agro-climatic zones defined by Douglas et al. (1992) and Level IV Ecoregions developed by the EPA were identified as key classification schemes currently in use within the Pacific Northwest region.

M9.2a *Systems modeling: TOA-MD performance outcomes for climate scenarios, AEZ*

- ✓ AEZ perspectives contributed to Objectives 1 and 2 team for the upcoming meeting in Pendleton, OR and during regular REACCH team meetings as requested.

M9.2c *AEZ: Climate change and adaptation and mitigation technology impacts on AEZ*

- ✓ The concept of dynamic AEZs was developed and four major AEZs were defined (Annual Crop; Annual Crop-Fallow Transition; Grain-Fallow; and Irrigated) for the REACCH study area (Figure 7).
- ✓ The dynamic AEZ concept was developed and presented at three conferences:
  - Huggins et al., 2011. Dynamic Agroecological Zones for the Inland Pacific Northwest. REACCH Launch Meeting, Feb. 24-25, 2011 (display).
  - Huggins et al., 2011. Dynamic Agroecological Zones for the Inland Pacific Northwest. Annual Meeting of the Sustainable Corn CAP, Nov. 7-9, 2011 (display).
  - Huggins et al., 2011. Dynamic Agroecological Zones for the Inland Pacific Northwest, USA. American Geophysical Union Annual Meeting, Dec. 4-9, San Francisco, CA (oral).
- ✓ The proportions of major crops and fallow were characterized for each of the four AEZs (Table 10).
- ✓ A comparison of cropland use between the new AEZ delineations and the agroclimatic zones of Douglas et al. (1992) was developed for the REACCH study area (Table 11).

- ✓ A draft white paper describing AEZ delineation as well as an outline of an AEZ paper series were developed, posted on REACCH Central Desktop and discussed during team meetings.

Broad Impacts

The AEZ concept as developed and presented represents a novel shift in traditional AEZ definition that enables a dynamic assessment of AEZ change over time in response to climate change or other biophysical or socioeconomic perturbations. In contrast to basing AEZ boundaries on relatively unchanging physical factors such as physiography or climate, our approach is to base major AEZ delineation on the annually NASS produced cropland data layer. This enables a spatio-temporal assessment of AEZs and crop constituencies as they respond to major biophysical and socioeconomic drivers. We think this approach could also be used for other regions of the country or world where spatially dense cropland data is available.

Training

Table 9. Students, postdocs, and support persons received training as part of REACCH activities

Dave Uberuaga	Research Technician	USDA-ARS
Jeff Perkins	Technical Support	Washington State University
Tabitha Brown	PhD Student, Soil Science	Washington State University
Gerard Birkhauser	PhD Student, Soil Science	Washington State University
Rachel Unger	PhD Student, Soil Science	Washington State University

Collaborations and "Integrated" Knowledge

Integrated collaborations within our project are just beginning. We plan to work closely with all Objective teams and integrating themes such as the LCA. A more comprehensive mindset regarding integrating themes such as AEZs continues to develop and these transdisciplinary efforts have been well received. Collaborations and synergies with other NIFA projects such as the Site-Specific Climate Friendly Farming project led by Dr. David Brown as well as a newly NIFA funded project on Biofuels are continuing to evolve.

Plan of Work YR 2

- ☐ Complete assembly of REACCH study area characterization data layers including down-scaled climate data and economic data from Objective 1 activities.
- ☐ Publish one manuscript on the concept and development of dynamic AEZs including AEZ characterization themes that describe these AEZs for the inland Pacific Northwest.

- ☐ Work with Objective teams to develop spatial data layers of biophysical as well as socioeconomic variables for the REACCH study area. Use biophysical and socioeconomic data layers to assess how well they explain the spatial distribution of the four major AEZs using analyses such as Random Forests and multivariate discriminant analysis.
- ☐ Aid in the development and submission of one manuscript on prediction of current AEZs using biophysical and socioeconomic variables.
- ☐ Explore use of predictor variables for representing future agroecological conditions including biophysical and socioeconomic responses to climate change.

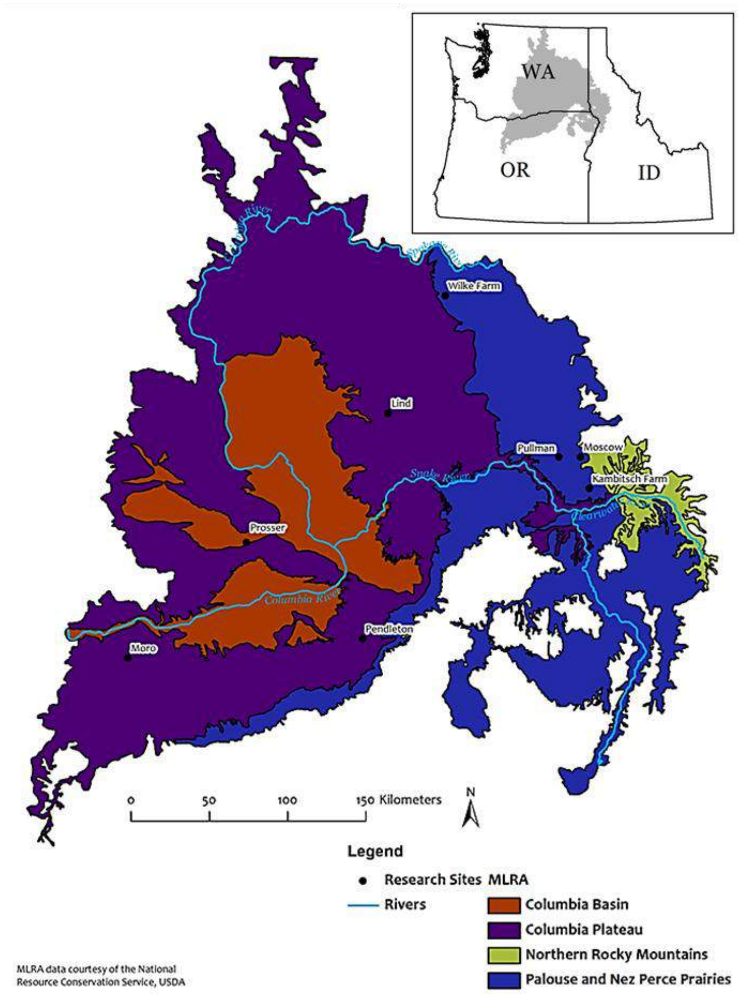

Figure 4. The Major Land Resource Areas (MLRA) used to delineate the REACCH study area

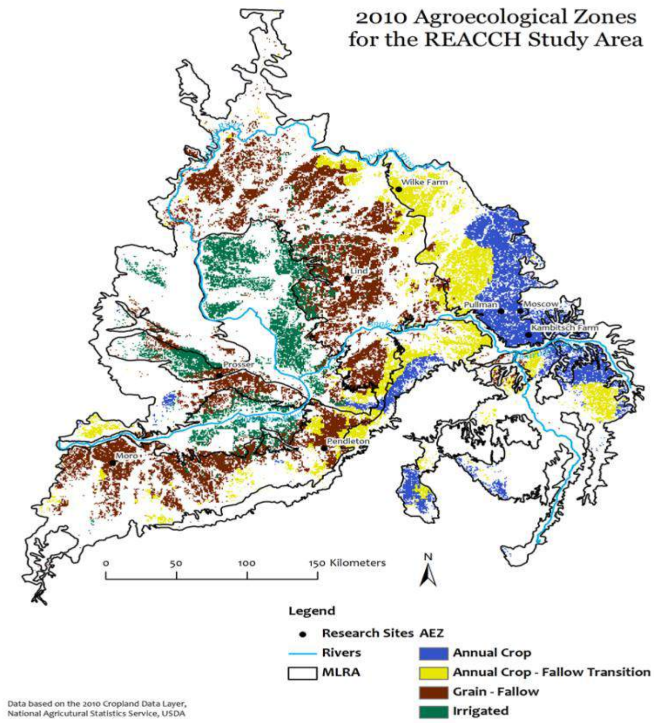

Figure 5. Four major Agroecological Zones (Annual Crop; Annual Crop-Fallow Transition; Grain-Fallow; and Irrigated) for the REACCH study area, 2010

Table 10. The percentage of major crops and fallow within the four agroecological zones (AEZ).
v

AEZ	Fallow	Winter wheat	Spring cereal	Grain legume	Canola	Alfalfa	Potatoes	Other	Total
	---%--								
Annual Crop	3	39	20	21	1	5	0	11	100
Crop - Fallow Transition	27	39	20	3	0	4	0	5	100
Grain - Fallow	48	45	3	0	0	1	0	3	100
Irrigated	9	16	5	4	0	16	8	42	100

Table 11. Comparison of the dynamic AEZ classification with the Douglas et al. (1992) agroclimatic zones

Douglas et al. (1992)	Dynamic AEZ			
	Annual Crop	Crop - Fallow Transition	Grain - Fallow	Irrigated
	------------------------------------ % ------------------------------------			
Annual Crop	67	29	4	1
Annual Crop-Fallow Transition	26	65	9	0
Grain-Fallow	2	20	59	18
Irrigated	0	1	20	78

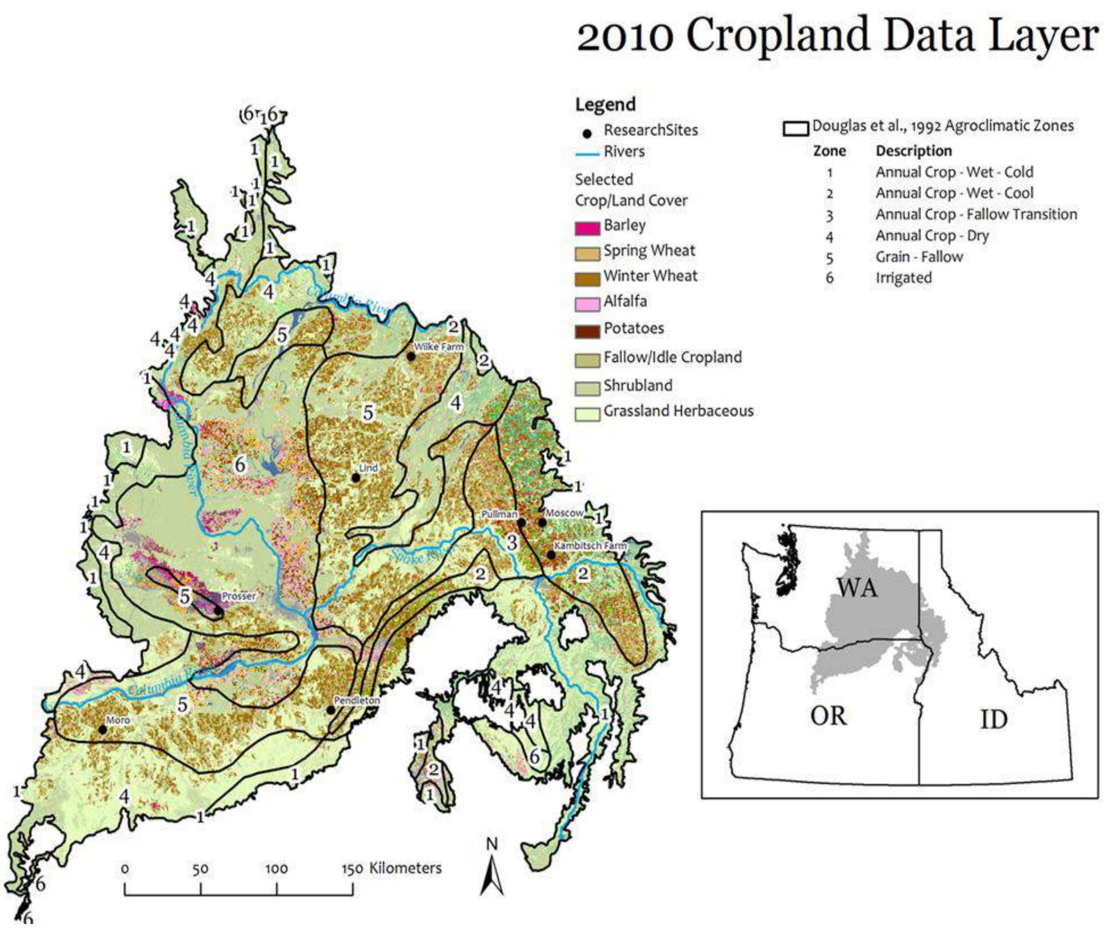

Figure 6. The 2010 cropland data layer for the REACCH study area (NASS, 2010) and the agroclimatic zones defined by Douglas et al., 1992.

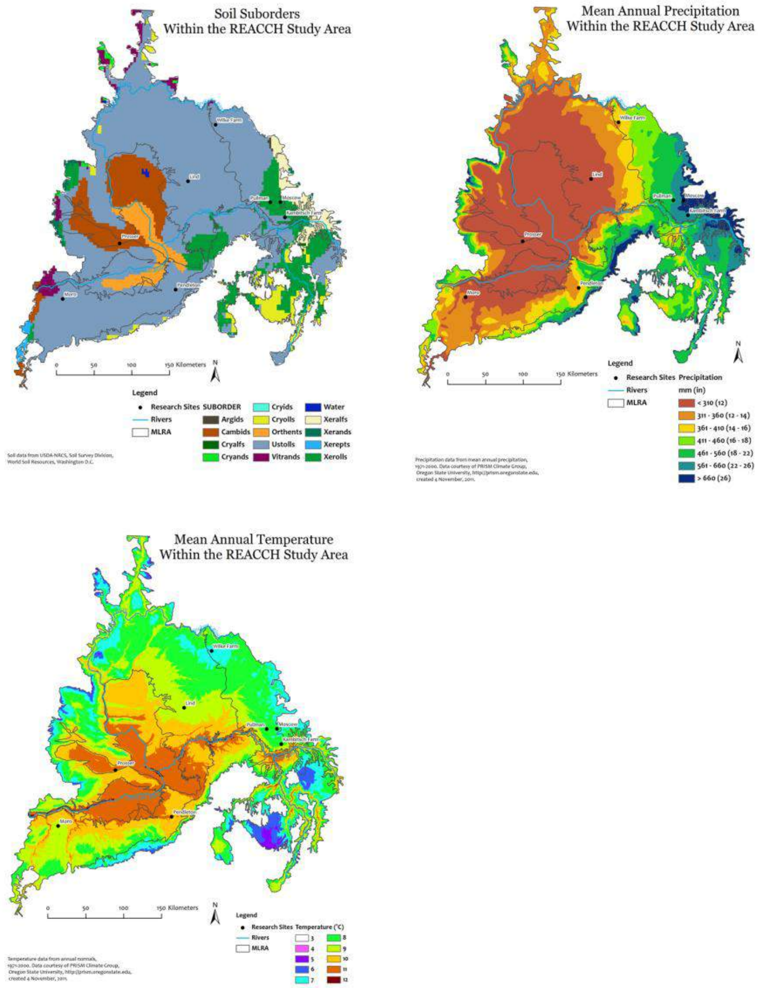

Figure 7. Soil suborders, mean annual precipitation and mean annual temperature for the REACCH study area.

Executive Summary

Lead: Claudio Stöckle stockle@wsu.edu

This cross-cutting aspect of the project is designed to integrate information from cropping systems modeling and alternative production trials to generate on-farm Life Cycle Assessment for current and projected cropping systems within the study region.

Achievements

The main objectives in YR 1 were to: **(1)** develop geo-referenced databases of weather (baseline and projected future) and customized soil databases; **(2)** develop software that facilitates scenario creation and allows performing unattended regional simulation runs; **(3)** conduct a "proof-of-concept" regional analysis including preparation of weather, soil, and crop/management databases, cropping systems model (CropSyst) geo-referenced simulation runs, and analyses using the TOA-MD model; **(4)** formulate a functional model of field N_2O emissions and a simplified single-pool soil organic carbon (SOC) model suitable for regional analyses; **(5)** initiate the formulation of a simple Life Cycle Assessment that utilizes simulated and observed inputs; **(6)** improve CropSyst to predict crop growth under climate change and elevated atmospheric CO_2 conditions.

Gridded (4x4 km) daily weather datasets were made available by climate modelers, including temperature, precipitation, solar radiation, humidity, and wind speed from 1979-2010 (historical baseline) and for projected future periods (2006-2035). The USDA-NRCS STATGO soil data base was used to extract averaged soil data required by CropSyst for each pixel. The model was upgraded to read pixel input data during run time, integrate cropping systems and management scenarios, and produce geo-referenced outputs. Software was coded and hardware was acquired to facilitate scenario creation and to perform regional simulations in unattended mode.

A proof-of-concept regional analysis for a winter wheat-fallow rotation was conducted over the entire REACCH study region. This activity allowed climate, cropping system, and economic modelers to implement and resolve technical issues associated with integrated analyses, providing an opportunity to test different methodologies and ensure readiness to analyze more complex cropping systems. The question remains about the comparative performance of regional analyses based on gridded data and those based on ground weather observations. The latter is possible in the study region given the adequate density of weather stations, but it has limitations due to the short duration of records in stations with sufficient weather variables to drive CropSyst or insufficient number of variables in those with long records. This year, methodologies were developed and tested to estimate solar radiation and relative humidity based on temperature data.

A functional model of N_2O emissions was formulated and a method for field parameter calibration was conceptualized that can utilize data from a multi-chamber experiment. An Excel Life Cycle Assessment (LCA) calculator was developed, which will be extended to link with gridded regional scenarios. Improvements to CropSyst were implemented including an updated water-use efficiency approach to calculate crop biomass production, an updated method to account for the effect of elevated atmospheric CO_2 concentration on water use and biomass production, and the development of a single-pool SOC model to replace the existing multiple-pool model. Involvement with the AgMIP allowed testing CropSyst (wheat and maize) at several locations worldwide.

Outcomes/Impacts for YR 1

Outcomes and impacts, defined as changes in knowledge, actions, or conditions, have been limited in YR 1 because our project is just beginning. There are none to report for LCA.

O***utputs YR 1***

Our primary output is a preliminary proof of concept model developed and shared with other project personnel. For a complete summary of outputs please see the accomplishments under Milestones and Deliverables listed below.

Milestones and Deliverables

D9.5c *LCA theme: global warming potential of current and projected cereal systems in IPNW*

- ✓ Development of geo-referenced weather (baseline and projected future) and customized soil databases spatially integrated with the CropSyst cropping systems simulation model.
- ✓ Development of software for scenario creation and unattended regional simulation runs.
- ✓ Completed "proof-of-concept" GIS-based regional analysis including databases, crop/management scenarios, cropping systems model (CropSyst) simulations, and economic model (TOA-MD).
- ✓ Formulation of a functional model of N_2O emissions and coding of a simplified single-pool SOC model suitable for regional analyses.
- ✓ Initiated the formulation of a simple Life Cycle Assessment approach that utilizes simulated and observed data.
- ✓ Participation in activities of the Agricultural Model Inter-comparison and Improvement Project and improvement of CropSyst capabilities to predict crop growth and yield under climate change and elevated atmospheric CO_2 conditions.

Plan of Work YR 2

- ☐ A comparison of regional analyses for a winter wheat-fallow rotation based on gridded and ground weather stations for the period 1979-2010 will be conducted as a means of validating the grid-based approach in this project.
- ☐ Using gridded weather, baseline and future weather-based regional analyses will be conducted for one typical (conventional management) wheat-based cropping system for each of the four agro-ecological zones in the study area: **(1)** continuous cropping; **(2)** two cropping years and one year of fallow; **(3)** alternate cropping and fallow years; **(4)** continuous cropping under irrigation. These runs will be useful for Objectives 1, 3 and 4.
- ☐ These new sets of runs will provide a baseline of climate change impacts on wheat-based systems and of long-term changes in SOC storage and N_2O emissions.

- ☐ The LCA tool will be programmed as a stand-alone utility linked to CropSyst to be used to evaluate carbon footprint of cropping systems at the scale of 4x4 pixels over the entire REACCH area.

Executive Summary

Lead: David Meyer david.meyer.email@gmail.com

YR 1 REACCH assessment activities were designed to be useful to REACCH participants and as well as USDA NIFA Program Directors. These utilization-focused (Patton, 2008) evaluation activities benefit the program in three ways. First, the qualitative information collected provides specific project improvement recommendations; these open-ended questions and interviews cast a broad net to help identify program strengths and challenges. Second, the quantitative evaluation activities help build a foundation of project management benchmarks and objective area performance metrics; these activities include common reporting definitions and templates as well as closed-ended surveys of participant attitudes and perceptions. Finally, and most importantly, is the sense of shared responsibility and collaboration REACCH participants gain as they help develop, implement, and analyze these program assessment tools.

Achievements

A key goal of REACCH project evaluation activities is to help participants design and use feedback tools that bring together multiple expertise areas and world views. This assessment process is intended to maintain an open and flexible approach that helps REACCH participants discover what we "know" as individuals and groups and begin to build the new communities of understanding that define transdisciplinary efforts. Such an approach is consistent with Klein's (2008) recommendation that evaluation of transdisciplinary efforts "evolves through a dialogue of conventional and expanded indicators of quality" (p. S122).

This evaluator's report will review the assessment efforts and formative evaluation procedures established during YR 1. The last section of the full report provides a SWOT analysis (strengths, weaknesses, opportunities, and threats) of the REACCH Project as of January 2012.

YR 2 Planned Activities

The evaluator will continue to participate in leadership meetings. A refined survey will be designed to track those measurements of team perceptions taken in YR 1 and additional components of team function as required or requested by the REACCH team. A report will be prepared towards the end of YR 2.

Transdisciplinary Integration

According to a transdisciplinary integration survey given in November 2011, nearly 75% of REACCH Project PIs/Co-PIs and Professional/Technical staff members worked in partnership with others outside of their primary, secondary or third disciplines on a weekly or monthly basis during the year *prior* to REACCH funding. The REACCH team is clearly experienced in working with different academic disciplines and demonstrates an awareness of the pitfalls and challenges of transdisciplinary knowledge integration. As the team learns more effective ways to manage this integration process, one task will be to better define the terms describing academic collaboration.

The terms multidisciplinary, interdisciplinary, and transdisciplinary are often confused because all three require some level of cross-disciplinary collaboration. The three activities differ in both the scope and depth of knowledge. As summarized in Table 12 multidisciplinary research retains the original disciplinary frameworks and academic identities; multidisciplinary research products are no more and no less than the simple sum of its parts. Interdisciplinary research integrates separate disciplinary data, methods, tools, concepts, and theories in order to create a holistic view or common understanding of a complex issue; interdisciplinary research products are an integration that is different from and greater than the sum of the disciplinary approaches. Finally, transdisciplinary research builds a comprehensive framework that transcends disciplinary world views. Like interdisciplinary approaches, transdisciplinary research is different than the sum of its parts, although the scope of the overall effort is more comprehensive and the parts may be more diverse. By providing an overarching synthesis that integrates disciplinary insights as well as the knowledge of broader stakeholders in society, transdisciplinary research may be better able to define and analyze social, economic, political, environmental, and institutional factors in human health and well-being (Stokols et al. 2003; Wagner et al. 2011).

Table 12. Overview of collaborative concepts (from Tress et al. 2006)

Multidisciplinary	Interdisciplinary	Transdisciplinary
• Multiple disciplines with goals set under one thematic umbrella • Loose cooperation of disciplines for exchange of knowledge • Development of new theory driven by disciplines	• Crosses disciplinary boundaries with goals set in common • Integration of disciplines • Development of integrated knowledge and theory	• Crosses disciplinary and scientific/academic boundaries • Integration of disciplines and non-academic participants • Development of integrated knowledge and theory among science and society

Project-Wide Assessment

The assumption used in evaluating the REACCH project is that the collaborative approaches outlined in Table 12 are complementary. Multidisciplinary collaboration, dominated by disciplinary concepts and demands, is not “less valuable” than more integrative approaches because complex climate mitigation issues certainly require disciplinary knowledge. Moreover, the required relationships, trust, and insights are likely to grow through these more familiar and discipline-specific collaborations.

A shared understanding of key disciplinary and societal contributions is required before these ideas can create a more holistic perspective or cross academic frontiers to form new disciplines. Thus, many of the activities taken to help support each collaboration model in Table 12 are part of an iterative process rather than a sequence of steps to a final goal of transdisciplinary integration.

Outcomes/Impacts YR 1

Outcomes and impacts, defined as changes in knowledge, actions or conditions, have been limited in YR 1 as our project is just beginning. The assessment surveys were conducted the end of YR 1. One outcome of this work is the inclusion of an assessment overview in the first annual REACCH project conference, Feb., 29-Mar.2, 2012. A potential impact could be increased efficiencies in project management, communication and cross project understanding.

Outputs YR 1

Pre-Launch (January to May 2011)

Events:

- ✓ Face-to-face pre-launch meeting held with Project Director, key Objective team leads and the Project Evaluator identified shared project goals, strategies for how to integrate diverse academic disciplines, growers, and other stakeholders into project.

Products:

- ✓ USDA NIFA RFA required a coordinated management plan that recognizes broader stakeholder needs and transdisciplinary knowledge integration. Budget included travel and support for face-to-face meetings

Activities:

- ✓ Discussion, review, and selection of cyberinfrastructure capabilities needed to coordinate individual and cross-project activities and information sharing.
- ✓ Pre-launch refinement of project objectives based on insights gained during planning process.
- ✓ Pre-launch prioritization survey of PIs and CoPIs completed March 2011 to help participants understand project scope, rank objectives according to their own priorities, and identify key areas for potential collaboration and integration (quantitative ranking completed on-line, discussion of results at Launch Meeting).
- ✓ Objective team leads wrote clear "One Pager" descriptions of what research results will provide growers and other stakeholders (distributed at launch meetinandshared on Center Desktop for others to use).

Launch Meeting (May 9-11, 2011)

<u>Events:</u>

- ✓ PIs/CoPIs and Professional/Technical staff participated in Toolbox Workshop (Eigenbrode et al. 2007) to help cross-disciplinary collaborators identify and address their philosophical disparities and commonalities.
- ✓ Launch Meeting presentations on topics that overlap all objective areas were given, including: non-technical presentations on climate modeling, how REACCH researchers might use cyberinfrastructure and related tools to further their work, cross-project education activities, and how to talk to non-scientific audiences about climate change.
- ✓ Launch Meeting sessions were held that focused on growers and other stakeholders including a session dedicated to finding ways to make research results relevant to and supported by growers and broader community.
- ✓ Evening poster session provided unstructured discussion time for all participants.

<u>Activities:</u>

- ✓ Key first year activities were identified based on collaboration presentation, discussion of prioritization survey results, and substantive overlaps between key project components (data management, modeling frameworks, agroecological zones, and education).

YR 1 Activities (May 2011 to January 2012)

<u>Events:</u>

- ✓ Twice monthly leadership meetings held (face-to-face meeting for about half of the participants with teleconference option for those not in Moscow, ID). Typical agenda include project-wide business as well as updates from each objective area
- ✓ Twice monthly telephone conferences beginning in November 2011 between the Project Director, Project Manager, and Project Evaluator used to further develop assessment process and make feedback more useful to participants. Call is announced on Central Desktop and open to other REACCH participants.

<u>Products:</u>

- ✓ Inter-institutional data management, authorship and publication agreements completed.
- ✓ Longitudinal growers' survey and interview guide that targets social and economic factors influencing farming decisions completed.

<u>Activities:</u>

- ✓ Teleconferences held within respective roles across CAP projects, including Project Directors, Project Administrators, and Project Evaluators to share project management practices and insights.
- ✓ Qualitative survey targeting all REACCH participants (PIs, collaborators, technical staff, growers, graduate students, and other stakeholders) used three open-ended questions and yields 91 comments regarding Project successes and improvement recommendations. Qualitative data analysis identified five major themes. Results will be summarized and shared with participants to inform project improvement planning at the annual meeting and during YR 2.

- ✓ Quantitative survey targeting PIs and professional/technical staff completed in November 2011 provides baseline data for longitudinal measure of transdisciplinary integration. Using questions from existing scales of transdisciplinary attitudes and behaviors (Masse et al. 2008), the data from the 41-item survey provides six statistically sound measures: frequency of cross disciplinary collaboration, collaboration satisfaction, satisfaction with face-to-face communication, team trust, attitudes toward transdisciplinary research, and project productivity. Besides benchmarking YR 1 attitudes for future analysis, these results will be shared with REACCH participants to inform project improvement planning at the annual meeting and during YR 2.
- ✓ A shared cyber-infrastructure platform (Central Desktop) facilitated information sharing and cross-project coordination, including shared documents, calendars, contact lists, common reporting templates, performance reports, and on-line discussions. Face-to-face training sessions and on-line support were provided.

Milestones and Deliverables

There are no milestones and deliverables assigned specifically to assessment and evaluation in YR 1. The expectations outlined in the grant proposal have been accomplished as outlined in this report.

During our annual meeting Feb. 29-Mar.2, 2012, we will solicit input form the project team to develop milestones and deliverables for assessment for YR 2.

Broad Impacts

The Project Director, Project Manager, and Project Evaluator have gained significant experience working with other large-scale CAP climate change projects via regularly scheduled teleconferences. These collaborations have provided a forum to discuss and identify best practices and share management tools where appropriate. Besides improving the overall project effectiveness and management expertise, these exchanges may provide USDA NIFA managers and other stakeholder insight into how to design future RFAs.

Training

- ✓ Ethnographic Inquiry into REACCH graduate student project beginning March 2012 will use ethnographic research methods to explore transdisciplinary research as a cultural phenomenon that reflects the knowledge and system of meanings guiding the group. Project is aimed at recognizing some of the micro, meso, and macro levels of the team process and the factors that support or hinder transdisciplinary integration.

Collaborations and "Integrated" Knowledge

The activities listed above highlight the attention given to collaborative processes as well as the steps taken to support introspection and integration (inter- and trans-disciplinary skills). The REACCH activities listed above support strong collaborations across the disciplines (multidisciplinary activities) and build the skills, insights, and structures for further inter- and trans-disciplinary integration across all REACCH Program participants.

Plan of Work YR 2

- ☐ Face-to-Face Meetings to Support Integrated Knowledge Development:
- ☐ Break- out sessions at first annual meeting will identify ways to further enhance transdisciplinary collaboration. Based on YR 1 feedback, additional face-to-face meetings are likely within objective areas and across all project participants and stakeholders.
- ☐ Improved preparation and integration of Stakeholder Advisory Committee (SAC): First annual meeting will include more preparatory work for SAC: questions will be sent early to identify key concerns and recommendation from this important group.
- ☐ Continued Utilization of Scientific Advisory Panel (SAP): SAP members will receive questions for continued discussion regarding disciplinary feedback as well as their feedback regarding REACCH transdisciplinary challenges and successes. These questions will include knowledge gaps, potential links to other projects and activities that we have overlooked, ways we can improve outreach to stakeholders and integration of broader societal goals, data management recommendations and discipline-specific objective area advice.
- ☐ Use of Formative Feedback to Improve Knowledge Integration
- ☐ The following ideas were collected from interviews and surveys of REACCH participants during YR 1 and suggest how knowledge might be better integrated across the REACCH project. These ideas will be further discussed, developed, and implemented during YR 2.
    - Create more data-sharing presentations / preliminary summaries of the content of work to date
    - Schedule more one-on-one discussions across PI's and between Project Director and individual PI's.
    - Structure additional RA / post-doc cross-objective interaction. Technical coordination and communication at the RA/post-doc level is critical.
    - Design additional mechanisms to facilitate the cross-objective discussions.

Table 13: SWOT Analysis of the REACCH Project
The SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis below provides the Project Evaluator's summary of key strengths, weaknesses, opportunities, and threats to the REACCH Project as of January 2012.

Strengths	Weaknesses
Strong progress during first year of operation within critical research areas. Project leadership (both the project lead and objective leads) has significant collaborative research experience and demonstrates strong research expertise, collaboration skills, and project management abilities. Use of Central Desktop as cyberinfrastructure facilitates information sharing and cross-project coordination Project management practices established during first year help orchestrate cross-project efforts, including twice monthly leadership teleconferences, project-wide tracking, and common reporting procedures. Prioritization of specific activities that may support cross-project knowledge integration (data management, modeling frameworks, agroecological zones and education) Inter-institutional agreements regarding cyber-infrastructure support, data sharing and publication addressed potential conflict areas. Successful recruitment of well-qualified technical personnel	Wide project scope requires on-going attention to management and coordination activities that takes time away from discipline-specific research activities Limitations on the number of formal opportunities for participation of the full SAC with the full REACCH Team make it challenging for many of the REACCH PI's to have a full sense of stakeholder interests/concerns regarding project outcomes GANNT schedules and planning tools inconsistently maintained across objective areas may impact cross-objective coordination. Some PIs and collaborators report that they have a limited understanding of project-wide goals and objectives Few face-to-face opportunities for cross-project planning during the first year.
Opportunities (external to Project)	**Threats (external to Project)**
Collaboration with other CAPs and similar agriculture-related climate change projects provides opportunity for learning from different research approaches and cross-project research results. Climate change impacts are different across the regional and not uniformly positive or negative: adaption and mitigation strategies that address new opportunities are likely to have stronger support and implementation rates.	Funding instability and subsequent changes in research plan (potential $1M cut in YR 2 and subsequent reducing in following years) Grower resistance to idea of climate change may limit full cooperation and input into Project Broader public may see climate change as a less urgent issue: gaining necessary social and political support may be challenging.

Concluding Statement

The REACCH project will create more sustainable, resilient agroecosystems and rural communities for the inland Pacific Northwest. To do so, will entail applying the best available science to anticipate changing climates and how they will impact our production systems. Our project will also reduce emissions of greenhouse gasses from the region's cereal production systems. We will find and promote approaches to meet these dual goals of adaptation to climate change and mitigation of greenhouse gas emissions that are effective, profitable and acceptable and for producers. We anticipate that the production landscape will be changed in the future to include reduced tillage, more crop diversification, better nutrient and water management practices, enhanced soil carbon reserves and better systems for forecasting and responding to changing pressures from pests, weeds and diseases. The project will create an unprecedented level of collaboration among our three land-grant universities and USDA ARS. We are committed to establishing a physical and cyberinfrastructure that will allow continued long-term, coordinated research beyond the term of REACCH to address future challenges to the region's agriculture. This will include an integrated-long term studies established on seven experimental farms throughout the region, an integrated system for managing and sharing data obtained from these experiments and related studies. Building upon existing healthy relationships between producers and scientists we will create a stronger partnership that extends the science and technology but profits from engagement with experienced producers. Our efforts in student and postdoc training will specifically teach approaches to deeply integrated research that will be needed by future scientists addressing complex issues such as climate change.

Technical Report

Integration of Modeling Framework

An important part of YR 1 activities for Objective 1 was to establish a preliminary data design and procedures to implement integrated climate-crop-economic modeling, using historical and down-scaled climate and climate model data, the CropSyst Model and the TOA-MD model. At the Objective 1 meeting held August 19 at the Pendleton, (Oregon) Experiment Station, Objective 1 team members discussed and agreed upon a design for a preliminary analysis of climate change impacts on farms using a wheat-fallow system, representative of about 1/3 of the REACCH study region, without adaptation, with all other model parameters (e.g., prices, costs of production, etc.) at base values. In the following discussion, this preliminary analysis is referred to as WF-1. The goal was to test this proof-of-concept approach, using downscaled climate data, CropSyst characterization of wheat-fallow land use and yields simulated with high resolution pixels and with economic data from the agricultural census at the scale of zip code zones (or spatially proximate aggregated zip code zones where numbers of farms are small in individual zip code zones).

Another important integration activity is technology scenario and socio-economic scenario design. A meeting is planned for members of Objective Teams 1 and 4 to discuss scenarios on February 10, 2012, at the Hood River Experiment Station. In addition, J. Antle participated in a socio-economic scenario design workshop, and as a co-leader of the AgMIP Economics Team created the concept of RAPs for agricultural model simulation. Antle prepared a draft manuscript on RAPs that will be finalized for publication in 2012 and used as a basis for the design of socio-economic scenarios for REACCH. J. Antle is also a co-leader of the economics team of AgMIP. AgMIP is conducting global agricultural economic model intercomparisons, and Antle will acquire data from that exercise to design price scenarios for the REACCH regional scenarios.

Climate Modeling Group (CM)

Historical Data

Abatzoglou developed a new gridded dataset of historical meteorological data that overcomes limitations in previously used spatially and temporally explicit data required for broad scale modeling efforts. The new observed gridded dataset provides the primary meteorological variables needed for most agricultural and ecological applications and is being used across several objectives to complement sparsely located, and often incomplete, station records to paint a more thorough picture of historical climatology for the study area. These data also serve as a baseline for downscaling of climate scenarios. A paper was written, submitted, and accepted for publication in the International Journal of Climatology (Abatzoglou, in press). The data derived products, such as growing-degree days (Figure 1.1), were provided to members of the broader REACCH group. Datasets and information are currently available at http://bit.ly/so55Ii, and CM is working with the data management group to seamlessly provide this data in various formats across REACCH objective groups. Abatzoglou and Mote are developing a paper on variability and trends in relevant variables in the PNW, an update and extension of Mote (Northwest Science 2003).

Downscaled Climate Modeling

For implementation of WF-1, Abatzoglou and Walden have made downscaled data available to REACCH researchers from the Third Coupled Model Intercomparison Project (CMIP3) available from two different down-scaling methods: the Multivariate Adaptive Constructed Analog (MACA; Abatzoglou and Brown, 2011) and the Bias-Corrected Statistical Downscaling (BCSD) methods. We have also implemented both MACA and BCSD methods to the new batch and format of the Fifth Coupled Model Intercomparison Project (CMIP5). The software for both of these methods has been ported to the High Performance Computing (HPC) center at the Idaho National Lab (INL), in anticipation of the large computational processing required to downscale the CMIP5 data. To improve the link between climate-agriculture and economics, Abatzoglou has downscaled the CSIRO-MK3.6 model (medium-high climate sensitivity) using the RCP 4.5 scenario of greenhouse gas concentrations. Downscaling was conducted for maximum and minimum temperature, maximum and minimum relative humidity, precipitation amount, wind velocity and downward shortwave radiation for the time period 1950-2100 using the aforementioned 4-km gridded meteorological dataset. An example of the richness of the modeling exercise can be seen in Figure 1.2, which shows changes in pertinent meteorological fields for the time period 2025-2049 versus historical conditions (1971-2000) for the first two weeks of May.

Mote and colleagues at OSU are comparing CMIP5 global model projections with previous generation CMIP3 global model projections, as well as regional simulations made through the North American Climate Change Assessment Program (NARCCAP). The overall story is similar in CMIP5 (Figure 1.3). First-year graduate student Sihan Li (supported in part by REACCH) is examining results of the new super-ensemble of 25-km. regional climate model simulations for Western US using volunteer computers.

Cyberinfrastructure

Our team participated in discussions with the new REACCH Environmental Data Manager about how best to provide climate model data to REACCH researchers. Our approach so far has been to use an existing data archive at INSIDE Idaho (http://insideidaho.org), which has the capability to serve data through various different access protocols (e.g., FTP, HTTP, OPeNDAP, ArcGIS toolbox). We have also discussed the need to provide demonstration models of how ArcGIS might be used to demonstrate REACCH research to stakeholders and the general public in an interactive manner.

Education

Walden conducted a half-day workshop for IGERT students (plus some interested faculty) on how to access downscaled climate model data using the OPeNDAP protocol and our new ArcGIS toolbox via INSIDE Idaho. This was in collaboration with Rick Rupp from WSU, who is a member of the CI team from Objective 8: Cyberinfrastructure and Data Management.

Crop Modeling

The grid configuration for the regional analyses uses the same grid of the geo-referenced weather dataset provided by the CM group. To utilize these data, utilities were added to the CropSyst model that can access and read files for each weather variable during run time and also read a STATGO data layer to obtain soil information for each grid point. The weather grid covers an area much larger than the REACCH study area and provides data for all grid points regardless if they correspond to lands not suitable for annual crops (i.e., water bodies, shrub land, etc.) or currently utilized for permanent crops (i.e., land occupied with orchards or similar permanent or very long-term land use). Satellite-based crop land data layers are available from the USDA for the years 2007, 2008, and 2010 (see Figure 1.5 showing the 2010 layers). This information was analyzed to produce a GIS data layer identifying lands suitable for annual crops (i.e., suitable for wheat-based rotations) and lands not suitable (see Figure 1.6 where the blue area corresponds to land currently used for crop production). In this way, with further GIS-based manipulation, we were able to determine the fraction of annual cropland included in each original 4x4 km grid cell for the entire REACCH study area (see AEZ report).

With weather, soil, and fraction of annual crop land defined for each 4x4 grid cell, 30-year CropSyst simulations for a winter wheat – fallow rotation using baseline (1979-2010) and future (2006-2035) weather were run for the entire REACCH region, including the area used for our wheat-fallow study. Yield, expressed as dry matter in kg/ha, were determined for each grid cell and year. Average yields are shown in Figure 1.7, where the colored area not in the legend corresponds to land excluded from the analysis because the predominant use is other than wheat-fallow. The output of these simulations was also presented in Excel format, with all the information needed to integrate yields at the scale of zip code areas, as required by the TOA-MD model. This proof of concept illustrates the feasibility of this approach, which can be used to model other production systems for comparison, to do so over selected parts of the region or conduct other investigations of the effect of climate on productivity.

The CS group is also conducting regional analyses based on measured daily weather and compares them with analyses based on gridded data. There is a high density of stations in the study region, however only the AgWeatherNet and Agrimet stations have sufficient weather variables reported to run CropSyst, while the NCDC stations only have precipitation and temperature data. To solve this problem, CS developed and tested methods to estimate solar radiation and maximum and minimum relative humidity from temperature. Mean estimated and observed solar radiation for weekly periods are highly correlated. Work continues for relative humidity estimations, with results showing a good performance of the methods used.

To test the impact of weather estimation errors in crop model simulations, average model outputs using observed and estimated solar radiation were compared imposing different levels of irrigation to impose variation in crop stress conditions. Results based on observed and estimated solar radiation are comparable and provide confidence on the methods utilized (Figure 1.7). The model run was conducted as a “proof of concept” to establish a complete methodological approach that integrates and links weather projections, soil databases, cropping systems/management scenario creation, automated grid-based simulation runs, output generation based on zip-code geo-referenced areas, and use of these outputs by TOA-MD. This approach can be refined, and coupled with AEZ characterization in the project to represent the actual cropping system heterogeneity of the region as REACCH moves forward.

Economics Group

Agricultural Census Data

To obtain access to the confidential, farm-level Agricultural Census data, an application was submitted and approval was granted by USDA. In addition, access to the Agricultural Resource Management Survey data through a data terminal located at the Agricultural and Resource Economics Department at OSU was sought and obtained. During 2011, work focused on accessing and utilizing the census data, which has to be used at the NASS office in Portland. PhD student Hongliang Zhang traveled to Portland periodically to utilize these data. Summary statistics needed to parameterize the TOA-MD model can be obtained from these data. The 2007 census data for wheat farms in the REACCH region are summarized in Tables 1.1 –1.6, where a wheat farm is defined for the purposes of developing our modeling approach as a farm producing primarily wheat or other crops, and with less than $5000/yr. of livestock expenses. Future applications of our approach can incorporate more diversified farming operations. The REACCH project research region includes 37 counties and 235 zip codes areas across Oregon, Washington and Idaho. Farms in the census data cannot be identified by legal address or spatial coordinates, but can be identified by zip code. According to census confidentiality rules, statistics such as means or standard deviations can only be reported for zip code areas or larger areas that contain enough farms so that individual farm's values cannot be inferred from the statistics.

Preliminary Design of TOA-MD Analysis

Implementing TOA-MD involves a sequence of steps (Figure 1.8). The population for the REACCH project has been identified as a set of 37 counties as identified in the project proposal. For implementation of the TOA-MD model, an additional step is to stratify the data into sub-populations that can be geographic, socio-economic, or by farming system characteristics. For the preliminary analysis of wheat-fallow systems, individual zip code regions with 10 or more farms are used as the primary stratum. For zip code regions with less than 10 farms, proximate regions are aggregated. There are 118 of these zip code regions within the 37 counties of the REACCH region. Another key component of TOA-MD design is the characterization of the farming system. For this preliminary WF-1 analysis, production activities were designated as wheat production, other crops production and livestock. Revenue and cost data were prepared on a per-farm basis.

The parameters of the TOA-MD model are means, variances, and correlation coefficients for variables needed to characterize the net returns distributions for the two systems considered in an analysis (the base system, designated as System 1, and the alternative system, designated as System 2). An important first step in data preparation is evaluation of data quality, including determination of data errors and outliers. The census data were found to be high quality, although a small number of outlying observations were found and deleted. The TOA group also worked on statistical methods to utilize census data for TOA-MD modeling. One limitation of census data is that cost of production is reported by expense category for the whole farm, but not by production activity (e.g., for wheat production as distinct from other crops). In order to model adaptation of systems to climate change, characterization of costs for each main production activity (i.e., wheat versus other crops) is useful, so a statistical cost-decomposition method was tested. Over the full sample, and for data averaged by zip code, the method was found to produce reasonable results (Table 1.5), however, for individual zip code regions with small numbers of observations some results were implausible (e.g., negative costs).

Education

Training for graduate students and faculty collaborators was provided in a 2-day workshop at OSU in June 2011.

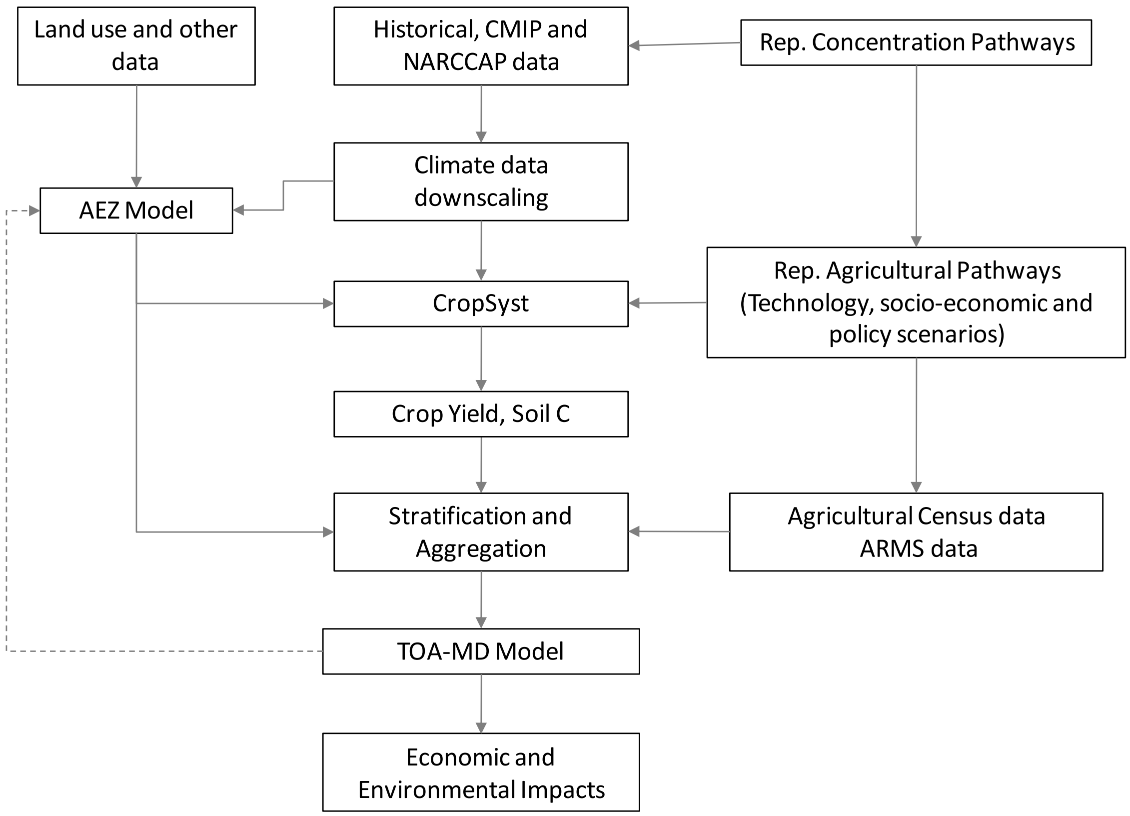

Figure 1.1. Framework for Coupling of the AEZ Model, Climate Data, the CropSyst model, and the TOA-MD economic model

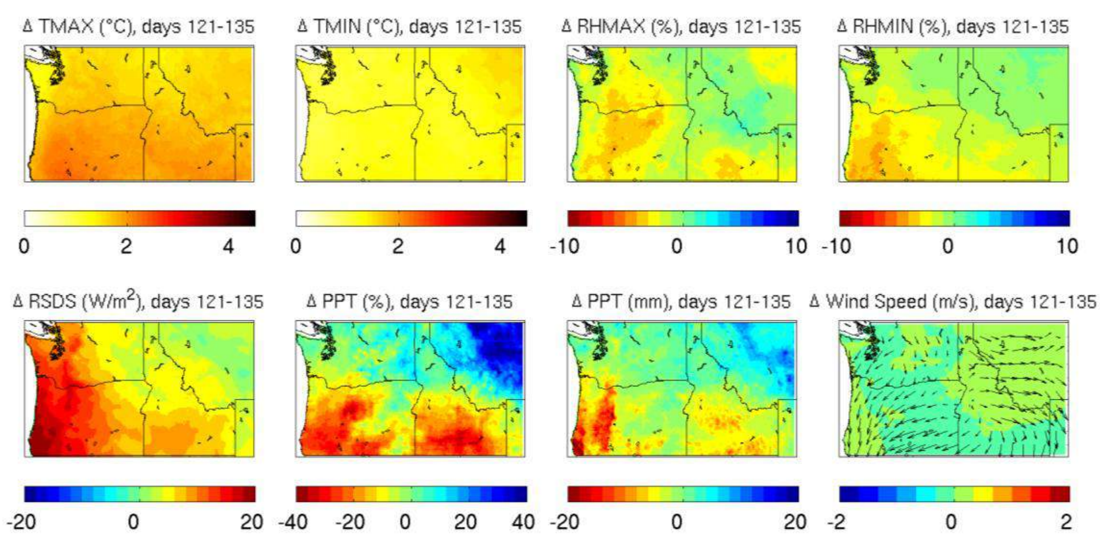

Figure 1.2. Changes in meteorological fields for the period 2025-2049 versus 1971-2000 averaged over the first two weeks of May. Data was downscaled using the MACA method at daily timescales from the CSIRO-MK3.6.0 run with RCP4.5 experiment.

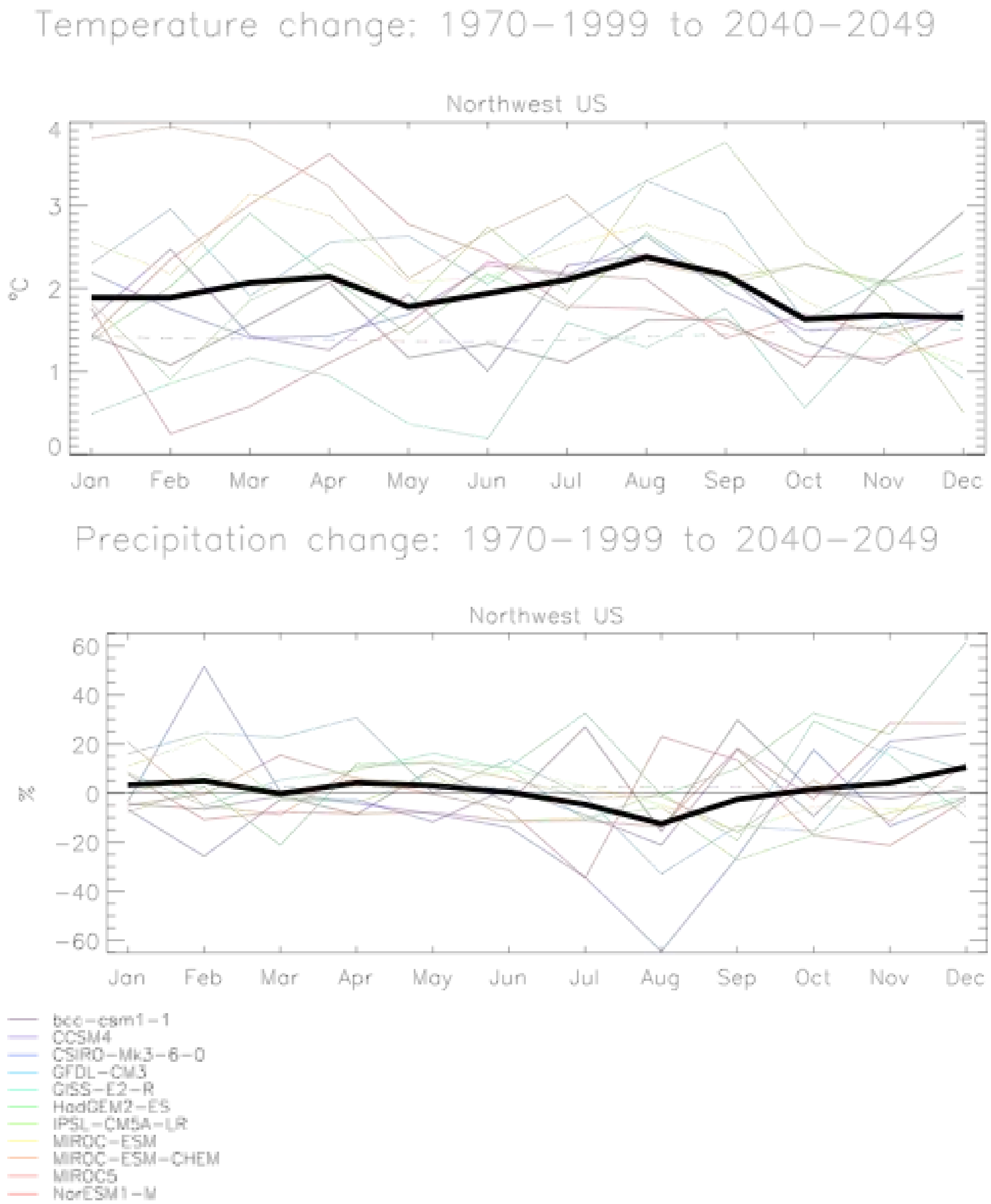

Figure 1.3. Changes in Northwest-average temperature (top) and precipitation (bottom) from 11 global models contributing to CMIP5 using the RCP6.0 greenhouse gas scenario.

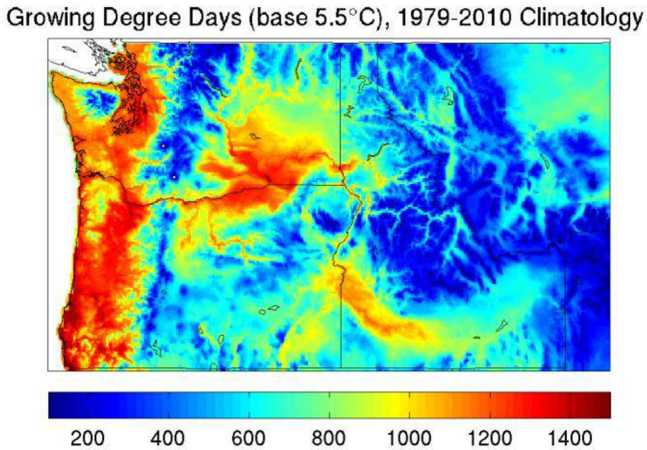

Figure 1.4. Map of cumulative growing degree days (base 5.5C, used in wheat growth models) averaged over 1979-2010.

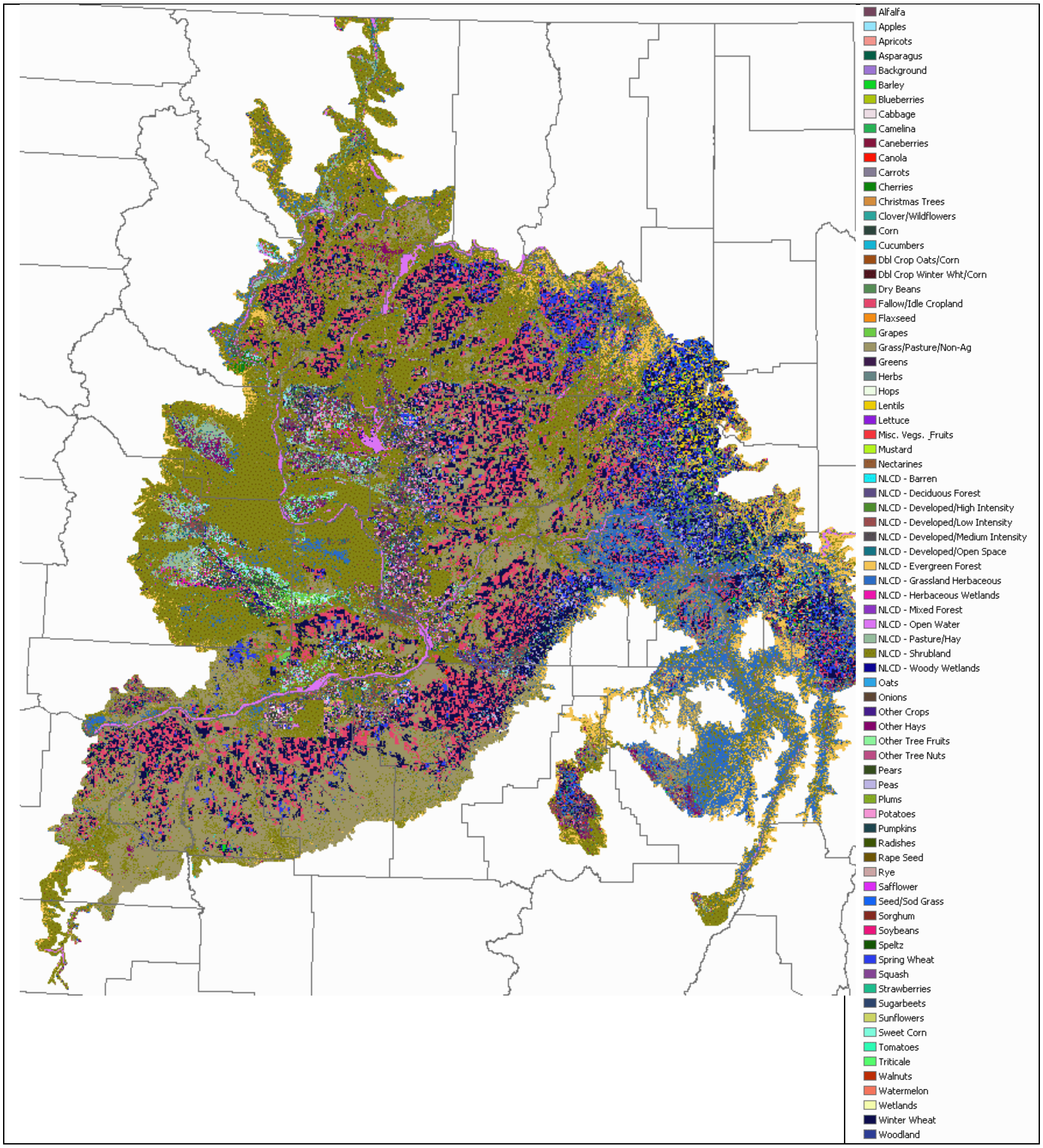

Figure 1.5. Crop land use in the REACCH region

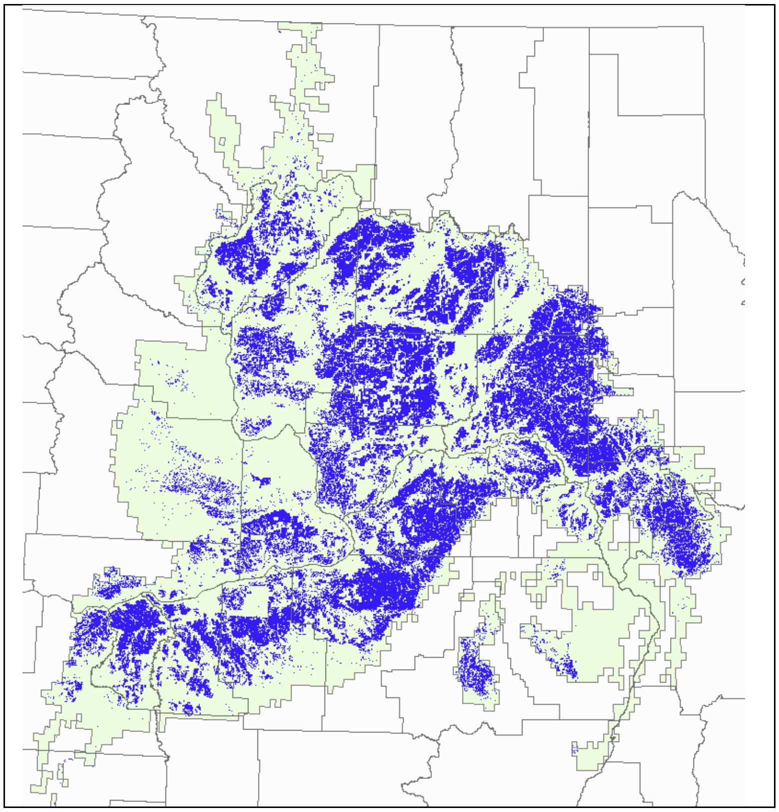

Figure 1.6. Cropland areas in the REACCH region

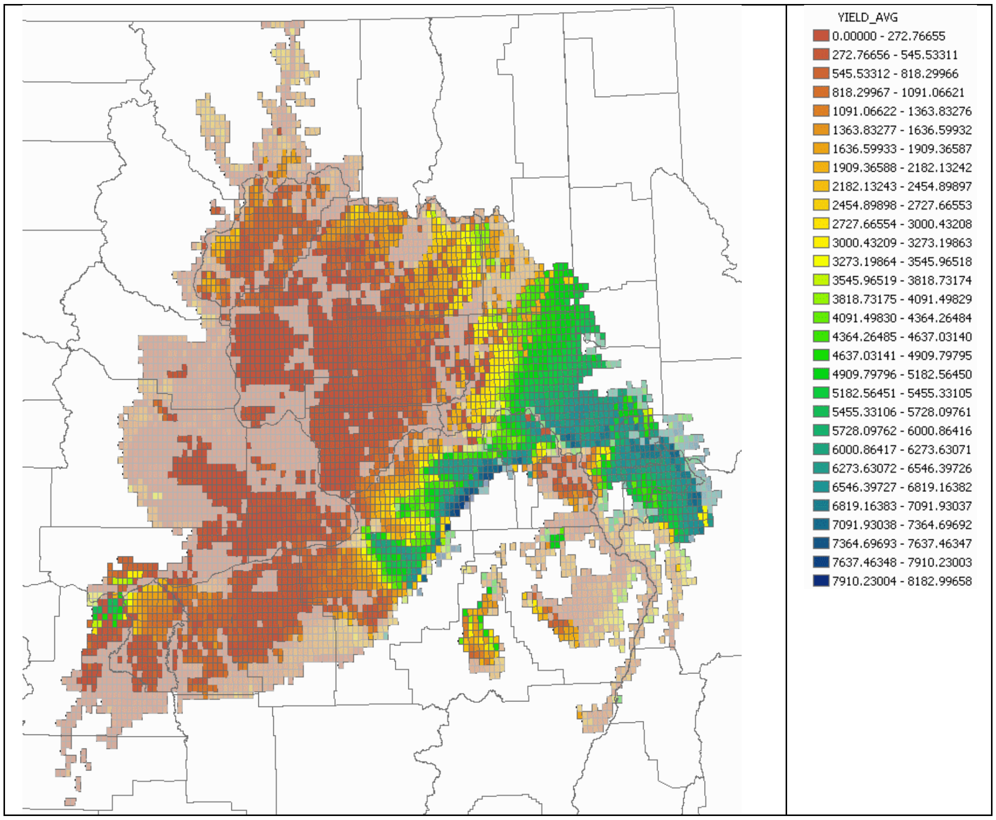

Figure 1.7. Average wheat yields simulated by CropSyst for the REACCH region (kg/ha drymatter) under a hypothetical wheat-fallow system. The run over the entire area was conducted as a "proof of concept" to establish a complete methodological approach that integrates and links weather projections, soil databases, cropping systems/management scenario creation, automated grid-based simulation runs, output generation based on zip-code geo-referenced areas, and use of these outputs by TOA-MD. The approach can be used to model other productions systems for comparison, to do so over selected parts of the region, or conduct other investigations of the effect of climate on productivity as REACCH moves forward.

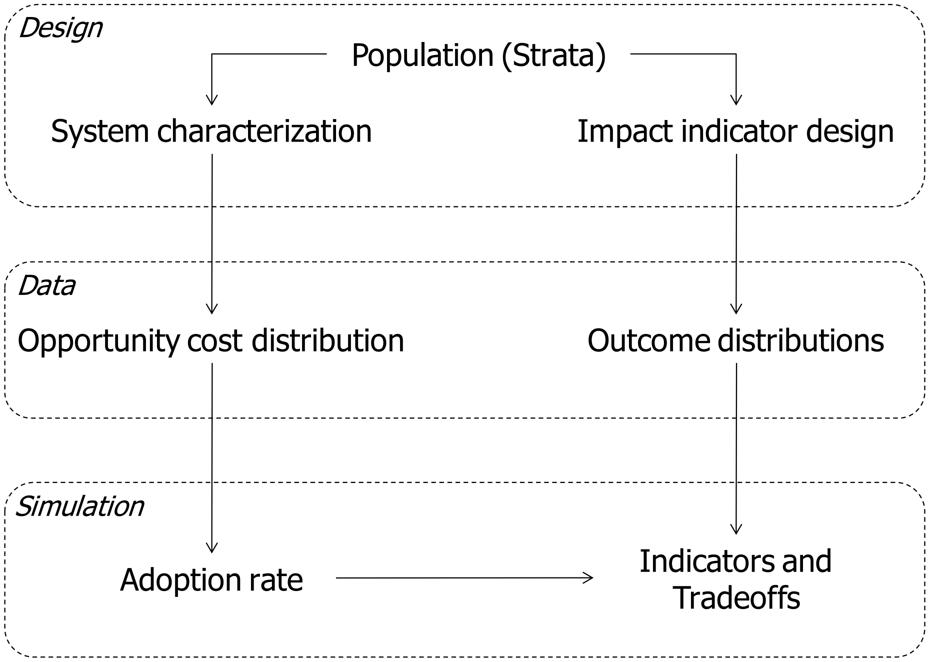

Figure 1.8. Components of TOA-MD Analysis

Table 1.1. Farm Population Characteristics of Wheat Farms in the REACCH Region

Variable	Description	Unit	Mean	Std
HH	Number of persons living the household in farm for principle operator	number	2.7	1.3
TCL	Farm size	acre/farm	1680.2	1537.3
CLHA	Cropland used for harvesting in farm	acre/farm	1033.5	868.7
HHSNR	Household numbers that share in net farm income	number	1.6	1.0
HHINC*	Household income for principle operator	classification	4.4	1.2
PINC	percentage of income from the operation for principal operator	number	60.9	34.1
CROI	Total cropland irrigated acres in farm	acre/farm	97.3	252.5
TLSI	Total livestock inventory in farm	number	19.8	71.6

** HHINC is a classification. 1- Less than $20,000; 2- $20,000 to $29,999; 3- $30,000 to $39,999; 4- $40,000 to $49,999; 5- $50,000 or more*

Table 1.2. Wheat Production of Wheat Farms

Variable	Description	Unit	Mean	Std
WHAC	Wheat acres in farm	acre/farm	770.5	748.6
WHPR	Wheat production in farm	bushel/farm	41864.4	40207.0
WHIAC	Wheat irrigated acres in farm	acre/farm	30.0	103.2
CLFALLOW	Summer fallow size in farm	acre/farm	414.5	682.1
WINWHAC	Winter wheat acres in farm	acre/farm	629.2	669.4
WINWHPR	Winter wheat production in farm	bushel/farm	35959.5	37038.4
WINIAC	Winter wheat irrigated acres in farm	acre/farm	20.7	82.9
SPRWHAC	Spring wheat acres in farm	acre/farm	140.8	264.3
SPRWHPR	Spring wheat production in farm	acre/farm	5859.6	10852.7
SPRWHIAC	Spring wheat irrigated acres in farm	acre/farm	9.2	46.8
WHY	Wheat yield	bushel/acre	61.1	26.6
WINWHY	Winter wheat yield	bushel/acre	57.7	31.2
SPRWHY	Spring wheat yield	bushel/acre	22.2	29.6

Table 1.3. Revenue of Wheat Farms

Variable	Description	Unit	Mean	Std
TVWH	Total value of wheat in farm	$/farm	239499.2	236189.7
WHRE	Wheat revenue per acre	$/acre	362.3	196.1
TVOC	Total value of other crops in farm	$/farm	108154.3	207145.7
OCRE	Other crops revenue per acre	$/acre	290.2	814.1
TGP	Total government payments in farm	$/farm	30476.2	33249.2
VCRP	Government payments received from CRP and WRP in farm	$/farm	8641.2	19017.4
TSL	Total value of livestock in farm	$/farm	6740.3	27349.4

Table1.4. Costs for Wheat Farms

Variable	Description	Unit	Mean	Std
TEXP	Total expenditure per farm	$/farm	237140.5	208985.6
EXPSEED	Total expenditure for seeds, bulbs, etc. per farm	$/farm	16066.9	18800.2
EXPCF	Total expenditure for commercial fertilizer per farm	$/farm	50094.6	53067.0
EXPCHEM	Total expenditure for agricultural chemicals per farm	$/farm	25186.9	30750.4
EXPHL	Total expenditure for hired labor per farm	$/farm	21512.2	39837.3
EXPCL	Total expenditure for contract labor per farm	$/farm	1672.2	11676.8
EXPCR	Total cash rent paid for land and buildings per farm	$/farm	20085.4	51468.5
EXPPT	Total property tax paid per farm	$/farm	5781.9	9102.5
EXPFO	Total expenditure for fuels and oils per farm	$/farm	22091.1	21093.9
EXPUT	Total expenditure for utilities per farm	$/farm	7126.8	14760.8
EXPSPM	Total expenditure for suppliers, repairs and maintenance cost per farm	$/farm	24898.8	25640.1
EXPCW	Total expenditure for customer work per farm	$/farm	5323.6	15246.6
EXPER	Total expenditure for equipment rental per farm	$/farm	2961.2	10436.9
PCOST	Production cost per acre	$/farm	313.5	425.8

Table 1.5. Statistical Cost Decomposition for Wheat Farms

Crop	Description	Unit	Mean	Std
WHCOST	Total expenditure for the wheat production per farm	$/farm	129609	128263
OCCOST	Total expenditure for other crops production per farm	$/farm	39686	88844

Table 1.6. Wheat Farm Net Returns

Crop	Description	Unit	Mean	Std
	Net returns for the whole farm	$/farm	167590	23329.9
	Net returns for the wheat production per farm	$/farm	145000	150212.3
	Net returns for other crops per farm	$/farm	41264	86174.5
	Net returns for livestock per farm	$/farm	5013	23329.9

Technical Report

2.1 Tower and Chamber-based Flux Site Operations and Analysis

Objective 2.1.1 Obtain instrumentation, identify sites and deploy flux systems

Instrumentation

The flux systems employ a fast response 3-d sonic anemometer to measure turbulent velocities and a co-located fast response open path CO_2/H_2O sensor to measure the corresponding CO_2 and H_2O turbulent concentration fluctuations. These measurements are used in the eddy covariance (EC) method to directly calculate CO_2 and H_2O fluxes:

$$F = w'c'$$

where w' is the fluctuating component of vertical wind speed and c' is the fluctuating component of the concentration of the species of interest. This approach has been widely used to measure fluxes of CO_2 and other trace gas species over a wide range of landscapes (Pressley et al., 2006; Velasco et al., 2009). To measure fluxes of N_2O, CH_4 or other trace gas species, additional fast response instruments are required. For N_2O, we employ a closed cell cavity ring-down spectrometer (Los Gatos Research, Inc.) which measures both N_2O and CO_2 simultaneously. We use a similar closed cell instrument (Picarro, Inc.) to measure CO_2 and CH_4 simultaneously. In addition to these fast response flux instruments each tower system includes a number of other slow sensors to measure basic meteorological conditions including wind speed, wind direction, pressure, temperature, ambient humidity, net radiation, photosynthetically active radiation, and precipitation. A list of the instruments is given in Table 2.1. The list also includes soil moisture and soil temperature probes and a soil heat flux sensor. Initially, we purchased two sets of instrumentation and then after the first system was successfully deployed, we purchased four more sets for deployment in 2012.

The automated chamber-based gas flux measurements use the LI-8100A Automated Soil CO_2 Flux System that we are currently coupling with Teledyne N_2O monitoring instrumentation. In addition each of the microplots have Decagon water and temperature sensors at 5 and 15 cm depths as well as PVC-constructed soil gas monitoring access chambers for manual extraction of soil gases.

Site Identification

During the summer and fall, we reviewed options for sites across the study region, and identified a conventional till and no till pair of sites at CAF in the annual cropping zone near Pullman, WA; a high rainfall conventional till site near Moscow, ID; a wheat/fallow site near Lind, WA; and two irrigated sites in central WA. During this period, we visited CAF and the neighboring conventional till site, and we finalized the tower location of the no-till CAF site. We also visited several locations in Idaho and have identified a cooperative grower and tentative field for the high rainfall site. We visited the Lind Experimental station and finalized a tower location on a wheat/fallow field very near the station. Members of the team visited an irrigated site near Prosser, WA, but the research operations at this site were subsequently stopped so further work is needed to identify suitable irrigated locations. A key part of the site identification process for a given location was consideration of the crop management practice, the field size and layout with respect to the prevailing winds, and ease of access. We employed flux foot print modeling (Hsieh et al., 2000 to help determine the final location for the tower at each site. The flux footprint is defined as the area upwind of the tower which contributes to the fluxes measured at the tower. For the 2 m measurement height used in the deployments, the footprint is estimated to be approximately 100 m. This range is shown in Figure 2.1 for the CAF site.

Table 2.1. Flux tower instrumentation and hardware

Number	Description	Model #	Associated Parts
1	10-ft Aluminum Tower	UT10	Base, Adjustable Mast, Grounding Kit
1	6-ft Sensor Crossarm	CM206	Mounting Kit
1	Data logger	CR3000-ST-SW-RC-NC	
1	Ethernet Interface and CFM	NL155_ST-SW	
2	2G CompactFlash Memory Card	CFMC2G	
1	MorningStar Sunsaver	SS-10-12V	Mounting Parts
1	Enclosure, 14x16"	ENC16/18-DC-SB-TM	Installation Kit
1	Sonic anemometer and CO_2/H_2O Open Path Gas Analyzer System	EC150-SH-SC-BB-GC	IRGA, CSAT, Temp Probe, EC100, Bosch tubing boom
1	Vaisala T/RH Probe	HMP155A-L20	Solar Radiation Shield
1	Kipp&Zonen Net Radiometer	NR-LITE2-L48	Mounting Kit
1	Texas Electronics Rain Gauge	TE525WS-L20	Mounting Equipment
1	MetOne Wind speed and direction	034B-L20	
1	LiCor Quantum PAR Sensor	LI190-SB-L20	Custom mount
1	Garmin. GPS Receiver	GPS16X-HVS	Magnetic Mount
2	Soil Heat Flux Plates	HFP01SC	
5	Decagon Soil Temp & Moisture Probes	5TM	
1	Line Quantum Sensor (Ceptometer)	LI-191	Handheld data logger
2	70W Solar Panels	SP70-L20	Mounting Hardware, Posts
6	Deep Cycle Marine Batteries		Battery Boxes

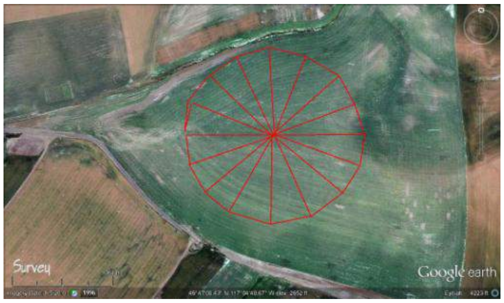

Figure 2.1. CAF flux tower location with 100 m flux footprint shown (in red).

Flux System Deployment and Operations

We set up the first flux system in the laboratory for test purposes during the summer, 2011 and then deployed it to the CAF no-till site in early August. Once the CAF site was operational, we worked on identification of a second site and finalized the Lind site in early October. The second flux system was installed in late October and began operations in early November. Photographs of these flux systems are shown in Figure 2.2.

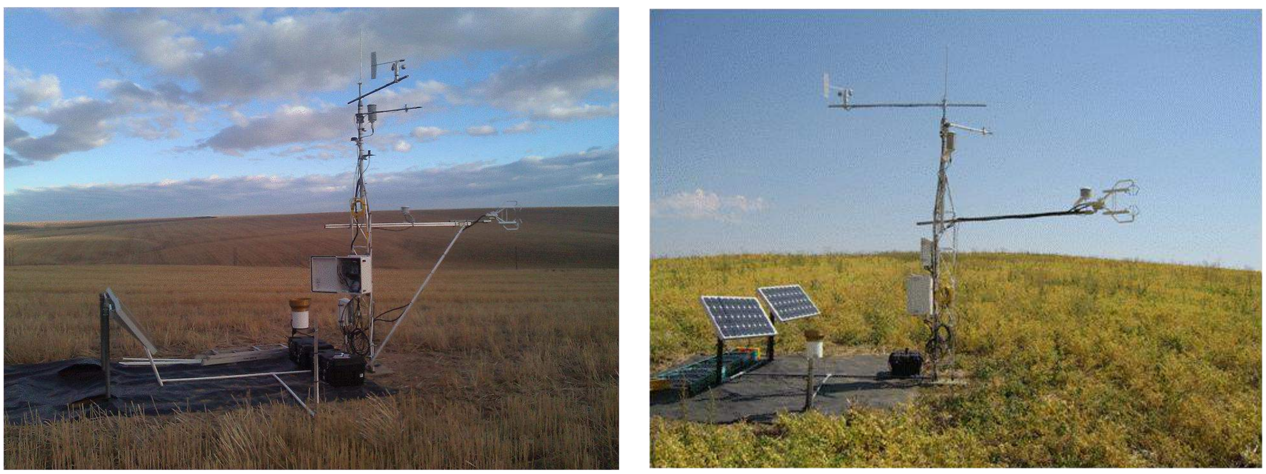

Figure 2.2. Photographs of the Lind (left) and Cook Agronomy Farm (right) flux tower sites.

Automated chambers were deployed on 64 micro-plots at the CAF with N, glucose and water treatments under the guidance of Dr. Dave Huggins, USDA-ARS (Figure 2.3 and 2.4).

Figure 2.3. Injection of N fertilizer on chamber study microplots, automated chambers, and chamber, environmental sensor array at the CAF

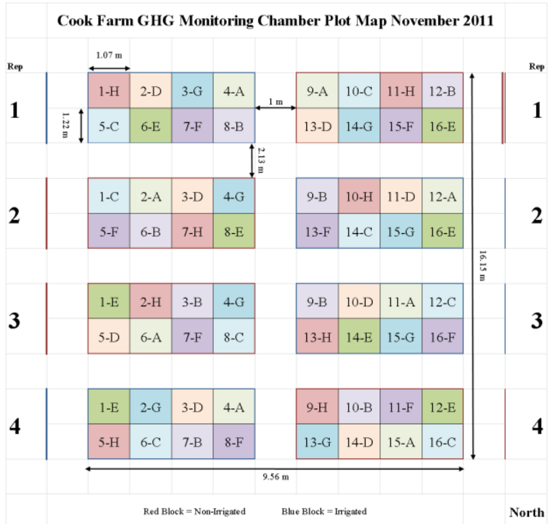

Figure 2.4. Microplot chamber-based, gas-flux field study at the CAF, treatments consist of four N levels, two glucose levels and two water levels.

2.1.3 Preliminary Data Analysis

Once the system at the CAF was in operation, we began to investigate methods for routine data reduction, quality assurance, and data post-processing. In particular, we began to examine two specific topics: **(1)** selection of a standard flux calculation scheme for processing of the data and **(2)** impact of local nighttime drainage flows on flux measurements. To calculate fluxes from eddy covariance data, there are a number of steps which must be employed. These include: **(1)** Convert raw data signals to scientific units, apply IRGA calibration coefficients, remove hard spikes and identify data gaps. **(2)** Identify and remove soft spikes which are large short-lived departures from the period means. **(3)** Perform coordinate rotation on 3-D velocity components. The aim is to eliminate errors due to sensor tilt relative to the terrain surface or aerodynamic shadow due to the sensor or tower structure. **(4)** Calculate the mean and standard deviation for each variable. **(5)** Remove means from each signal to obtain fluctuations (prime quantities). **(6)** Apply a low pass filter to all the processed variables to eliminate the presence of a possible trend in the 30 min.. time series (added for cross report consistency). **(7)** Calculate 30 min.. average vertical fluxes for momentum, sensible heat, latent heat, and CO_2. **(8)** Account for the effects of density fluctuations upon the fluxes, applying the Webb corrections (Webb et al., 1980) citation to water vapor and CO_2. **(9)** apply a second phase of quality control. All measured or derived variables (30 min.. averages) are submitted to a plausibility test and are rejected if they fall outside statically defined constraints for each variable (e.g. wind speed not to exceed 25 m s^{-1}).

In previous flux studies, we have employed our own calculation codes to handle these various steps, but for the REACCH program, we investigated the use of two different programs both based upon community efforts to standardize the way fluxes are calculated. First, Campbell Scientific, Inc. provides a data acquisition program with the flux instrumentation that includes eddy flux calculations. These are conducted in real-time and provide 30 min. average fluxes. The flux tower systems include a cell phone modem so these calculated fluxes are automatically downloaded remotely to a central data computer in our labs at WSU on a daily basis. Second, we visit each site approximately every two to three weeks to download the raw 10 Hz data and then we process these raw data using a free software package from Licor, Inc. called Eddy Pro. This package is based upon community efforts to develop standardized methods for treating flux data. Eddy Pro includes options for additional correction schemes and represents a more complete method for compiling flux results.

We have conducted initial comparisons of the Campbell and Eddy Pro calculations and find that overall, there is good agreement between the two methods, but there are intermittent times when the two methods show quite different results (Figure 2.3).

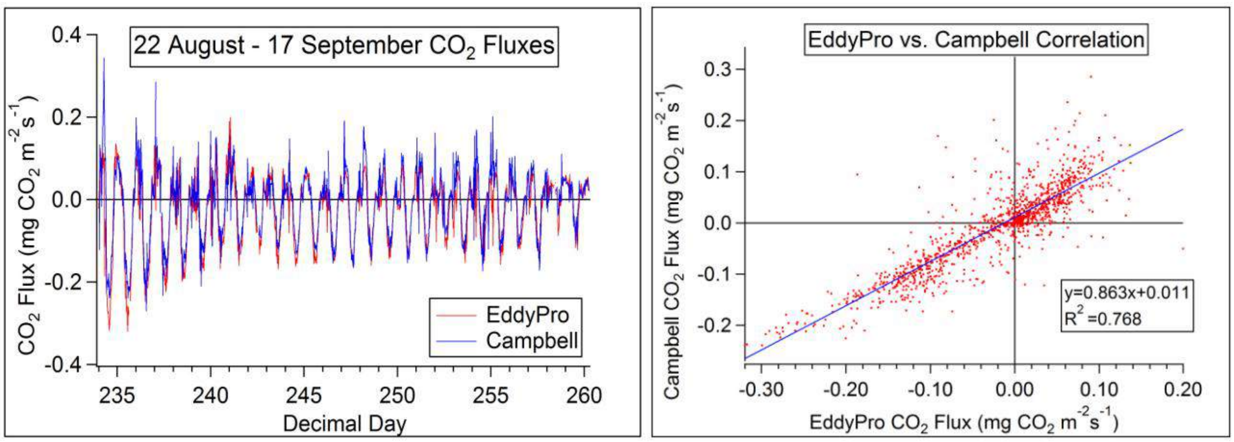

Figure 2.5. Comparison of CO_2 fluxes calculated using the Campbell and EddyPro software packages (time series, left; correlation, right). On the basis of these comparisons, we can employ the Campbell results, available in real-time, to check the operation of the systems and for preliminary display of results on the web. However, we will post-process the raw data using EddyPro to produce final, archived flux results.

Data processing and analysis is ongoing as we develop standard procedures for applying EddyPro and producing specific data products. An example of the type of results we will produce is shown in Figures 2.4 and 2.5 for the CAF site before harvest in early September and after harvest in late October. Before harvest there is a distinct diurnal pattern $C0_2$ in fluxes reflecting daytime uptake due to photosynthesis and nighttime respiration. During this period, C is accumulating on a daily basis. After harvest the diurnal pattern is different and shows elevated respiration during the day and reduced respiration at night. During this period there is a steady loss of carbon on a daily basis.

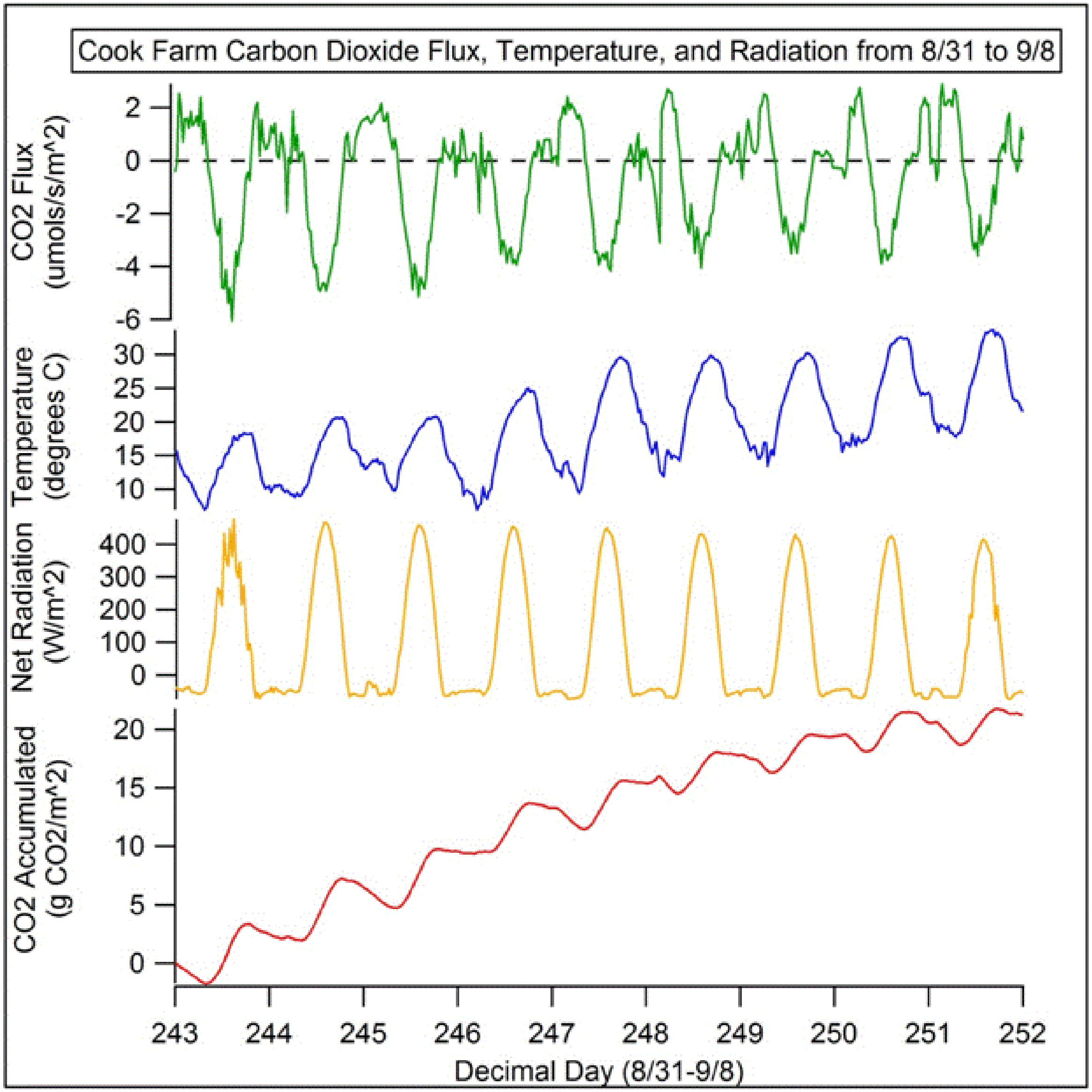

Figure 2.6. CO_2 flux, temperature, net radiation and accumulated CO_2 (top to bottom) for August 31, through September 8, 2011 at the CAF no-till site.

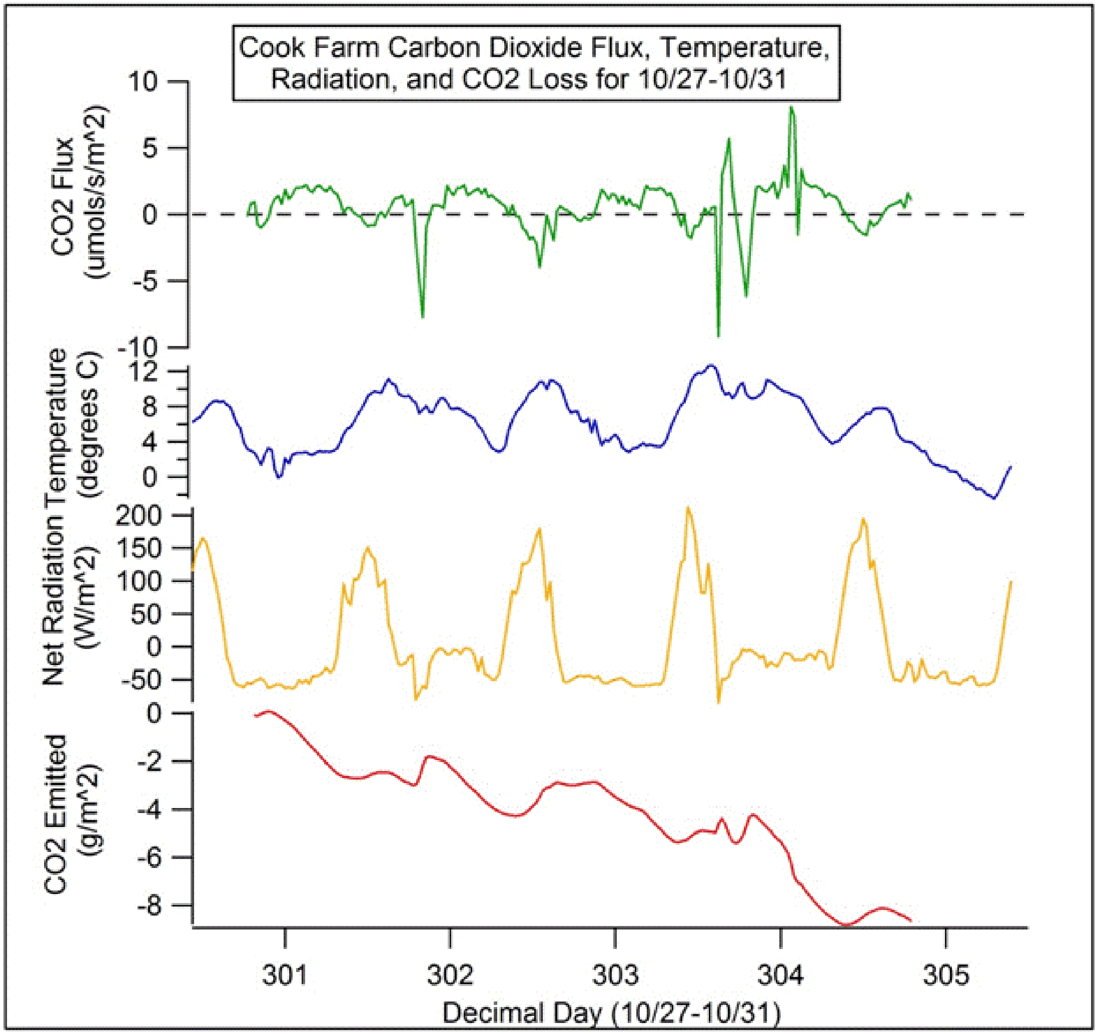

Figure 2.7. CO_2 flux, temperature, net radiation, and accumulated CO_2 loss at the CAF no-till site during October 27 through October 31, 2011. Harvest occurred on September 30, 2011 and seeding/fertilization occurred on October 22, 2011

2.3 Water Erosion Measurements and Analysis

YR 1 progress under "Water Erosion Measurements and Analysis" milestone in Objective 2 were conducted under the guidance of Dr. Erin Brooks in the Dept. of Biological and Agricultural Engineering at the University Idaho. The overall objective was to provide total carbon and inorganic nitrogen export at various scales and treatments within the high precipitation region of the Palouse. The major tasks for the first year of the project were to establish monitoring sites, establish lab protocols and begin initial data collection. A summary of the major milestones for each of these tasks is provided below.

Field -scale and watershed-scale monitoring sites were selected based on proximity related to Objective 2 and 3 gas flux measurements, availability of historic data sets, and travel distance. The majority of the data collection sites were focused in the high precipitation zone. The major data collection sites are identified in Figure 2.6. The watersheds range in size from 1 km^2 to 7,000 km^2. At the smallest scale (1 km^2) both a conventional tillage catchment and a no-till catchment were selected.

2.3.1 Field-scale Monitoring

The CAF was selected as the field-scale no-tillage catchment (Figure 2.7). This site is owned by WSU and operated by USDA-ARS scientists involved in the REACCH project. The site has good historic data on soil nitrogen and carbon distribution, crop rotations, and nitrate export from a drain tile from the site. This site is also being heavily monitored for nitrogen movement as part of the Site-Specific, Climate-Friendly Farming (SCF) project funded through a USDA-NIFA grant. YR 1 progress involved installing a permanent flume at the tile line outlet which continuously monitors flow, electrical conductivity, temperature, and takes event-based water samples. A surface runoff flume was also installed at the site which provides continuous flow and automated event-based water sampling capabilities. Lysimeters and shallow wells were installed at 13 locations within the catchment to monitor spatial patterns in nitrate concentrations throughout the bowl using funding from the SCF project. A drain gauge was also installed in the bowl to quantify nitrate leaching.

In order to compare the impact of management practice on carbon and nitrate export we have tentatively selected a paired conventional tillage site. The site is similar in size to the CAF site and it is maintained in a similar three year winter wheat, spring grain, and legume rotation. The site is owned by a long-term reputable farmer in the region and is located approximately 10 km to the east of the CAF (Figure 2.7). Preliminary manual sampling has begun at the site; however no permanent equipment has been installed. The primary limitation to this site is access during spring runoff especially for the gas flux equipment that will be installed at the site. There is little historic data available at this site.

2.3.2 Watershed-scale Monitoring

Since the fluxes of carbon and nitrogen can be largely affected by in-stream processes we selected a 40 km^2 watershed (Paradise Creek above Moscow at Darby Rd.) as a comparison to the carbon and nitrogen loading from the 1 km^2 sites. As seen in Figure 2.8, the small-scale conventional tillage site is nested within this watershed. This site has been monitored extensively by Dr. Boll and Dr. Brooks since 2001 and provides a rich historic data set. The monitoring station provides continuous stream flow, turbidity, temperature, electrical conductivity, and event-based water samples. For the past six years these event-based water samples have been analyzed for nitrate, total phosphorous, and Ortho-phosphorous. These water samples are now being sub-sampled for carbon analysis. Samples from a second location, downstream of the city of Moscow (not shown in Figure 2.8), have also been analyzed during this first year to evaluate the carbon loading from the city of Moscow.

The Palouse River at Hooper, WA gauge was selected to provide regional-scale export from the high precipitation zone (Figure 2.8). Stream flow measurements at this site date back to the late 1800s. This site also has historic measurements of total organic carbon

(TOC), dissolved organic carbon (DOC), and particulate carbon (PC). Although the site has extensive historic data, preservation of the samples is a problem especially during the warm summer months. Water samples need to be preserved immediately upon collection to avoid CO_2 losses in the sampler. This preservation problem and the travel distance to the site have limited the number of samples collected to date. Through the second year we will be investigating preservation options and quantifying the losses of C during winter conditions versus summer conditions. The CO_2 losses may be negligible during cold winter months which would allow the use of an automated water sampler to collect event-based samples. The accuracy of baseline loading calculations is highly dependent upon the availability of event based water samples.

2.3.3 Field Data Analysis

Data collection at each of the sites did not begin until June of 2011 and therefore yearly loading calculations are not available for the first year. Figures 2.9 and 2.10 show DOC and nitrate measurements for each of the sampling sites, respectively. The preliminary C data suggest that tile line outflow during the summer provides a fairly constant source of C to the stream network (Figure 2.9). These initial data also suggest that C load is increasing through the city of Moscow. Since C measurement started after the spring flows in 2011 it is difficult to assess the magnitude of C which is delivered during storm events. In the Paradise Creek watershed, stream flow, turbidity, and suspended sediment concentration data were collected (Figure 2.11). With these historic existing data at the Paradise Creek site it is possible to calculate nitrate load and sediment load. If calculated according to the 2011 water year (10/1/2010-9/30/2011) the total sediment load and nitrate load passing through the Paradise Creek stream gauge located above the city of Moscow was 700 Tonnes and 24 Tonnes, respectively.

2.3.4 Soil Erosion Modeling across Spatial Scales

There was nothing significant to report regarding the erosion modeling during year 1. Initial analysis focused on examining long term trends and relationships present in existing data sets. As seen in Figure 2.12 for much of the year the total organic C is composed primarily of dissolved organic C. The data show a slight decreasing trend in total and dissolved organic C at the Hooper stream gauge site. During peak flow events the total organic C is closely related to suspended sediment, see Figure 2.12. These historic data sets, in addition to more observed data collected at the smaller watershed, will be useful for modeling C loading.

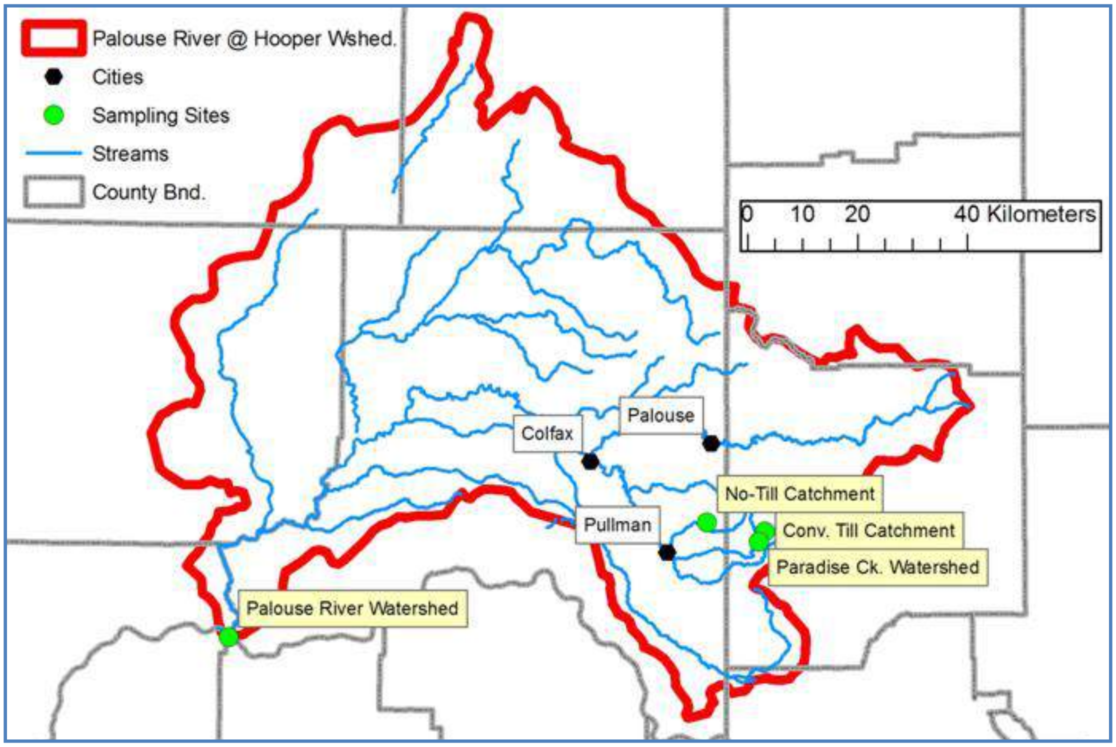

Figure 2.8. Baseline data collection sites

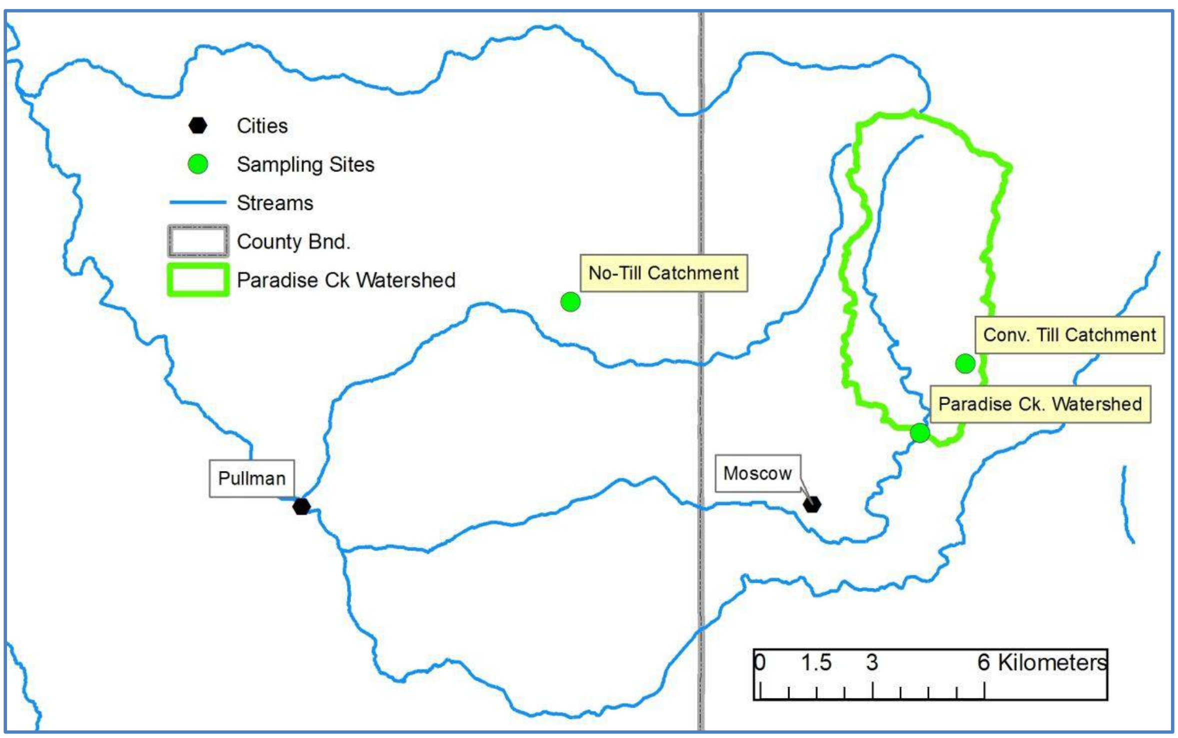

Figure 2.8. Small and intermediate scale monitoring sites

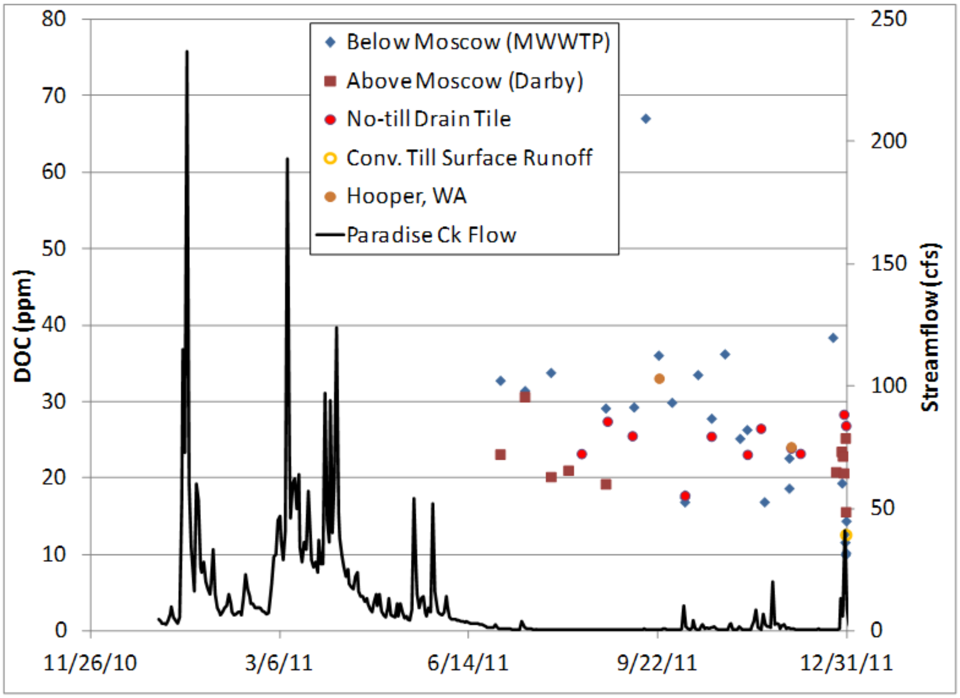

Figure 2.9. Dissolved Organic Carbon (DOC) measurements at various sampling locations during 2011

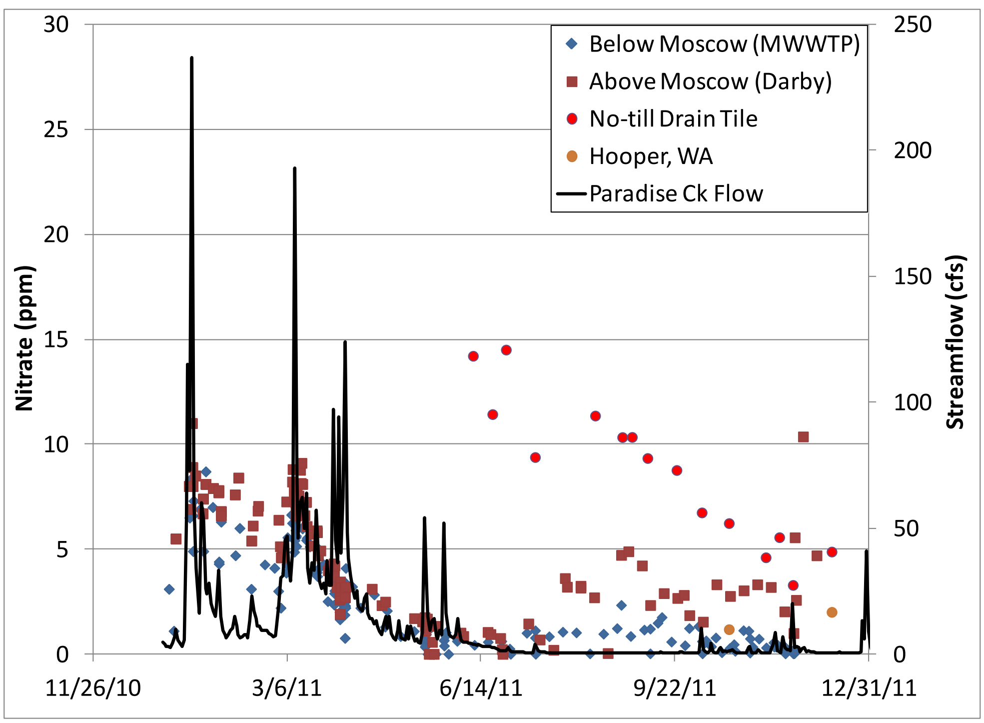

Figure 2.10. Nitrate measurements at each of the monitoring sites during 2011

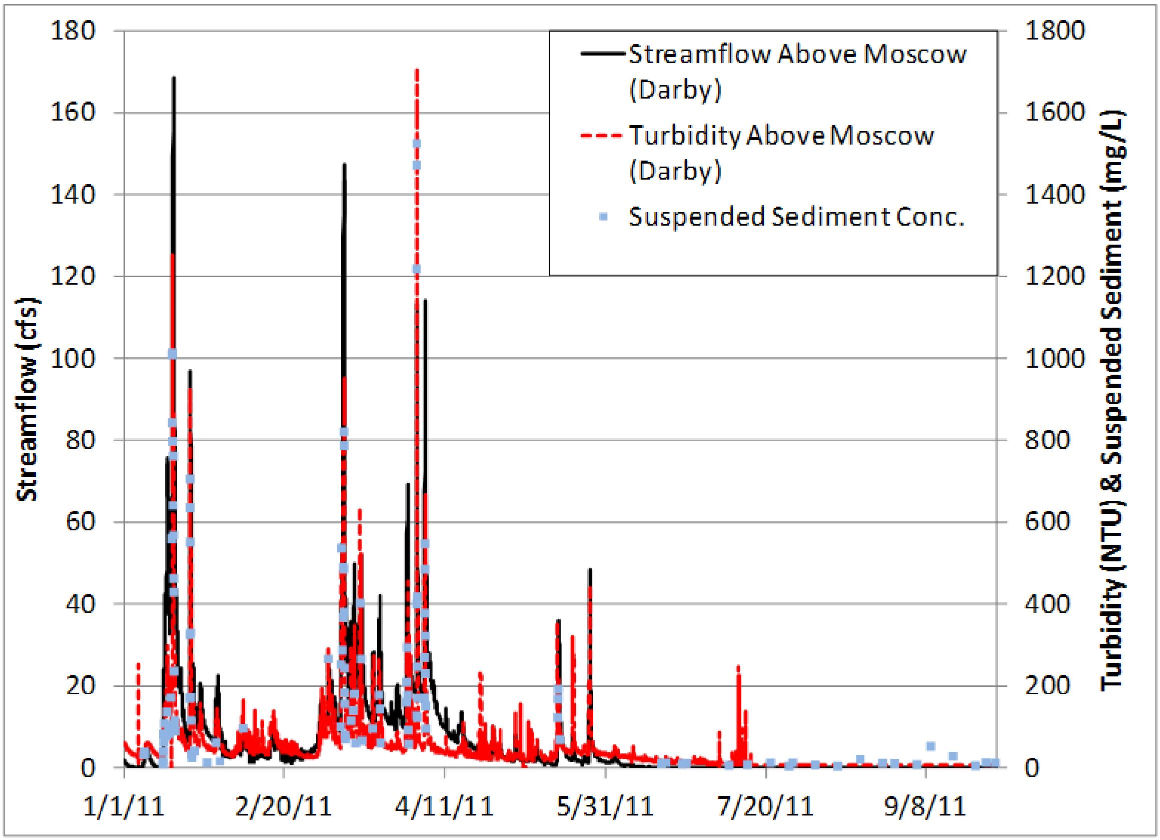

Figure 2.11. Stream flow, turbidity and suspended sediment concentration data collected at the Paradise Creek stream gauge located above the city of Moscow at Darby Road.

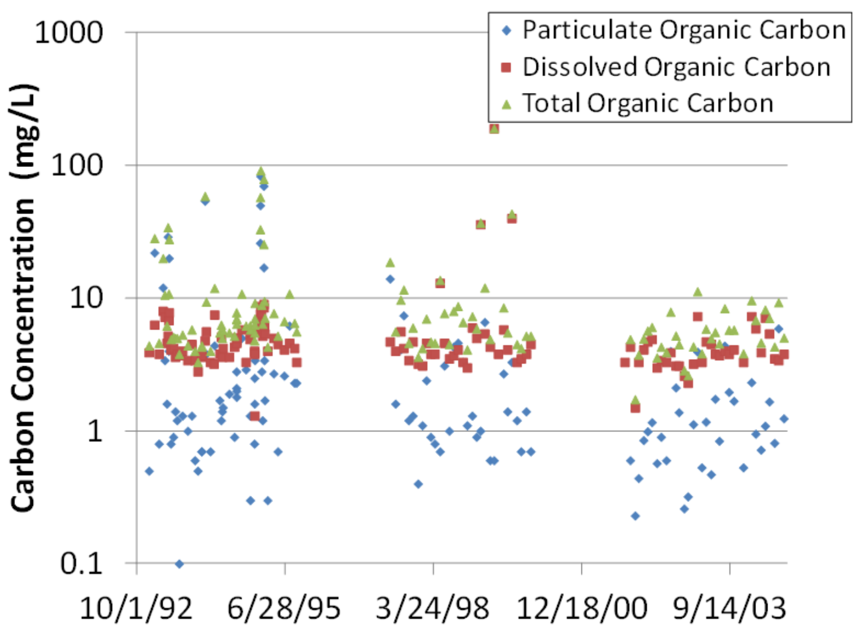

Figure 2.12. Historic observed total organic carbon, particulate carbon, and dissolved organic carbon at the USGS stream gauge station on the Palouse River at Hooper.

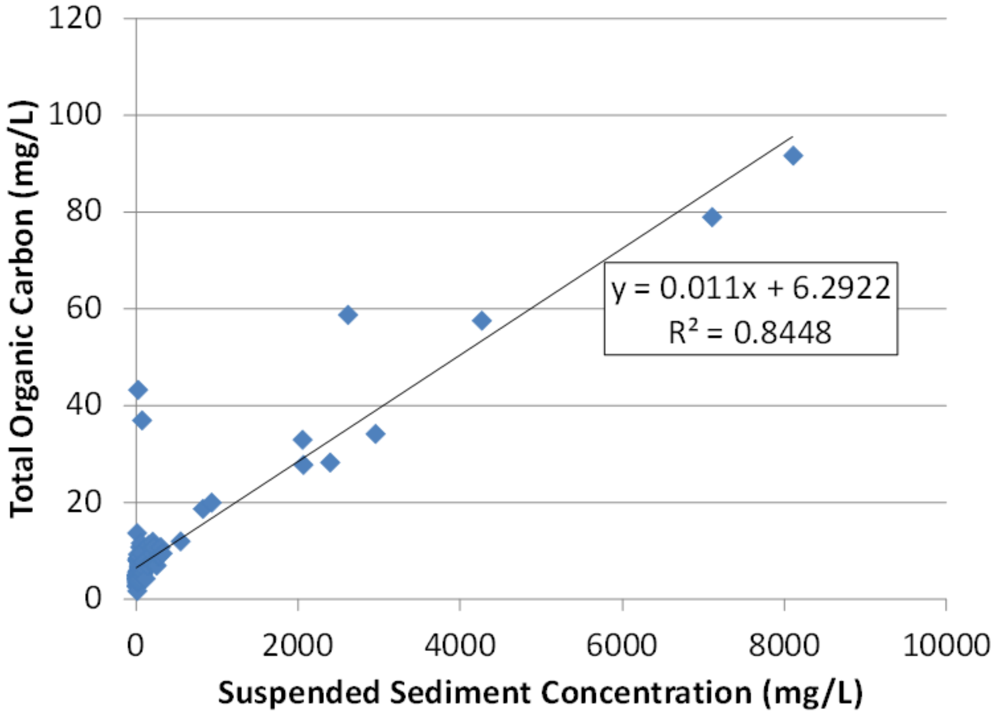

Figure 2.12. Relationship between observed suspended sediment concentration and observed total organic carbon at the USGS stream gauge station on the Palouse River at Hooper.

A network of field experiments described below have been identified or established to provide REACCH with ground-truthing data on GHG fluxes as well as the viability of cropping system management alternatives (Figure 3.1).

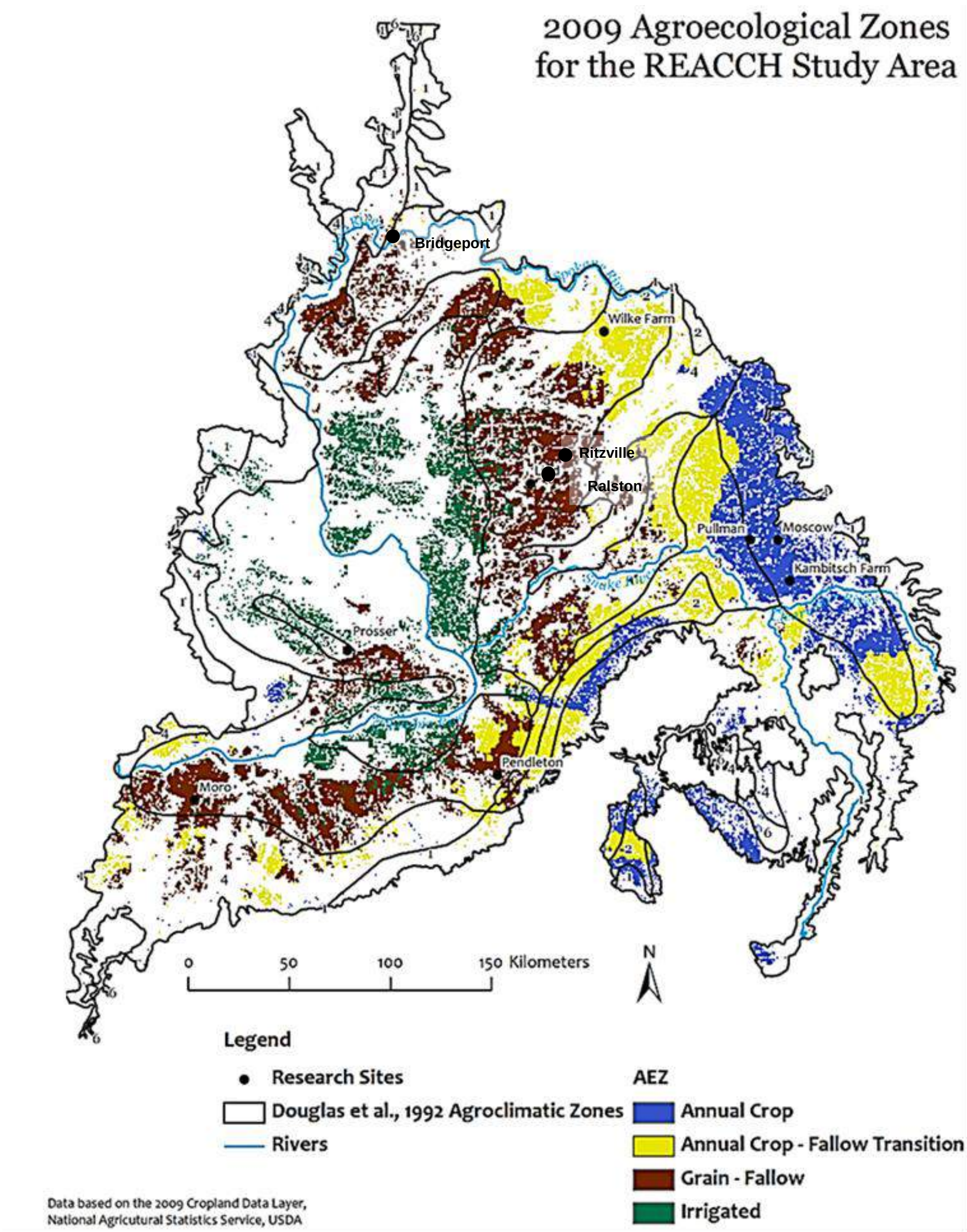

Figure 3.1. Regional network of REACCH field experiments and associated agroclimatic zones (Douglas et al., 1992) and AEZ delineations (see AEZ pages xx). AEZ 1 = Annual Crop; AEZ 2 = Annual Crop – Fallow Transition; AEZ 3 = Grain – Fallow; AEZ 4 = Irrigated.

A. Site Descriptions and Activities

1. AEZ 1-UI Kambitsch Farm, Moscow ID; site lead: Jodi Johnson-Maynard

Cropping system variable: Tillage/residue management

Plots at the Kambitsch farm were established to study the impact of conventional and conservation tillage on soil properties and crop growth in 2000. Prior to 2000 the land was managed using conventional methods. Tillage treatments (20 x 80 m each; conventional tillage and chisel plow) were replicated four times across a hill slope. Three sections (each 27 m by 160 m) running north and south (up and down the slope) were planted to either winter wheat, spring barley or spring pea. Pea followed barley, barley was seeded into winter wheat residue and winter wheat followed pea. Due to the lack of randomization in the position of crops relative to one another, comparisons of crop effects were not possible.

Figure 3.2. Tillage trial at Kambitsch Farm at the University of Idaho

To improve the design for statistical analyses the plots were altered in fall 2010 for the 2011 cropping year. The new plot plan has the same tillage treatments running east to west (across the slope). Each tillage treatment is split into three crop zones planted to either pea, spring cereal or winter wheat. A replication was added to both the bottom and the top of the experimental plot, resulting in a total of five replicates per tillage treatment. The original individual tillage strips still exist so archived data is applicable. Tillage plots are 60 x 264 ft. Crop subplots are 20 x 264 ft. (4 ft. alley between tillage strips).

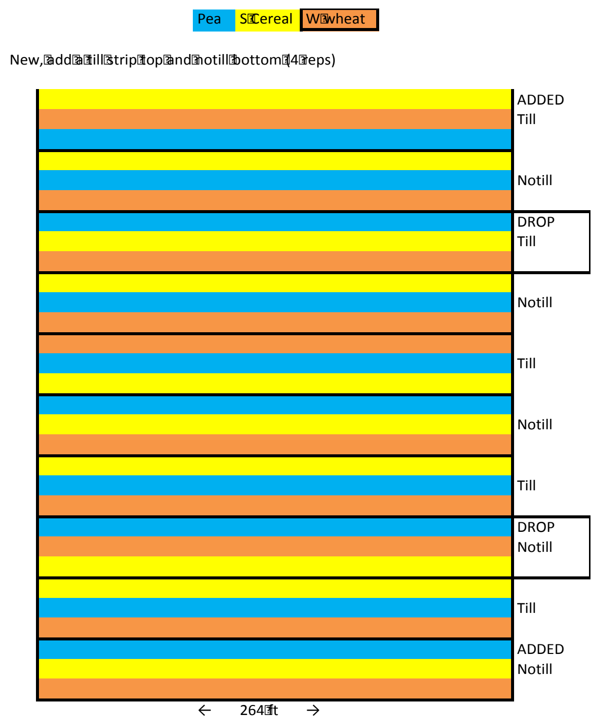

Figure 3.3. Tillage trial map: Kibitsch Farm, University of Idaho

Management for 2011 crop year: Winter wheat plots were planted with Brundage 96 on 10/14/2010 at 95 lbs. per acre along with 250 lbs. per acre of 31-10-0-7 fertilizer. Spring wheat was planted to Alturas on 5/19/2011 at 100 lbs. per acre along with 150 lbs. per acre of 31-10-0-7 fertilizer. Spring wheat received less fertilizer because the entire study was top dressed with 100 lbs. of 40-0-06 earlier in the spring. The pea strips were planted to Aragorn peas on 5/19/2011 at 120 lbs. per acre.

2. AEZ-1, WSU Cook Agronomy Farm, Pullman, WA; site lead: David Huggins

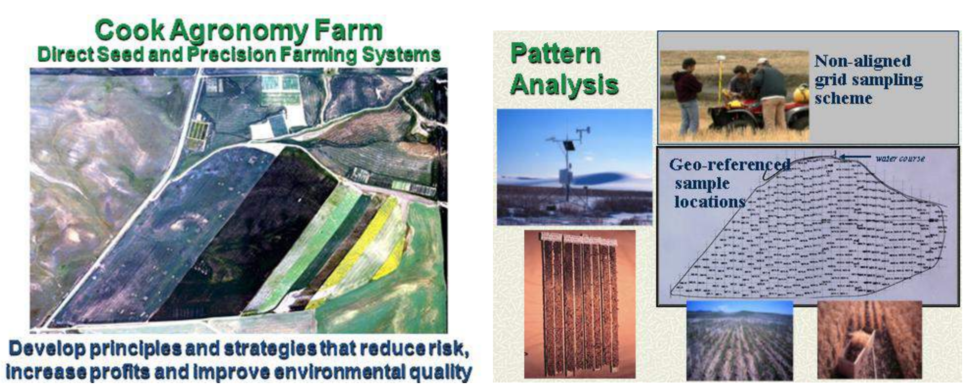

Figure 3.4. WSU Cook Agronomy Farm overview (left) and related activities (right)

Cropping system variables: site-specific N management, crop intensification/diversification, residue management

Starting in 1999, 369 geo-referenced sampling points over 37 ha of the Cook Agronomy Farm have been intensively sampled for soil, crop and terrain properties and combined with a developing environmental sensor network to provide data critical for understanding and modeling biophysical processes (C, N, water) and economic performance over time. Baseline soil samples (0-1.5 m) were collected at 182 geo-referenced points across a 37 ha field in 1999. The field was converted to NT in 1999 and six crop rotational treatments imposed in 2001- 2009. The crop rotations consist of 3-year, winter wheat-x-spring wheat sequences where x represents spring and winter counterparts of canola, pea and barley. These rotations have contrasting inputs of C and N that have likely created differences in soil C and N cycling characteristics. The complexity of soil and terrain attributes coupled with the imposed rotations offers a suitable environment for studies on landscape regulation of soil processes and crop performance (e.g. yield, grain quality). Completed activities at the CAF that support this research include: **(1)** creation of a digital elevation model (DEM) using a survey grade global positioning system; **(2)** determination of terrain attributes including slope, aspect, curvature, catchment area, wetness index, flow direction, flow accumulation and global irradiance based on DEM; **(3)** ground sensing of apparent electrical conductivity (ECa) using electromagnetic induction (Geonics, Inc.); **(4)** establishment of a nonaligned, randomized grid sampling design consisting of 369 geo-referenced sample locations (averaging 1 point every 30 m); **(5)** detailed morphological descriptions of soil horizonation and features and baseline soil characterization at alternating geo-referenced grid points (182 locations); **(6)** sampling (2 m^2 microplots) of crop yield, grain protein, aboveground biomass, soil water and mineral N (prior to spring planting and following physiological maturity), and aboveground C, N and S at harvest at the geo-referenced locations for hard red spring wheat, spring barley, hard red winter wheat, and five additional alternative crops; **(7)** installation of a weather station and two energy balance sites with instrumentation for continuous water and temperature sensing and energy balance at key topographic locations; **(8)** initial (1999) base-line soil sampling (0-10 cm depth increments to 30 cm and by soil horizon to 1.5 m) at 182 geo-referenced locations and analyses for total C, N, S, organic C, bulk density and pH. Soil sampling (0-10 cm depth increments to 30 cm and by soil horizon to 1.5 m) and C/N/S analyses (Leco C/N/S analyzer) was repeated in 2008 at the 182 geo-referenced locations and is currently being compared to the initial baseline data. SOC levels and changes in SOC will be related to terrain, soil and crop performance data of the different rotations using multivariate, spatial analyses and regression techniques. Carbon additions from aboveground biomass measurements will be related to changes in soil cover the ten year period to assess C inputs required for maintaining SOC. An N balance and relative efficiencies of N use on a rotational basis is also being assessed.

3. AEZ 1-WSU/USDA Palouse Conservation Field Station, Pullman, WA; site lead: D. Huggins

Cropping systems variables: crop rotation, rotational N cycling and management

Figure 3. 5. Overview of WSU/USDA Palouse Conservation Field Station

The Agroecosystem Research Trial (ART) was established at the PCFS in the fall of 2001 and consists of five different farming systems. The five farming systems are: perennial grass (PAT) (tall wheatgrass) harvested as a biofuel; continuous NT annual crops with all cereals (NTC) or including a grain legume (NTL); a Conservation Reserve Program planting consisting of two native perennial grasses (NAT); and a low soil disturbance organic farming system (OAT). The five farming systems were replicated nine times in a randomized complete block consisting of field scale strips across 35 ha. The strips are a minimum of 11 m wide to accommodate field-scale equipment and field strip length varies from 100 to 350 m to capture significant portions of landscape variability. In the spring of 2002, five geo-referenced monitoring points were established (one per treatment) in each of the nine replications (45 total points) to serve as locations for future treatment comparisons. The monitoring points were selected according to terrain and soil features to minimize differences in initial environmental conditions so that future measurements would reflect farming system effects. Baseline soil samples (0 to 1.5 m depth) were collected and analyzed for total C/N/S, bulk density and pH. Soil samples for water and mineral N (0-1.5 m) and aboveground biomass and yield are assessed each year. Fifteen of the sites (3 replications of 5 treatments) are monitored for soil water (0-1.5 m), air temperature, wind speed, solar radiation and relative humidity. We hypothesize that these farming systems will have the following order from most to least accumulation of soil C and N over time: PAT>NTL>NTC>NAT>OAT. Farming system differences in measured variables will be evaluated using a mixed model ANOVA with repeated measures.

Small plot replicated research on PCFS is also being conducted to evaluate N responses in canola N uptake and N carryover in wheat or pea crop sequencing. This experiment serves as a research site for PhD students Hammac and McClellan. Spring canola is grown with vary N rates from 0-160 lb. N/acre in 40 lb. incremental treatments, +/- S. Yield, grain protein and oil content/concentration and residue biomass, C/N are measured to assess N fertility responses and N carryover to succeeding crops. The canola is followed by wheat or pea to assess N carryover effects on wheat and pea N uptake, soil N mineralization and appearance of soil nitrate, ammonium. Following these spring crops, winter wheat is then planted with uniform 100 lb. N/acre, which is then followed again with variably N treated canola.

4. AEZ 1- Boyd family farm, Pullman, WA; AEZ 3 – Moro, OR; site lead: Ian Burke

Figure 3.6. Location of CRP transition experiments at Boyd family farm near Pullman, WA (left) and near Moro, OR (right)

Cropping Systems variables: crop intensification/diversification, residue management

The overall goal is to determine the most effective and economic transition program from CRP to crop production, while preserving soil C and maximizing water and N use efficiencies. Specific objectives include: **(1)** Compare rate and timing of undercutter and glyphosate applications for removal/control of CRP of perennial grasses and weeds in CRP lands; **(2)** Identify troublesome weed and crop combinations and weed control measures in former CRP ground in likely transition crops; **(3)** Determine if pathogen populations increase after CRP takeout, and whether there is any difference between a low-disturbance herbicide- based takeout and a tillage-based takeout; **(4)** Determine if CRP grass N rapidly mineralizes and contributes to increased N uptake and N use, which would reduce N fertilizer requirements in crops grown after CRP; **(5)** review relevant research and previously funded STEEP projects in an extension bulletin. A considerable amount of CRP ground is likely to transition back to crop production in the next 3 years. Therefore, research is needed to define transitional practices and management systems to conserve accumulated soil organic matter. The research will focus on the control of the existing CRP vegetation, while maintaining accumulated plant residue. Specifically, research is needed to determine effective direct-seed inputs for residue conservation and management, effective herbicide inputs for the control of bunchgrasses and troublesome perennial weeds in former CRP land in the various rainfall zones, disease pressure in former CRP land, and nitrogen utilization and carbon conservation using direct-seed inputs.

Following a STEEP funded study of methods for killing CRP grasses and weeds in preparation for crop production, current experiments at Pullman, WA and Moro, OR have focused on the CRP to crop transition in support of Objective 3. One trial has been established in Pullman, WA, while a second trial was established in Moro, OR. The two trials are different. The Pullman trial treatments include winter wheat and spring wheat rotations with two different fertility levels. Additional treatments include winter and spring pea and canola as alternative crops for the transition. The trial in Moro, OR, focuses on a low rainfall transition approach incorporating fertility, fall and spring plantings, and an evaluation of wireworm control.

5. AEZ-2 WSU Wilke Farm, Davenport, WA; site lead: Aaron Esser

Figure 3.7. Farm-scale research field operations (left) and soil sampling (right) at WSU Wilke Farm, Davenport, WA.

Cropping systems variables: crop intensification/diversification, site specific N management

The WSU Wilke Research and Extension Farm remains in a direct seeded cropping system that utilizes no-till fallow, winter wheat, and spring cereals. Broadleaf crops remain a viable option and may be substituted with spring cereal when weed pressures and market price create opportunities for profitable production. Winter canola or pea may also be substituted for winter wheat if a profitable opportunity is available. In spring of 2004 the decision was made to combine the twenty-one, 10 acre plots from our previous no-till, alternative crop project into seven plots with a 3 and 4-year flex crop rotation. This was done to make “the farm” easier to farm, reduce production risk, and gather meaningful data focused on direct seeded flexible cropping systems. This transition was also done to create more ground suitable for small plot research focused on improving the profitability of conservation based farming systems in the intermediate rainfall zone. The north side of the farm remains in continuous cereal grain production.

As part of REACCH, site-specific N management trials will be established on the farm-scale crop rotation strips described above. In an adjacent small plot rotation trial that began in 2011, spring canola and camelina will be inserted into wheat-fallow rotations to intensify and diversify the rotation in this transitional AEZ.

6. AEZ 2- OSU Columbia Basin Agricultural Research Center, Pendleton, OR; site lead: Stephen Machado

Figure 3.8. Overview of OSU Columbia Basin Agricultural Research Center, Pendleton, OR

Cropping systems variables: tillage/residue management, N fertility, recycled C,N byproducts, crop intensification/diversification

Long-term research guides future agricultural development by identifying the effects of crop rotation, variety development, fertilizer use, aerial and surface contamination, organic amendments on soil productivity and other beneficial soil properties. Deterioration of soils can be ameliorated or prevented by judicious insight in biological, chemical or physical reactions in soil. Comprehension and evaluation of many changes often requires 10-20 years to identify and quantify. Soil microflora and soil-borne plant pathogens require from 2-8 years in a new cropping sequence or tillage system to reach a stable equilibrium.

The Pendleton Agricultural Research Center has several ongoing long-term experimental sites. The earliest was started in 1931, the latest in 1997. The Residue Management and Tillage-Fertility experiments are among the oldest replicated research experiments in the western U.S. All have a documented history of crop variety, tillage, date of seeding, and grain yield. The studies are representative of most of the cropping systems in the Pacific Northwest intermountain cereal region that receives less than 18-inches of precipitation. All research activities on the long-term experiments are presently monitored by an oversight committee consisting of five members from Oregon and one each from Washington and Idaho.

The Long-term research experiments at Pendleton, Oregon
Year Initiated Symbol Experiment Name Treatment Variables
1931 GP Grass Pasture None
1931 CW Continuous Cereal Fertility
1931 CR Residue Management Nitrogen, Manure, Burning
1940 TF Tillage-Fertility Tillage, Fertility
1963 WP Wheat-Pea Tillage, Fertility 1991-99
1982 SF No-till Wheat Nitrogen
A no-till continuous cereal trial (NT) with fertility and seed drill variables was established in1997.

Grass Pasture (GP):
This site contains no experimental variables, but has been maintained since 1931. It is 150 feet wide by 360 feet long, and is dissected in the southern half by a drainage way. Slope ranges from 0 to 3%, with a southwest aspect for the northern half. Soil depth is about 4.0 feet. This site approximates a near-virgin grassland and serves as a base-line for evaluating changes in the other systems. It is periodically reseeded with introduced grass selections,occasionally fertilized, and infrequently irrigated. The dominant grass species is tallfescue *(Festuca arundinacea* Scheeber) with lesser amounts of bulbous bluegrass (*Poabulbosa* L.), green foxtail (*Setina viridis* (L.) P. Beauv.) and yellow foxtail (S. *pumila* (Poiret) Roemer & Schultes). This site received limited grazing from 1931 to 1985. It has not been grazed since, but vegetation is clipped once or twice during summer growth. Above-ground productivity has been measured since 1996.

Continuous Cereal (CW):
This experiment was established in 1931. The original experiment consisted of three adjacent sites, two 284 by 304 feet cropped annually to winter wheat (*Triticum aestivum* L.), and one 132 by 304 feet cropped annually to spring wheat. The original design consisted of eight plots, each 38 by 132 feet, at each site. The eight plots received no fertilizer from 1931 to 1943, different rates of N (0 to 150 lb. N acre^{-1} yr^{-1}) from 1943 to 1951, no fertilizer from 1952 to 1959, and 80 ± 10 lb. N acre^{-1} after 1960.

The site was modified in 1977. The southern 66 by 304 feet of the winter wheat section was abandoned to make room for an equipment yard. The spring wheat site was abandoned, and spring wheat then grown on the north 132 by 304 feet of the winter wheat experiment. The spring wheat site was divided in half in 1982, with the south 66 by 304 feet thereafter cropped to spring barley. The present experiment now consists of three 66 by 304 feet sections cropped to winter wheat, spring barley, and spring wheat, each grown every year in the same location. This experiment currently serves as a cereal monoculture baseline for comparing other crop rotations, all under conventional tillage. Each crop site is moldboard plowed just prior to planting of that crop, and receives both chemical and mechanical weed control. Slope ranges from 0 to 1%, and soil depth from 4.5 to 6.0 feet. For yield determination, each site is divided into four 66 by 76 foot sections corresponding to the initial plots (1+2, 3+4, 5+6, and 7+8). Since 1995, a 12-by-

284 foot strip in all crops receives no N and the remaining 54-by-284 feet in each receives 80-N. This permits an evaluation of N response in annual cropping. The experiment has periodically received P and S fertilization since 1982.

Residue Management (CR):
This is the most comprehensive of the long-term experiments. It was established in 1931 and has had only two major revisions (1967, 1979). The rotation is winter wheat/fallow and the tillage is conventional (moldboard plow). The experimental design is an ordered block consisting of nine treatments (10 originally) and two replications. The experiment contains duplicate sets of experiments that are offset by one year so that data can be obtained annually. Plot size is 38 by 132 feet. Replicates differ in soil depth, slope, and soil N content. Replicate I is shallower than II (3.5 vs. 6.0 feet), more level (0-2 vs. 2-4% slope), and had higher N content in the top 12 inches of soil in 1931 (0.123 vs. 0.113% N). A single medium-tall variety (Rex M-1) was grown from 1931 to 1966. Modern semi-dwarf varieties have been grown since (Nugaines 1967-1973; Hyslop 1974-1978; Stephens 1979-1991; Malcolm 1992-1995, Stephens 1996-present).

Winter wheat is seeded in mid-October and harvested in mid-July. Fall stubble burns are implemented in late September. Spring stubble burns are implemented and organic amendments applied in the spring of the fallow year (late March - early April from 1931-1994; late April-early May since then. Late-winter or early-spring herbicides are used to control vegetative growth in wheat stubble until plots are plowed. Plots are plowed 8 inches deep within 3 days after spring burning. Soil is then smoothed with a field cultivator/harrow. Weeds are controlled by tillage during the fallow phase and with herbicides during the crop phase. Nitrogen fertilizer is applied 5-15 days prior to seeding of wheat. Lister furrows (first initiated in 1989) are now routinely installed each fall between plots to channel runoff water out of the experiment rather than being left to run onto adjacent plots. The burn plots have in recent years begun to show slower infiltration and greater surface runoff than that in plots where residue is incorporated. Furrows are dug in both the wheat and stubble phases. Furrows are taken out in late March and seeded to spring wheat to prevent moisture and nitrate buildup between plots. Delayed spring tillage for fallow was implemented in 1994 in contrast to previous plowing in late March. Wheat stubble now receives a herbicide in either late-fall or early-spring to control downy brome and volunteer wheat. This permits delaying spring plowing until late April or early May where soil is not as wet. This change avoids spring tillage when soils are wet and eliminates 2 to 4 tillage operations.

The C and N content of the upper 24 inches of soil has been determined about every 10 years (1931, 1941, 1951, 1964, 1976, 1986, and 1995). Straw yield, grain and straw N content, and the nutrient content of organic amendments have been determined since 1977. Straw yield and nutrient uptake from 1931 to 1976 has been estimated by utilizing variety trial data coupled with periodic measurements in this experiment.

Tillage-Fertility (TF):
These plots were established in 1940 and have had major revisions in 1952, 1962, and 1988. The rotation is winter wheat/fallow. This experiment has only one set of plots, thus

yield is obtained only in odd years. Treatment history and plot layout is shown in Table 5. The experimental design is a randomized block split-plot, with three replications. Main plots consist of three primary tillage systems (moldboard plow, offset disk, and subsurface sweep) and subplots of six fertility levels (currently, N rates from 0 to 160 lb. N acre-1 in 40 lb. increments, with one duplication). Individual plot size is 18 by 132 feet. Primary tillage is performed in April. Secondary tillage and other cultural operations are the same for all treatments. All plots are smoothed 4-6 inches deep with a field cultivator and harrow following primary tillage. They are then rod-weeded four to five times between April and October to control weeds and maintain seed zone moisture. Nitrogen fertilizer is applied about October 1 and winter wheat seeded about October 10. Nitrogen was broadcast as ammonium nitrate (21-0-0-24S) from 1963 to 1987, and thereafter as urea-ammonium nitrate (32-0-0) shanked 6 inches deep with 10-inch band spacing. The experiment relies on both mechanical and chemical weed control, but the stubble mulch treatments have occasionally received extra chemical treatment when grassy weeds have been a problem. The replicates in this experiment differ in soil depth by virtue of landscape position. Replicate 1 (6.9 + 0.3 feet deep) is located on a north-facing 3% back slope, Replicate 2 (4.4 + 0.8 feet) on east-west facing foot slopes of 0 to 2%, and Replicate 3 (3.7 + 0.3 feet deep) on an east-facing 2% back slope. Medium-tall soft white winter wheat was grown from 1940 to 1962, and semi-dwarf soft white winter wheat since. Straw yield and grain and straw N content have been determined since 1977.

Wheat/Pea (WP):
This experiment was established in 1963, with modifications in 1972, 1976, and 1989. It is located on nearly-level land, with 0-1% slope. Soil depth is generally 6 feet. Crop rotation is winter wheat/pea. Treatment history and plot layout is shown in Table 6. The experimental design is a randomized block with four replications. Each replication contains eight plots (four treatments duplicated within each replication). Duplicate treatments allow yearly data collection for both wheat and peas. Individual plot size is 24 by 120 feet. Tillage intensity ranges from maximal- to minimal-inversion of crop residue. The current tillage treatments are **(1)** fall chisel; **(2)** fall plow; **(3)** spring plow; **(4)** no-till.

Vine residues are now left on the plot rather than removed. Vine yield and nutrient content is determined. Uniform distribution of peas residues following harvest is a problem in most years. Semi-dwarf soft white winter wheat is seeded after October 10 whenever soil moisture is sufficient for germination and early crop growth using a double disk drill with 7-inch row spacing. Peas are seeded in late March or early April, and harvested in June or July. The type of peas grown was changed from fresh-green processing to dry-edible seed in 1989. From 1963 to 1988, wheat received 40-80 lb. N acre-1 as ammonium nitrate (34-0-0) broadcast prior to seeding. In 1989-1990, each wheat plot received 20 lb. N acre-1 as 16-20-0-14S. In 1991-1992, one half of each plot received 80 lb.. N acre-1 and the other half received no additional N. Nitrogen application reversed in 1993-1994, with the half receiving 80-N for the previous wheat crop receiving no additional N two years later. This rotation of N fertilization will continue. This change was instituted to better evaluate N needs of wheat in a wheat/legume rotation. Peas receive 20 lb. N acre-1 as either ammonium sulfate (21-0-0-24S) or ammonium phosphate sulfate(16-20-0-14S) broadcast every pea crop. The east half of the experiment received1800 lb. lime acre-1 in 1976. A 24 x 24 foot area on the western edge of certain plots was fumigated with methyl bromide in the early 1980s.

No-Till Wheat (NT):
This experiment was established in 1982 and modified in 1983, 1988, and 1997. It is located on level land with 0-1% slope. Soil depth is 4.6 + (±?) 0.3 feet. This site was cropped to wheat/fallow in earlier years, generally with some form of conventional tillage. The experimental design consists of 10 treatments and four replications. Plot size is 8 by 100 feet. The original treatments consisted of two sets of five N rates (0, 50, 100, and 150 lb. N acre-1 banded below seed, and 100 lb. N acre-1 surface broadcast) and a residue-burning variable (burn, no burn). It was cropped annually from 1983 to 1988 in a winter wheat/spring wheat rotation. The crop rotation was changed in 1989 to winter wheat/fallow in 1989. The burn variable was discontinued, and a date of seeding (September, October) variable superimposed in its place. The broadcast N treatment was terminated in 1993 and N rates adjusted to align with those in other long-term experiments (0, 40, 80, 120, 160 lb. N/acre). The date of seeding variable was discontinued in 1997, and the experiment revised such that odd-number treatments were cropped in odd-numbered years and even-numbered treatments in even-number years. This retains the N rates, and allows for crop yield to be determined yearly for a wheat/fallow system. An identical set of no-till plots was added immediately north of the present experiment in 1997 to compare crop and soil parameters during early stages of no-till adoption with that for a long-term no-till system and a mold board plow system. Odd-numbered treatments were cropped to spring wheat in 1997 to start the system revision. Winter wheat will be grown in future years.
The experiment is strictly no-till, with no tillage other than for seeding and stubble flailing. Herbicides are used to control weeds in both fallow and crop. This experiment was implemented to evaluate N fertilizer effects on crop yield and soil quality under no-till cropping.

7. AEZ 3-OSU Moro, OR; site lead: Stephen Machado

Figure 3.9. Field day (left) and planting operation (right) at OSU Sherman Research Station at Moro, OR.

Cropping systems variables: tillage/residue management, crop intensification diversification

Recent climate models have predicted that temperatures and precipitation will increase at a rate of 0.5ºF per decade. To this end, research is needed to develop cropping systems adaptable to the changing climate. With increase in precipitation, annual cropping of winter wheat would be possible and work to perfect this system should be conducted. Furthermore, given that agriculture contributes about 8% of greenhouse gases, cropping systems that mitigate climate change should be developed. Preliminary results from Moro LTE showed that continuous winter wheat under DS sequestered more C than other treatments but produced the lowest yields. Developing viable annual cropping systems may help mop up excess CO2 from the atmosphere. Camelina [*Camelina sativa* (L.) Crantz is a small seeded Brassica that can grow in the PNW. It produces yields of 800 to 2500 lb./acre with an oil content ranging from 29 to 39% (Putnam,1993). The oil is suitable for biodiesel with characteristics similar to soy biodiesel. It is a low input crop that matures quickly and uses less water than many spring crops grown in the PNW. This makes it suitable for rotation with winter wheat, the PNW main crop. The project objectives are to **(1)** Develop profitable and sustainable cropping systems for north-central Oregon and south central Washington; (**2)** Develop cropping systems that contribute to bioenergy; (**3)** Develop cropping systems that mitigate global warming potential. The following rotations (1-8) are being evaluated in this study:

1. Winter wheat-conventional fallow (CT)
2. Winter wheat-chemical fallow (DS)
3. Continuous winter wheat (DS)
4. Continuous spring wheat (DS)
5. Continuous spring barley (DS)
6. Winter wheat-spring barley-chemical fallow (DS)
7. Winter wheat-winter pea (DS)
8. Winter wheat-camelina (DS)

The following measurements will be taken to generate information needed to fulfill the objectives.

Objective 1: Residue cover; C sequestration; microbial biomass, function, and community structure; water infiltration; available soil moisture; water use efficiency; soil physical and chemical characteristics; wind and water erosion; diseases; weeds; grain yield; and inputs for evaluating profitability.

Objective 2: A winter wheat-camelina rotation is going to be introduced. Camelina is short season spring crop that uses less water. Camelina will introduce crop diversity and produce oil for biofuels. This work will supplement other camelina agronomic (variety and fertility) experiments planned for the PNW pending funding.

Objective 3: Direct seeded cropping systems generally sequester more C than conventional system involving tillage. Treatments 2-8 will be compared with treatment 1 (conventional fallow) to determine if these systems are indeed sequestering more C. Of particular interest is the annual winter wheat under DS, which has shown to sequester more C than all treatments. Improvements in yield of this particular system could result in better returns for this system.

8. AEZ 3-Jirava Farm, Ritzville, WA; site leader: William Schillinger

Figure 3.10. Overview (left) and alternative crop, safflower (right) at WSU long term cropping systems experiment on Ron Jirava's farm near Ritzville, WA.

Cropping systems variables: residue management, crop intensification/diversification

A long-term alternative cropping systems project using direct seed and conservation tillage practices was initiated in 1997 on the Ron Jirava farm near Ritzville, WA. Annual precipitation has been lower than the long-term average during 7 of the past 10 years (the 2006, 2010, and 2011 crop years were the exceptions). These drought conditions have not favored the economics of intensive (i.e., no fallow) cropping. Rizoctonia bare patch first appeared in 1999 but has declined to near zero levels in the past four years. This is the first documentation of natural suppression of Rhizctonia bare patch in long-term no-till in the United States. Soil organic matter in no-till treatments in the 0-to 2-inch layer has increased to that of the native undisturbed soil during the course of this experiment. Phase IV of the experiment began during the 2010 crop year. This new phase of the experiment will run for six years from 2010 to 2015.

The soil at the experiment site is a Ritzville silt loam. The soil is more than six feet deep with no rocks or restrictive layers and slope is less than 1%. Thirty-year average annual precipitation for the site is 11.5 inches. The field where the experiment is conducted was in an intensive tillage-based WW-SF rotation for more than 100 years before the onset of the experiment.

In Phase I (1997-2000) of the experiment, cropping systems treatments were: **(1)** a 4-year safflower (SAF)-yellow mustard (YM)-soft white spring wheat (SW)-SW crop rotation; **(2)** a 2-year SW-spring barley (SB) rotation and; **(3)** continuous annual SW. Experimental design was a randomized complete block with four replications. Each crop in all rotations occurred each year in 60- by 500-ft plots, making a total of 28 plots. The

4-year rotation was designed primarily to test the effects of back-to-back broadleaf crops on the epidemiology of soil fungal diseases that plague monoculture wheat.

In Phase II (2001-2004) of the experiment, existing plots were split along the long axis (i.e., from 60-by 500-ft to 30-by 500-ft for a total of 56 plots) to introduce the following cropping systems: **(1)** a 4-year WW-WW-SW-SW rotation; **(2)** a 4-year WW-SB-YM-SW rotation ; **(3)** a 2-year SW-SB rotation (retained from Phase I); **(4)** a 2-year hard white spring wheat (HW)-SB rotation**; (5)** continuous annual SW (retained from Phase I); **(6)** continuous annual HW.

For Phase III (2005-2009), treatments are: **(1)** a 4-year WW-SB-SW-chemical fallow (CF) rotation; **(2)** a 4-year WW-SB-SW-tilled summer fallow (under cutter method) rotation; **(3)** a 2-year SW-SB rotation; **(4)** a 2-year SW-SB rotation; **(5)** continuous annual SW; **(6)** continuous annual HW.

An advisory group meeting was held in October 2009 to determine crop rotations for the next six years of the study (i.e., Phase IV, 2010-2015). The Phase IV crop rotations are **(1)** a 3-year CF-triticale-SW rotation; **(2)** a TF-WW-SAF rotation; **(3)** a 3-year TF-WW-SW rotation, **(4)** a 2-year WW-TF rotation; **(5)** a 2-year SW-SB rotation; **(6)** continuous SW. Note that the continuous annual SW and the 2-year SW-SB rotations have been in place since 1997. In addition to the above, a small-scale 3-year TF-winter pea-SW rotation study was initiated in 2010 on land adjacent to the long-term study. All four phases of the experiment were designed in consultation with an advisory group of regional dryland wheat farmers.

The 20-acre Jirava site has been carefully managed through the years to maintain the integrity of the experiment. We know the exact history of each of the 56 plots. We feel that, with current technology, the Jirava site perhaps represents the lower precipitation boundary where intensive cropping may be an economically viable alternative to WW-SF. Therefore, knowledge and success stories generated from the Jirava experiment should be applicable throughout the 11-to 14-inch annual precipitation zone.
n

Growing Conditions and Grain Yields in 2011. Crop-year (September 1 – August 31) precipitation for 2011 at the Jirava site was 13.01 inches. For the second year in a row (2 out of 15 years), we were able to establish winter triticale into carryover soil moisture in no-till fallow that produced a grain yield of 3.11 tons/acre (grain mass equivalent of 104 bushels/acre of wheat). Early planted winter wheat yielded 75 bushels/acre. Re-crop (i.e., no fallow) spring wheat grain yield (in the various rotations) ranged from 43 to 46 bushels/acre. Spring barley grown in a 2-year rotation with spring wheat produced 1.23 tons/acre. Safflower grain yield was 1091 lbs./acre.

Natural Suppression of Rhizoctonia Bare Patch with Long-Term No-Till. Rhizoctonia bare patch caused by *Rhizoctonia solani* AG-8 is a major fungal root disease in no-till cropping systems. In a 15-year experiment, Rhizoctonia first appeared in year 3 in all no-till plots and reached peak levels by year 8. Rhizoctonia infected all crops grown with long-term no-till, including winter wheat, spring wheat, spring barley, yellow mustard, and safflower. The area of bare patches has been measured in mid-June every year in all plots with a backpack-mounted GPS unit. The area of bare patches began to decline in year 9 and reached near zero levels by year 12.

Rotation Benefits of Spring Barley on Subsequent Wheat Grain Yield. Crop rotation treatments evaluated over the 15 years include a 2-year soft white spring wheat (SW) – spring barley (SB) rotation versus continuous annual SW. The SW and SB varieties used are Alpowa and Baronesse, respectively. These crops have always been planted no-till. Long-term average annual precipitation at the site is 11.4 inches, but only an annual average of 10.40 inches has occurred since the inception of the study. There has been high year-to-year variability in grain yields for both SW and SB. One consistent pattern has occurred. Spring wheat grain yields following SB are generally greater than monoculture SW. This SW grain yield boost following SB is not significantly different every year, but there are statistical differences when averaged over the 15 years. The 15-year average grain yield of SW after SB is 32.4 bu/acre compared to 30.6 bu/acre for monoculture SW. We have intensively measured soil water dynamics in this experiment and can say with certainty that the SW yield differences are not due to water. More likely, the yield increase is due to less Rhizoctonia bare patch disease pressure when SB is included in the rotation.

Grain yields of winter wheat grown after tilled summer fallow (WW-SF) were compared to those of continuous annual no-till spring wheat (SW) near Ritzville, WA during the past 15 years. Grain yields of WW-SF were relatively stable and averaged 53.7 bu/acre over the 15 years compared to 30.6 bu/acre for continuous annual SW. Profitability of cropping systems fluctuates widely due to many factors such as cost of diesel, herbicides, and other inputs. However, as a general rule of thumb, re-crop SW needs to yield 65% of that of WW-SF to be equally profitable. Using this measure, SW was equally as profitable as WW-SF in 5 of 15 years at Ritzville. A model has been developed to help farmers decide when it may be desirable to plant spring cereals (in lieu of summer fallow) based on measured over-winter soil water storage and expected spring rainfall.

9. AEZ 3-Hennings Farm, Ritzville, WA; site leader: Frank Young.

Figure 3.11. Ron Henning looking at residue management plots (left) and overview (right) of USDA-ARS/WSU long term cropping systems experiment a farm near Ralston, WA.

Cropping systems variables: residue management, crop intensification/diversification
The No-Till Integrated Spring Cropping Systems Research Project, better known as the "Ralston Project" was initiated on the Curtis and Erika Hennings farm in the fall of 1995 near Ralston, WA. The goal of the project was to develop new no-till spring cropping systems to either supplement or replace the traditional winter wheat-fallow system. The focus of the project's treatments was a compromise between scientists' interests and growers' needs expressed during planning meetings. During Phase I (1995-2000) of the project the treatment rotations consisted of: **(1)** reduced-till winter wheat/fallow; **(2)** no-till soft white spring wheat/chemical fallow; **(3)** no-till continuous hard red spring wheat; and **(4)** no-till hard red spring wheat/spring barley. During Phase II (2000-2002) the integrity of the no-till plots and reduced-till winter wheat-fallow plots was maintained although no data was collected because of a lack of funds. Phase III (2003-2007) of the project contained four new rotation systems that included two crop rotations per rotation system. The four rotation systems included: **(1)** reduced till winter wheat/fallow; **(2)** no-till facultative spring wheat/chemical fallow and no-till facultative spring wheat/no-till spring wheat; **(3)** no-till spring oat/no-till spring triticale; and **(4)** light-tilled spring barley/no-till hard white spring wheat and no-till spring barley/no-till hard white spring wheat.

The experimental design was a randomized complete block, with four replications of the four different crop systems on 30 ft. by 500 ft. plots in two adjacent fields. This arrangement allowed each crop within each rotation (system) to be grown every year.

From 1995 to 2000 scientists from 10 disciplines evaluated treatments annually for: **(1)** weed population dynamics; **(2)** soil fertility; **(3)** variety/pest resistance; **(4)** soil moisture and erosion control; **(5)** pest incidence; **(6)** grain yield and quality; and **(7)** economic profitability and risk. From 2003 to 2007 (Phase III) disciplines involved included soils, weed science, plant pathology, agronomy and economics. As with Phase II, Phase IV maintained the previous plot integrity of reduced tillage winter wheat/fallow and no-till without data collection.

Previous Findings and Publications. To date we have eight publications from the Ralston Project including seven peer reviewed journal manuscripts and one book chapter. Topics include wind erosion, entomology, weed science, cropping systems, facultative spring wheat, and rural sociology. Currently four more are in the process of being written including pathology, C/N, agronomy, and systems.

Major Findings. After 5 years of Phase I research, it was found that none of the continuous no-till spring cropping systems were economically viable. When precipitation was 1 ½ to 2 times the long-term average, the systems were profitable, however in three of the five years these systems lost money. On the other hand, the no-till spring cereal systems reduced winter annual grass weed infestations, winter wheat diseases, and decreased wind erosion compared to the traditional winter wheat/fallow system. This study for the first time documented that Hessian fly is a serious problem in hard red spring wheat in the low-rainfall zone and that host plant resistance was effective against this pest. Scientists also discovered that applying 2/3 of N in the fall and 1/3 at the time of planting in the spring that hard red spring wheat made 14% protein every year. A major finding from Phase III was that the facultative spring wheat/chemical fallow system appeared to perform similarly to the winter wheat/fallow system under normal environmental conditions. The adoption of facultative wheat would spread out fall planting and summer harvesting, control problem winter annual grass weeds, and would not rely on seed-zone soil moisture for germination and emergence like winter wheat.

Future Research. Phase V is currently being conducted for the REACCH Project at Ralston with the objective to compare the effect of fall wheat harvested with a stripper header and conventional header on seed zone and profile soil moisture, residue produced, residue decomposition, soil quality, and yield. Moisture is the single most limiting resource in the wheat/fallow region of the PNW. The goal of the stripper header is to increase soil moisture by increasing crop residue. This process would allow growers to transition to a no-till chemical fallow system which would alleviate the weed, disease, and erosion problems that plague the traditional wheat/fallow system. The studies will be conducted on large-scale main plots and small satellite areas (see the attached map). Where treatments will include: **(1)** traditional wheat/fallow vs. no-till wheat/chemical fallow; **(2)** tall winter wheat vs. tall triticale; **(3)** stripper header vs. conventional header; **(4)** flailed stubble vs. standing stubble. Data to be collected includes crop yield, postharvest residue, fall and spring soil moisture in 6-ft profile, C/N, nitrate ammonium, total C and N. The Ralston Project is the longest-running, no-till research site on a grower's farm in the PNW.

10. AEZ 3 Troutman Farm, Bridgeport, WA. Site leader: Frank Young.

Figure 3.12. Small plot research (left) and grower adoption of canola (right) at near Bridgeport, WA.

<u>Cropping systems variables: crop intensification/diversification</u>

Research and extension on canola seedbed establishment, variety selection and weed management in the north central WA wheat-fallow region has led to rapid crop diversification in the area and increased canola acreage by showing dramatic benefits to wheat production in the region. A replicated on-farm trial is under development, to assess impacts of winter canola insertion into winter wheat-fallow for improving weed control and wheat yield and quality. Alteration of chemical rotation will be integral to build up glyphosate resistance, and rotating glyphosate-tolerant with non-glyphosate-tolerant canola in rotation with wheat will be a key element of this research.

11. AEZ 4 WSU Irrigated Agriculture Research and Extension Center, Prosser, WA; site leaders: Hal Collins, Bill Pan

Figure 3.13. Crop rotation and tillage plots established at WSU IAREC near Prosser, WA.

<u>Cropping systems variables: crop intensification/diversification, residue management</u>

Wheat is produced in the irrigated regions of the inland PNW as a rotational crop that helps break disease, pest and weed cycles of higher value cash crops such as sweet corn, potato and fresh pea. In the central Columbia Basin, an abundance of good quality irrigation water, sunny days, productive soils and long growing season all contribute to a very rich agricultural region. However, the high inputs of water and nitrogen, shallow and fragile soils also contribute to environmentally sensitive production systems prone to water and air quality problems, and GHG production. Residue management, judicious use of N fertilizers, and insertion of winter cover crops will help remediate these environmental impacts. Past winter cover crop research in the region has demonstrated that overwintering cereal or brassica cover crops can recycle in excess of 100 kg N/ha that would otherwise leaching below shallow root zones of summer crops.

A new cropping systems experiment was established in fall 2011 to investigate winter cover crop and no-tillage management effects on crop productivity and water and N use efficiencies, as well as C, N cycling and budgets. A brassica cover crop will be inserted into an irrigated rotation: winter wheat- w. triticale cover crop-sweet corn-mustard cover crop- fresh potato to increase biomass C,N returns to soil, provide more surface residues for wind erosion control. Summer crops will be no-tilled where feasible. Plots are triplicated with 4 replicates per treatment to grow each crop in each year. Plots have been set up to accommodate chamber measurements of C, N gas fluxes across one replicate of all treatments simultaneously for a single crop.

Table 3.1. Summary of treatments experiments on the farms

	Wilke Farm	Cook Agronomy Farm	Palouse Conservation	Hennings Farm	Troutman Farm	Jariva Farm (Ritzville)	Kambitsch Farm	Prosser Station	Pendleton Station	Boyd Family Farms	Moro Station
Site specific N management	■	■									
Crop intensification/diversification	■	■		■	■	■		■	■	■	■
Residue management		■		■		■	■	■		■	■
Crop rotation			■								
Rotational N cycling and management			■								
Tillage							■		■		■
N fertility, recycled C, N byproducts									■		

B. REACCH Cropping System Win-Win Scenarios: Summary of Short-Medium Term Societal and Farm Benefits, and Long term Climate Change Adaptation and Mitigation. *How do we keep farmers in business, ensure their long term sustainability, while slowing climate change? Consider the following cropping systems strategies and technologies and their potential to collectively address these goals.*

Table 3.2.

Cropping System Management Strategies and Technologies (and project linkages)	Short-Medium Term Benefits to Farmers, Communities and Environment (1-10 years)	Long-term Climate Change Mitigation and Adaptation Benefits to Global Sustainability (40+years)
Reduced tillage, chemical fallow/undercutting w/o soil inversion, direct seeding Link to long term Cook (WSU), Kambitsch (UI), Pendleton and Moro (OSU) trials, and more recent Loescher-Othello (WSU) irrigated trials	• Decreased soil erosion and stream sedimentation • Increased soil organic matter leads to increased soil water holding capacity, increased water infiltration by increasing soil aggregation and worm activity • Increased nutrient cycling and nutrient storage capacity	Soil C storage reduces CO_2 emissions
Crop intensification: -more winter crops -more perennials -fallow replacement with crop	• Immediate increase in food, fuel, feed production for an increasing world population • Increased farm productivity and increased potential farm income	• More photosynthesis, CO_2 fixation/removal from the atmosphere • More straw biomass, more soil C sequestration
Crop diversification: increased % legumes in rotation with wheat Note: Currently, legumes account for < 10% of acreage Link to ongoing crop rotation studies at Cook, PCFS, Moro, Othello	• Broadleaf crop in rotation breaks disease, insect cycles • Broadleaf allows better grass weed control • Biological N fixation reduces rotational N fertilizer costs per unit yield	• Reduction in global GHG emissions generated during N fertilizer production • Preserve natural gas used in N fertilizer production • Reduced reactive soil N that would otherwise lead to greater N_2O emissions
Crop diversification: Increased % oilseeds in rotation with wheat Note: Oilseeds account for < 1% of the crop acreage Link to ongoing crop rotation	• Broadleaf crop in rotation breaks disease, insect cycles • Broadleaf allows better grass weed control • Glyphosate resistant canola offers the only available RR crop that can be grown in	• Increase net productivity and PS, more C fixation • Increase soil C sequestration, reduce carbon dioxide in atmosphere • Improve N cycling and use, reduce nitrous oxide emissions • Adaptation of short season

studies at Kambitsch, PCFS, Othello, Moro	PNW rotations • Strong tap root improves soil structure, water infiltration	crops will help avoid increasing summer heat and drought stress
Wheat Class and Variety Custom Fitting to AEZ Note: New project linkage to Triticacae CAP, and regional genetics/breeding drought/heat stress projects, and WA variety test result analysis (McCracken, Guy, Koenig et al.)	• Improved probability of protein-based wheat premiums to individual growers • Improved overall regional wheat quality and market reputation • Matching drought and heat tolerant varieties to appropriate AEZs	• Avoiding poor matching of wheat class and variety with AEZ avoids needs for excess N fertilization and resulting poor N use efficiencies, reactive soil N and GHG emissions. • Development of new heat and drought tolerant germplasm more adaptable to climate change
Prescription N management ***-Soil test and climate based N recommendations*** -Variable N management across landscapes Note: less than ½ growers' base N applications on regular soil testing, even less practice variable N management. Link to 1) AFRI Climate Friendly Farming: Precision N management, 2) NSF NSPIRE studies on N cycling in rotational oilseed and legume crops (4 current grad students), 3) grower survey on soil testing (Mahler, UI)	• Reduced N fertilizer costs • Avoids N over-fertilization that causes yield reductions • Reduced nitrate contamination of surface, ground water	• Reduction in global GHG emissions generated during N fertilizer production • Preserve natural gas used in N fertilizer production • Reduced reactive soil N that would otherwise lead to greater N_2O emissions • Avoiding N over fertilization reduces reactive soil N that that would otherwise lead to greater N_2O emissions
Recycle organic C, N byproducts: manure, biosolids as soil amendments Link to long term Cogger (WSU) biosolids project; Climate Friendly Farming smart C/N; Pendleton long term manure trial	• Improves soil organic matter with affiliated soil quality and productivity benefits (see reduced tillage) • Supplements and reduces synthetic N fertilizer input costs if sources are in close proximity • Recycles valuable nutrients • Reduces landfilling biological wastes	• Tightens global nutrient cycles and reduces N_2O, CO_2 emissions compared to other waste disposal pathways • Reduction in global GHG emissions generated during N fertilizer production • Preserve natural gas used in N fertilizer production

Technical Report

The goal of Objective Team 4 is to determine social and economic factors influencing agricultural management, technology adoption and development of policy to improve production efficiency while mitigating greenhouse gas emissions. In year one, we designed a longitudinal survey and identified 42 growers to interview in order to establish a baseline from which to measure change in these factors over the 5 year life of the REACCH project. Included below are: **1)** the Longitudinal Survey Logbook & Scrapbook; **(2)** the General Survey of Wheat Producers.

Longitudinal Survey Logbook & Scrapbook

This logbook and scrapbook will be used as the longitudinal survey progresses to highlight each grower's crop-related events for every year of the project (Figure 4.1). Pages include areas to record emergence dates, planting dates, harvest dates, and average yields (Figure 4.2). In addition, each year has space provided to include photos, annual changes in weed, pest, and disease management, and specific notes or observations (Figure 4.3).

Figure 4.1. Grower logbook & scrapbook for the longitudinal survey

Emergence Dates

	Winter wheat	Spring wheat
2011		
2012		
2013		
2014		
2015		

Planting Dates

	Winter wheat	Spring wheat
2011		
2012		
2013		
2014		
2015		

Harvest Dates

	Winter wheat	Spring wheat
2011		
2012		
2013		
2014		
2015		

Average Yield

	Winter wheat	Spring wheat
2011		
2012		
2013		
2014		
2015		

Figure 4.2. These pages will be used to record emergence dates, planting dates, harvest dates, and average yields in the grower logbook & scrapbook.

Figure 4.3. The longitudinal survey logbook & scrapbook has pages for photos, recording annual changes in weed, pest, and disease management, and specific notes or observations for each year.

Survey Instruments for the Longitudinal Survey

The grower survey consists of three parts: **(1)** schedules of farm operations used to produce winter and spring wheat (separate sheets for each survey) (Table 4.1); **(2)** a list of machinery used to produce wheat on their farm, including estimates of value, usage, and repair costs (Table 4.1); **(3)** a general survey that tracks information on their crop rotation, the location of their farm, yearly changes in pest observations, use of technology, fertilizer use, and general Extension-related questions. This survey is completed during the in-person interview with the growers (see below).

WHEAT OPERATIONS (CIRCLE) : SPRING WHEAT WINTER WHEAT SOFT WHITE HARD RED CLUB YEAR_____________

Operation	Date	Times Over	Equipment: Tooling	Equipment: Owned	Equipment: Rented	Equipment: Custom Hire	Cost Per Unit if Rented: $	Cost Per Unit if Rented: Unit	Cost Per Unit if Custom Hire: $	Cost Per Unit if Custom Hire: Unit	Ac./Hr.: Machine	Ac./Hr.: Labor	Fuel Consumption Per Machine Hour	Type, Cost, and Amount of Materials Used Along With Any General Comments
Spray Roundup	15-Oct	0.5	455HP tractor, sprayer	x tractor	sprayer $5/ac		$5				40	44	0.4 gal/ac	12 oz. Roundup
Spray Roundup	18-Apr	1	455HP tractor, sprayer	x tractor	sprayer $5/ac						40	44	0.4 gal/ac	32 oz. Roundup
Spray Roundup	3-Jun	1	455HP tractor, sprayer	x tractor	sprayer $5/ac						40	44	0.4gal/ac	32 oz. Roundup
Spray Roundup	24-Jul	1	455HP tractor, sprayer	x tractor	sprayer $5/ac						40	40	0.4gal/ac	45 oz. Roundup
Seed	15-Sep	1	455HP tractor, 35' no-till drill	x tractor							20	22	1 gal/ac	100# seed/ac plus 90-10-12 or 90-10-15 (N-P-S)
Spray weeds	8-Apr	1	455HP tractor, sprayer	x tractor	sprayer $5/ac						40	44	0.4gal/ac	$35/ac broadleaf and grass control herbicides (varies)
Harvest	30-Jul	1	combine	x							10	12	1.3 gal/ac	
Hauling 500 bu per load	Aug		tandem axle truck	x									4miles/gallon	10 miles roundtrip

Table 4.1. Sample schedule of operations for the longitudinal survey of growers

Type of Machine (include model & year)	Current Value	Years of Life	Annual Hours of Use	Salvage Value	Annual Repairs (Materials)	Annual Repairs (Labor Hours)
Crawler, Challenger 65	$20,000	10	500	$10,000	$1,000	24
Wheel tractor, JD 7520	$10,000	10	400	$5,000	$750	16
Plow, IH 800, 9 bottom	$4,000	10	200	$2,000	$300	8
Plow, IH 800, 9 bottom	$4,000	10	200	$2,000	$300	8
Cultivator, Hesston 36'	$4,000	10	100	$2,000	$300	8
Cultivator, Hesston 36'	$4,000	10	100	$4,000	$300	8
Harrow, springtooth 53'	$2,000	10	100	$2,000	$150	8
Disk, Miller 18'	$4,500	10	200	$2,000	$200	8
Drill, JD 8500	$11,500	10	200	$5,000	$500	16
Sprayer, McGregor 70'	$5,000	10	100	$2,500	$300	16
Combine, JD 9600	$52,000	10	200	$10,000	$1,000	24
Combine, Gleaner N7	$15,000	10	100	$5,000	$500	16
Semi, Peterbilt with trailer	$40,000	10	200	$10,000	$500	24

Table 4.2. Sample machinery complement for the longitudinal survey of growers

General Survey of PNW Wheat Producers

Thank you for taking time to assist with this longitudinal study of weather-related impacts on PNW wheat producers. We would like to record your observations as they relate to wheat production on your farm. We welcome your input as we begin to establish a baseline for wheat production practices in your area. Each year we will note any changes relative to previous years, from 2011 through 2015, in both this short questionnaire and two forms (schedule of operations and machinery list).
Important weather-related markers that we would like to track for spring and winter wheat include planting and harvest dates, emergence dates for spring and winter wheat, and pest-related activities (insect, weed, and disease infestations). This information will help guide research and extension programming for wheat producers in this important production region.

1. Please describe your typical cropping sequence, and percentage of each crop on your farm.
   Year 1:
   Crop 1: ____________%___ Crop 2:_____________%___ Crop 3: _____________%___
   Crop 4: ____________%___ Crop 5:_____________%___ Crop 6: _____________%___
   Year 2:
   Crop 1: ____________%___ Crop 2:_____________%___ Crop 3: _____________%___
   Crop 4: ____________%___ Crop 5:_____________%___ Crop 6: _____________%___
   Year 3:
   Crop 1: ____________%___ Crop 2:_____________%___ Crop 3: _____________%___
   Crop 4: ____________%___ Crop 5:_____________%___ Crop 6: _____________%___
   Year 4:
   Crop 1: ____________%___ Crop 2:_____________%___ Crop 3: _____________%___
   Crop 4: ____________%___ Crop 5:_____________%___ Crop 6: _____________%___ **Year 5:**
   Crop 1: ____________%___ Crop 2:_____________%___ Crop 3: _____________%___
   Crop 4: ____________%___ Crop 5:_____________%___ Crop 6: _____________%___ **Year 6:**
   Crop 1: ____________%___ Crop 2:_____________%___ Crop 3: _____________%___
   Crop 4: ____________%___ Crop 5:_____________%___ Crop 6: _____________%___

   Comments ____

2. Do you manage your fields differently based on landscape position (hillside, draw, north slope, south slope, bottomland), in terms of crop choice, rotation, residue management, etc.?

   YES NO

   If yes, please describe ____

   ____

3. The following questions refer to insect pests in your area.

a. Please indicate what pests you have observed in your winter wheat.

	Winter Wheat			
	Not observed	Observed but not a pest	A pest we are currently controlling.	A pest that we are not able to control.
Aphids				
Cereal leaf beetle				
Cutworm				
Hessian fly				
Wireworm				

b. Please indicate what pests you have observed in your spring wheat.

	Spring Wheat				
	Not observed	Observed but not a pest	A pest we are currently controlling.	A pest that we are not able to control.	N/A
Aphids					
Cereal leaf beetle					
Cutworm					
Hessian fly					
Wireworm					

c. Over the past 5 years, have you noticed any changes in pressure from any of these insects?

	Not observed	Large Decrease	Some Decrease	No Change	Some Increase	Large Increase	N/A
Aphids							
Cereal leaf beetle							
Cutworm							
Hessian fly							
Wireworm							

4. Fertilizer Practices:

   A. What sources of information do you use for determining fertilizer rates? Circle all that apply.
      a. price
      b. yield mapping
      c. historical yields
      d. nitrate soil testing
      e. organic matter soil testing
      f. plant tissue testing
      g. other ___________________________

   B. Do you apply different rates of fertilizer across fields of the same crop?
      YES NO

   C. Do you use any form of nitrification inhibitors or slow release fertilizers? If so, which products do you use?

   ____

5. Please indicate your level of involvement in the following programs.

	Never participated	Participated in the past but not currently	Currently participating	My farm is not eligible for this program
Conservation Reserve Program (CRP)				
Conservation Reserve Enhancement Program (CREP)				
Wetlands Reserve Program (WRP)				
Environmental Quality Incentive Program (EQIP)				
Conservation Stewardship Program (CSP or CStP)				
Soil & Water Conservation District Programs				
State Conservation Programs				
Conservation Compliance				

6. What type of internet access do you have on your farm?

   None   Dial-up   Broadband satellite   Broadband cable   Fiber optic

   Other______________________________

7. How often do you consult the internet for farm-related reasons, such as checking the weather or markets?
   a. Daily
   b. Weekly
   c. Monthly
   d. Never

8. Do you use a cell phone on your farm operation?   YES   NO

   If yes, approximately what percent of your farm-related calls are done on the cell phone? _________%

10. Can you access the internet with your cell phone?   Yes   No

11. What level of service do you use from your agricultural chemical suppliers?

    i. Full-service (chemical company supplies the field reps, delivers the chemicals, supplies applicators, and fills applicators)
    ii. Minimum service (you use chemical company's applicators but you must transport the chemicals)
    iii. No service
    iv. Other ____

12. Describe any changes in weather patterns you have observed in your area, and any impacts from these on your farming operation.

    ____

    ____

    ____

13. How often do you use your local Extension office for farm-related assistance or attend Extension related activities, such as field days or farm tours?

____FREQUENTLY (3 -4 TIMES PER YEAR OR MORE)

____OCCASIONALLY (ABOUT 1 -2 TIMES PER YEAR)

____RARELY (ONCE EVERY YEAR OR TWO)

____NEVER (I HAVE NEVER CONTACTED MY LOCAL EXTENSION OFFICE)

14. Do you consult Extension websites for ag-related information?

    ____YES

    ____NO

15. Please feel free to comment on farm-related information you currently use or would like to see on Extension websites.

    ____

    ____

    ____

16. What roles do you see for Extension in terms of dealing with any effects associated with changes in weather patterns?

    ____

    ____

    ____

17. What roles do you see for university research in terms of dealing with any effects associated with changes in weather patterns?

    ____

    ____

    ____

18. Do you have any other concerns or comments related to this project?

    ____

    ____

    ____

Thank you very much for your participation in this research project!

We very much appreciate your time and effort.

Technical Report

Milestone 5.1 *Baseline Sampling*

To establish baselines of key organisms affecting cereal cropping systems, sampling was undertaken at multiple sites throughout the region. Sampling intensity differed with organism type due to differences in biology and sampling methods (Figure 5.1). The samples were stratified, by AEZ and included samples taken on cooperator farms and at research stations within REACCH (Table 5.1). Sampling at research stations was designed to establish baselines anticipating installation of alternative cropping systems at these sites in project years 2 and beyond. Sampling will continue to provide comparisons

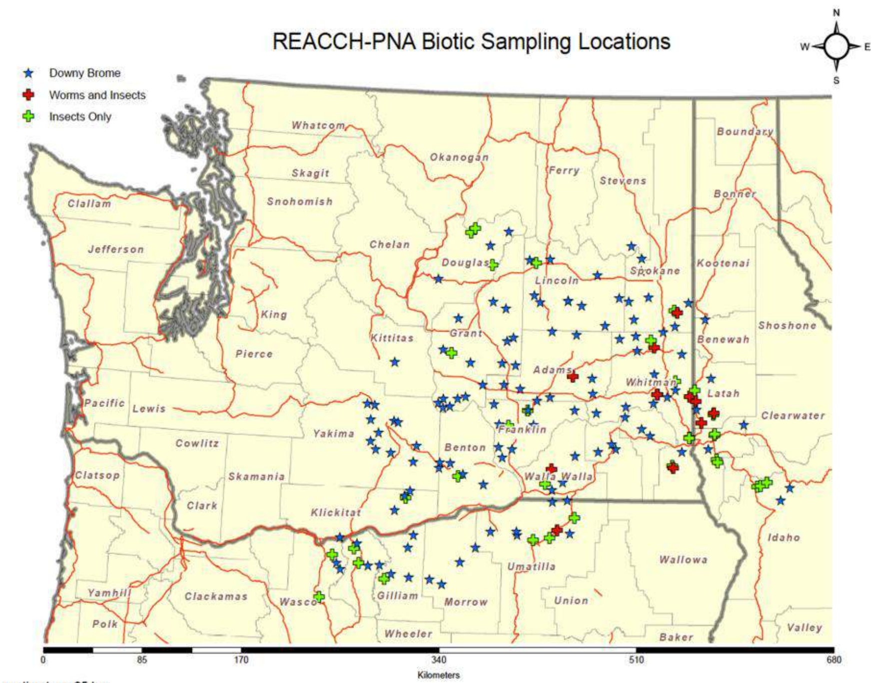

Figure. 5.1. Locations at which samples were taken to establish baselines across the region. Insects were sampled by sweep-netting and dissecting plants and visual assessments of damage. Earthworms were sampled by digging pits. Downy brome was sampled by assessing seed banks from soil samples.

Table 5.1. Numbers of sites sampled for earthworms and insects by AEZ in 2011

	Agroclimatic Zone (AEZ)*						
	1	2	3	4	5	6	Total
Earthworms							
Cooperator fields sampled	5	2	2	5	5	4	23
Research stations sampled	1	0	0	2	2	0	5
Aphids, Hessian fly, Cereal Leaf Beetle							
Cooperator fields sampled	10	6	5	8	8	7	44
Research stations sampled	2	0	0	2	2	0	6

*****AEZ as determined in Douglas et al. 1990 (see AEZ p. TR 10.1-TR 10.2 for additional explanation**)**

Earthworms

Research Question: How are earthworms distributed across the AEZs of the study region?
Earthworms were sampled in selected cooperator fields and research stations across the study area. These preliminary data showed that earthworm density is impacted by both soil environmental conditions as well as management (Table 5.2). While preliminary, the 2011 earthworm density estimates reveal interesting trends that we will further investigate in 2012. Earthworm density appears to be greater in the higher rainfall zones (1 and 2). Within zone 6 (lowest rainfall) no earthworms were found. The transition zones between 5 and 6, therefore, will be more intensively sampled to quantify the precise environmental conditions where earthworms are not expected to survive. It is interesting that earthworms were absent from the irrigated fields in zone 6. The lack of earthworms despite the correction of a limiting factor (water) suggests that another factor is limiting in zone 6, or that there is not a viable source of earthworms to colonize the irrigated sampling sites. Results were very different in zone 5, where irrigated field sampled had extremely high earthworm density. Finally, there appears to be a greater difference between density values in conventional tillage (CT) and ConsT (Conservation tillage) fields in the drier zones (4 and 5) as compared to within zone 1. The positive impact of ConsT practices on stored soil moisture may give the worms in the drier climatic zones a greater advantage as compared to within the wetter zone.

Table 5.2. Earthworm densities by Agroecological Zone (AEZ)* and tillage type, 2011

AEZ	Tillage Type**	Density (individuals/m^2)
1	CT	112
1	ConsT	131
2	ConsT	403
3	ConsT	81
4	CT	0
4	ConsT	41
5	CT	3
5	ConsT	141
5	ConsT Irrigated	1498
6	CT	0
6	CT Irrigated	0
6	ConsT	0

** AEZ as determined in Douglas et al. 1990*
*** CT = conventional tillage, ConsT = conservation tillage (minimum tillage to direct seeding, practices vary)*

Insects

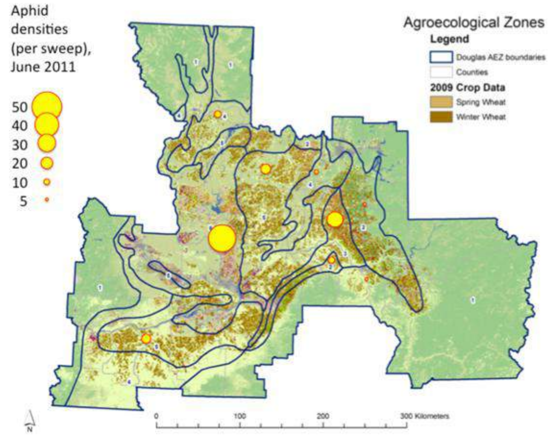

Figure 5.2. Aphid densities per sweep by AEZ in 2011

Research question: What is the current abundance and distribution of key insect pests of wheat in the region?

Approaches and methods: Insects were sampled using transects and sweep-netting for aphids, transects and visual counts for CLB, and by digging out and dissecting seedlings for Hessian fly. Hessian fly was absent from the samples, which confirms perceived trends in reduction of the density of this pest across the region, possibly because of the successful, consistent deployment of resistance genes in newer, widely grown varieties. CLB is currently suppressed in the region due to successful biological control. We only detected crop injury in two sites. Aphids were present in most sites. Average densities (insects per sweep) have been averaged by AEZ for plotting (Figure 5.2). The figures are total aphids and have not been separated by species for this plot.

Aphids were also sampled using pan traps at the experiment stations in the project during June and from Sept. – Nov. Aphids were collected from the traps but processing is incomplete at this time.

Weeds

Research objectives
1. Establish a collection of downy brome (*Bromus techtorum*) biotypes to study genotypic and phenotypic variation across climatic zones of eastern Washington, north central Oregon, and western Idaho.
2. Study how conservation tillage and crop rotation practices affect weed species composition and distribution across the landscape.

Approaches and methods: Downy brome biotype collection
1. Downy brome biotype sampling for 2011 was completed during June and July. 65 locations were sampled from across the region in 2011.
2. These biotypes, along with 96 collected in 2010, are being propagated under common garden conditions to remove any phenotypic variation due to the environment they were collected in or maternal influences. Currently over 130 geographically distinct biotypes are being propagated. Once these biotypes have been propagated, variations in phenotype and genotype among biotypes will be compared to variations in climatic zones in the region.

3. Long-term climate change models will then be utilized to predict how distribution of downy brome biotypes will be impacted by climate change and ultimately how this distribution will impact regional grain production.
4. An established model of downy brome seed production based on climatic conditions (Ball et al. 2004) is being paired with long-term climate change models to predict the effect of climate change on downy brome seed production. The results of this pairing of models will provide long-term predictions of when is the optimal time to control downy brome in grain production systems.

Approaches and methods: Weed seed bank
1. Soil cores were taken in 1999, 2007and 2010 from 369 geo-referenced locations across the Cook Agronomy Farm (CAF) to analyze the weed seed bank.
2. Samples were germinated and species emergence was recorded weekly over the course of the studies.

Results: Weed seed bank
Terrain attributes and cropping systems of the CAF were assessed as predictors of viable weed seed levels within the seed bank. The 1999 and 2007 data were analyzed using Poisson generalized linear model (GLM) and zero-inflated Poisson regression model. The 2010 data will be analyzed using the same methods. Analyzed weed species were mayweed chamomile (*Anthemis cotula)*, wild oat (*Avena fatua*), common lambsquarters (*Chenopodium album*), and Italian ryegrass (*Lolium perenne*), which are of particular concern in the region's cereal production systems. Terrain attributes and cropping systems do effect the viable weed species distribution within the weed seed bank.

Pathogens

Research objectives
1. Establish a baseline of soil-borne pathogen (fungi and nematodes) populations that affect dry-land wheat across the AEZ and climatic zones of eastern Washington. **2**. Establish a baseline of pathogen populations at the experimental farm sites prior to application of cropping system treatments.

Biogeographical baseline
1. Completed 2nd year of nematode sampling across eastern Washington- 90 sites in 2010 and 84 sites in 2011. Counts of root lesion (*Pratylenchus* spp.) and cyst nematode (*Heterodera avenae*) was made from soil samples taken in May and June. We have been analyzing the root lesion nematode data by correlating with climatic data sets for temperature and moisture. One data set is from 1961-1990, from the USDA Forest Service, at a 4-km scale model. The other data set is from John Abatzoglou, from 1979-2011.
2. Analyses are being completed for a two- year survey in 2008 and 2009 of *Fusarium culmorum* and *pseudograminearum*, from eastern Washington and NE Oregon, using factor analyses and comparing with climatic data.
3. We have a two-year collection of *Rhizoctonia* spp. from eastern Washington, taken in 2009 and 2010. These will be identified by sequencing, to provide a species profile.

4. Completed temporal sampling for *Rhizoctonia* at three locations- Lind, Ritzville, and Starbuck, and *Pythium* at three locations- Farmington, Garfield, and Pullman. Samples were taken monthly, and will be analyzed for *Rhizoctonia* and *Pythium.* The idea is to see how these populations vary over the season, in response to soil and climatic variables. Populations will be quantified with real-time PCR.

Experimental farms (see Appendix G for more information)

1. We have conducted monthly sampling at Lind, WA from Mar.-Nov. 2011 on irrigated vs. non-irrigated plots. There are 4 replicated plots of each treatment. We sampled soil for DNA extraction for *Rhizoctonia* and *Pythium.* Real-time PCR work is not complete.
2. We completed a second year of grid sampling for *Pratylenchus* at the CAF on Field A, 120 samples. Results will be analyzed with CART (Classification and Regression Tree) analysis. Baseline data for other experimental farms will be collected in spring 2012.

Results: Nematode survey

Both data survey sets (Figure 5.3-5.4 and 5.5-5.6) show strong positive correlations with monthly precipitation during the growing season (Figure 5.7), and a weaker negative correlation with maximum temperatures during the growing season. In 2011, populations only correlated with mean temperatures in Jan-March. We also used the AEZ model from the AEZ Team (see AEZ pages TR 10.1-TR 10.6), with cropping intensity data at a scale of 12 km. In 2010, there was a positive correlation with intensity of the cropping system- i.e. more nematodes in annual vs. wheat-fallow systems (Figure 5.8). However, because nematode populations in the upper soil profile are highly influenced by both temperature and moisture in the soil, time of sampling is a major constraint for interpreting patterns across a wide geographical area. In addition, the environmental conditions were quite different in the two years. Spring 2011 was very wet and cool, and moisture may not have been limiting in May in the low-rainfall areas, hence the lack of correlations.

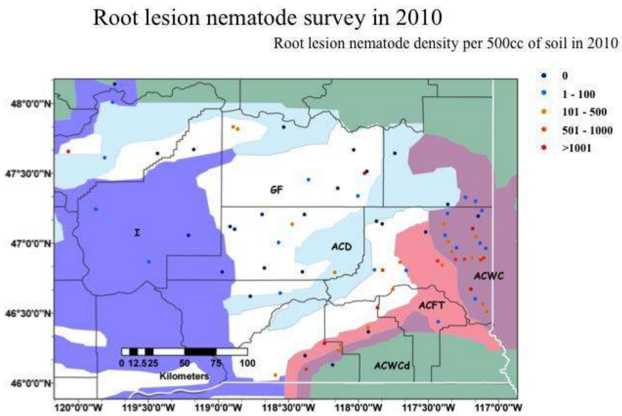

Figure 5.3. Population of root lesion nematodes in different Agroclimatic zones of eastern Washington developed by Douglas et al. (1992) on the basis of precipitation, growing degree days, and soil-type. Agroclimatic zones are represented by color polygons: I- irrigated, GF- Grain-Fallow, ACD- Annual Crop-Dry, ACFT- Annual Crop-Fallow-Transition, ACWC- Annual Crop-Wet-Cool, ACWCd- Annual Crop-Wet-Cold.

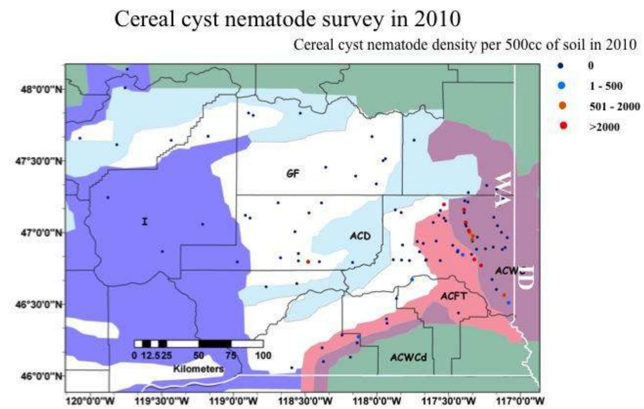

Figure 5.4. Population of cereal cyst nematode in different Agroclimatic zones of eastern Washington developed by Douglas et al. (1992) on the basis of precipitation, growing degree days, and soil-type. Agroclimatic zones are represented by color polygons: I- irrigated, GF- Grain-Fallow, ACD- Annual Crop-Dry, ACFT- Annual Crop-Fallow-Transition, ACWC- Annual Crop-Wet-Cool, ACWCd- Annual Crop-Wet-Cold.

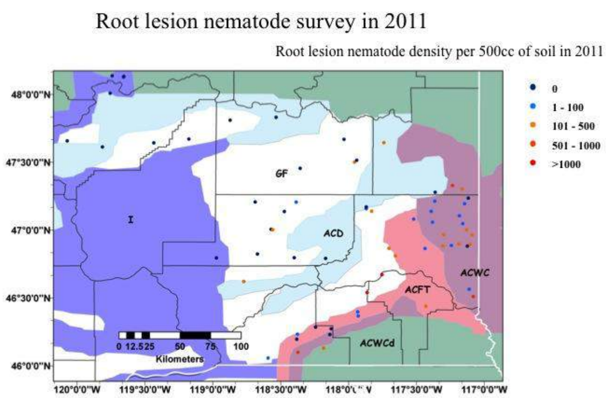

Figure 5.5. Population of root lesion nematodes in different Agroclimatic zones of eastern Washington developed by Douglas et al. (1992) on the basis of precipitation, growing degree days, and soil-type. Agroclimatic zones are represented by color polygons: I- irrigated, GF- Grain-Fallow, ACD- Annual Crop-Dry, ACFT- Annual Crop-Fallow-Transition, ACWC- Annual Crop-Wet-Cool, ACWCd- Annual Crop-Wet-Cold.

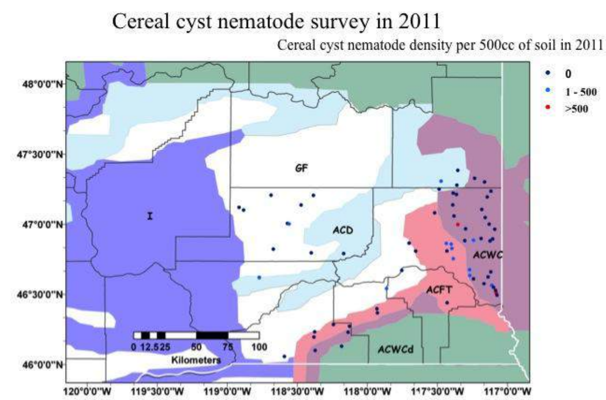

Figure 5.6. Population of cereal cyst nematode in different Agrocliamtic zones of eastern Washington developed by Douglas et al. (1992) on the basis of precipitation, growing degree days, and soil-type. Agroclimatic zones are represented by color polygons: I- irrigated, GF- Grain-Fallow, ACD- Annual Crop-Dry, ACFT- Annual Crop-Fallow-Transition, ACWC- Annual Crop-Wet-Cool, ACWCd- Annual Crop-Wet-Cold.

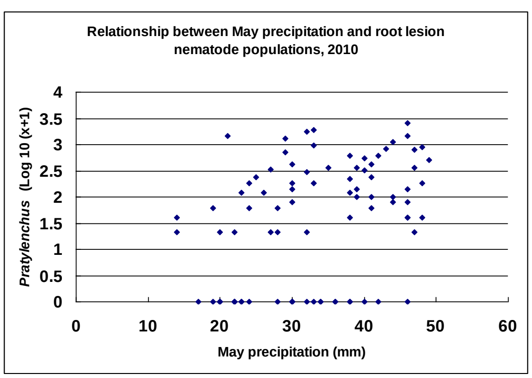

Figure 5.7. Relationship between *Pratylenchus* populations in 2010 and total precipitation in May. Based on 1979-2011 data, model derived by John Abatzoglou, Univ. of Idaho. R=0.293, P=0.005

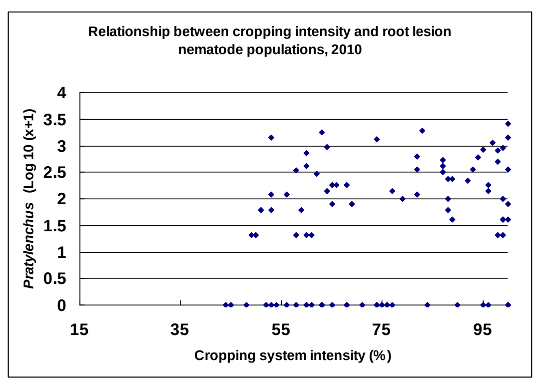

Figure 5.8. Relationship between *Pratylenchus* populations in 2010 and cropping system intensity. Based on AEZs derived from NASS cropping system layer, 2007 (see AEZ, page xx).

Milestone 5.2 *Models of Projected Potential Pest Severity*

Cereal Leaf Beetle Model

In the absence of natural enemies CLB is constrained by climatic variables. Olfert et al. (2004) used a climate-based simplified dynamic model (CLIMEX™) to map the relative suitability "Ecoclimatic Index" (EI) for CLB in North America. This index is greatest in the Mid-Atlantic States and parts of the Midwest, and is substantial in most of the Northwest (PNW), consistent with CLB distribution. Our model follows the logic of CLIMEX but uses the available downscaled projections for the region's climate to generate a suitability index (SI) with a potential annual maximum of 100, estimated each year for the historical (1971-2000) and projected (2046-2066) periods. The index scales from 0 to 100. Climate variables are daily mean, min and max temperatures, precipitation, evapotranspiration and day length, gridded at 8km. Responses were relative growth as determined by temperature and soil moisture, limited by a diapause period triggered by temperature, day length (Table 5.1). Stress indices for cold, heat and soil moisture were also incorporated.

Table 1. Parameters for calculating CLB Suitability Indices

Temperature

Limiting low average weekly temperature	6.5 °C
Lower optimal average weekly minimum temperature	7.0 °C
Upper optimal average weekly maximum temperature	26.0 °C
Limiting high average weekly maximum temperature	35.0 °C

Soil Moisture

Limiting low soil moisture	0.02
Lower optimal soil moisture	0.10
Upper optimal soil moisture	1.00 (saturated)
Limiting high soil moisture	1.50

Diapause

Diapause induction day length	14 h
Diapause induction temperature (average weekly minimum)	11.0 °C
Diapause termination temperature (average weekly minimum)	6.0 °C
Diapause development days	120

An example of output for the model is provided in Figure 5.9.

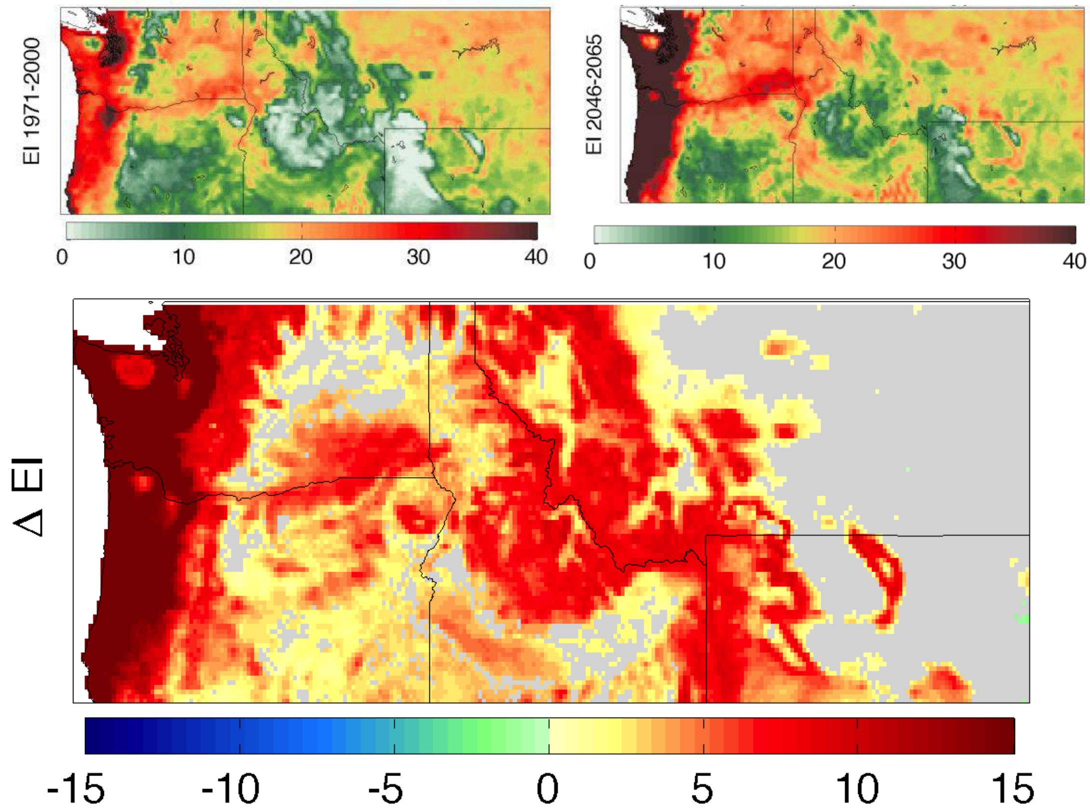

Figure 5.9. Top left: Map of current CLB SI values for WA, OR, ID and MT at an 8 km resolution based on average weekly temperature and ppt. from historical data (1979-2010). Top right: Map of current CLB SI values for WA, OR, ID and MT at an 8 km resolution based on downscaled climate models. Bottom: Change (difference between current indices and projections for decades spanning mid century).

The CLB index indicates the relative potential for CLB pressure based on weather related factors alone (precipitation, soil moisture, air temperature). Other factors, including biological control, management practices and shifts in vegetation have not been incorporated. As the model is developed, these factors can be incorporated.

Another modeling approach projects phenology based on degree day accumulations. These are available for the CLB. Examples in Fig. 5.10 show that the dates of two key phenological events (diapause termination and egg hatch) occur heterogeneously across the landscape because of the variable climates. By midcentury the dates of these events tend to shift earlier in the year, but the shifts are neglible in some locations and strong in other.

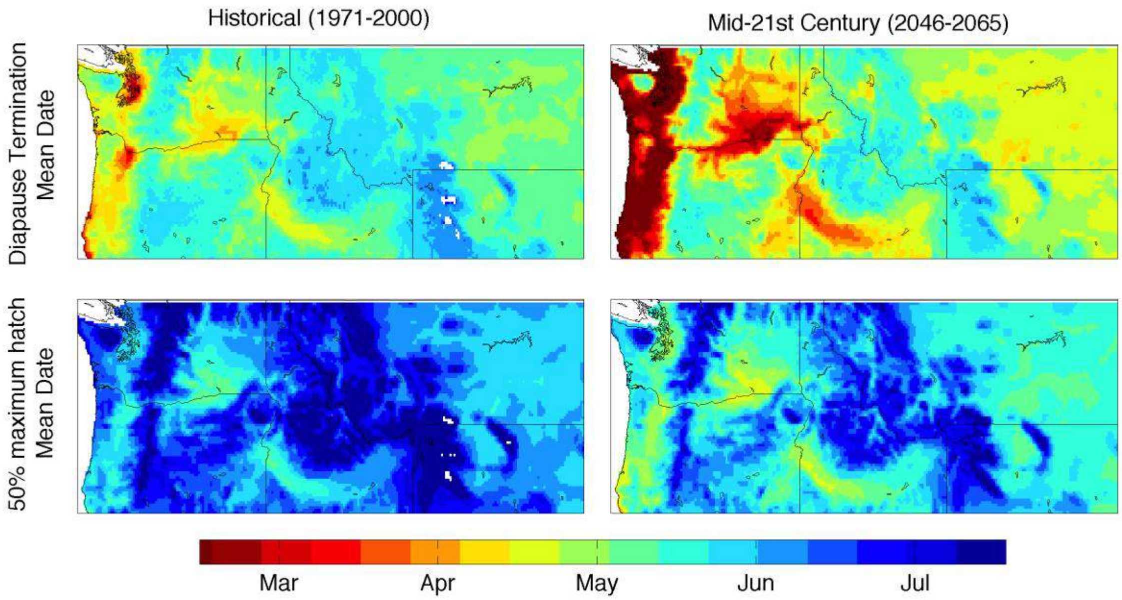

Fig. 5.10. Maps showing projected shifts in two components of CLB phenology based on historical and projected climate data. The upper panels illustrate date of termination of the winter diapause and the lower panels illustrate date of 50% egg hatch.

The same type of models can be constructed for other organisms for parameters like those available for CLB can be obtained from the literature or estimated from greenhouse and growth chamber studies. We will be constructing index and phenology models for weeds, pathogens and insects following similar approaches.

Technical Report

Two surveys (one for K-6 and one for 7-12th grade teachers) were developed collaboratively by REACCH participating faculty. The surveys were designed to determine: **(1)** How frequently do K-12 teachers incorporate agricultural and climate change topics into their curriculums; **(2)** What are elementary teachers' perceptions of agriculture and climate change; **(3)** What agricultural topics are teachers most comfortable integrating into their curriculums; **(4)** What barriers do teachers identify to incorporating agricultural and climate change topics?

Due to the amount of data collected, we focused on elementary teachers in this summary. Results from high school teachers were similar.

Methods

All public schools within the study area were identified (Table 6.1). The email addresses from teachers in all 312 public schools within the study region were obtained from the school websites or through direct contact with the school administration. A total of 4,221 K-6 teachers were identified for inclusion in the survey. The majority of schools and teachers were from Washington State.

Table 6.1. Breakdown of the number of teachers surveyed in each state.

State	Schools	Teachers Identified
Idaho	40	404
Oregon	36	336
Washington	236	3,481
Totals	312	4,169*

14 declined to complete the survey, 34 contacts bounced back, and 4 only partially responded

The survey instrument included demographic questions and 6-point Likert scale questions to describe teacher views of agriculture and climate change and the integration of these topics into their curriculum. Other questions were designed to determine their comfort with agriculture and climate change topics and their perceived barriers to incorporation of these topics. Face and content validity were established by a panel of experts representing several departments in the interdisciplinary work group of the project. Institutional Review Board approval was granted prior to the beginning of data collection. Because of the large study area, the descriptive nature of the instrument, and the inability to select a representative pilot group, the researchers decided *a priori* to conduct a post-hoc reliability analysis of the instrument. The Cronbach's alpha reliability of the instrument was .94.

Data were collected in the fall of 2010 utilizing Dillman's (2007) tailored design method. Teachers were sent a pre-notice email notifying them that they had been selected to participate in a research study and informing them of the purposes of the study. One week later, the survey was sent via SurveyMonkey®. The initial response rate was 6% (252). A reminder email with the survey was sent out one week later, and for three subsequent weeks, bringing the total response rate to 17.46% (*n* = 728). Because of the relatively low response rate, and the nonprobability sampling method, the results should be interpreted with caution, and should not be generalized beyond the respondents. Shih and Fan (2008) found that web-based surveys can have lower response rates than mailed surveys; a difference of 10% or more was not uncommon. Additionally, Shih and Fan (2008) indicated that response rates vary based on population and teachers show a preference for mailed surveys. Nonetheless, the large size of the target population and the cost of mailed surveys precluded their use in this study. Non-response error was controlled by comparing late respondents to on-time respondents. The researchers determined *a priori* that on-time respondents were individuals who responded to the first two contacts. The data from the two groups were compared using a t-test for independent samples. No significant differences were found between early and late respondents, therefore the data were combined. The data were analyzed using SPSS v. 19.

Findings

Teachers in this study averaged 43 years of age and had been teaching for an average of 18 years. The respondents were 81% female. Teachers were asked what size community they were raised in: 26 % reported Urban, 31% Suburban, 24% Rural (community of ≤10,000), and 17 % reported they were Rural (raised on farm or ranch). Grade level is reported in Table 6.2.

Table 6.2. Grade Levels of teachers responding to the survey

	n	%
Kindergarten	83	12.1
1st Grade	74	10.8
2nd Grade	92	13.4
3nd Grade	101	14.7
4th Grade	98	14.3
5th Grade	99	14.4
6th Grade	53	7.7
Combined Grades	87	12.7

Teachers were asked how frequently they integrated agricultural topics into their curriculums (Table 6.3). The largest response category was 2-3 times per year (26.7 %). 5.3 % of teachers reported that they never integrate agricultural topics.

Table 6.3. Frequency of integration of agricultural topics

	f	%
Daily	26	3.6
2-3 times per week	110	15.2
Once per week	114	15.8
2-3 times per month	137	19.0
Once per month	104	14.4
2-3 times per year	193	26.7
Never	38	5.3

Teachers' perceptions of agriculture were assessed by asking their level of agreement with a series of statements about what agriculture includes (Table 6.4). Overall, teachers agreed that the topics included were a part of agriculture. Plant Science, Soil Science and Animal Science had the highest levels of agreement while Social Sciences, Floriculture, and Fiber Processing had the lowest levels of agreement. Over 80 % of respondents *Strongly Agreed* that Plant Science and Soil Sciences were included in agriculture, while only 32.2 % *Strongly Agreed* that Social Sciences are a part of agriculture. The majority of teachers (62.8%) strongly agreed that climate change issues were a part of agriculture.

Table 6.4. Teachers' perceptions of topics included within agriculture

Agriculture Includes. . .	1		2		3		4		5		6	
	f	*%*	*f*	*%*	*f*	*%*	*F*	*%*	*f*	*%*	*f*	*%*
Plant Science	18	2.5	3	0.4	3	0.4	22	3.1	94	13.1	580	80.6
Soil Science	21	3.0	2	0.3	3	0.4	23	3.3	92	13.0	564	80.0
Animal Science	21	2.9	9	1.2	8	1.1	34	4.7	118	16.4	537	73.6
Ecology	20	2.8	3	0.4	7	1.0	38	5.3	149	20.8	500	69.7
Environmental Science	24	3.4	3	0.4	5	0.7	46	6.4	122	17.0	516	72.1
Horticulture	21	2.9	6	0.8	7	1.0	43	6.0	124	17.4	511	71.8
Rangeland Science	21	3.0	5	0.7	11	1.5	42	5.9	130	18.3	502	70.6
Natural Resource Management	19	2.7	9	1.3	11	1.5	51	7.2	144	20.2	479	67.2
Biology	22	3.1	9	1.2	12	1.7	63	8.7	164	22.7	451	62.6
Wildlife Mgt. & Biological Cons.	18	2.6	8	1.1	17	2.4	59	8.4	175	24.9	426	60.6
Food Processing	23	3.2	7	1.0	22	3.1	55	7.7	165	23.0	444	62.0
Climate Change Issues	30	4.2	10	1.4	16	2.2	50	7.0	160	22.4	449	62.8
Human Nutrition	16	2.3	11	1.5	17	2.4	80	11.3	161	22.6	426	59.9
Forestry	18	2.5	14	2.0	25	3.5	84	11.8	162	22.8	409	57.4
Biochemistry	22	3.1	12	1.7	21	3.0	107	15.1	188	26.5	360	50.7
Human Health	18	2.5	18	2.5	27	3.8	106	14.8	188	26.3	359	50.1
Marketing	25	3.5	19	2.7	36	5.1	99	13.9	206	28.9	327	45.9
Fiber Processing	21	3.0	17	2.5	38	5.5	133	19.3	196	28.4	285	41.3
Floriculture	21	3.1	11	1.6	16	2.4	91	13.6	165	24.7	364	54.5
Social Sciences	16	2.3	31	4.4	72	10.2	145	20.5	215	30.4	228	32.2

Note: 1= Strongly Disagree, 2 = Moderately Disagree, 3 = Mildly Disagree, 4 = Mildly Agree, 5 = Moderately Agree, 6 = Strongly Agree

Teachers reported their comfort levels of integration of various agricultural topics into their curriculums (Table 6.5). Teachers were the most comfortable with Human Nutrition, over 50 % of teachers indicated they *Strongly Agreed* that they were comfortable integrating this topic. Teachers agreed they were comfortable with Plant Science, Natural Resource Management, and Food Systems. The items with the least agreement were Floriculture, Fiber Processing and Biochemistry. Over 60% of teachers disagreed that they were comfortable integrating Biochemistry in their classes, and 61% disagreed that they were comfortable integrating Fiber Processing into their curriculums. Overall, 76%

of teachers surveyed indicated that they were comfortable integrating climate change topics. However, only 23% indicated that they strongly agreed with the statement.

Table 6.5. Teachers' comfort with integration of agricultural topics

I am comfortable integrating _____ into my curriculum	1		2		3		4		5		6	
	f	*%*	*f*	*%*	*f*	*%*	*f*	*%*	*f*	*%*	*f*	*%*
Human Nutrition	14	2.0	10	1.4	24	3.5	88	12.7	205	29.8	354	50.9
Plant Science	24	3.4	24	3.4	41	5.8	112	15.9	207	29.4	295	42.0
Natural Resource Management	27	3.9	15	2.2	35	5.1	141	20.3	208	30.0	267	38.5
Food Systems	35	5.0	33	4.7	52	7.5	169	24.3	193	27.8	213	30.6
Animal Science	39	5.6	36	5.2	65	9.4	165	23.8	176	25.4	213	30.7
Forestry	38	5.6	37	5.4	75	11.0	216	31.7	163	23.9	152	22.3
Climate Change Issues	49	7.1	52	7.5	64	9.2	168	24.3	198	28.6	161	23.3
Soil Science	56	8.2	40	5.9	99	14.6	175	25.8	160	23.6	149	21.9
Horticulture	50	7.4	53	7.9	96	14.3	198	29.5	159	23.7	116	17.3
Food Processing	53	7.8	59	8.7	99	14.6	197	29.0	155	22.8	117	17.2
Wildlife Mgt. & Biological Cons.	63	9.4	51	7.6	110	16.3	183	27.2	158	23.5	108	16.0
Marketing	76	11.2	71	10.5	146	21.6	193	28.6	132	19.5	58	8.6
Rangeland Science	84	12.6	68	10.2	138	20.7	207	31.0	115	17.2	55	8.2
Floriculture	103	16.2	81	12.4	137	20.9	175	26.7	93	14.2	63	9.6
Fiber Processing	138	2.08	119	17.9	153	23.0	143	21.5	70	10.5	41	6.2
Biochemistry	144	21.8	115	17.4	138	20.9	164	24.8	67	10.1	33	5.0

Note: 1= Strongly Disagree, 2 = Moderately Disagree, 3 = Mildly Disagree, 4 = Mildly Agree, 5 = Moderately Agree, 6 = Strongly Agree

Teachers were asked their level of agreement with barriers to incorporation of agricultural topics (Table 6.6). Over 75% of teachers *Strongly Agreed* with the statement that a barrier was the time available in the curriculum, while 67.5% *Strongly Agreed* with the statement related to time to prepare integrated lessons. Most teachers disagreed with the statement related to visible personal benefits (63.4 %). Teachers also disagreed (54.5 %) that a barrier they faced was the visible benefit to their students, however, 9.2 % *Strongly Agreed* with the statement.

Table 6.6. Teachers' perceived barriers to integration of agricultural topics

Barriers I face when attempting to integrate agriculture are . . .	1		2		3		4		5		6	
	f	*%*	*f*	*%*	*f*	*%*	*f*	*%*	*f*	*%*	*f*	*%*
Time available in the curriculum	10	1.4	8	1.1	10	1.4	31	4.4	109	15.3	544	76.4
Time to prepare integrated lessons	13	1.8	13	1.8	16	2.3	48	6.8	140	19.8	477	67.5
Available curricula	16	2.3	16	2.3	30	4.3	121	17.2	217	30.9	303	43.1
Funding	22	3.2	27	4.0	61	9.0	125	18.4	174	25.6	271	39.9
Comfort with subject matter	39	5.6	51	7.4	52	7.5	157	22.7	222	32.1	171	24.7
Support from the Administration	77	11.3	74	10.9	135	19.9	116	17.1	140	20.6	138	20.3
Support from colleagues	95	14.1	70	10.4	136	20.1	140	20.7	144	21.3	91	13.5
Visible benefits to students	136	19.9	101	14.7	136	19.9	116	16.9	133	19.4	63	9.2
Visible personal benefits	161	24.4	111	16.8	146	22.2	109	16.5	87	13.2	45	6.8

Note: 1= Strongly Disagree, 2 = Moderately Disagree, 3 = Mildly Disagree, 4 = Mildly Agree, 5 = Moderately Agree, 6 = Strongly Agree

Teachers were asked their level of agreement with a series of statements related to the integration of agriculture into their curriculum (Table 6.7). Teachers agreed (95 %) with the statement that "Basic knowledge of agriculture is important in making socially responsible and healthy decisions on a daily basis." With regards to the ability to integrate agriculture into elementary curriculums, 20 % of teachers disagreed that "Elementary teachers are able to integrate agriculture into the curriculum." Teachers agreed that agriculture should be incorporated at all grade levels.

Table 6.7. Teachers' perceptions of integration of agriculture in general

Item	1		2		3		4		5		6	
	f	*%*	*f*	*%*	*f*	*%*	*f*	*%*	*f*	*%*	*f*	*%*
Integration of agricultural topics would enhance my curriculum	10	1.4	21	3.0	43	6.2	245	35.1	232	33.2	147	21.1
Elementary teachers are able to integrate agriculture into the curriculum	25	3.6	53	7.6	67	9.6	240	34.3	174	24.9	141	20.1
Basic knowledge of agriculture is important in making socially responsible and healthy decisions on a daily basis	2	0.3	8	1.1	24	3.4	149	21.2	231	32.9	288	41.0
Agriculture should be integrated into the curriculum at the elementary level	14	2.0	23	3.3	59	8.5	221	31.7	193	27.7	187	26.8
Agriculture should be integrated into the curriculum at the junior high school level	2	0.3	9	1.3	36	5.2	123	17.7	266	38.4	257	37.1
Agriculture should be integrated into the curriculum at the high school level	2	0.3	4	0.6	17	2.5	95	13.7	198	28.7	375	54.3

Note: 1= Strongly Disagree, 2 = Moderately Disagree, 3 = Mildly Disagree, 4 = Mildly Agree, 5 = Moderately Agree, 6 = Strongly Agree

Teachers were asked at what grade levels instruction in agriculture occurred in their school district and where it should occur (Table 6.8). Teachers indicated that the greatest amount of instruction in agriculture in their school district occurred at the 9-12 level (56 %), while the least amount occurred at the 7-8 level (30 %). Teachers also reported where they thought instruction in agriculture should occur. Most teachers indicated that instruction in agriculture should take place at all grade levels, with 67.4 % of teachers reporting that instruction should take place at the 9-12 level.

Table 6.8. Where does/should agricultural instruction take place?

	K-3		4-6		7-8		9-12	
	f	%	*f*	%	*f*	%	*f*	%
Where DOES Instruction in agriculture take place in your school district	221	30.8	253	35.3	219	30.5	408	56.9
Where SHOULD Instruction in agriculture take place in your school district	394	55.0	473	66.0	481	67.1	491	67.4

Implications and Recommendations

The first research question was to identify how frequently teachers incorporate agricultural topics into their curriculums. The majority of respondents reported they only incorporate agricultural topics two to three times per month or less. A small percentage reported that they never incorporate agriculture into their curricula. This finding contrasts with recommendations by the Natural Resource Council (NRC), 1988 and 2009 that all students have some instruction in agriculture.

The second research question was to describe elementary teachers' perceptions of agriculture. Overall, teachers agreed that the specified subject areas were included in agriculture. Respondents identified Plant Science, Soil Science, and Animal Science as most representative of agriculture whereas Social Sciences, Floriculture, and Fiber Processing were least identified with agriculture. However, it is concerning that some teachers, albeit a small percentage, disagreed that some items were a part of agriculture. This finding indicates a continued lack of agricultural literacy among some elementary teachers. If teachers do not consider a topic as a part of agriculture, they may place a low value on it and will therefore not incorporate it into their curriculum (Eccles & Wigfield, 2002; Malecki, 2004). Over 60% of teachers strongly agreed and over 90% agreed that climate change is a part of agriculture.

Teachers were asked their levels of comfort with various agriculture topics. Teachers reported overall comfort with most items. They were most comfortable integrating Human Nutrition, Plant Science and Natural Resource Management and the least comfortable with Biochemistry and Fiber Processing. It appears that teachers in this study were fairly comfortable with most topics. Given the relatively high levels of comfort with these subject areas, it is unlikely that the reason behind low levels of incorporation is teachers' lack of familiarity with agriculture. It is interesting to compare the responses for topics included in agriculture with the comfort level of incorporating that topic. For example, 50% of teachers agreed that biochemistry is a part of agriculture, yet only 5% strongly agreed that they were comfortable integrating it into their lessons. For climate change, while over 60% of teachers thought that it is a part of agriculture, only 23% strongly agreed that they were comfortable integrating it into their curriculums (Figure 6.1).

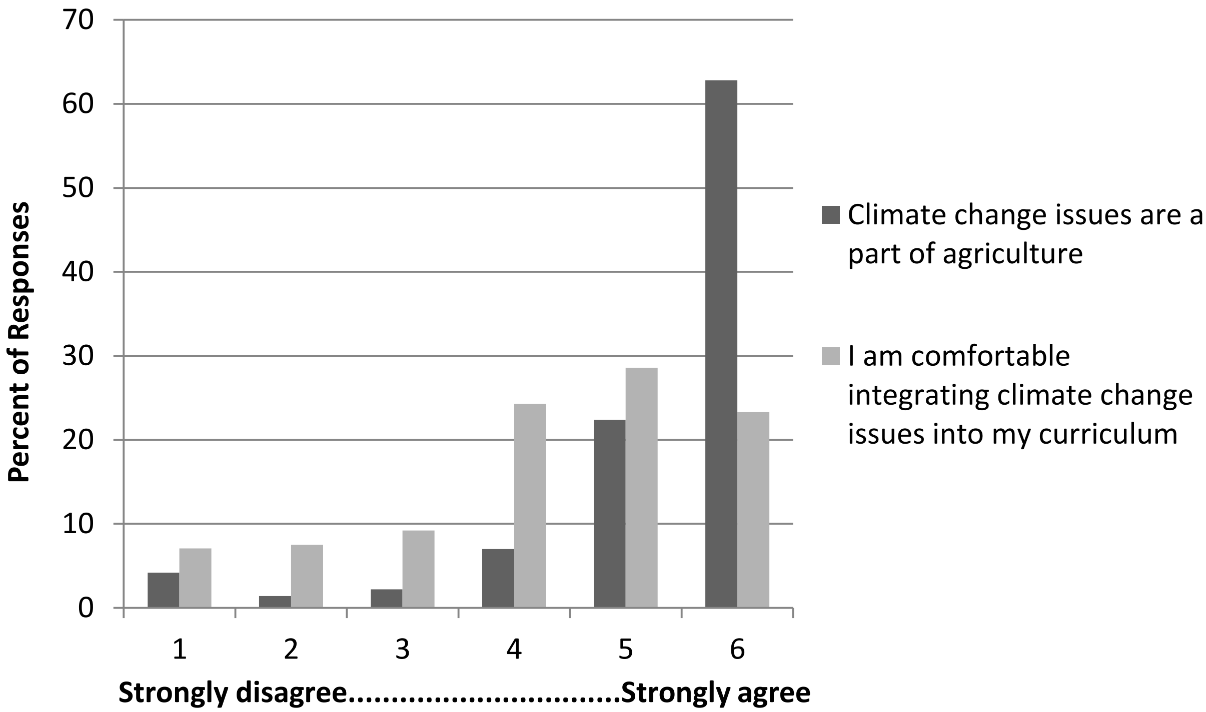

Figure 6.1. Discrepancy between the percentage of teachers who agree that climate change is a part of agriculture and the percentage who strongly agree that they are comfortable integrating it into their curriculums.

The fourth research question was to identify barriers teachers face in the incorporation of agriculture topics. Teachers reported that time available in the curriculum and time to prepare lessons as the greatest barriers to integration. This finding supports the conclusions of prior researchers (Knobloch & Ball, 2003). The lack of available curricula was also a limiting factor in integration for these teachers. Teachers did not agree that a lack of visible benefit to students or personal benefits was a barrier to integration. Additionally, they agreed that integration enhances their curriculum and that basic knowledge of agriculture is important. These findings indicate that teachers value agriculture; therefore it is unlikely that the lack of integration is due to their perceptions of the importance of agriculture.

Teachers reported where agricultural instruction occurs in their school district and where it should occur. Most teachers reported that instruction should take place at all levels, with the highest agreement at the 9-12th grade level. However, the percentages of teachers who report that instruction does occur at was notably lower. The discrepancy between where teachers think instruction should occur and where it does occur is problematic. Teachers at different grade levels have different beliefs as to what is being taught at various levels.

Recommendations

- Low-cost curricula that include agricultural topics should be provided to teachers. Based on teachers indicating that time is the most important barrier, this curriculum should be easy to incorporate, should meet content standards, and have supplemental materials to increase teachers' knowledge of the subject matter.

- In-service and professional development experiences should be provided to elementary teachers to promote the integration of agricultural topics. Topics that teachers strongly associate with agriculture (plant and soil science for example) but don't feel comfortable with may serve as the most beneficial areas to focus on in curriculum development. Climate change issues (Figure 1) fall into this category.
- University educators should provide resources to enhance communication between teachers in different grade levels to ensure that systemic education in agriculture is occurring throughout each school district.

- Agriculture teachers should take initiative to assist elementary teachers in the integration of agricultural topics.

Technical Report

During YR 1 the Objective 8 team has achieved and made progress primarily towards the first two major objective categories as laid out in the initial REACCH proposal (8.1 and 8.2). Objective 8.1 focused on developing the supporting elements for our REACCH cyberinfrastructure and data management strategies, including: **(1)** an initial CI assessment; **(2)** a data policy development; **(3)** memorandum of understanding development; **(4)** the hiring of the REACCH Data Manager and planning for the use of other personnel and server resources.

Objective 8.2 focuses more specifically on planning for and beginning operational elements of our data management plan with oversight by the REACCH Environmental Data Manager (Seamon), Project Manager (Daley Laursen), Objective 8 Team Lead (Gessler) and the REACCH Principal Investigator (Eigenbrode). This includes: **(1)** development of the REACCH web site, which will be the main tool for interfacing with the public, educators and our stakeholders; **(2)** extension of REACCH's already in-place intranet collaboration portal. REACCH uses Central Desktop project management system software (http://www.centraldesktop.com) for all elements of internal project coordination within and between project management and the objective and science team leads; **(3)** construction of the REACCH research data portal that will be used initially by REACCH scientists acquiring data and eventually by the broader group of students, researchers, educators, stakeholders and the public through both direct access and through the implementation of web-based applications. This data portal will be accessible thru REACCH's public portal.

Objective 8.3 entails the development of sustainability elements of our cyberinfrastructure and data management strategies and longer-term development of new proposals and collaborations to continue building our resources. The tasks associated with this objective will be primarily structured in years 3-5 of the REACCH project.

Planning funds were used initially to begin assessing current cyberinfrastructure and data management resources between the four partner institutions of the University of Idaho, Oregon State University, Washington State University and the USDA Agricultural Research Service. This included visits to all potential experimental stations and research sites that are a part of the REACCH project. We also visited the Kellogg Biological Station Long Term Ecological Research Site managed by Michigan State University as the only agricultural LTER site within the national LTER network. We specifically interacted with their data management personnel and toured their data management facilities to make collaborative connections. The REACCH Objective 8 team lead (Gessler) is currently serving as the cyberinfrastructure working group lead for the NSF funded EPSCOR Water Resources in a Changing Climate project that has many similar data management challenges and objectives. This project developed and has implemented one of the first data management policies as now required by the National Science Foundation. This policy lays out the specifications for all researchers to plan for moving their data into publicly accessible data repositories that use established national and international metadata standards. The REACCH project is leveraging this existing policy, using it as the foundation for our REACCH data management framework that all researchers must abide by. It follows stringent NSF requirements and will provide a strong basis for the long term archival and access and use of the REACCH datasets for regional, national and international use. These requirements also ensure that all REACCH datasets will meet newly developing standards for data citation and interactive access via web-based services that can be structured to operate as stand-alone applications or as applications within various application-based software packages such as the ArcGIS® geospatial analysis software.

In a similar manner to the data policy developed by the previously mentioned NSF project, an institutional memorandum of understanding was developed and signed by collaborating institutions and their Vice President's for Research to formalize collaboration on development of cyberinfrastructure and data management strategies to support research. We have adapted this MOU for review and use by the four collaborating REACCH institutions. While the Data Policy formalizes expectations for individual researchers and data developed as part of the REACCH project, the MOU establishes a collaborative agreement at the upper levels of administration between the institutions to support data management via complementary internal institutional resources critical to maintaining our collective research infrastructure. We realize that REACCH data management resources are limited and it is critical that we leverage and build on other efforts related to cyberinfrastructure and data management.

Perhaps the most important achievement during YR 1 has been successful hiring of the REACCH Environmental Data Manager. A search committee was established with the Objective 8 Team lead and representatives from each collaborating institution. This team developed a job description, advertised, interviewed and successfully hired the top candidate. He started in his position in late November 2011. The Data Manager is now interacting weekly with the Objective 8 team leader, the Project Manager, and PI to plan for use of the other Objective 8 personnel resources related to web development and programming. There is regular interaction with all objective teams.

During the summer of 2011 a REACCH web development team was formed led by the Objective 8 team lead and the Project Manager. The team reviewed a variety of web sites to evaluate the look, feel, and functionality of various web sites to initially inform our development of the components required for our REACCH web site. We developed draft documents specifying these elements and gathered media to provide graphic content to the web site. We met with personnel from the UI's Northwest Knowledge Network project to plan for resourcing and development of our REACCH web site. NKN is providing server resources, portal technology software and content management software based on the Concrete 5 open source content management system. The REACCH Environmental Data Manager developed a preliminary REACCH web site mock up during December 2011 and the Web Team is providing iterative feedback on expanding the skeleton structure of the web site. Current plans aim for a REACCH web site launch during March 2012. In parallel to the web site development the Data Manager is planning for establishment and launch of complementary research data portal and database management components. These elements are currently being researched and specified and will be detailed in the REACCH Data Management plan during the spring of 2012.

At the end of YR 1 the REACCH PI (Eigenbrode), Objective 8 Team Lead (Gessler), Environmental Data Manager (Seamon) and Project Manager (Daley Laursen) have established weekly meetings to review progress and coordinate interaction with the NKN and other collaborative efforts. We are also formalizing the roles and responsibilities of the team and are evaluating options for use of personnel resources related to web development and programming. We are currently evaluating options for contributing resources to the Northwest Knowledge

Network on a contractual basis to implement various elements of our Web and Data Management plan.

The REACCH data management architecture and design have been initially developed during YR 1 of the project (Figure 8.1).

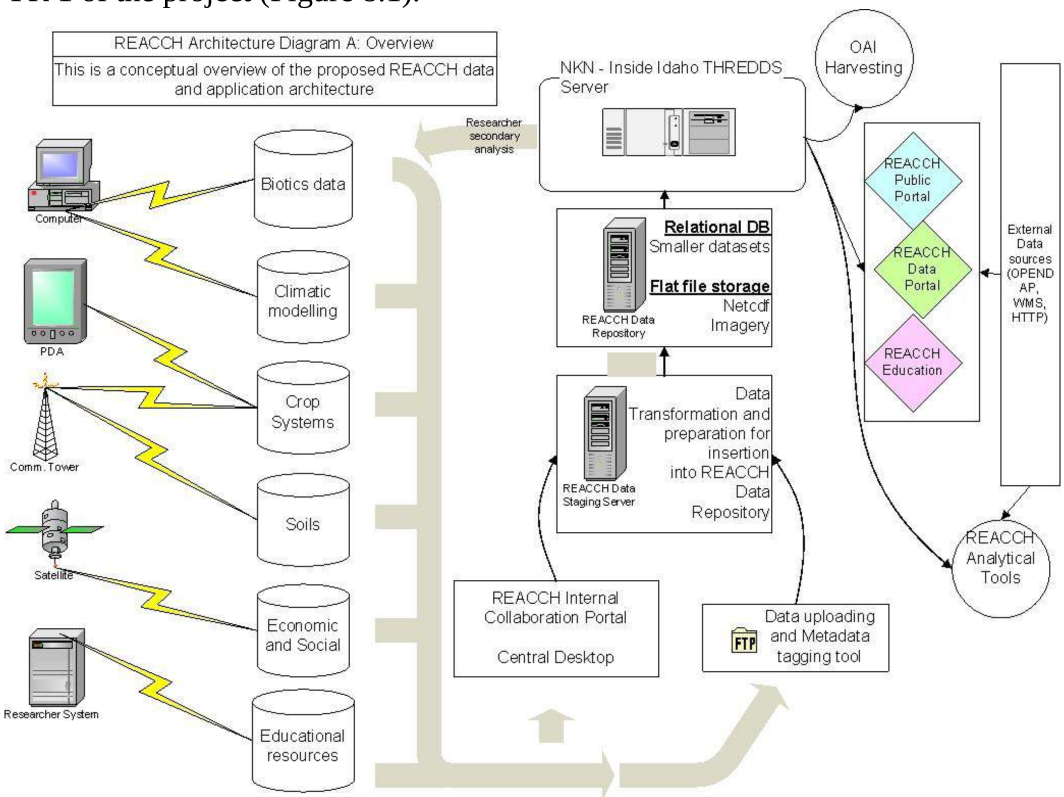

Figure 8.1. Draft proposed REACCH data management technical architecture

Notable items from Figure 8.1:

<u>THREDDS server:</u> THREDDS, or Thematic Realtime Environmental Distributed Data Services, is server software used for scientific data cataloging and discovery, developed by the University Consortium for Atmospheric Research (UCAR). The THREDDS data server is a web server that provides metadata and data access to scientific datasets, using protocols such as OPENDAP, Open GIS Consortium WMS and WCS, and HTTP. REACCH will be using a distributed data services model, where data stored in REACCH repositories can be combined with data from other remote locations. The THREDDS data server approach will be used to expose large scientific datasets (>25GB) for analysis without the need for actual data transfer (Domenico, et al, 2002).

<u>Relational database management</u>: Given the diverse aspect of REACCH data, there are some datasets that will better fit into a relational database model. As such, a part of the REACCH data management model is a relational database component.

<u>REACCH analytic tools:</u> The REACCH broad data management strategy is to provide a wide range of methods for data access and analysis. One method is thru the use of compiled analytic tools that connect to REACCH data for dynamic analysis and review.

The organizational data structure for REACCH is under development and will be refined in YR 2. An example organizational data structure is showed below (Figure 8.2).

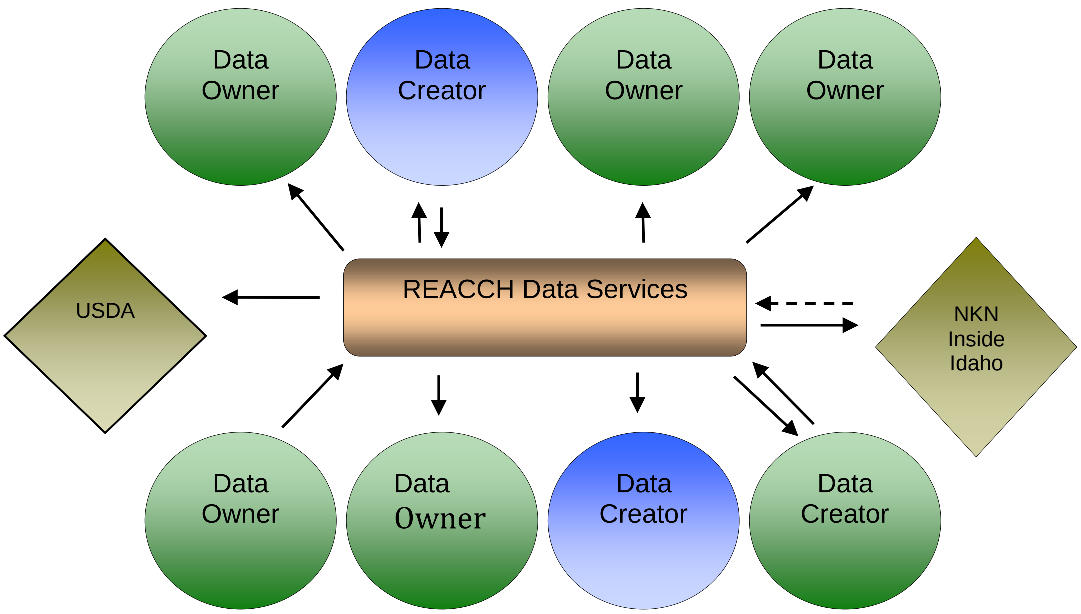

Figure 8.2. Example draft REACCH data management organizational data framework

Figure 8.2 describes a semantic data model for data control and management. Under this approach, a fixed number of defined roles are described, in order to define responsibilities based on a standard template and structure. Given REACCH's diversity of data and science disciplines, such an organizational approach will be essential for controlling and managing data as it flows in and out of REACCH repositories.

As noted above, strong organizational and structure with regards to data flow, insertion, analysis, management, and sustainability require equally complex processes for organization and structure. Such structure will allow for extensive research efforts in later years of the project.

Technical Report

The AEZ concept is central to project-wide integration for the REACCH project and will enable researchers, stakeholders, students, the public, and policymakers to acquire a more holistic understanding of the interrelationships of agriculture, climate change and the development of mitigation and adaptation strategies. Agroecological zones (AEZs) are often defined by integrating multiple layers of biophysical (e.g. climate, soil, terrain) and occasionally socioeconomic data to create unique zones with specific ranges of land use constraints and potentials (FAO, 1996). We have taken a different approach to defining AEZs that assumes current agricultural systems and land uses have emerged as a consequence of biophysical and socioeconomic drivers. Therefore, during YR I of the REACCH project, we explored the concept that AEZs can be derived from the geographic distribution of major agricultural systems (e.g. the grain-fallow zone) in the Inland Pacific Northwest. By defining AEZs in this way, we expect to: ***(1)*** *provide baseline information that geographically delineates the boundaries of current AEZs and subzones and therefore the capacity to evaluate shifts in AEZ boundaries over time;* (2) *assess the biophysical (e.g. climate, soils, terrain) and socioeconomic factors (e.g. commodity prices) that are most useful for predicting and correctly classifying current AEZs, subzones, or future shifts in AEZ boundaries;* ***(3)*** *link climate mitigation and adaptation strategies to relevant AEZs;* ***(4)*** *integrate biophysical and socioeconomic data sources to pursue a transdisciplinary examination of climate-driven AEZ futures.*

During the first year of the REACCH project the following objectives were achieved: **(1)** we used the Major Land Use Areas (MLRA) comprising MLRA 7 (Columbia Basin), 8 (Columbia Plateau) and 9 (Palouse and Nez Perce Prairies) and a small portion of 43A (Northern Rocky Mountains) to define the REACCH study region in the Inland Pacific Northwest (Figure 9a.1); **(2)** we developed methodology to define major AEZs for the REACCH study area within the Inland Pacific Northwest based on single years of National Agricultural Statistical Service (NASS) cropland data (Figures 9a.2 and 9a.4); **(3)** we characterized the major AEZs with respect to soils, climate, and crops grown (Figure 9a.3 and Tables 9a.1 and 9a.2).

Defining AEZs

The NASS cropland use data layer designates land use on an annual basis at a 56-m (3136 m^2) and more recently a 30-m resolution. For a given year, these data do not directly identify agricultural systems (e.g. crop rotations) that would occur on an agricultural field. If land use changes on an annual basis, however, it should be possible to infer predominant agricultural systems useful for AEZ designation from fields that are adjacent to one another as long as large enough areas are included. Four agricultural systems were defined for consideration as major AEZs within the REACCH study region: **(1)** annual cropping (no annual fallow); **(2)** annual crop-fallow transition (e.g. 3-yr rotations with fallow every 3rd year); **(3)** grain-fallow, 2-yr; **(4)** irrigated. To determine areas large enough to identify AEZ designation, the proportion of a given area in fallow (not annually cropped) was calculated for increasingly larger areas surrounding each 56-m cell ranging from 100-m to 24-km with the expectation that cropland use proportions at an optimal area would enable AEZ designation for every 56-m cell. The irrigated AEZ was defined as an annual cropping region (<10% fallow) where mean annual

precipitation was less than 330 mm. The proportion of fallow was also used to define the dryland farming AEZs where the grain-fallow AEZ was >40% fallow; annual crop-fallow transition AEZ, 10 to 40% fallow, and annual cropping AEZ <10% fallow.
Major results were as follows:

- The four major AEZ's were defined based on the 12-km scale using the proportion of fallow for the years 2007, 2009 and 2010 (Figure 9a.4).
- The proportion of wheat, fallow and other cropland uses showed distinct differences among the four major AEZs (Table 9a.1).
- Differences in cropland use percentages were evident in comparing the dynamic AEZs with Douglas et al. (1992) agroclimatic zones (Table 9a.2).

Future Activities

Defining AEZ's and relevant subzones directly from the cropland data layer on an annual basis would enable dynamic AEZ delineation, subject to annual variation in biophysical and socioeconomic drivers (e.g. climate, fuel or fertilizer prices and technological advancements) that impact agricultural systems and AEZ characteristics over time. Defining AEZs based on current cropland use allows further analyses with the goal of relating various biophysical and socioeconomic data layers to AEZs in order to gain an understanding of how multiple factors influence realized AEZs. This includes AEZ variation that can occur at finer temporal and spatial scales than has been possible with previous approaches.
During year two we expect to:

- Complete assembly of characterization data layers including down-scaled climate data and economic data from Objective 1 activities;
- Publish one manuscript on the concept and development of dynamic agroecosystems for the inland Pacific Northwest;
- Work with Objective 1 team to develop spatial data layers of bioclimatic and other biophysical variables (e.g. PET, GDD, soil depth) as well as socioeconomic variables for the REACCH study area. Use biophysical and socioeconomic data layers to determine how well they can explain the spatial distribution of the four major AEZs using analyses such as Random Forests and multivariate discriminant analysis.
- Aid in the development and submission of one manuscript on prediction of AEZ's using biophysical and socioeconomic variables;

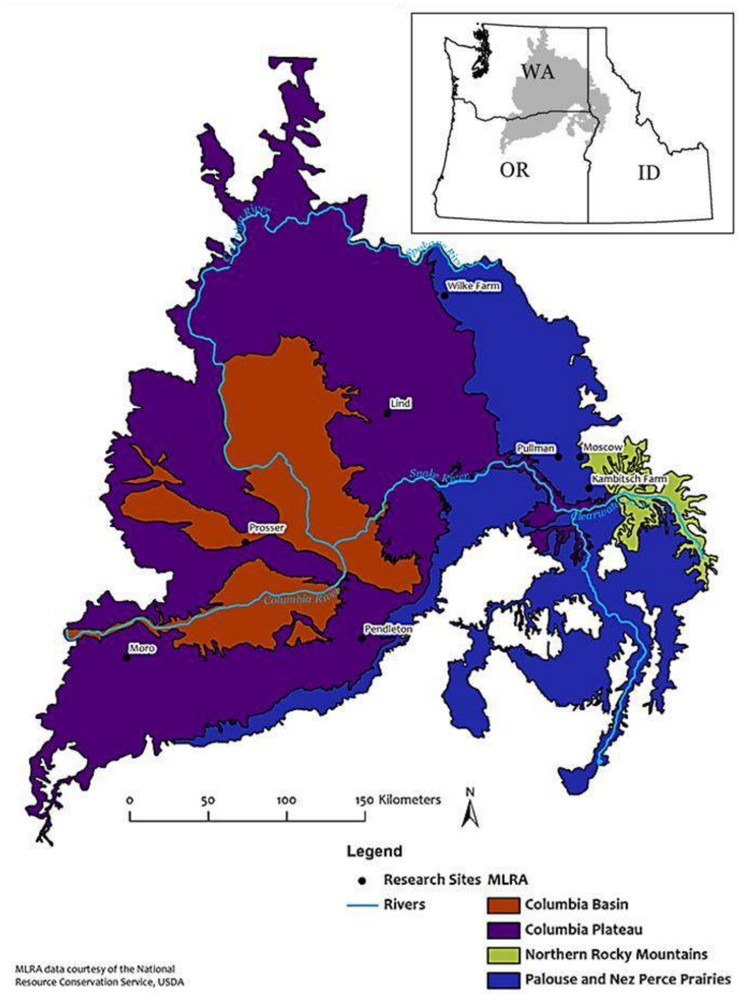

Figure 9a.1. The Major Land Resource Areas (MLRA) used to delineate the REACCH study area.

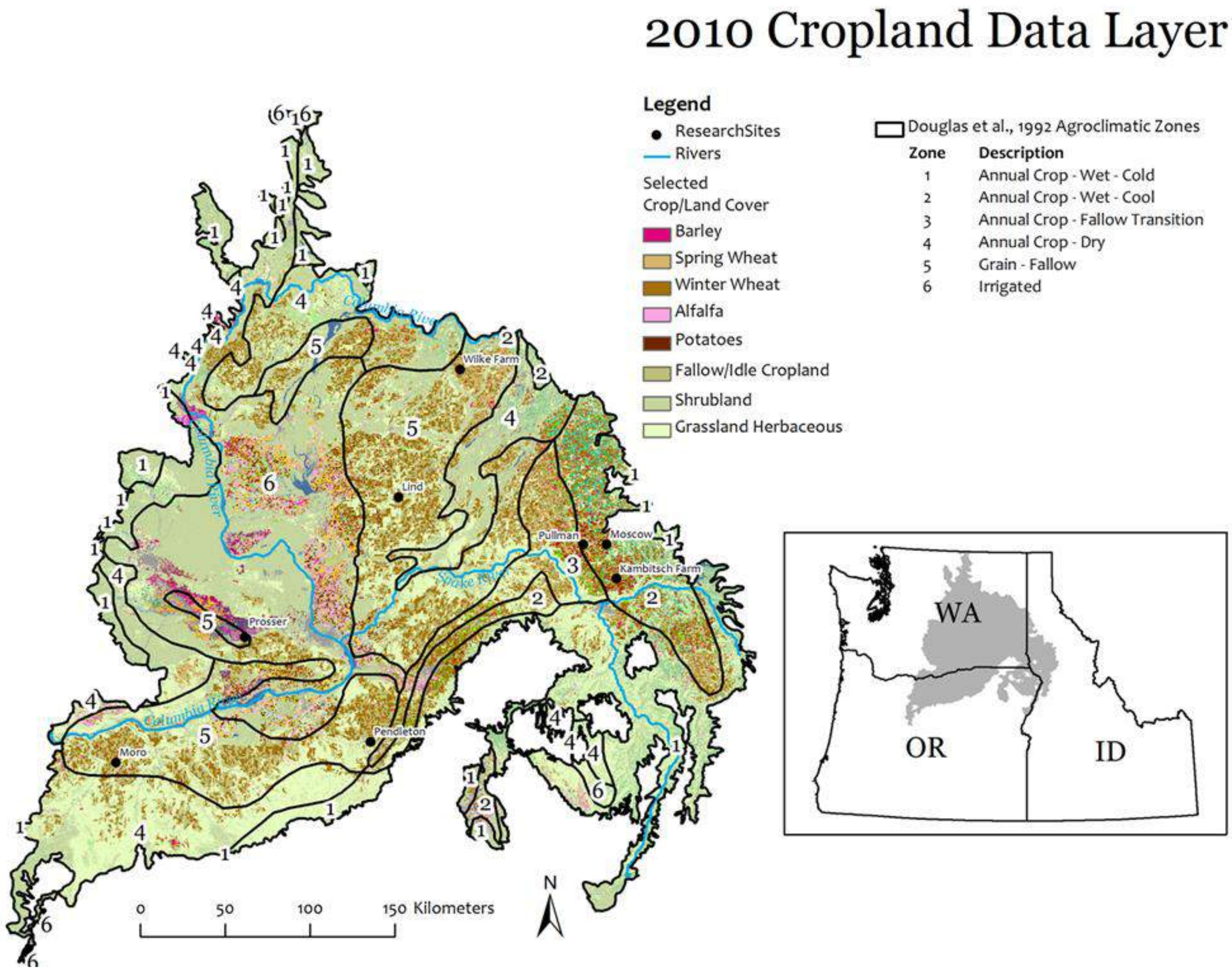

Figure 9a. 2. The 2010 cropland data layer for the REACCH study area (NASS, 2010) and the agroclimatic zones defined by Douglas et al., 1992.

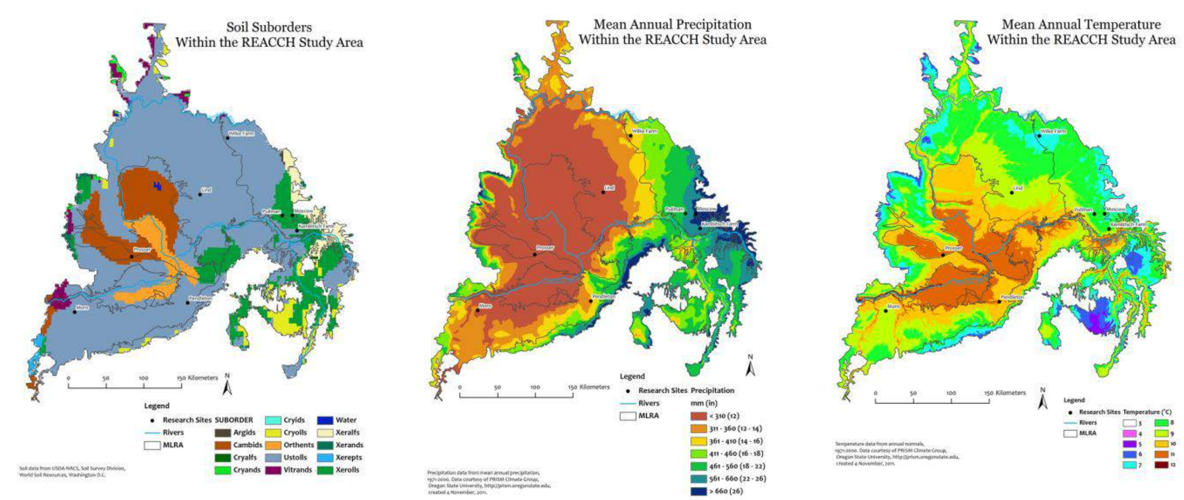

Figure 9a.3. Soil suborders, mean annual precipitation and mean annual temperature for the REACCH study area.

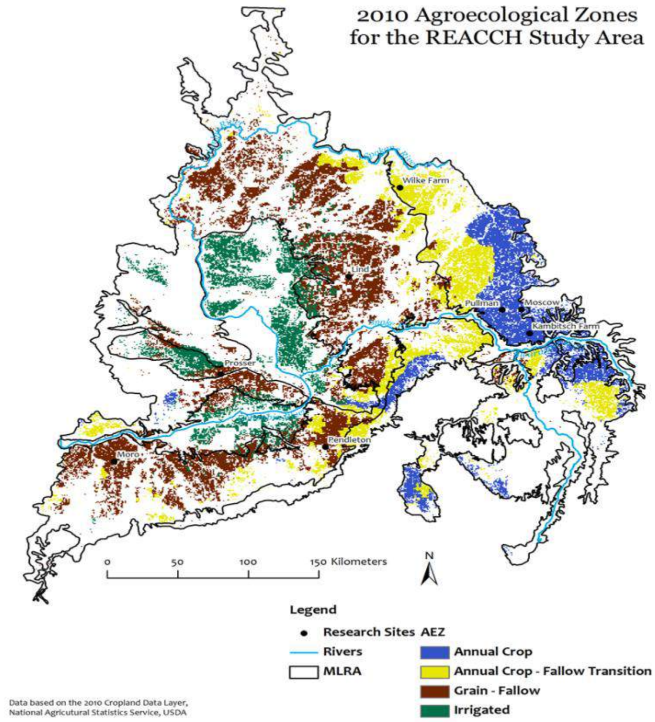

Figure 9a.4 Four major Agroecological Zones (Annual Crop; Annual Crop-Fallow Transition; Grain-Fallow; and Irrigated) for the REACCH study area, 2010.

Table 9a.1. The percentage of major crops and fallow within the four agroecological zones (AEZ).

AEZ	Fallow	Winter wheat	Spring cereal	Grain legume	Canola	Alfalfa	Potatoes	Other	Total
	--%--								
Annual Crop	3	39	20	21	1	5	0	11	100
Crop - Fallow Transition	27	39	20	3	0	4	0	5	100
Grain - Fallow	48	45	3	0	0	1	0	3	100
Irrigated	9	16	5	4	0	16	8	42	100

Table 9a.2. Comparison of the dynamic AEZ classification with the Douglas et al. (1992) agroclimatic zones

	Dynamic AEZ			
	Annual Crop	Crop - Fallow Transition	Grain - Fallow	Irrigated
Douglas et al. (1992)	------------------------------------ % ------------------------------------			
Annual Crop	67	29	4	1
Annual Crop-Fallow Transition	26	65	9	0
Grain-Fallow	2	20	59	18
Irrigated	0	1	20	78

Technical Report

Baseline gridded (4x4 km) daily weather data were made available by climate modelers of the REACCH team in netCDF format, which has the advantage of being spatially and temporally explicit. The dataset includes daily temperature, precipitation, solar radiation, humidity, and wind speed from 1979-2010, which is the historic period to be used as the baseline in this project. A similar dataset for projected future weather was made available using the same format, of which we are currently utilizing the period 2006-2035. The weather projection was made utilizing the representative concentration pathway (the new IPCC denomination for previous "emission scenarios") RCP4.5 assumption for CO_2 emission. Weather projections using RCP8.5, a more feasible emission scenario, will be available later. However, global atmospheric CO_2 concentrations projected for these two scenarios are not different until 2050 and should not affect cropping system simulations. Atmospheric CO_2 emissions are not only important for weather projections, but associated atmospheric concentrations also affect water use, biomass production by crops, and CropSyst yield predictions.

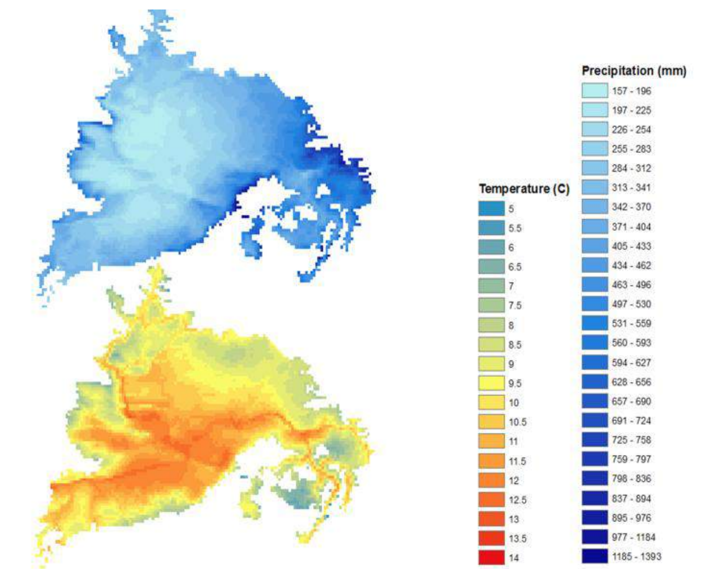

Figure 9b.1. Baseline annual precipitation and mean temperature, averaged for 1979-2010 period.

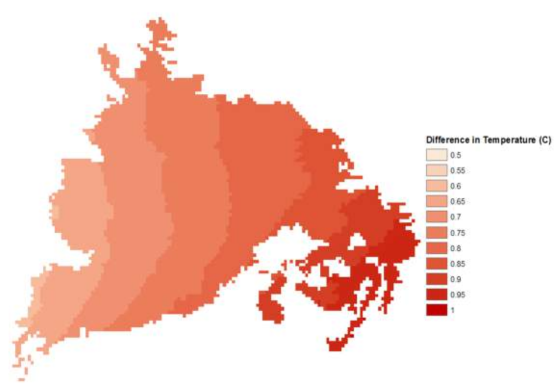

Figure 9b.2. Future temperature (2006-2035) minus baseline (1979-2010) temperature

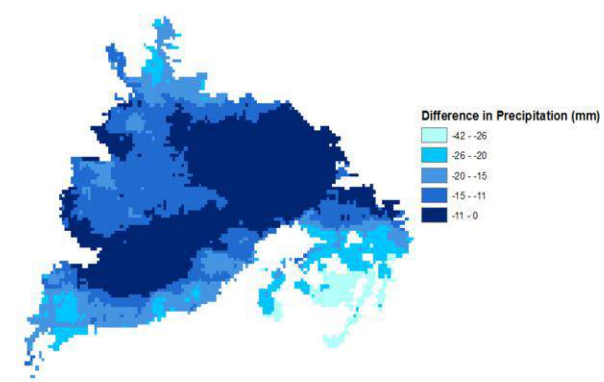

Figure 9b.3. Future precipitation (2006-2035) minus baseline (1979-2010)

These emissions often tend to offset partially (or even totally under some conditions) the impact of global warming on the productivity of wheat-based systems (Stockle, et.al. 2010). Figure 9b.11 shows mean annual precipitation and temperature averaged for the 1979-2010 period. Figures 9b.2 and 9b.3 show precipitation and temperature differences calculated using the average value for future minus the average for baseline periods. Warming shows a pattern of increasing difference (from 0.5 to 1^{o}C) from west to east. Precipitation shows a pattern of decrease of annual average amounts, typically in the order 0 to 20%, with some areas experiencing smaller or greater decrease. How projected change affects seasonal precipitation distribution is not discussed.

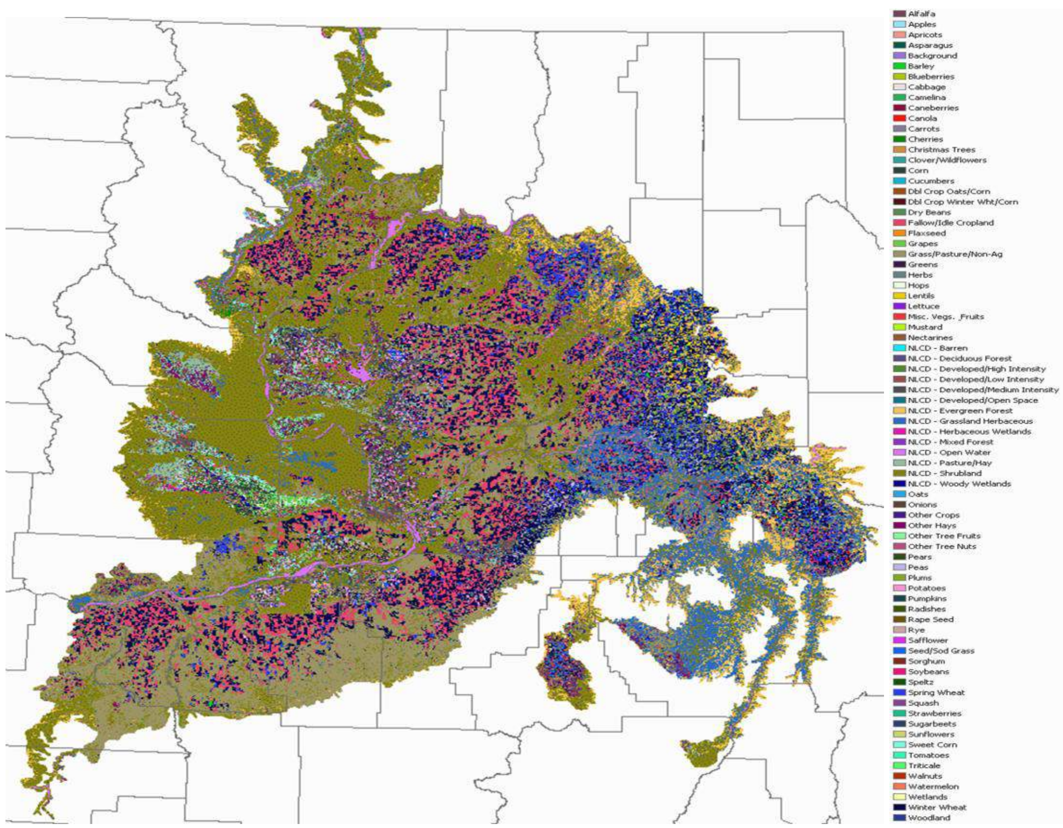

Figure 9b.4. Satellite-based 2010 USDA crop land data layer for the REACCH study region.

The grid configuration for regional analyses uses the same grid of the geo-referenced weather dataset. To utilize these data, utilities were added to the CropSyst model that can access and read the netCDF files for each weather variable during run time and also read a STATGO data layer to obtain soil information for each grid point. The weather grid covers an area much larger than the REACCH study area and provides data for all grid points regardless if they correspond to lands not suitable for annual crops (i.e., water bodies, shrub land, etc.) or currently utilized for permanent crops (i.e., land occupied with orchards or similar permanent or long-term land use). Satellite-based crop land data layers (CDL) are available from the USDA for the years 2007, 2008, and 2010 (Figure 9b.4 shows the 2010 CDL). This information was analyzed to produce a GIS data layer identifying lands suitable for wheat-based rotations (shown in blue in Figure 9b.5). In this way, with further GIS-based manipulation, we were able to determine the fraction of

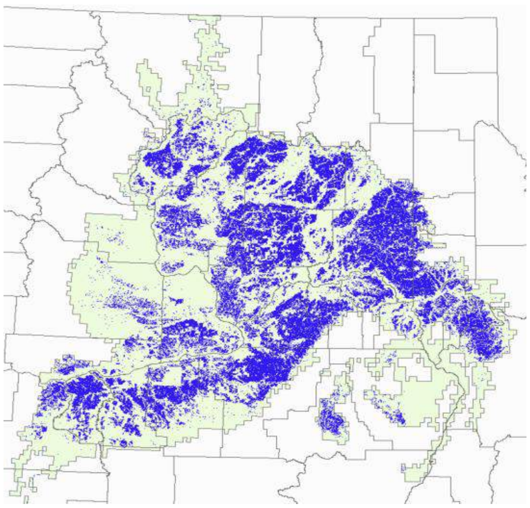

Figure 9b.5. Land area (marked in blue) suitable for wheat-based rotations.

annual crop land included in each original 4x4 km grid cell for the entire REACCH study area.

With weather, soil, and fraction of annual crop land defined for each 4x4 grid cell, 30-year CropSyst simulations for a winter wheat – fallow rotation using baseline (1979-2010) and future (2006-2035) weather were run for the entire REACCH region. Yield, expressed as dry matter in kg/ha, were determined for each grid cell and year. Average yields for baseline weather are shown in Figure 9b.6, where the black area corresponds to not-suitable land excluded from the analysis. Figure 9b.7 shows the difference between future minus baseline yields. The output of these simulations are also provided in Excel format, with all the information needed to integrate yields at the scale of counties or zip code areas, the latter as required by the TOA-MD model.

We are also preparing to conduct regional analyses based on daily weather measured in ground-based weather stations, which will be compared with analyses based on gridded data.

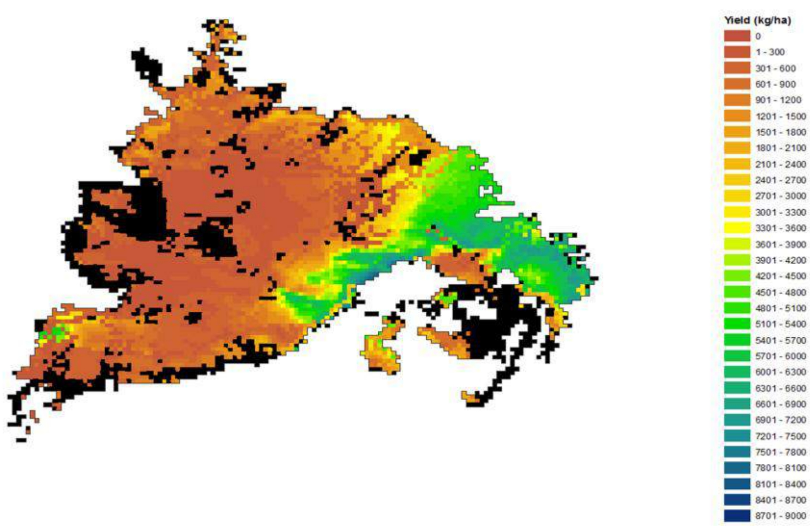

Figure 9b.6. Baseline grain yields for winter wheat-fallow scenario (kg/ha dry matter)

Figure 9b.8 shows all the stations available for the region from threes sources: WSU WeatherNet; Agrimet; NCDC. The area outside the REACCH study region is shown in grey. It can be seen that there is a high density of stations in the study region.

However, only the AgWeatherNet and Agrimet stations have sufficient measured weather variables to run CropSyst. The NCDC stations only have precipitation and temperature data.

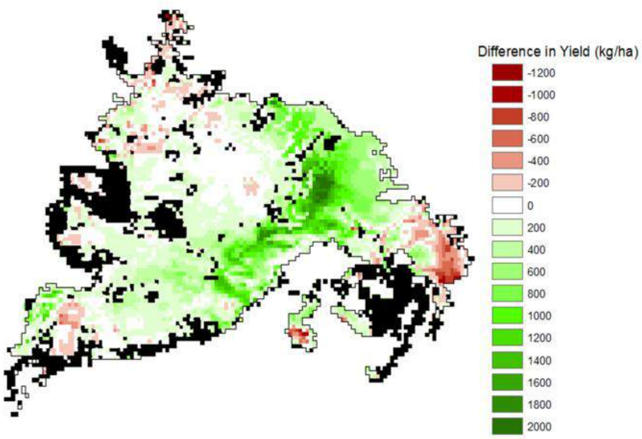

Figure 9b.7. Grain yields difference (Future – Baseline yield) for a winter wheat-fallow scenario

To solve this problem, we have developed and tested methods to estimate solar radiation and maximum and minimum relative humidity from temperature. To evaluate these methods, we selected stations as shown in Figure 9b.6, where the stations marked "independent" correspond to stations used to stations used to evaluate the methods, while the remaining stations were used to parameterize the estimation methods.

The estimation of solar radiation from temperature was based on the Campbell-Donatelli method (Donatelli and Campbell, 1998). Relative humidity and wind speed were based on methods developed by Stöckle et al. (2004). Regional parameters were determined based on local parameters for all the stations included in Figure 9b.9, except the "independent" stations that were used for verification. Figure 9b.10 shows mean estimated and observed solar radiation for weekly periods, and it is representative of the quality of estimated values. Estimations for daily periods (not shown) result in more scatter, but weekly periods are more representative of performance for cropping systems simulations, where the details of weather in periods of less of one week are not critical unless systematic biases are present, which is not the case. We are currently completing relative humidity estimations, but results thus far show a good performance of the methods used (Figure 9b.10).

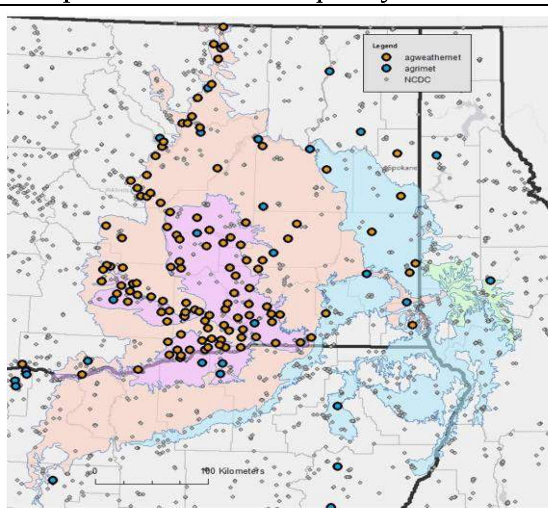

Figure 9b.8. REACCH study area with surrounding weather stations. Agweathernet (orange) and Agrimet (blue) are complete stations while NCDC (grey) are thermo-pluviometric only.

To test the impact of weather estimation errors in crop model simulation outputs, 30-year yield average simulated using observed and estimated solar radiation were compared imposing different levels of irrigation from dryland to full irrigation, allowing significant variation in crop water stress conditions.

Three methods of solar radiation parameter estimation were compared: **(1)** locally-estimated parameters; **2)** regional parameters (one set of parameters for the entire area); **(3)** parameters obtained from the closest station. As shown in Figure 9b.11, the trend of results based on observed and estimated solar radiation are comparable, providing confidence on the methods utilized.

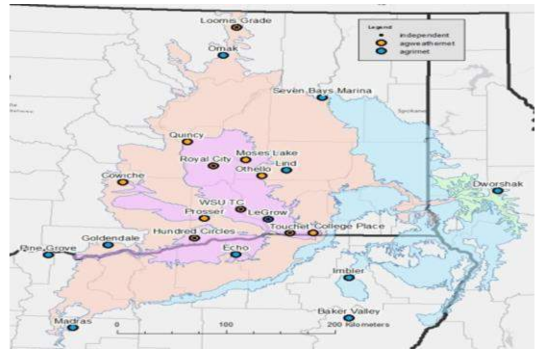

Figure 9b.9. Map of stations used to parameterize and test weather data estimation methods.

The next task will be to prepare complete weather records for the period 1979-2010 of all weather stations in the study region with temperature data for this period. Thiessen polygons will be used to delineate the area of influence of each station, which combined with geo-referenced soil data will allow us to produce similar regional simulation runs as obtained using gridded data. Regional runs with the two methods will be compared using integrated yield values for zip-code areas.

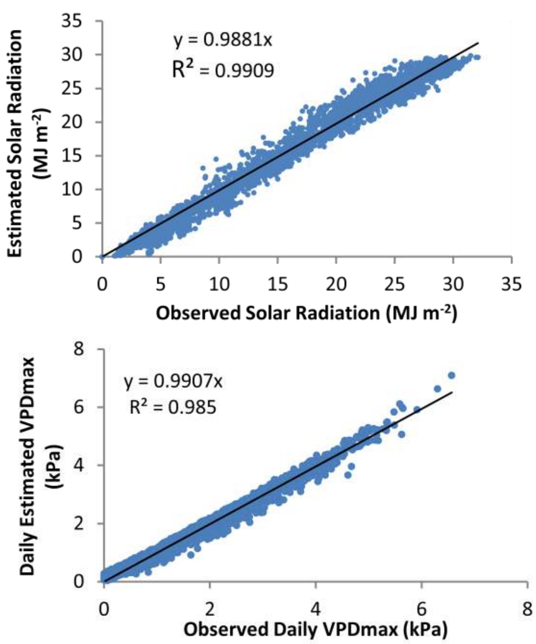

Figure 9b.10. (Above) A comparison of estimated and observed weekly average in Lind, WA (n = 3270): (below) solar radiation (MJ m^{-2}), (Below) maximum vapor pressure deficit.

Two important components of the GHG emission picture for wheat-based cropping systems in the region are changes in SOC storage and N_2O emissions derived from denitrification and nitrification. CropSyst currently has a SOC model that considers four pools with different oxidation rates and C/N ratios. However, this model requires a period of equilibration to existing cropping systems and management to partition the initial SOC among the four pools, with steady-state typically reached after 50 to 100 years of simulation. This is not practical considering that this process must be repeated for each pixel in the study region. Therefore, a single-pool approach requiring minimum calibration was coded into CropSyst, following the formulation and procedures presented by Kemanian and Stockle (2010). For denitrification, the following functional model was conceptualized: $D_a = D_p \min(F_N, F_R) F_W$, where D_p is potential denitrification, and F_N, F_R, and F_W are reduction functions (values from 0 to 1) depending on soil nitrate, soil respiration, and soil water content, respectively (Figure 9b.12).

Parameters for D_p and the reduction functions can be approximated from data in the literature, but a better approach would be to use data from a recently deployed field multi-chamber experiments (see Obj. 2) to determine parameters by optimization. A multivariate optimization procedure (e.g., the Downhill Simplex Optimization method) will be used once experimental data become available, with the reduction functions parameters fluctuating within a narrow range (there is good amount of supporting data for this) while D_p will be allowed to fluctuate freely.

A Life Cycle Assessment (LCA) tool was developed in Excel to evaluate the carbon footprint of cropping systems. The tool accounts for direct and indirect emissions of CO_2, N_2O and CH_4. Direct emissions are from soil and from field operations during the growing season and depend on soil characteristics and state (e.g., water, nutrients, temperature) and operations such as tillage, fertigation and irrigation events as well as the long-term land use changes. Indirect emissions comprise the production footprints associated with farming inputs and energy and equipment use. The tool receives input of simulated direct emissions from cropping systems models and develops a database and a knowledge base to, respectively, estimate indirect and other direct emissions. The database is built in a compatible format with the U.S. Life Cycle Inventory by importing GHG emissions from licensed LCA inventory databases to account for the production footprints of agronomical, fuel and material supplies. The knowledge base is part of the LCA tool computational framework and includes an LCA model for each field operation.

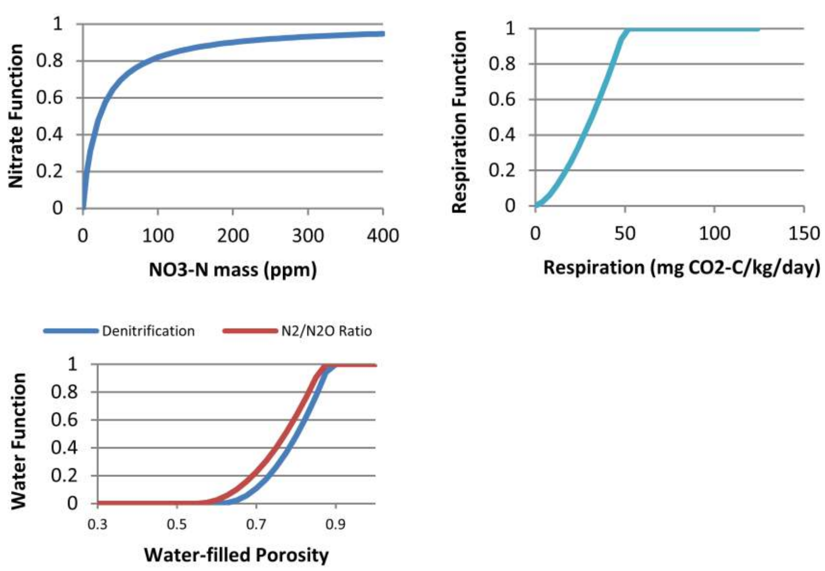

Figure 9b.12. Potential denitrification reduction functions.

Interactions between REACCH activities and other significant projects related to climate change impact assessment are important. Active participation in the Agricultural Model

Inter-comparison and Improvement Project (AgMIP) this year has helped gaining perspective about regional analyses using cropping system models, strength and weaknesses of crop models used for climate change responses, and avenues for improvement. AgMIP is a distributed climate-scenario simulation exercise for historical model inter-comparison and future climate change conditions with participation of multiple crop and world agricultural trade modeling groups around the world. This year, CropSyst and other models were tested using experimental data for wheat and maize from several world locations, allowing us to reduce model calibration to a minimum and gain appreciation of the robustness of the model structure to simulate crop growth under a wide range of conditions. This experience has proved useful to advance REACCH cropping systems simulation objectives.

REACCH partnerships and collaborations continued, initiated or pursued in YR 1

Other Current Climate Change CAPs, University of Florida, Iowa State University
REACCH is working closely with Sustainable Corn.org (Iowa State University leading) and PINEMAP.org (University of Florida leading), two $20M projects funded in the same cohort with REACCH. The project directors, Lois Morton and Tim Martin meet monthly in phone conference with REACCH director Eigenbrode. The three project directors are working on an article presenting the importance of interdisciplinary collaboration for large-scale problems such as the effects of climate change on agricultural systems. The directors will participate in one another's annual meetings in 2012. The project managers for the three projects also meet regularly by phone.

Climate Change AFRI, Washington State University
Site-Specific Climate Friendly Farming (CCF) is a NIFA-funded climate change project designed to develop an improved model that captures the variability over space and time of nitrous oxide emissions and related processes for complex agricultural fields under different management regimes and construct a field-scale, site-specific, decision-support tool for climate change mitigation by linking soil and crop sensor data to hydrology, cropping systems, and economic models. REACCH is sharing expertise and instrumentation with CFF to improve the accuracy and applicability of our monitoring and cropping system models. Several REACCH PIs are also PIs on CCF.

Triticeae CAP, University of California at Davis
Although only initial contacts with TCAP PIs at WSU and UI have been made, long-term plans will be to work with this project to assist with evaluation of wheat lines with phenotypes suitable for long term projected wheat production systems in the region.

Northwest Knowledge Network, University of Idaho
The Northwest Knowledge Network (NKN) is a data management system that provides storage, retrieval and protection services across the life cycle of data. NKN serves researchers, educators, and the public specializing in cross-disciplinary data and its application to issues of note in the state and northwest region. NKN is led by the University of Idaho Library (UI-L) and Research Office (UI-ORED), in cooperation with the Idaho National Laboratory (DOE-INL) with the Idaho EPSCoR Cyber-infrastructure program (EPSCoR-CI)

The NSF-Toolbox Project, University of Idaho
This NSF-funded project at the University of Idaho is designed to improve communication and collaboration among interdisciplinary scientists. Project Director Michael O'Rourke has worked with PIs and will work with students and postdocs to help improve collaborative literacy and promote successful teamwork within REACCH.

BioEarth Project, Washington State University
This project within Washington State University's Center for Environmental Research, Education & Outreach (CEREO) is developing a regional-scale Earth Systems Model (EaSM) that is an integration of existing atmospheric, terrestrial, aquatic, and human systems models focusing on climate variability and carbon-nitrogen-water dynamics in the Pacific Northwest. Several REACCH PIs are also part of BioEarth and the modeling approaches employed in the two projects will be complementary.

Biofuels Cropping Systems Research and Extension Project, Washington State University
This WSU-led project with multiple sources of funding is focused on supporting the grower and industry-based movement to diversify cropping system agronomics and markets through increased adoption and production of oilseed crops. The cropping system diversification efforts complement and contribute to design of the alternative production systems being examined within REACCH and designed to improve adaptation to climate change and mitigation of GHG emissions. Several REACCH PIs are involved in BCSR.

Idaho EPSCoR, University of Idaho
The current EPSCoR project includes hydroclimatology, ecological change, economic and policy modeling. A focus is the hydrology of the Snake and Salmon River watersheds and how projected climate change might affect the timing and magnitude of mountain snow packs and snowmelt. The climate modeling expertise and cyberinfrastructure of EPSCoR is closely linked to those within REACCH and contribute to its efforts.

NSF-IGERT, Washington State University
The NSPIRE IGERT ("Nitrogen Systems: Policy-oriented Integrated Research and Education") at WSU is a multidisciplinary program focusing on nitrogen cycling and effective communication with public policy makers. Some NSPIRE students will be jointly supported by REACCH and NSF-IGERT

NSF-IGERT, University of Idaho
The University of Idaho IGERT, ("Evaluating Resilience of Ecological and Social Systems in Changing Landscapes of Costa Rica and Idaho") is training 24 doctoral students working in interdisciplinary teams in Idaho and Costa Rica. One of the student teams works in the Palouse region within the purview of REACCH and shares two faculty mentors with REACCH. Interactions are planned among the students in the two programs.

NASA Innovations in Climate Education (ICE) project, University of Idaho
This project focuses on working with regional teachers to assist them in bringing climate into the classroom. REACCH and ICE are collaborating on developing and delivering summer workshops for science teachers beginning in 2012.

Regional Partners

- The Department of Interior's Northwest Climate Science Center (NW CSC), a partnership of Oregon State University, the University of Idaho, the University of Washington and the US Geological Survey, is one of eight regional centers in a permanent nationwide network established to provide scientific information, tools, and techniques to anticipate, monitor, and adapt to climate change. NW CSC resources include a broad array of climate related expertise, data management and cyber-infrastructure services and a 23 member executive stakeholder advisory system. Several REACCH PIs are active in NW CSC leadership. Although NW CSC's mission is comprehensive, REACCH is bringing in the agricultural perspectives important for its mission.
- Oregon Climate Change Research Institute (OCCRI), based at Oregon State University (OSU), is a network of over 100 researchers at OSU, the University of Oregon, Portland State University, Southern Oregon University, and affiliated federal and state labs. REACCH PI, Phil Mote is director of OCCRI and is assisting with ensuring effective collaboration.
- Pacific Northwest Environmental Organizations have established the Northwest Regional Biocarbon Initiative (NW RBI) as a mechanism for advancing practices and policies that mitigate climate change in terrestrial ecosystems in the PNW. With REACCH guidance, NW RBI has adopted a policy position statement inclusive of agricultural practices researched and validated by the REACCH project.
- Columbia River Supply and Demand Forecast. Washington Department of Ecology. Kruger, co-PI and Extension Lead
- Life-cycle Analysis of Pacific Northwest Feedstocks for Biofuel Production. US EPA. Kruger, PI
- Organic Waste to Fuels. Washington Department of Ecology. Kruger, PI
- Needs Assessment: What is the state of knowledge of private forest landowners regarding global climate change and the impacts to western forests? US Forest Service. Kruger, PI
- PNW Climate Impacts Research Consortium. NOAH RISA. Kruger coordination with John Stevenson
- Organic Footprints Project. USDA. Kruger coordination with Project Leader Lynne Carpenter-Boggs
- Idaho Regional Optical Network. (IRON) facilitates advanced networking among institutions in Idaho and the Northern Tier States.

National Partner

- The Kellogg Biological Station Long-Term Ecological Research Site (KBS-LTER). Shared vision and interests have spawned and will sustain exchanges and collaboration.
- Consortium of Universities for the Advancement of Hydrologic Science, Inc., an NSF sponsored consortium of 125 universities providing support for the study of terrestrial components and processes of the global water cycle.
- DataONE, supported by the NSF, ensures preservation and access to multi-scale, multi-discipline, and multi-national science data.

Pending Collaborations

REACCH has provided letters of support for three proposed climate-related NIFA projects.

- Oilseed Biofuels CAP, University of Idaho: Field to Fuel in the Pacific Northwest, project lead Matt Morra
- Livestock Climate CAP, Washington State University: Program for Research and Extension that Promotes the Adaptation of Ruminant Enterprises (PREPARE): Mitigation and Resilience in the Face of Climate Variability, project lead, Kris Johnson
- Western Conifer Climate CAP, Oregon State University: Western Conifer Climate Change Consortium, project lead Glenn Howe

Grant Proposals Submitted relevant to REACCH

- Preparing PNW Agricultural Educators to Respond to Climate Change Needs: Needs Assessment and Professional Development for Sustainable Agriculture. Submitted to Western SARE. Kruger, PI

Foundations

REACCH builds upon several long-term, successful regional projects addressing agricultural sustainability, soil conservation and reduced emissions from agriculture. In addition to the CFF project listed above:

- Solutions to Environmental and Economic Problems (STEEP) is an interdisciplinary research/education program focusing on developing profitable cropping systems technologies for controlling cropland soil erosion and protecting environmental quality, initiated in 1975. STEEP's legacy of successful research and extension has helped set the stage for REACCH.

Dr. Senthold Asseng, Associate Professor Department of Agricultural and Biological Engineering, University of Florida at Gainesville

Dr. Asseng's research interests are in systems analysis to understand, compare and improve the productivity and sustainability of atmosphere-crop-soil systems changing over time and space and at different scales. He specializes in impact and adaptation of climate variability and climate change on cropping systems.

Dr. Matthew Baker, Dean of the College of Outreach and Distance Education, Texas Tech University

Dr. Baker is responsible for the administration of graduate and undergraduate print and electronically-delivered distance learning courses and programs, off-campus instruction and instructional sites, and non-credit outreach programs. Texas Tech offers more than 30 outreach and distance education programs.

Dr. Karen Garrett, Department of Plant Pathology, Kansas State University at Manhattan

Dr. Garrett specializes in plant disease ecology, ecological genomics, agricultural biodiversity and resistance gene deployment, disease in natural systems, statistical applications in biology, international agriculture.

Dr. Richard Howitt, Professor Social Sciences and Humanities, University of California, Davis

Dr. Howitt specializes in Resource Economics, Environmental Economics, Quantitative Methods, Econometrics, and Operations Research.

Dr. Kari Norgaard, Associate Professor Department of Sociology, University of Oregon, Eugene

Dr. Norgaard has published and taught in the areas of environmental sociology, gender and environment, race and environment, climate change, sociology of culture, social movements and sociology of emotions.

Dr. Phil Robertson, Professor of Ecosystem Science, W. K. Kellogg Biological Station and Department of Crop and Soil Sciences, Michigan State University

Dr. Robertson research interests include the biogeochemistry and ecology of field crop ecosystems, including biofuel systems, and in particular nitrogen and carbon dynamics, greenhouse gas fluxes, and the

The Stakeholder Advisory Committee (SAC) is a group of individuals that represents all aspects of involvement in this project including growers, agricultural industry, citizen groups, K-12 educators, and state and federal agencies.

Name		Organization
Karma	Anderson	US EPA Region 10
Dave	Barton	Former Extension Agent, Northstar Guidance Co.
Lori	Brogoitti	Pacific Northwest Direct Seed Association
Steve	Campbell	NRCS
Kirk	Cook	Washington State Department of Agriculture
Berk	Davis	Pacific Northwest Direct Seed Association
Tracy	Erickson	Washington Association Conservation Districts
Jim	Fitzgerald	Executive Director, Far West Agribusiness Association
Bill	Flory	Idaho Wheat Commission
Tanner	Hawkins	Chr.Env. Committee, Oregon Wheat Commission, Oregon Wheat Growers League
Mark	Hogen	Idaho Soil and Water Commission
Kevin	Hudson	Tribal Farming Manager, Confederated Tribes of the Umatilla Indian Reservation
Travis	Jones	Idaho Grain Producers
Rick	Jones	Pacific Northwest Direct Seed Association
Mary Beth	Lang	Washington Department of Agriculture
Patrick	Mazza	Climate Solutions, NW Regional BioCarbon Initiative
Fred	Morscheck	McGregor Company
Jeff	Newtson	Grower
Eric	Odberg	Grower
Mariah	Ostheller	Grower
Stephanie	Page	Oregon Department of Agriculture
Jim	Peterson	Vice President, Limagrain (Wheat Research)
Jennifer	Pollard	High School Teacher
Walter	Powell	Grower Association
Blake	Rowe	CEO/Admin Oregon Wheat Commission, Oregon Wheat Growers League
Mark	Sheffels	President, PNW Direct Seed Association
Tana	Simpson	Asst. Administrator, Oregon Wheat Commission, Oregon Wheat Growers League
Mary	Palmer Sullivan	Washington Grain Alliance
Ben	Vitale	Climate Trust
Cathy	Wilson	Idaho Wheat Commission
Dick	Wittman	Grower, consultant
Jerry	Zahl	Chair: Pendleton Station Liaison Commission
Russ	Zenner	Grower

Popular Press YR 1

Goodwin, P. Idaho Plays a Lead Role in New Northwest Regional Climate Science Center. National Science Foundation (NSF) Experimental Programs to Stimulate Competitive Research in Idaho (EPSCOR), Summer, 2011, (Message from the Director).

Gradin, J., 2011. Sunshine and grain. Argonaut 11/4/11, University of Idaho

Husky, K., 2011. UI received $20 million for climate research. Moscow/Pullman Daily News 2/19/11, Moscow, ID.

Karnowski, S., 2011. USDA spending $60 million to study effects of ‘climate change’ on crops. Associated Press.

Loftus, B., 2011. Collaborate, innovate: $20 million research project unites Northwest scientists tracking effects of climate change on agriculture. Oct. (pp. 10-14). University of Idaho Alumni Magazine.

Loftus, B., 2012. Success in solving PNW soil erosion problems led to new $20 million grant. Programs and People. Winter (pp. 18-19). University of Idaho College of Agricultural and Life Sciences.

Martin, J., 2011. NIFA announces grants to study the effects of climate change on agricultural and forest production. Feb. (pp. 18-19) United States Department of Agriculture.

Mendiola, M., 2011. Advanced Studies: Idaho universities are doing impressive research designed to benefit the Northwest and the world. Oct. (pp.10-15) Alaska Airlines: Horizon Edition.

Snyder, C., 2011. Climate changes and small grain. Ag Weekly.

Weaver, M., 2012. Western innovator researcher looks at big picture. Capital Press.

Weaver, M. 2011. PNW climate change research funded. Capital Press.

Weaver, M. 2011.Climate change project kicks off: Massive research effort funded by USDA grant. Capital Press.

REACCH Membership List

Last Name	First Name	Objective	Affiliate/University
Abatzoglou	John	1,2,AEZ	UI
Allwine	Eugene	2	WSU
Antle	John	1, 4	OSU
Baxter	Heather		Student, WSU
Beard	Taylor	6	Student, MS, WSU
Belltawn	Burgen	3	OSU
Birkhauser	Gerard	AEZ	Student, PhD, WSU
Bosque-Perez	Nilsa	5	UI
Boylan	Ryan	2	Student, MS, UI
Brooks	Erin	2	UI
Brown	David	2	WSU
Brown	Tabitha	7, AEZ	Student, PhD' WSU
Burke	Ian	5, AEZ	WSU
Capalbo	Susan	1,4,AEZ, LCA	Professor, OSU
Chi	Jinshu (Jackie)	2	UI
Collins	Hal	3	USDA-ARS, Prosser, WA
Daley Laursen	Dianne	7,8	Project Manager, UI
Donlon	Hilary	4	UI
Eigenbrode	Sanford	1,5,7,9 AEZ,LCA	Project Director, UI
Esser	Aaron	3	WSU
Gessler	Paul	1, 6, 7, 8	UI
Gollany	Hero	3	USDA-ARS, Pendleton, OR
Gosz	James R	9	UI
Graves	Laurel	2	Student, Undergrad, WSU
Hammac	Ashley	3,6	Student, MS, WSU
Hasart	Brandon	3	Student, Undergrad, WSU
Henshaw	Donald	8	USDA Forest Service
Huggins	Dave	1, 2, 3, 7, AEZ	USDA-ARS, Pullman, WA
Hughes	Megan	3	Student, MS, WSU
Jinshu	Jackie	6	WSU
Johnson-Maynard	Jodi	3, 5, 6	UI
Kane	Stephanie	4	UI
Kantor	Sylvia		WSU
Kelley	Chris	2	Student, PhD
Kostyanovsky	Kirill	2	Post-Doc, WSU
Kruger	Chad	2, 7	WSU

Last Name	First Name	Objective	Affiliate/University
Lamb	Brian	1, 2	WSU
Lawrence	Nevin	5	WSU
Li	Shihan	1,6	Student, OSU
Machado	Steve	3, 5, 6	OSU
McCellan	Tai	3,6	Student, PhD, WSU
Madsen	Isaac	3	Student, PhD, WSU
Meyer	David	all	REACCH Project Evaluator, Boise State University
Mote	Phil	1	OSU
Mwenji	Jolene	3	Research Associate, WSU
O'Rourke	Michael	1	Professor, UI
Painter	Kate	4	UI
Pan	Bill	2, 3, 7, AEZ	WSU
Paulitz	Tim	5	USDA-ARS, Pullman, WA
Perkins	Jeff	AEZ	UI
Petrie	Steve	7	OSU
Pressley	Shelley	2	WSU
Roe	Dennis	4	UI
Rupp	Rick	1, 2, 8, AEZ	WSU
Schillinger	Bill	3, 7	WSU
Seamon	Erich	8	Environmental Data Manager, UI
Sharratt	Brenton	2	USDA-ARS, Pullman, WA
Stevenson	John		OSU
Stockle	Claudio	1, 2,. 3, AEZ	WSU
Swan	Mark	3	WSU
Tedrow	Linda	8	UI
Thill	Donn	3	UI
Uberuaga	David	2	WSU
Umiker	Kari		
Unger	Rachel	AEZ	Student, PhD
Velez	Jonathan	6	Assistant Professor
Walden	Von	1, AEZ	Associate Professor, UI
Waldo	Sarah	2,6	Student, PhD
Walsh	Chealsea	6	Student, Grad, ui
Wolf	Kattlyn	6	UI
Wu	Ying	5	OSU
Wulfhorst	JD	4	UI
Yorgey	Georgine		WSU
Young	Frank	3	WSU
Zhang	Honliang	1,6	Student, PhD, OSU

Acronym	Definition
ACD	Annual Crop – Dry
ACFT	Annual Crop - Fallow – Transition
ACWC	Annual Crop - Wet – Cool
ACWCd	Annual Crop - Wet – Cold
AE	Agro-ecozone
AEZ	Agro-ecological Zoning
AG-8	Anastomosis Group #8
AgMIP	Agricultural Model Inter-comparison and Improvement Project
AgriMet	Pacific Northwest Cooperative Agricultural Weather Network
AgWeatherNet	Washington Agricultural Weather Network
ART	Agroecosystem Research Trial
ASA	American Statistical Association
ASABE	American Society of Agricultural And Biological Engineers
Biotic	Of or having to do with life or living organisms
BCSD	Bias Corrected Statistical Downscaling
BSWE	Biological Systems and Water Engineering
C	Carbon
CAF	Cook Agronomy Farm
CAP	Climate Agricultural Project
CART	Classification and Regression Tree
CD	Central Desktop
CDL	Cropland Data Layer
CEREO	Center for Environmental Research, Education & Outreach
CH_4	Methane
CF	Conventional Fallow
CFF	Climate Friendly Farming
CI	Cyber Infrastructure
CLB	Cereal Leaf Beetle *(Oulema Mebanopus)*
CLIMEX™	Climate Change Experiment
CM	Climate Model Group
CMIP3.5	Coordinated Model Inter-Comparison Project 3.5
C0	Carbon Monoxide
CO_2	Carbon Dioxide
ConsT	Conservation tillage
CR	Residue Management
CropSyst	Cropping Systems Simulation Model
CRP	Conservation Reserve Program
CS	Crop Modeling Group
CSSA	College Student Services Administration
CT	Conventional tillage
CUAHSI HIS	Consortium of Universities for the Advancement of Hydrologic Science, Inc.

CW	Continuous Cereal
D	Deliverable(s)
DataONE	Data Observation Network for Earth
DEM	Digital Elevation Model
DNA	Deoxyribonucleic acid
DOC	Dissolved Organic Carbon
DOE	Department of Energy
DS	Direct Seed
EaSM	Earth Systems Model
EC	Eddy Covariance
Eca	Electrical Conductivity
El	Eco-Climate Index
EPA	Environmental Protection Agency
FOI	Freedom of Information
GCAM	Global Change Assessment Model
GF	Grain Fallow
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GLM	Generalized Linear Model
GMC	Global Climate Model
GP	Grass Pasture
GPS	Global Positioning System
ha	Hectare (10,000 square miles or 2.47 acres)
H_20	Water
HPC	High Performance Computing
HTTP	Hypertext Transfer Protocol
HW	Hard Wheat
Hz	Hertz
I	Irrigated
ICE-Net	Intermountain Climate Education Network
IGERT	Integrated Graduate Education And Training Research
INL	Idaho National Lab
INW	Inland Northwest
IPCC	Intergovernmental Panel on Climate Change
IRB	Institutional Review Board
IRGA	Infrared Gas Analyzer
IRON	Idaho Regional Optical Network
KBS	Kellogg Biological Station
Km	Kilometer
LCA	Life Cycle Assessment
LTE	Long Term Evolution
LTER	Long-Term Ecological Research Site
LS	Longitudinal Survey

Lysimeter	A device for measuring water percolation through soil
MACA	Multivariate Adaptive Constructed Analog
M	Milestone(s)
MLRA	Major Land Use Areas
MOU	Memorandum of Understanding
N	Nitrogen
$N_2 0$	Nitrous Oxide
NARCCAP	North American Climate Change Assessment Program
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service
NCDC	National Climatic Data Center
NetCDF	Network Common Data Form
NKN	Northwest Knowledge Network
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NSF	National Science Foundation
NSF EPSCoR	NSF Office of Experimental Program to Stimulate Competitive Research
NSF LTER	NSF Long Term Ecological Research Network
NSPIRE	Nitrogen Systems Policy-Oriented Integrated Research & Education
NT	No Till
NAT	Native Agroecosystem Trial
NTC	No Till Cereal
NTL	No Till Legume
NW CSC	Northwest Climate Science Center
NW-RBI	Northwest Regional Biocarbon Initiative
OAT	Organic Agroecosystem Trial
OPeNDAP	Open Source Project for a Network Data Access Protocol
OCCR1	Oregon CVlimate Research Institute
OSU	Oregon State University
P	Phosphorus
PAT	Perennial Agroecosystem Trial
PC	Particulate Carbon
PCFS	Palouse Conservation Field Station
PCR	Polymerase Chain Reaction
Phenology	Science of relations between climate and biological phenomena
pH	Acidity or Basicity of an Aqueous Solution
PI	Principle Investigator
PNA	Pacific Northwest Agriculture
PNW	Pacific Northwest
PPT	Precipitation
PRISM Climate Group	Highest-Quality Spatial Climate Gridded Data , Oregon State University

QA	Quality Analysis
RAP	Representative Agricultural Pathway
RCP4.5	IPCC Representative Concentration Pathway 4.5
RCP8.5	IPCC Representative Concentration Pathway 8.5
REACCH PNA	Regional Approaches to Climate Change in Pacific Northwest Agriculture
REU	Research Experience for Undergraduate
RISA	Regional Integrated Sciences and Assessments
S	Sulfur
SAC	Stakeholders Advisory Committee
SAF	Safflower
SAFN	Sustainable Aviation Fuels Northwest
SAP	Scientific Advisory Panel
SARE	Sustainable Agriculture Research Education
SAS	Statistical Analysis Systems
SB	Spring Barley
SCF	Site-Specific Climate Friendly Farming
SDE	Staff Development for Educators
SF	Summer Fallow
SI	Suitability Index
SOC	Soil Organic Carbon
SOP	Standard Operating Procedures
SPSS	Statistical Package for the Social Sciences
SRN	Sustainable Research Networks
SSP	Shared Socio-economic Pathway
SSSA	Soil Science Society of America
STATSGO	State Soil Geographic Database
STEEP	Solutions to Environmental and Economic Problems
SW	Spring Wheat
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TCAP	Triticeae Climate Agricultural Project
TF	Tillage Fertility
THREDDS	Thematic Realtime Environmental Distributed Data Services
TOA	Economic Modeling Group
TOA-MD	Tradeoff Analysis Model for Multi-dimensional Impact Assessment
TOC	Total Organic Carbon
UCAR	University Consortium for Atmospheric Research
UI	University of Idaho
USDA	United States Department of Agriculture
USDA ARS	United States Department of Agriculture Agricultural Research Service
USDA NIFA	United States Department of Agriculture National Institute of Food and Agriculture
USGS	United States Geological Survey
VPR	Vice President of Research

WBCS	Washington Biofuels Cropping System
WCS	Web Coverage Service
WF-1	Preliminary analysis of wheat-fallow system
WMS	Web Map Service
WP	Wheat/Pea
WSU	Washington State University
WW	Winter Wheat
YM	Yellow Mustard

References Cited:

Abatzoglou, J. T. 2012. Development of gridded surface meteorological data for ecological applications and modeling. International Journal of Climatology, accepted.

Ball, D. A., S. M. Frost, and A. I. Gitelman. 2004. Predicting timing of downy brome (*Bromus tectorum*) seed production using growing degree-days. Weed Science 52: 518-524.

Dillman, D. A. 2007 Mail and internet surveys: The tailored design method. Hoboken, NJ: John Wiley & Sons, Inc.

Douglas C.L.J., D. J. Wysocki, J. F. R. Zuzel, J. F. Rickman and B. L. Klepper. 1990. Agronomic Zones for the Dryland Pacific Northwest. In: Pacific Northwest Extension Publication, PNW 354. http: //extension.oregonstate.edu/catalog/pdf/pnw/pnw354.pdf.

Eccles, J. S., & Wigfield, A. 2002. Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*, 109-132. doi: 10.1146/annurev.psych.53.100901.135153

Eigenbrode, S.D., O'Rourke, M., Wulfhorst, J.D., Althoff, D.M., Goldberg, C.S. Merrill, K., Morse, W., Nielsen-Pincus, M., Stephens, J., Winowiecki, L, and Bosque-Pérez, N.A., 2007. Employing Philosophical Dialogue in Collaborative Science. BioScience, 57: 55- 64.

Hsieh, C.I., Katul, G., Chi, T., 2000. An approximate analytical model for footprint estimation of scalar fluxes in thermally stratified atmospheric flows, Advanced Water Resources 23, 765-772.

Klein, J.T., 2008. Evaluation of interdisciplinary and transdisciplinary research: a literature review. American Journal of Preventive Medicine. 35(Suppl.2), S116–S123.

Knobloch, N. A., & Ball, A. L. 2003. *An examination of elementary teachers and agricultural literacy coordinators' beliefs related to the integration of agriculture.* Retrieved from http://www.agriculturaleducation.org.

Liang, Y., H.T. Gollany, R.W. Rickman, S.L. Albrecht, R.F. Follett, W.W. Wilhelm, J.M. Novak, and C.L. Douglas. 2009. Simulating soil organic matter with CQESTR (v.2.0): Model description and validation against long-term experiments across North America. Ecol. Modeling. 220:568-581

Machado, S.M., K. Rhinhart, and S.E. Petrie 2006. Long-term cropping system effects on carbon sequestration in eastern Oregon. J. Environ. Qual. 35:1548-1553.

Malecki, C. L., Israel, G. D., & Toro, E. 2004. *Using "Ag in the classroom" curricula: Teachers' awareness, attitudes, and perceptions of agricultural literacy* (AEC 370). Retrieved from University of Florida, Florida Cooperative Extension Service and Institute of Agricultural and Food Science: http://edis.ifas.ufl.edu

Masse, L.C., Moser, R.P., Stokols, D., Taylor, B.K., Marcus, S.E., Morgan, G.D., Hall, K.L., Croyle, R.T. and Trochim, W.M. 2008. Measuring collaboration and transdisciplinary integration in team science. American journal of preventive medicine, 35: S151-S160.

National Research Council. 1988. Agricultural Literacy. *Understanding Agriculture: New Directions for Education* (pp. 1-65). Washington, DC: National Academy Press

Olfert, O., and R. M. Weiss. 2006. Impact of climate change on potential distributions and relative abundances of *Oulema melanopus*, *Meligethes viridescens* and *Ceutorhynchus obstrictus* in Canada. Agriculture Ecosystems & Environment 113: 295-301.

Olfert, O., R. Weiss, S. Woods, H. Philip, and L. Dosdall. 2004. Potential distribution and relative abundance of an invasive cereal crop pest, *Oulema melanopus* (Coleoptera: Chrysomelidae), in Canada. The Canadian Entomologist 136: 277-287.

Patton, M.Q. 2008. Utilization-focused evaluation (4th ed.). Thousand Oaks, CA: Sage.

Shih, T, & Fan, X. 2008. Comparing response rates from web and mail surveys: A meta-analysis. *Field Methods*, *20*, 249-270. doi: 10.1177/1525822X08317085

Stokols, D., Fuqua, J., Gress, J., Harvey, R., Phillips, K., Baezconde-Garbanati, L., et al., 2003. Evaluating transdisciplinary science. Nicotine & Tobacco Research. 5(Suppl. 1): S21– S39.

Tress, B., G. Tress, and G. Fry. 2006. Defining concepts and the process of knowledge production in integrative research. Pages 13-26 in B. Tress, G. Tres, G. Fry, and P. Opdam, editors. From landscape research to landscape planning: aspects of integration, education and application. Wageningen UR.

Wagner,C.S., Rossner, J.D., Bobb, K., Klein, J.T., Boyack, K.W., Keyton, J., Rafols, I., Borner, K., 2011. Approaches to understanding and measuring interdisciplinary scientific research (IDR): A review of the literature. Journal of Informetrics. 165:14-26.