Adapting Dryland Cereal Production to Climate Change

Professor Sanford D. Eigenbrode

ADAPTING DRYLAND CEREAL PRODUCTION TO CLIMATE CHANGE

Cereal production is vulnerable to climate change. **Professor Sanford Eigenbrode** is the Project Director of Regional Approaches to Climate Change for Pacific Northwest Agriculture (REACCH), a project that was initiated to address the challenges facing cereal systems in the Pacific Northwest USA**.** The project team organised a conference in November 2015 to share their findings and consolidate knowledge from experts on five continents. Here, we present the findings from this conference, which offer a range of solutions and challenges for adapting cereal systems worldwide to climate change.

The REACCH Project

Climate change presents a serious threat to global food security. Major staple crops systems face challenges worldwide due to ongoing and projected changes in precipitation and temperature. Among the most vulnerable are cereal systems in semi-arid regions, which are extremely vulnerable to fluctuations in precipitation and elevated temperatures. In the major semi-arid cereal growing area of the inland Pacific Northwest (Idaho, Oregon and Washington in the USA), scientists predict accelerating rising temperatures, accompanied by drier summers and wetter winters.

The challenge is to retain productivity in this rain-fed cereal system through crop resilience under changing water and temperature regimes. This can involve diverse solutions, such as reducing soil erosion and restoring soil fertility through different production practices and crop rotations, exploiting genetic resources to improve heat tolerance, water use efficiency and nitrogen use efficiency of cereals, and maintain or improve resistance to pests and diseases.

Addressing the challenge of climate change therefore requires a multidisciplinary approach that integrates knowledge from across many scientific domains. To achieve this, the United States Department of Agriculture's National Institute of Food and Agriculture (USDA-NIFA) funded a coordinated agricultural project called 'Regional Approaches to Climate Change – Pacific Northwest Agriculture' (REACCH – https://www.reacchpna.org). This seven-year project was led by a team of researchers from the University of Idaho, Washington State University, Oregon State University, and the USDA's Agricultural Research Service.

'The REACCH project was initiated in 2011 to ensure sustainable cereal production in the inland Pacific Northwest,' explains the Project Director, Professor Sanford Eigenbrode. 'Participants from many disciplines related to agricultural, climate, socioeconomics, and information sciences engaged in an integrated research, education, outreach and extension effort to study complex cereal production systems and their responses to drivers of change.'

Adapting Cereals to Climate Change

To share their findings with specialists working on cereal systems globally, the REACCH team organised a conference, entitled 'Transitioning Cereal Systems to Adapt to Climate Change' (TCSACC – https://aridcereals.nkn.uidaho.edu), at the Minneapolis Convention Centre in November 2015. Experts from 17 countries attended the conference, with backgrounds ranging from agronomy, plant physiology, crop protection, plant breeding and genetics, to computer modelling, sociology and economics. The conference emphasised the integration of diverse aspects of complex agricultural systems.

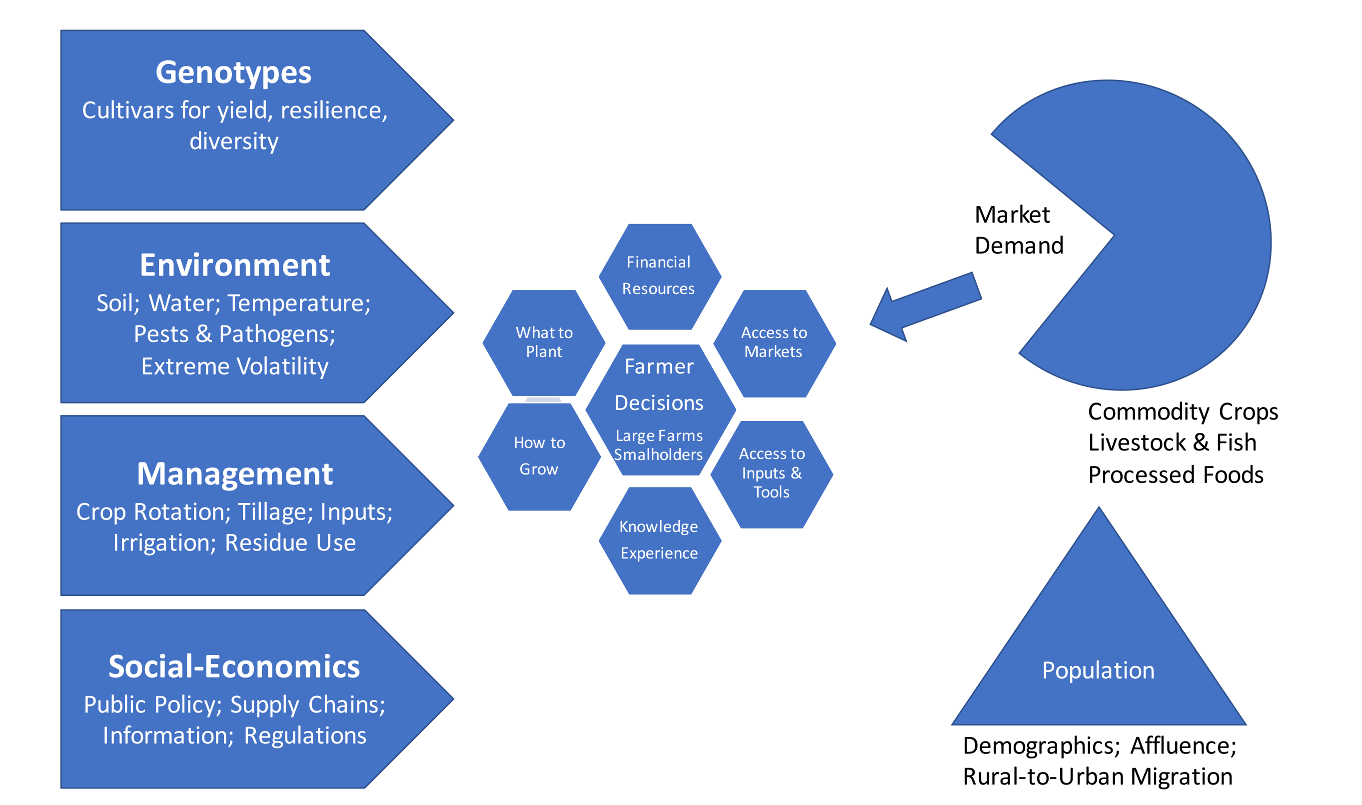
The goals of the workshop-style conference were to strengthen the global network of researchers addressing the impacts of climate change on semi-arid cereal-based systems, to share approaches to achieve multidisciplinary collaboration towards advancing climate change resilience in cereal systems, and to identify the necessary elements of a collaborative research agenda for advancing global food security.

In a paper published this year in *Frontiers in Ecology and Evolution*, Professor Eigenbrode and his colleagues Professor Patrick Binns and Dr David Huggins summarised the conference themes and conclusions, and suggested steps for action.

Water Scarcity

Cereal production systems in semi-arid habitats are mainly limited by available water. Climate change predictions suggest that water will become scarcer in many regions where cereals are grown. Agronomic approaches to increase water use efficiency include fallow periods, prudent tillage and residue management, and novel crop rotations. The REACCH project, for example, experimented with using different rotational crops (such as winter canola, winter pea and triticale), and water conserving technologies such as harvesting equipment that leaves enough post-harvest biomass in the field to trap winter moisture.

Professor Eigenbrode and the team noted that more research is needed to identify



Schematic representation of cereal production as a social-ecological system. The domains of environmental conditions of soil quality, precipitation, fresh water access, temperatures, pest pressures and extreme weather events, genotype properties of cultivars, annuals, perennials, root structure; biological N fixing stress tolerance, agronomic management of crop diversity, tillage, input use, animal integration residue retention, and social-economic factors that affect market demand, price signals, capital investment, public incentives, regulations, research; and cultural customs and attitudes all interact to establish the context, motivation and resources that influence farmers' decisions concerning how to adapt to changing climate regimes.

and evaluate the ability of alternative rotational crops and agronomic practices to improve the efficiency of water use. Climate projections can help farmers make decisions about which rotational crops to plant, while the availability of a wider range of economically-viable crops and methods would facilitate this type of adaptive management.

Plant breeding research is enabling cereals to improve their water and nutrient use efficiency, and drought resistance. However, TCSACC participants stressed the need for further improvements in the global coordination of these efforts. Studies have shown that when an approach that combines genetics (G), environment (E) and management (M) is deployed, yield and quality increases are greater than for approaches based only on a single technological innovation. At TCSACC, it was agreed that this approach should be extended to include societal factors that influence management decisions (i.e. G × E × M × S).

Discussions at the TCSACC conference also identified key needs for advancing crop adaptation to climate change, including improved technology for genomic selection, universal data-sharing, and better utilisation of cropping system models.

Managing Data

Professor Eigenbrode and his colleagues believe that developing climate-resilient cereal varieties will require the integration of empirical and modelling approaches. This is because it is impractical to conduct sufficient empirical studies replicated across variable production landscapes. Future solutions will therefore combine virtual cropping system models with field data collected using more accurate and affordable sensors and data acquisition systems. For example, the REACCH team used the CropSyst crop modelling system to guide their research on climate change and cereal production, which can be extended to evaluate the various rotational cropping systems needed for adapting to climate change.

In partnership with the University of Idaho's Northwest Knowledge Network (NKN), the REACCH team developed their own capabilities to acquire, store and manipulate data for semi-arid cereal production systems in the Pacific Northwest region. To optimise crop modelling, however, scientists need to draw upon the results of research conducted globally, through improved access to data.

Discussions at the TCSACC conference concluded that a key research restraint worldwide is the inadequate capacity and capability of existing data repositories to support accessibility to diverse data sets. The consensus was that new approaches are needed to acquire and manage diverse types of data relevant to entire crop production systems, and to share these across semi-arid regions. The data management system developed by the REACCH team was conceived as an eventual node within a broader collaboration to enable this type of data sharing.

Protecting Crops

Models for cereal production systems under pressure from climate change have often ignored associated changes in pressure from insect pests, diseases and weeds. Attempts to do so are difficult, due to the complexity of these interactions. However, studies have shown that climate-induced stress makes plants more susceptible to pests, pathogens and competition from weeds.

In their review focusing on the insect pests of wheat and climate change, Professor Eigenbrode and his colleague, CSIRO scientist Dr Sarina Macfadyen found that only 12 species had been studied, mostly using specific approaches such as population modelling, although better understanding requires multiple approaches in combination. Similarly, more research is needed into the effects of climate change on pathogens and weeds in cereal systems.

Within the REACCH project, pests, diseases and weeds were framed within a broader systems approach. The team's ongoing work involves incorporating insect feeding into process-based crop models for wheat such as CropSyst – for example, the effects of projected climate change on the damage to yield caused by the cereal leaf beetle.

As identified at the TCSACC conference, researchers need to start filling certain knowledge gaps concerning pests and climate change in cereal systems, including coupling long-term records of pest abundance with historical climate records. Furthermore, agronomic practices such as alternative tillage, rotation and nutrient management schemes are also likely to influence pests, disease and weed risks, warranting their monitoring as part of evaluations of alternative practices designed to adapt to climate change.

Mitigating Greenhouse Gases

Climate change impacts crop productivity, but crop production also contributes to climate change. Therefore, alongside adapting cereal systems to changing climates, it is also important to minimise the negative impacts of agriculture on the climate system. Agriculture is responsible for around 11% of total greenhouse gas emissions worldwide, with approximately 65% of this due to nitrous oxide emissions from agricultural soils, exacerbated by poor agricultural practices. Effective adaptation practices could therefore achieve 'win-win' benefits in terms of crop yields and more efficient use of nitrogen fertilisers, resulting in both improved productivity and reduced nitrous oxide emissions.

Researchers at the TCSACC conference noted that improved monitoring of greenhouse gas emissions from different cereal production and nutrient management practices is needed to identify how emissions could be minimised. In the INPW, the REACCH team looked at conventional and alternative wheat production systems under different precipitation regimes, in chambers that enabled nitrous oxide emissions to be measured. Their models indicated that nitrous oxide emissions in the region are less than those estimated by the Intergovernmental Panel on Climate Change (IPCC), though recent data from other regions of the USA showed higher-than-predicted emissions.

Social and Economic Factors

Agricultural systems are also social-ecological systems. Successfully adapting to climate change will depend upon technological capabilities, the economic costs and returns of adopting new practices, and factors that govern the behaviour of producers. In northern temperate regions, farmers have often been reluctant to accept the validity of climate change, reducing their likelihood of adopting new

practices. Studies have found that perception of risk varies, and is influenced by the level of indebtedness, awareness of alternative practices, age and other factors.

Social and economic dimensions were incorporated into the REACCH project at several levels. For example, modelling crop performance under different climate scenarios enabled the research team to project impacts on economic returns. The team also carried out surveys that assessed farmers' attitudes and perceptions about climate change, to guide research priorities and communication strategies. A key take-home message from the TCSACC conference was that integrated agricultural research responses to climate change should strive to understand sociological forces and incorporate them into interdisciplinary assessments and strategies.

Going Forward

In the final section of their *Frontiers in Ecology and Evolution* paper detailing the outcomes of the TCSACC conference, Professor Eigenbrode and his colleagues concluded: 'Based on discussions within TCSACC and this review, progress to achieving more integrated and effective approaches for addressing the challenges of climate change in semi-arid systems will be accelerated by improved interdisciplinary and intersectoral integration that can address production at a comprehensive systems level.'

TCSACC participants endorsed the importance of nurturing existing networks of scientists working to help cereal systems in semi-arid regions transition to respond to the changing climate. Professor Eigenbrode has said that the collaborations established during the REACCH project will continue. Action Steps undertaken since the conference include the establishment of an international Expert Working Group on Wheat Agronomy and a 'Community of Interest' within the Agronomy Society of America that is focusing on adaptation strategies for dryland cereal systems.

In summary, the conference addressed and endorsed a list of eight needed components of actionable research going forward:

- Establish coordinated, large scale, transdisciplinary efforts
- Consider genotype x environment x management x societal interactions
- Improve integration among knowledge communities
- Consider global context of production systems
- Develop more inclusive cropping system models
- Enable comprehensive data management and data sharing
- Include landscape and ecosystem services perspectives
- Establish and support existing global networks

Meet the researcher

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Professor Eigenbrode is a University Distinguished Professor and Professor of Entomology at the University of Idaho. He received his education at Cornell University, where he gained his BS and MSc, and then his PhD in 1990. Following this, he worked as a postdoctoral scientist at Cornell University, the University of California and the University of Arizona. He became Assistant Professor of Entomology at the University of Idaho in 1995, and he has been Professor of Entomology in the Department of Plant, Soil and Entomological Sciences there since 2006. More recently, he became Adjunct Professor of Entomology at Washington State University. Professor Eigenbrode's main research interests are ecology, chemical ecology, biological control, insect-plant interactions, host-plant resistance, and virus-plant-vector interactions.

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REFERENCES

SD Eigenbrode, WP Binns and DR Huggins, Confronting climate change challenges to dryland cereal production: a call for international collaborative, transdisciplinary research and producer engagement, Frontiers in Ecology and Evolution, 2018, 5, 164. http://doi.org/10.3389/fevo.2017.00164

SD Eigenbrode and S Macfadyen, The impact of climate change on wheat insect pests: current knowledge and future trends, in 'Achieving sustainable cultivation of wheat, Volume 1: Breeding, quality traits, pests and diseases', ed. P Langridge, 2017, 545–567 (Cambridge, UK: Burleigh Dodds Science Publishing).

JM Antle, JE Mu, H Zhang, SM Capalbo, PL Diebel, SD Eigenbrode, CE Kruger, CO Stockle, J Wulfhorst, and JT Abatzoglou, Design and use of representative agricultural pathways for integrated assessment of climate change in U.S. Pacific Northwest cereal-based systems, Frontiers in Ecology and Evolution, 2017, 5, 772. http://doi.org/10.3389/fevo.2017.00099

C Stöckle, Higgins, R Nelson, J Abatzoglou, D Huggins, W Pan, T Karimi, J Antle, SD Eigenbrode, and E Brooks, Evaluating opportunities foran increased role of winter crops as adaptation to climate change in dryland cropping systems of the U.S. Inland Pacific Northwest, Climatic Change. https://doi.org/10.1007/s10584-017-1950-z

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