



Canadian Foundation for Climate
and Atmospheric Sciences (CFCAS)

Fondation canadienne pour les sciences
du climat et de l'atmosphère (FCSCA)

Final Progress Report

Project Title: Quantifying Agricultural Drought in Western Canada

DRI Investigator: Paul Bullock

1.0 Project Work

1.1 Provide a summary description of a) the objectives of the study, b) the scientific findings and c) the project work undertaken.

The main objective of the project was to characterize and quantify agricultural drought on the Canadian prairies.

Sub-objectives:

- Identify drought indices that correlated closely with Canadian Prairie spring wheat yield and several quality parameters
- Validate and if necessary modify the soil water component of PAMII for spring wheat using detailed soil water and meteorological data obtained from five different sites in MB and SK
- Compare spring wheat evapotranspiration (ET) estimates from the modified PAMII to those obtained using the FAO56 Penman-Monteith and a simplified water balance method to determine the best means to obtain ET values
- Evaluate regional scale crop yield data as an indicator of agricultural drought
- Evaluate the possibility of using new Moderate Resolution Imaging Spectroradiometer (MODIS)-NDVI data to forecast crop yield on Canadian Prairie and identify the best period for making reliable yield forecasts

1.3 Describe the tangible results or the measurable outputs generated by the project and how these results have been taken up by user groups for policy development or operational improvements.

The research identified indices based on evaporative demand and water balance (supply versus demand) were more strongly correlated to wheat yield and quality than indices based on water supply (precipitation) or crop water use. Thus, common meteorological drought indices such as % of Normal Precipitation and Standardized Precipitation Index are not the best choice to reflect agriculture drought impacts.

The research found very similar values of ET were obtained using either the modified PAMII model or the FAO56 Penman-Monteith approach.

Regional scale crop yield data provided a coarse resolution assessment of agricultural drought but could not distinguish between areas that were affected by drought and those affected by excess moisture. These data are also not available for many months after the growing season and thus cannot be used for drought preparedness planning.

An analysis of MODIS NDVI data and its correlation to census agricultural region yields of four agricultural crops in western Canada during the period 2000 through 2006 demonstrated that 10-day composite MODIS NDVI data from the late June to late July period provides a good indication of crop yields by census agriculture region and can provide this information prior to the harvest of the crops.

2.0 Impact

2.1 Describe in broad terms how your work has contributed to the overall objectives of DRI and to our scientific understanding of drought.

We know that typical indicators of meteorological drought do not provide the best indication of the intensity and extent of agricultural drought. We know that derived agrometeorological parameters (evapotranspiration) provide a more accurate characterization of crop response to drought. We also know that MODIS images can provide an accurate indication of crop yield on the prairies prior to the harvest of the crop and, thus, provide useful information for drought preparedness planning.

2.2 Describe the significance / impact of the results in terms of some or all of the following areas:

- **The impact of the project on government policy development (federal, provincial or municipal);**
- **How the project has expanded contacts in partner organizations, or increased cross-disciplinary cooperation;**
- **Whether and how it has enhanced or improved the reliability of predictive methods related to the science;**
- **The impact of the project on your own institution (e.g. helped attract new students or personnel);**
- **Whether it has improved or increased the acquisition of funds from other agencies, or led to new partnerships;**
- **Any links with international initiatives and the potential impact of these (e.g. profile of Canadian science, influence on international programs);**
- **Any commercial or social application the results may have had or could have;**
- **The anticipated impact of the work on Canadians and their well-being;**

Paul Bullock has been invited to participate in a multi-provincial/state initiative on the development of agricultural adaptation strategies for climate change in the Northern Great Plains of North America.

The results of the DRI project has generated interest and financial support from the Canadian Wheat Board, Manitoba Water Stewardship, Manitoba Agriculture, Food and Rural Initiatives and Manitoba's Agricultural Research Development Initiative to develop a system to generate

real-time modeled values of soil moisture for the prairies using an expanding network of real-time weather stations for data input.

A visiting scientist took part in some of the research in 2009 and provided a valuable contact to the Rubber Research Institute in Kerala, India.

Moisture demand (i.e. potential evapotranspiration) has been shown to be more strongly related to wheat yield and quality than precipitation. Therefore, improved accuracy of meteorologically-based agricultural drought indices can be achieved based on these methods. Drought monitoring is normally performed using drought indices to provide decision makers with information on drought severity. In some cases, drought indices can be used to trigger drought contingency plans and financial support programs, if they are available. More accurate characterizations of agricultural drought will help improve the response to drought by various provincial and federal agencies by providing more accurate information on the extent and intensity of agricultural drought. This will facilitate a more appropriate level of response to drought and help to ensure that program payments are targeted effectively to assist those most in need.

MODIS NDVI (10-day composite) data from late June through late July is significantly correlated to census agricultural region yields of 4 major crops. Thus, these data can provide a means to delineate the spatial extent of agricultural drought based on yield deviations.

Improved agricultural drought monitoring and assessment helps all Canadians by ensuring better allocation of public funds in situations where severe drought results in government support.

4.0 Reverse Impact Statement

4.1 Provide a reverse impact statement, describing what would have happened in terms of the project, the resulting science and the impacts on users/stakeholders, if the work had not been funded by CFCAS.

Without the funding, the research results described would not have been generated. A graduate student (M.Sc.) and a post-doctoral fellow would not have received any training and would not be working at two important institutions (Manitoba Hydro, University of Manitoba). The collaborations and follow-up research would not have been developed.

5.0 Follow-on Science

6.0 Dissemination

6.1 Provide information on the dissemination of the research results (publications, including journal names and whether refereed), conference contributions, seminars, workshops or videos, websites or other methods of transferring the results.

Refereed Journal Articles:

Gervais, M.D., Mkhabela, M., Bullock, P.R., Raddatz, R.L. and Finlay, G.J. Comparison of standard and actual crop evapotranspiration estimates derived from different methods on the Canadian Prairie. Hydrological Processes (in review 13 Sep 2010)

Mkhabela, M.S., Bullock, P.R., Raj, S., Wang, S. and Yang, Y. Crop yield forecasting in the Canadian prairies using MODIS NDVI data. *Agricultural and Forest Meteorology* (in review 9 Apr 2010)

Gervais, M.D., Bullock, P.R., Mkhabela, M., Finlay, G.J. and Raddatz, R. 2010. Improvements to the accuracy of modelled soil water content from the 2nd generation Prairie agrometeorological model. *Canadian Journal of Soil Science* 90: 527-542.

Mkhabela, M.S., Bullock, P.R., Gervais, M.D., Finlay, G.J. and Sapirstein, H.D. 2010. Assessing indicators of agricultural drought impacts on spring wheat yield and quality on the Canadian prairies. *Agricultural and Forest Meteorology* 150: 399-410.

Saiyed, I., Bullock, P.R., Sapirstein, H.D., Finlay, G.J., and Jarvis, C.K. 2009 Thermal time models for estimating wheat phenological development and weather-based relationships to wheat quality. *Canadian Journal of Plant Science* 89: 429-439

Conference and Scientific Meeting Presentations:

Mkhabela, M., Bullock, P.R., Gervais, M.D., Finlay, G.F., Raj, S., Wang, S. and Yang, Y. Development of agricultural drought indices, evaluation of PAMII moisture and ET estimates and crop yield forecasting on the Canadian Prairies using MODIS-NDVI data. 5th Annual Drought Research Initiative Workshop, Winnipeg, Manitoba, May 2010.

Bullock, P.R., Mkhabela, M.S., Gervais, M.D., Finlay, G.F. and Wang, S. Agricultural drought. Drought Research Initiative Manitoba Users' Workshop, Winnipeg, MB, January 2010

Mkhabela, M., Bullock, P.R., Gervais, M.D., Finlay, G.J. and Sapirstein, H.D. Evaluation of meteorological indicators of agricultural drought impacts on spring wheat yield and quality in the Canadian Prairies. Canadian Society of Soil Science Annual Meeting, Guelph, ON, August 2009

Mkhabela, M., Bullock, P.R., Raj, S., Wang, S. and Yang, Y. Predicting crop yield in the Canadian Prairies using MODIS NDVI data. Canadian Society of Soil Science Annual Meeting, Guelph, Ont., August 2009

Wang, S., Yang, Y., Trishchenko, A., Luo, Y., Geng, X., Bullock, P. and Mi, N. Drought impact characterization using remote sensing and ecosystem modeling. 2009 Joint Assembly, American Geophysical Union, Toronto, Ontario, May 2009

Bullock, P.R. Assessing agricultural drought in Western Canada with census agricultural region crop data. 4th Annual Drought Research Initiative Workshop, Regina, Saskatchewan, January 2009

Bullock, P.R. Quantifying Drought: How dry is it, really? Department of Entomology Seminar Series, University of Manitoba, Winnipeg, Manitoba, October 2008

Bullock, P.R. Agricultural drought. Drought Research Initiative Theme 1 Workshop, Winnipeg, Manitoba, September 2008

Gervais, M., Bullock, P.R. and Raddatz, R. 2008. Prairie agrometeorological model (PAM2nd): Calibration of Modeled Soil Water for Spring Wheat. Canadian Society of Soil Science Annual Meeting, Prince George, B.C., July 2008

Bullock, P.R. Agricultural drought assessment: an update. 3rd Annual Drought Research Initiative Workshop, Calgary, Alberta, January 2008

Gervais, M., Bullock, P.R. and Raddatz, R. A soil water budget approach to improving evapotranspiration estimates from the 2nd generation prairie agrometeorological model. Drought Research Initiative Evaporation Workshop, Saskatoon, Saskatchewan, May 2007.

Bullock, P.R. Agricultural drought indices. Drought Research Initiative Evaporation Workshop, Saskatoon, Saskatchewan, May 2007.

Bullock, P.R., Finlay, G.J., Jarvis, C.K., Sapirstein, H.D., Naeem, H. and Saiyed, I. Quantifying Agricultural Drought: An assessment using western Canadian spring wheat. 2nd Annual Drought Research Initiative Workshop, Winnipeg, Manitoba, January 2007.

Bullock, P.R. Moisture stress: a plant's perspective. 1st Annual Drought Research Initiative Workshop, Saskatoon, Saskatchewan, January 2006

Posters:

Mkhabela, M., Bullock, P.R. and Gervais, M.D. Environmental indicators of agricultural drought impacts on spring wheat in Western Canada. 4th Annual Drought Research Initiative Workshop, Regina, SK, January 2009.

Gervais, M., Bullock, P.R. and Raddatz, R. 2008. Modeled evapotranspiration for spring wheat from the 2nd generation prairie agrometeorological model. Canadian Society of Soil Science Annual Meeting, Prince George, B.C., July 2008

Gervais, M. and Bullock, P.R. 2008. Calibration of the 2nd generation prairie agrometeorological model for spring wheat. 3rd Annual Drought Research Initiative Workshop, January 17-18, Calgary, Alberta

6.2 Describe data management/sharing activities including organization of the metadata. Also, are the data being archived, and how will they be made available to other researchers?

Agricultural drought indices, census agricultural region crop yield rankings and census agricultural region MODIS NDVI decadal data, along with the metadata, are being made available through the DRI data archive.

6.3 Comment on any outreach or public information activities, including press interviews or other media interest or reports. Has the project helped to popularize science or increase public awareness?

Both radio and television interviews with prairie media concerning drought conditions.

7.0 Training

7.1 Quantify student and PDF involvement (indicate the level of each: undergraduate, masters, doctorate or PDF). If possible and within the Federal Privacy Act rules governing the collection of personal information, provide a general indication of their subsequent employment (i.e., university, industry, government, other, etc.), and indicate whether the employment was foreign or domestic.

Masters student – Mark Gervais (now employed with Manitoba Hydro)

Post-doctoral fellow – Dr. Manasah Mkhabela (now a research associate, University of Manitoba)

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