Request for Information (RFI) – ARS Long-Term Agro-Ecosystem Research

The R. J. Cook Agronomy Farm, Pullman, WA

The *R. J. Cook Agronomy Farm (CAF),* (http://css. wsu.edu/cook/) was launched as a long-term, direct-seed cropping systems research program by a team of USDA-ARS and Washington State University (WSU) scientists in 1999 (Fig. 1). The 57-ha CAF is located near Pullman, WA in the high annual rainfall zone (550 mm). The CAF has soils and landscapes representative of dryland annual cropping systems and provides research data applicable to over 1 million ha in WA and 405,000 ha in ID. The complexity of the CAF landscape offers a highly suitable environment for studies on landscape controls over soil and crop physiological processes. The CAF is managed with continuous direct-seeding techniques using commercial-scale equipment. Process-oriented and applied research is conducted at plot, landscape and farm scales to advance knowledge of field-scale biophysical and economic processes with the overall goal to further develop direct-seed cropping systems, precision agriculture technologies and decision aids.

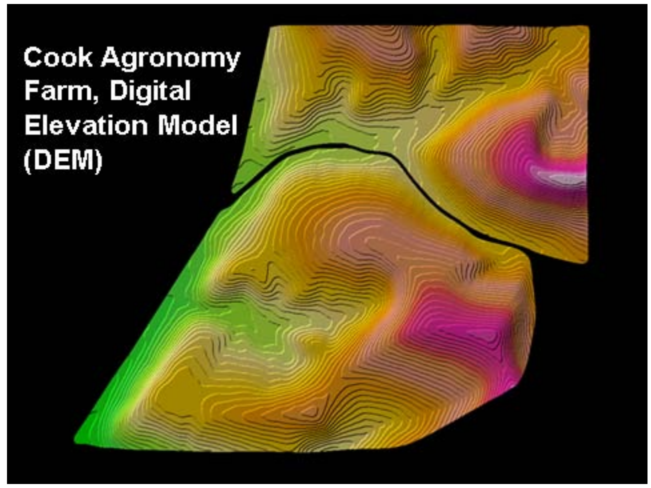

Figure 1.The R.J. Cook Agronomy Farm, 57-ha DEM.

Recent and on-going research

The CAF functions as a key research facility for a suite of agricultural research projects that involve trans-disciplinary research efforts developed through an on-going partnership among three Land Grant universities (Washington State University, University of Idaho and Oregon State University) and the USDA-ARS. These research projects include: USDA CSREES NIFA Planning Grant Award "Sustainable Agroecosystems Science Long-Term Agroecosystem Project" (LTAP); USDA NIFA CAP grant award "Regional Approaches to Climate Change for Pacific Northwest Agriculture" (REACCH); and USDA NIFA Standard grant award "Site-Specific Climate Friendly Farming" (SCF). In addition, the CAF is a major research site for the USDA-ARS CRIS 212 Climate Change, Soils & Emissions project "Mitigating Agricultural Sources of Particulate Matter and Greenhouse Gas Emissions in the Pacific Northwest" (Lead scientist, David Huggins, Land Management and Water Conservation Research Unit). The following summarizes key elements of these projects and the role of the CAF and associated USDA-ARS scientists.

LTAP: Funded in 2009, this project initiated the development of a CSREES (now NIFA) Sustainable Agroecosystems Science Long-Term Agroecosystem Project focused on dryland cereal-based production systems in the Inland Pacific Northwest (IPNW). The LTAP represents an important part of a coordinated network of national projects focusing on agricultural soil organic carbon (SOC) and reflecting the heterogeneity among US production systems. The IPNW LTAP addressed three requisites for integrating technical, biogeophysical, and socioeconomic aspects to sustaining SOC in agroecosystems: (1) to clearly communicate the existing health of the agroecosystems and the long-term prospects for continued productivity and profitability; (2) to provide a landscape perspective for studying the agricultural systems and policies that emphasizes the connections to local and regional environments; and (3) to address the critical needs for investment in education and training for future farmers and stakeholders. The CAF is key to the LTAP effort as baseline (1999) and subsequent sampling (2009) of the soil profile, 0-1.5 m, was conducted by USDA-ARS scientists (D.R. Huggins and J.L. Smith) to characterize SOC at 182 geo-referenced points across a 37-ha field in order to assess management and soil/landscape interactive effects on SOC (Co-P.I., D.R. Huggins)

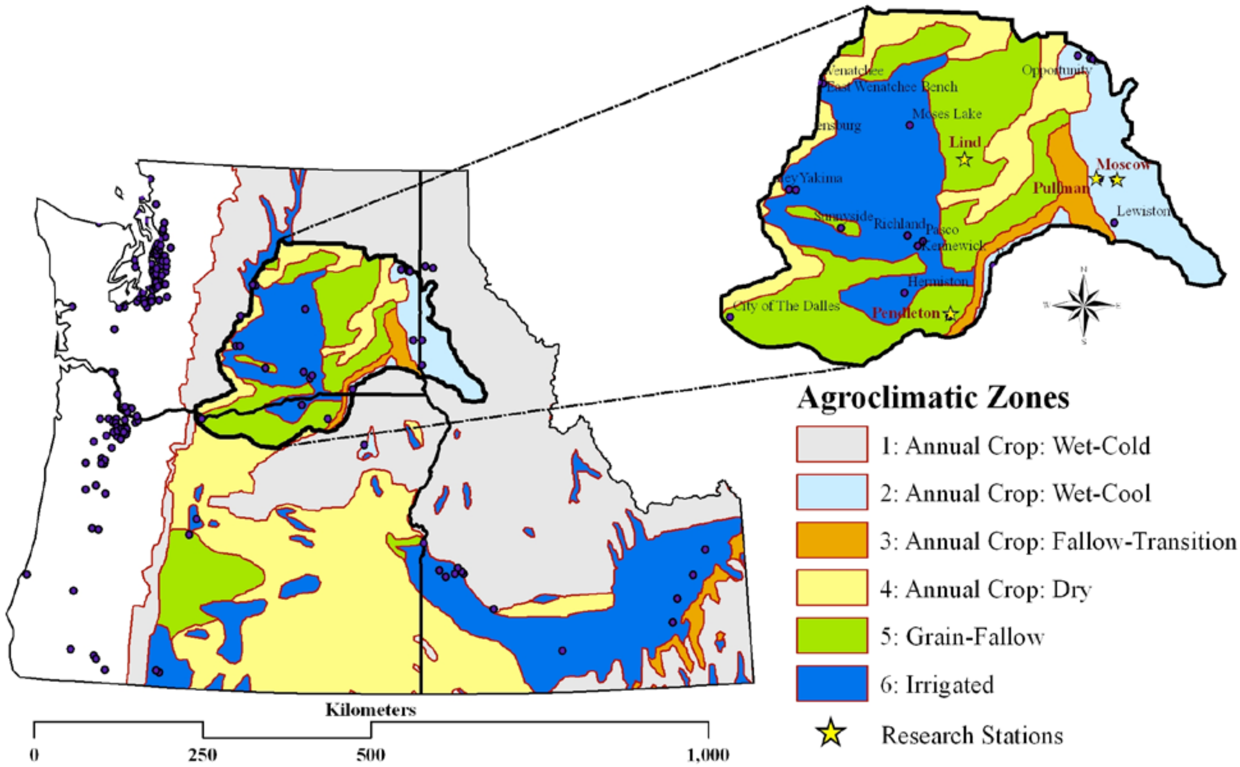

Figure 2. The study region for the IPNW SAS-LTAR. Agroclimatic zones are based on precipitation, temperature regimes and cropping system (listed). The project addresses zones 2 to 5, where dryland cereal-based systems predominate. Stars identify locations of four experiment stations (including CAF) that serve as important sources of data for farmers within each region.

REACCH: An Integrated Cooperative Agricultural Project entitled "Regional Approaches to Climate Change for Inland Pacific Northwest Agriculture (REACCH) was initiated in 2011 by scientists from three Land Grant universities and the USDA-ARS to increase the capacity of Inland Pacific Northwest cereal production systems to adapt to and mitigate climate change. The nine objectives of the project are:
Objectives 1-5: employ climate, cropping systems and economic modeling to establish an integrated theoretical framework for understanding the interactions between climate and agriculture in the region; assess alternative production systems for adapting to and mitigating climate change to meet NIFA targets for reduced emissions and increased efficiency; monitor soil carbon, nitrogen, energy, water efficiency and greenhouse gas production under current and alternative cropping systems; employ social and economic surveys, economic modeling to understand the factors governing alternative system adoption; examine implications of climate change for crop pests, pathogens, and weeds.
Objective 6: assist K-12 teachers in developing relevant curricula, and train graduate and undergraduate students to address climate change in agriculture.
Objective 7: engage stakeholders and provide them with information needed to respond to climate change.
Objective 8: build institutional capacities for continued research, extension and education concerning climate change and agriculture.

Objective 9: employ transdisciplinary synthesis, including a life cycle analysis, for a holistic, system-wide understanding and basis for appropriate responses to climate change in Inland Pacific Northwest agriculture.

The CAF is a primary research location for REACCH project objectives that involve the monitoring of greenhouse gases, cropping system assessment of N and water use efficiency, economic analyses and biophysical modeling, all at the landscape and watershed scale. USDA-ARS scientists on the project are Co-P.I.s: D.R. Huggins, B.S. Sharratt, F. L. Young, and T.C. Paulitz.

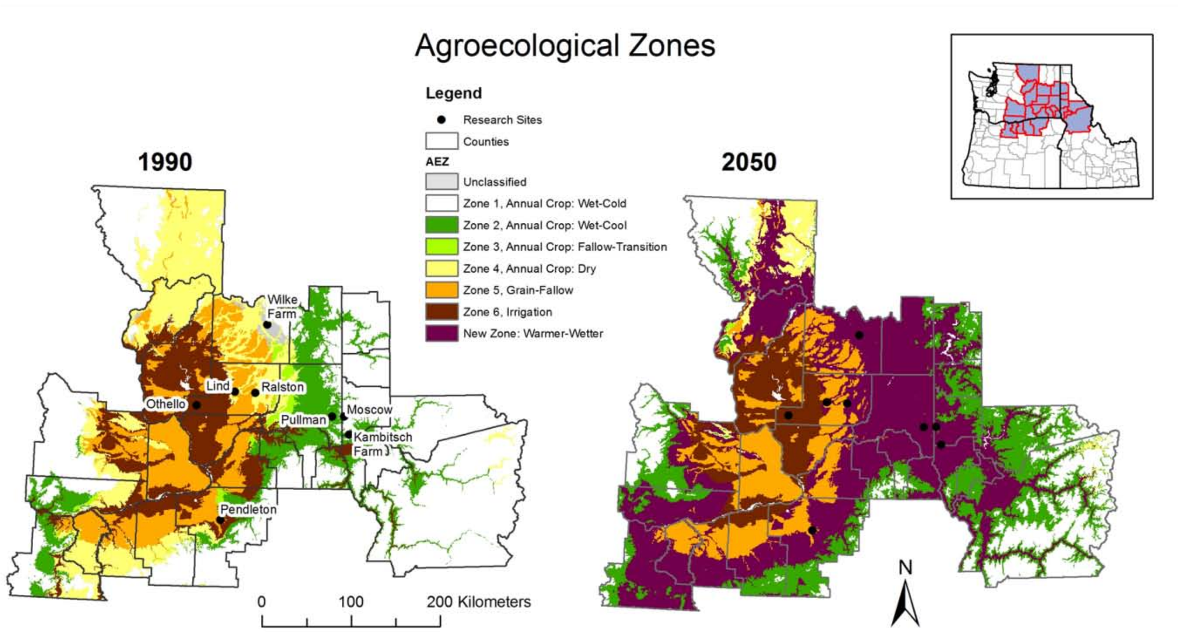

Figure 3. Agroecological Zones (AEZ) of the inland Pacific Northwest Region are the focus of REACCH. Zonation is based on data from WorldClim Global Climate Data (http://worldclim.org) with criteria for delineation after Douglas et al. (1990). Predominant cropping systems are based on production records and observation. Projection for 2050 was generated from the Canadian Centre for Climate Modeling and Analysis global climate model with the A2 emission scenario for CO2 and climate surface interpolation (Hijmans et al. 2005). Locations of experiment stations (including CAF) for long-term REACCH trials are indicated.

SCF: The Site-Specific Climate Friendly Farming (SCF) project was initiated in 2011. Site-specific nitrogen (N) management has the potential to mitigate climate change by reducing agricultural N_2O greenhouse gas emissions and by helping growers adapt to changing climate through the development of decision support systems to scientifically manage cropping practices and N applications for maximum profit and minimum N losses (NO_3^- leaching and N_2O emissions). Project scientists will integrate a proven biophysical crop growth model (CropSyst) with a management-oriented landscape hydrology model (Soil Moisture Routing) and a farm-scale economic model. The Palouse wheat-based cropping region in Eastern Washington and Northern Idaho serves as an ideal study area for the SCF, with mean annual precipitation from 200 to 750 mm, substantial soil variability and hilly terrain. To improve the CropSyst N_2O emission module, we are deploying at the CAF, cutting-edge field analyzers to make extensive (32 chambers) and continuous N_2O and CO_2 flux measurements as part of a series of cropping systems experiments looking at the effects of crop density and N application rates on N_2O emissions, NO_3^- losses, water and N use efficiency. To parameterize the coupled model at a scale and resolution needed for site-specific management, we are using a penetrometer-deployed Visible and Near-Infrared spectrometer to map key soil features at the CAF and a combination of terrestrial LiDAR, airborne LiDAR and red-edge satellite imagery to map crop growth and N content. The hydrology model is being calibrated using distributed wireless soil/water sensor arrays on five fields, and the coupled model will be rigorously tested on an additional four uncalibrated fields. The CAF is serving as the primary, Tier 1 site where intensive monitoring of landscape and watershed scale processes is occurring. Co-P.I.s on the SCF project are USDA-ARS scientist J.L. Smith and D.R. Huggins.

USDA-ARS CRIS 212: The project entitled "Mitigating Agricultural Sources of Particulate Matter and Greenhouse Gas Emissions in the Pacific Northwest" was initiated in 2010. Mitigating greenhouse gas (GHG) emissions produced by agricultural practices will contribute toward reducing atmospheric GHG's and sustaining soil resources. Intensive tillage, coupled with inefficient use of N fertilizer increases GHG emissions, notably nitrous oxide (N_2O) and carbon dioxide (CO_2), which drive climate change. Related to the CAF, this project will: (1) increase process-level knowledge of soil C and N cycling and factors regulating GHG emissions; and (2) develop conservation cropping systems and precision N management strategies that mitigate GHG emissions. Studies include assessment of: (1) soil C and N cycling and emissions of GHG's as influenced by soil, terrain and cropping system drivers; (2) N use efficiency under conventional and site-specific N management and (3) the impact of conservation-based practices such as reduced tillage and crop rotation on mitigation of GHG emissions. Anticipated deliverables include: (1) databases for the GRACEnet and REAP national programs; (2) regional summary documents of GHG and soil C sequestration for action agencies and stakeholders; and (3) decision-aids for conservation practices that reduce GHG emissions from agricultural fields, while increasing N use efficiency and soil C storage.

Specific research at the Cook Agronomy farm: Baseline sampling at the CAF was initiated in 1999 when 369 geo-referenced points were established in a non-aligned systematic grid (Fig. 4). These locations serve as sampling and monitoring points for many of the following research projects.

a. *Soil C and N processes*
b. *Landscape hydrology*
c. *Water quality*
d. *Greenhouse gas monitoring*
e. *Weed seed-bank dynamics*
f. *Soil-borne pathogens*
g. *Residue management*
h. *Precision agriculture*
i. *Direct-seed cropping systems*
j. *Biophysical modeling*
k. *Economic analyses*

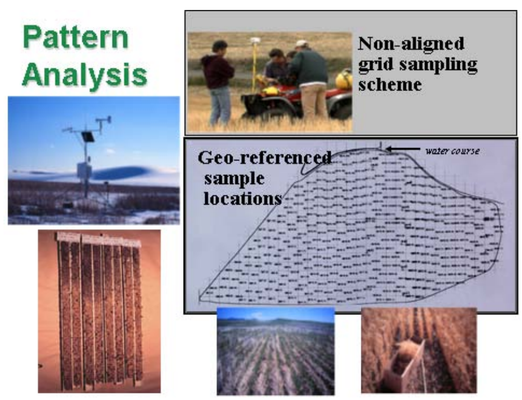

Figure 4. Geo-referenced sample and monitoring locations at the CAF.

Soil C and N processes: One objective at the CAF is to investigate roles of environmental and management drivers on soil C and N cycling as factors regulating GHG (N_2O, CO_2) emissions from agricultural soils. USDA-ARS scientists Smith and Huggins are: (1) determining soil C sequestration rates and CO_2 flux as influenced by agroecosystem drivers (e.g. soil, topography, micro-climate, organisms, management); and (2) determining biogeochemical dynamics of soil C and N including N_2O flux as influenced by agroecosystem drivers (e.g. soil, topography, micro-climate, organisms, management). These studies are under Objective 3 of the CRIS 212 and are part of GRACEnet (Greenhouse Gas Reduction through C sequestration and Carbon Enhancement Network) and REAP

(Renewable Energy Assessment Project) which have been established to provide information on management impacts on greenhouse gas emissions and soil C status. This research assesses conversion from conventional tillage to no-tillage and crop rotation effects on rates of soil C storage (and consequent effects on CO_2 equivalents) across variable soil and landscape-scale attributes of the CAF. 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-present. 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 (1999 to present) 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; and (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) were repeated in 2009 at the 182 geo-referenced locations and are 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 C on a landscape basis for the ten year period to assess SOC sequestration. Other activities that support this research at the CAF are development of a relational database (Access) with metadata; and enterprise budget analyses for nine years of cropping systems trials.

Landscape hydrology: The Palouse region, comprising of deep eolian loess soils in eastern Washington and northern Idaho, provides an ideal test bed in which to study the inter-related spatial variability of landscape hydrology, agricultural C/N cycling, and GHG emissions for a range of soil, topographic and climatic conditions. Regionally, mean annual precipitation (MAP) ranges from ~300 mm in the lower elevation western region to 750 mm in the higher elevation eastern regions. To the west, calcic horizons with minimal structural development dominate. Moving east, pH values drop and argillic horizons become more common, grading into dense fragipans in Latah County, ID. These argillic and fragipan horizons in the central and eastern regions of the Palouse greatly restrict water flow and root development, resulting in extensive lateral and vertical H_2O and solute movement on the Palouse. The Palouse also offers some of the hilliest cultivated land in the US, producing highly variable field conditions with respect to soil, elevation, slope, aspect, microclimate, water storage and movement. Research sites (farm fields) utilized for the SCF project were assigned to three tiers according to decreasing measurement intensity: <u>Tier 1)</u> the centrally located CAF is hosting intensive and extensive measurements, sensor networks, and experimentation; <u>Tier 2)</u> four no-till farms spanning the Palouse climate-soil gradient have been identified for instrumentation and measurements focused on spatial modeling; and Tier 3) a second set of four no-till farms spanning the Palouse climate-soil gradient will be utilized to independently validate spatial and process models developed on the five Tier 1 and 2 sites.

Topographically driven flows of water and highly soluble NO_3^- through landscapes cause greater N_2O emissions at topographic positions in which water and NO_3^- are gathered than at positions from which they are shed. Science-based site-specific N management requires an ability to sense and/or model field-scale hydrologic processes. The catena concept posits that topography controls hydrology and soil formation. On landscapes where this relationship holds true, both hydrologic dynamics and soil properties can be predicted using digital terrain models. However, perhaps in a majority of landscapes, topography-hydrology-soil relationships are far more complex. Studies to date at the CAF have evaluated spatial patterns of stored soil water (Ibrahim, Hesham M. and David R. Huggins. 2011. Spatio-temporal patterns of soil water storage under dryland agriculture at the watershed scale, J. of Hydrology 404: 186-197); and the field-scale distribution of snow (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 Soil Water Storage. Nov.-Dec. 2011 issue ASABE). Current research at the CAF is evaluating small watershed, soil and landscape influences on hydrologic processes as a part of the SCF project. The CAF currently hosts a wireless sensor array measuring volumetric water content (θ), temperature (T), and electrical conductivity (EC) at 42 distributed locations. At each location, five ECH2O-TE probes (Decagon Devices, Inc. Pullman, WA) are installed at 30-cm depth intervals from 30 to 150 cm, and connected to Em50R Data Loggers (Decagon Devices) with radio transmitters. A Decagon DataStation and CR850 data logger (Campbell Scientific, Inc., Logan, UT) collect radio-transmitted sensor data, and a Raven 1000 CMDA cell modem (AirLink Communications, Hayward, CA) allows data to be downloaded via a static Internet protocol (IP) address. This system has functioned flawlessly for three years, though cables must be disconnected and buried during field operations. Additional measurements and monitoring with the SCF project include 15 min surface runoff and drain tile flow using dataloggers, pressure sensors, and flumes. The loggers trigger water samplers to capture event based nitrate, total carbon and sediment loading. We have 13 locations on the CAF where we have installed shallow (30 cm) and deep (1 m) suction lysimeters which will be used to quantify spatial and temporal changes in nitrate concentrations within a small internal catchment of the CAF. We also have established shallow screened wells at each of the 13 locations to track changes in perched water levels in addition to three deep wells to track deep groundwater above basalt. We have installed pvc line sources in one hillslope at the CAF to conduct hillslope-scale chloride and bromide tracer studies. We currently have one drain gauge installed at the main weather station to track vertical water fluxes and nitrate leaching below the root zone (5 ft) throughout the year with plans to install two more of these in the near future on a north and south slope. We are also working with Decagon Devices to install and test large weighing lysimeters (next spring) which will allow measurement of evapotranspiration, vertical water fluxes below the root zone, and nitrate leaching. We plan to map saturated areas, surface soil moisture and snow distribution throughout the winter/spring. These monitoring efforts will be combined with other SCF project objectives to construct high spatial resolution (< 30 m), field-scale soil feature maps using a penetrometer mounted Visible and Near-Infrared sensor and digital soil mapping techniques. In addition, the SCF project objectives include testing and application of novel laser-based (terrestrial LiDAR scanner, years 1-4 of project, and aerial LiDAR scanner, years 3-5) and multispectral remote sensing techniques (from RapidEye, Inc., a prime USDA vendor, providing imagery including red-edge measurements every 5.5 days with a 6-m spatial resolution) to dynamically map spatial patterns of crop biomass, LAI, N content, and chlorophyll content throughout the growing season at the CAF for inclusion in field-scale biophysical and economic models.

Water quality: Studies to date at the CAF include monitoring of water flows and nitrate concentrations associated with artificial subsurface drains (tile lines) and surface waters (Keller, C. Kent, C.N. Butcher, J.L. Smith and R.M. Allen-King. 2008. Nitrate in Tile Drainage of the Semiarid Palouse Basin. J. Environ. Qual. 37:353–361). This long-term CAF project continues with the evaluation of buffer strips as well as sources of nitrate using stable oxygen isotope analyses funded through an NSF IGERT project (NSPIRE) as well as the REACCH project (J.L. Smith is the USDA-ARS scientist involved with this research).

Greenhouse gas monitoring: Greenhouse gas (GHG) flux measurements at the CAF were initiated in 2011 under the REACCH and SCF projects with scientific leadership from Smith and Huggins. A total of 64 automated chambers (four LI-COR LI-8150-16 multiplexers with 16 connected 8100-104 long-term 20-cm diameter soil flux chambers, CO_2 flux, coupled to Teledyne, N_2O flux, each fitted with a Decagon Devices, 5TE soil moisture, temperature, and electrical conductivity sensor) were deployed on microplots at the CAF with treatments consisting of water, nitrogen supply and available C. Future studies are planned to assess GHG flux at different landscape positions on the CAF to characterize the spatial and temporal variability of N_2O fluxes and to record the timing of major flux events. Coupled with these studies will be additional microplot experiments with episodic treatments designed to examine N_2O flux dynamics through the controlled application of water, N and available C. Field-scale measurements of GHG were initiated at the CAF in 2011 under REACCH using micrometeorological eddy covariance (EC) flux methods in conjunction with the point-scale measurements. The WSU Laboratory for Atmospheric Research has primary responsibility for these EC measurements.

Weed seed-bank and soil-borne pathogen dynamics: Extensive geo-referenced grid sampling has been used at the CAF to monitor changes in weed seed banks and soil-borne pathogens with the imposition of no-tillage crop rotations across soils and landscapes. Dr. Tim Paulitz (USDA-ARS plant pathologist) has documented pathogen changes over time while Dr. Ian Burke (WSU weed scientist) has monitored weed seed-bank changes.

Residue management: Crop residues are considered to be an important lignocellulosic feedstock for future biofuel production. Harvesting crop residues, however, could lead to serious soil degradation and loss of productivity. Research at the CAF has evaluated trade-offs associated with harvesting residues including impacts on soil quality, soil organic C and nutrient removal. Cropping systems data collected at 369 geo-referenced points on the 37-ha CAF were used to estimate lignocellulosic ethanol production from winter wheat residues as well as trade-offs with respect to soil organic matter, soil erosion, soil quality and nutrient removal as a part of USDA ARS REAP (Huggins and Kruger, Site-Specific Trade-offs of Harvesting Cereal Residues as Biofuel Feedstocks. Biomass and Bioenergy, in review).

Precision agriculture: Current research at the CAF (Huggins) illustrates the large within-field variations in wheat yield and protein (Fig. 5) and the inadequacy of current N recommendations. In this example, uniform N applications were applied to achieve targeted goals of 4 Mg/ha of grain with 140 g/kg protein. Results of this strategy were spring wheat yields that ranged from 1 to 5 Mg/ha, grain protein that ranged from 110 to 180 g/kg (Fig. 5), N uptake efficiencies that ranged from 12 to 48% of available N supplies and estimated N losses of 50 to 100% of applied N fertilizer (Huggins *et al.*, 2010). We hypothesize that site-specific N rates must be coupled with wheat stand density manipulation so that both N and water use are seasonally regulated. Winter wheat is currently grown in a three-year rotation on 1/3rd of the CAF. As part of the CRIS 212 and SCF research, field studies are underway in locations scheduled for winter wheat and in landscape positions that have been identified to have low (southern aspects with argillic horizon), medium (northern aspects without argillic horizon) and high (footslopes) water storage potential

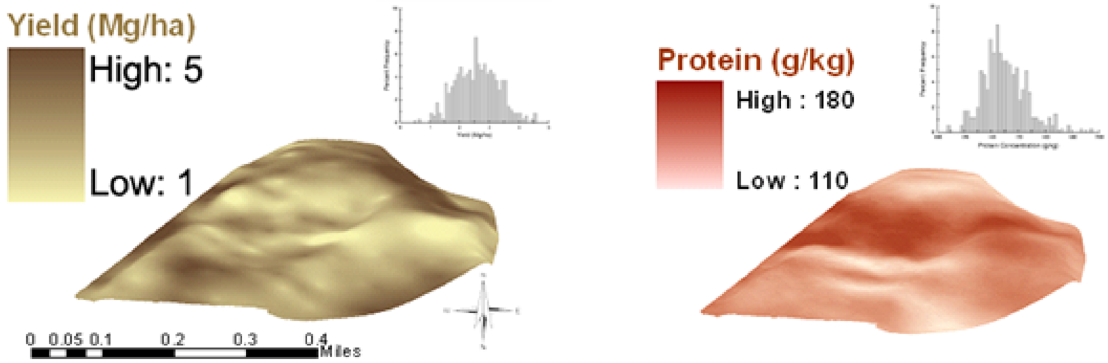

Figure 5. Uncorrelated spatial patterns and histograms of spring wheat grain yield and protein over the 37 ha Cook Agronomy Farm (Huggins et al., 2010).

and related wheat yield. Within each of these landscape positions, N rate and seeding density experiments have been established and both water and N use efficiency are being assessed.

Key precision agricultural technologies that are available at the CAF to complement this research are: (1) a combine-mounted grain yield monitor; (2) an on-line NIR spectrometer that is combine-mounted to measure grain protein; (3) a global positioning system (GPS) receiver for geo-referencing elevation and position measurements; and (4) a variable rate controller for applying N fertilizer and seed.

Biophysical modeling: The CropSyst model developed by C. Stöckle (WSU) will be used in the REACCH and SCF studies to conduct field-scale (CAF) as well as regional climate change impacts and mitigation baseline and projections. CropSyst is a multi-year, multi-crop model developed as an analytical tool to study the effect of climate, soils, and management on cropping systems productivity, water use and hydrology, nutrient cycling and fate, and the environment. CropSyst has been evaluated and used in the US Pacific NW and in many world locations. In addition to its capabilities for evaluating cropping systems, SOC dynamics and GHG emissions, CropSyst was recently enhanced to assess the effect of climate change on agricultural systems, including plant responses to increasing warming and atmospheric CO_2 and to assess the potential for carbon sequestration in the PNW. These capabilities, linked to climate and socio-economic models, will be exploited during the REACCH project to describe current and predicted cropping system performances pertaining to mitigation and adaptation in a GIS framework. Parameters in CropSyst can be set to represent conditions in current and anticipated climatic conditions within specific zones of the study region. Monitoring and experimental data from field studies including those at the CAF will be used to calibrate and evaluate the model.

Cropping system and economic analyses: Economic analyses at the CAF include simple enterprise budgets that serve to make comparisons among the different crop rotations as well as an economic modeling component using the recently developed minimum-data tradeoff analysis model (TOA-MD), a new approach to agricultural systems modeling based on statistical characterization of the population of farms in a stratum (Antle and Valdivia 2006, Antle 2010). The cropping system studies are under the leadership of D.R. Huggins (USDA-ARS) while the economic analyses associated with the CAF are being conducted by faculty at the University of Idaho (Painter) and at Oregon State University (Antle, Capalbo). The TOA-MD is an extension of earlier work on farm- and regional scale integrated assessment modeling to assess greenhouse gas mitigation and climate impact adaptation. The TOA-MD model has been validated and shown to produce results comparable to more elaborate, data-intensive models and can be used to analyze the adoption of new production technologies or systems such as those intended to mitigate GHGs or adapt to climate change, using outputs from crop simulation models to measure the productivity of the new systems. TOA-MD is also designed to evaluate the adoption of systems based on their estimated changes in GHG emissions, together with policy incentives such as carbon offsets, conservation subsidies, or payments for ecosystem services. The TOA-MD is a parsimonious model that can be implemented with either primary (e.g., farm survey) or secondary (e.g., *USDA - NASS - Census of Agriculture*) economic data, together with technical data such as GHG emissions, crop productivity, and environmental impacts. For the REACCH project, the performance of cropping systems designed to mitigate GHGs or to adapt to climate change such as those at the CAF will be investigated under alternative climate and policy scenarios.

Research network

The CAF is a part of an overall regional network of experiment station and on-farm collaborators within the PNW. The LTAP, REACCH, SCF and CRIS 212 research projects have worked toward establishing this network to ensure that research at the CAF is contextual and integrated with other locations across the region. To aid this process, the REACCH project initiated the development of agroecological zones (AEZ' s) for the PNW under the scientific leadership of USDA-ARS scientist D.R. Huggins. The AEZ concept is typically employed as a descriptive tool to assess the spatial distribution of crop-relevant resources, their capabilities, and the potential for future uses as part of strategic planning. In the REACCH project we are using projected AEZs to anticipate and develop mitigation and adaptation strategies. Thus the AEZ is part of a prescription for land management, given climate change. The CAF is an integral component of this overall geospatial-temporal context.

Relational database and cyber-infrastructure

The database for the CAF is currently in Microsoft Access. This database is being upgraded to create a legacy dataset complete with metadata as a part of ongoing research efforts through the LTAP and REACCH projects. Dr. Gessler (U of Idaho) is leading efforts to build the legacy datasets for the CAF. Recommendations of database structure and metadata base standards from the cyberinfrastructure team (LTAP and REACCH studies) are in the process of being tested using the CAF database as an example. Expected outcomes of this effort include database organization complete with metadata for the CAF research site and further recommendations for proceeding with other databases (e.g. Pendleton long-term datasets). Cyberinfrastructure (CI) includes computing infrastructure, data, models, collaboration and visualization tools, and intellectual capacity to geographically dispersed, scientists and stakeholders. CI will therefore be essential for inter-institutional engagement in research, research-based education, and outreach concerning climate change and IPNW agriculture. The regional climate models for the REACCH study will depend upon distributed sensor networks, remote sensing data layers, and other regional data. State of the art methods for uploading, archiving, accessing, and synthesizing large amounts of data will be employed to run and interpret these models and to incorporate data acquired from our various research objectives and the legacy data that pertain (e.g. Brown and Huggins 2010). We will, as part of the REACCH and LTAP projects, utilize cyberinfrastructure and data management policies similar to those in place for LTER and other long-term projects, and will be linked closely with the Idaho-Nevada-New Mexico NSF EPSCoR project *Water Resources in a Changing Climate*. The REACCH project is in the process of hiring a full time information specialist who will work with the PIs and institutions to oversee CI development, a web development specialist, and a programmer. One PhD student will focus on aspects of CI for use in communication with farmers and other stakeholders. The Information Specialist and supporting personnel will: (1) create a policy data library, (2) migrate legacy data to an integrated database, (3) disseminate data to faculty and develop and test user interfaces, (4) ensure interoperability with other networks, (5) develop a shared cyber environment across the project, (6) build cybernetworking capacity among the partner universities and USDA-ARS, (7) investigate, improve, and maintain cybercollaborative support for the project including the use of smartphone applications.

Physical facilities and personnel

The Land Management and Water Conservation Research Unit is located on the Washington State University campus (Johnson Hall). Unit scientists are located on campus (Johnson Hall) and include Dr. David Huggins, soil scientist, Dr. Ann Kennedy, soil microbiologist, Dr. Brenton Sharratt, Research Leader and soil scientist, Dr. Jeff Smith, soil biochemist, and Dr. Frank Young, agronomist. These scientists have 108 scientists years of research experience in the IPNW. Over this period of years, scientists have produced 240 peer-review publications and 50 book chapters. Unit scientists have been successful at securing grants with a total allocation in FY2012 expected to be $650,000. The level of processed-based understanding of agroecosytems is exemplified above under the section heading entitled " Specific research at the Cook Agronomy Farm". At the CAF, Unit scientists have contributed to a better understanding of the agroecostyem by examining soil C and N processes, landscape hydrology, water quality, greenhouse gas emissions, weed seed-bank dynamics, soil-borne pathogens, residue management, precision agriculture, direct-seed cropping systems, biophysical modeling, and economic analyses. Unit support staff includes one secretary, six laboratory or field technicians, and one farm manager. Three of the scientists (Drs. Huggins, Kennedy and Smith) associated with the CRIS 212 have laboratory space on campus (Johnson Hall) while the remaining scientist on the CRIS (Dr. Sharratt) has laboratory space at the Palouse Conservation Field Station. Each of the scientists associated with the CRIS is assisted by one technical staff. The USDA-ARS soil biochemistry (Smith) and soil microbiology (Kennedy) laboratories in Johnson Hall are equipped with a C/N/S analyzer, gas chromatographs for fatty acid and trace gas analyses and mass spectrophotometer for ^{15}N and ^{13}C analyses. The soil microbiology laboratory adjoins a clean air room, with biosafety hoods for sterile transfer and microscope, and a room for media preparation. The laboratories are equipped with computers for data input and manipulation and literature searches. Other equipment available in laboratories includes temperature controlled water circulators, digital photographic equipment, fiber analyzer and near infrared spectrometer. Several freezers, refrigerators and two ultracold freezers are available for sample storage.

The WSU Cook Agronomy Farm (CAF) has a large building that houses field equipment, office, walk in cooler and sample processing space. Equipment associated with the CAF includes direct seed drills, sprayers, mowers, balers, and a variety of tillage and precision farming equipment. The farm is six miles from the USDA Palouse Conservation Field Station and the staff share additional cultivation and soil sampling equipment as well as labor and expertise during critical periods. The farm is managed and operated by Ryan Davis (WSU) along with technical staff from individual research programs.

Institutional commitment

The original organizers of the CAF envisioned a 100-year plus research project that would serve as a legacy research site and database for the Palouse region. Since its inception in 1999, the CAF research effort has garnered significant support from contributing partners as well as research grants (Fig. 6). Now through the combined efforts and partnership of the three Land Grant universities and the USDA-ARS, the CAF is a part of a well-funded, vibrant research effort that includes the LTAP, REACCH, SCF and USDA-ARS CRIS 212 projects. It is the intention of the Co-P.I.'s of these research efforts to establish a lasting legacy. Find enclosed support letters from USDA-ARS and WSU.

Figure 6. Research partnerships and grant support at the R.J. Cook Agronomy Farm.