Multi-Model approach to study the impact of climate variability on the productivity of wheat systems

M. Ahmed[1], T. Karimi[1], R.L. Nelson[1], C.O. Stöckle[1]

[1]Biological system Engineering, Washington State University, WA 99164-6120

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REACCH Regional Approaches to Climate Change – PACIFIC NORTHWEST AGRICULTURE

Abstract

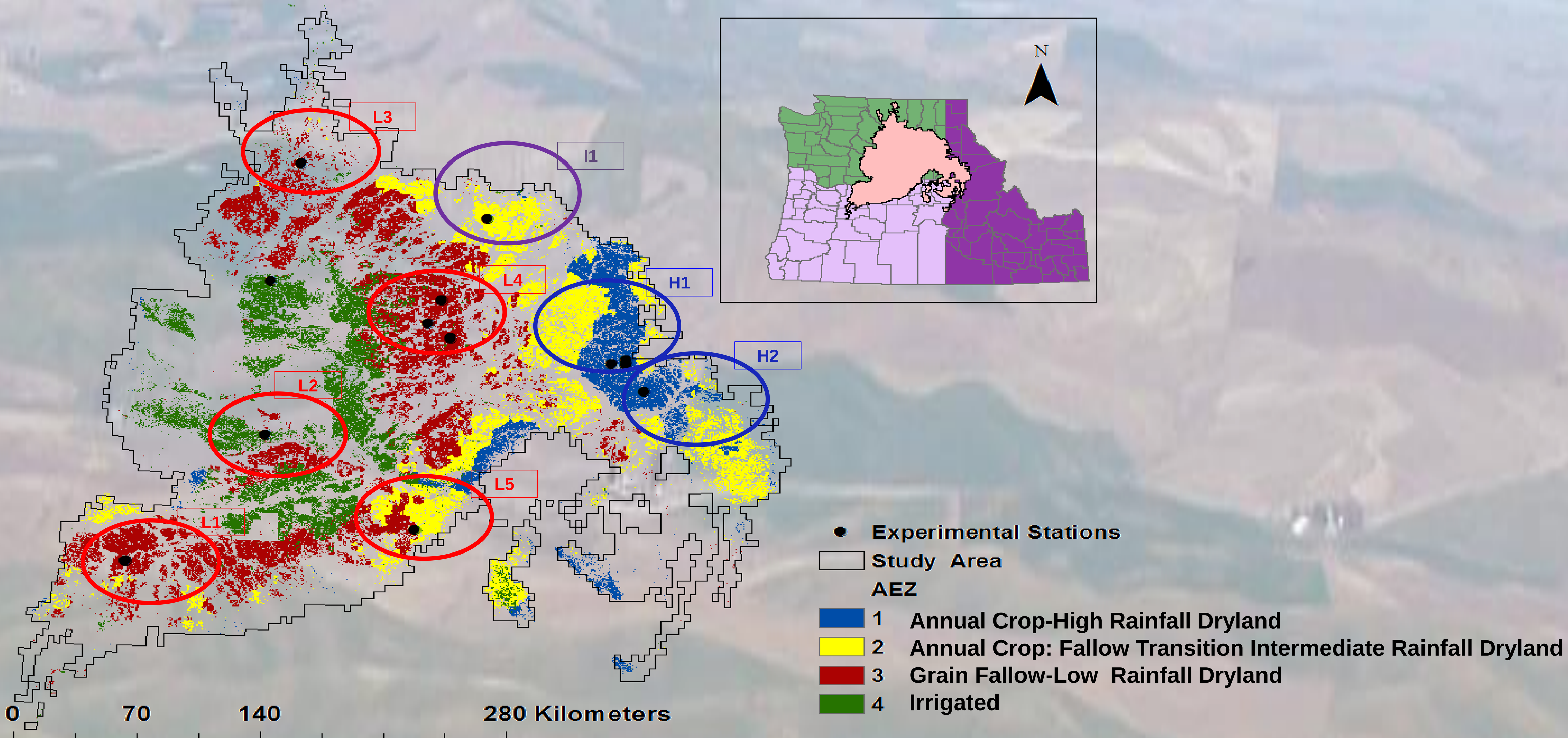
As part of the USDA NIFA-funded project "Regional Approaches to Climate Change for Pacific Northwest (PNW) Agriculture", a regional assessment of yields, water and carbon footprint for baseline and future climatic conditions is being conducted using computer models. REACCH aims at ensuring the long-term viability of cereal-based farming in the Pacific Northwest and at identifying farming practices that can help minimize impacts on productivity and reduce GHG emissions under climate change. Gridded daily weather data (4x4 km) for the period 1979 – 2010 are available for baseline simulations. For future weather, daily data projected by 14 GCMs for two representative concentration pathways (RCP) (4.5 and 8.5 W m^{-2}) are being used, for a total of 28 future weather scenarios. An ensemble of 5 wheat growth models extracted from CropSyst, APSIM-Wheat, CERES-Wheat, STICS and EPIC are being coded to run under the platform of CropSyst. This platform will provide input/output operations and scenario creation capabilities (weather, soils, crop rotations, management), and will simulate hydrologic processes, including all components of the water balance, and nutrient cycling. This approach will allow the simulation of wheat yields using different wheat growth modeling approaches under a common set of environmental conditions. Growth of rotational crops other than wheat will be simulated using CropSyst crop modules. The main objective of this multi-model study is to reduce the uncertainty associated with individual wheat growth models, with the expectation that model ensembles will provide a better estimation of future outcomes as typically accepted by the climate modeling community. Preliminary evidence has shown that the use of ensembles of crop growth models can also be an effective approach to reduce uncertainty.

Methodology

Regional simulations for wheat based cropping systems have been conducted using APSIM-Wheat and CERES-Wheat while STICS, EPIC and CropSyst are in progress. Gridded daily weather data (4x4 km) for the period 1979 – 2010 were used for baseline simulations. For future weather, daily data projected by 14 GCMs for two representative concentration pathways (RCP) of atmospheric CO_2 (4.5 and 8.5 W m^{-2}) were used, with a total of 28 future weather scenarios at 14 different sites (Fig.1).

The REACCH region has been divided into 4 agro-ecological zones (AEZ): low, intermediate and high precipitation dryland cropping and an irrigated (Figure 1). Each AEZ has a typical conventional tillage (CT) cropping system. Drier conditions in summer and warmer temperatures specially in summer have been projected for this region.

Figure 1. REACCH study area



Low rainfall sites (L1 – L5)

1. Sherman County
2. Benton County
3. Douglas County
4. Adams County
5. Umatilla County

Intermediate rainfall sites (I1)

1. Lincoln County

High rainfall sites (H1 – H2)

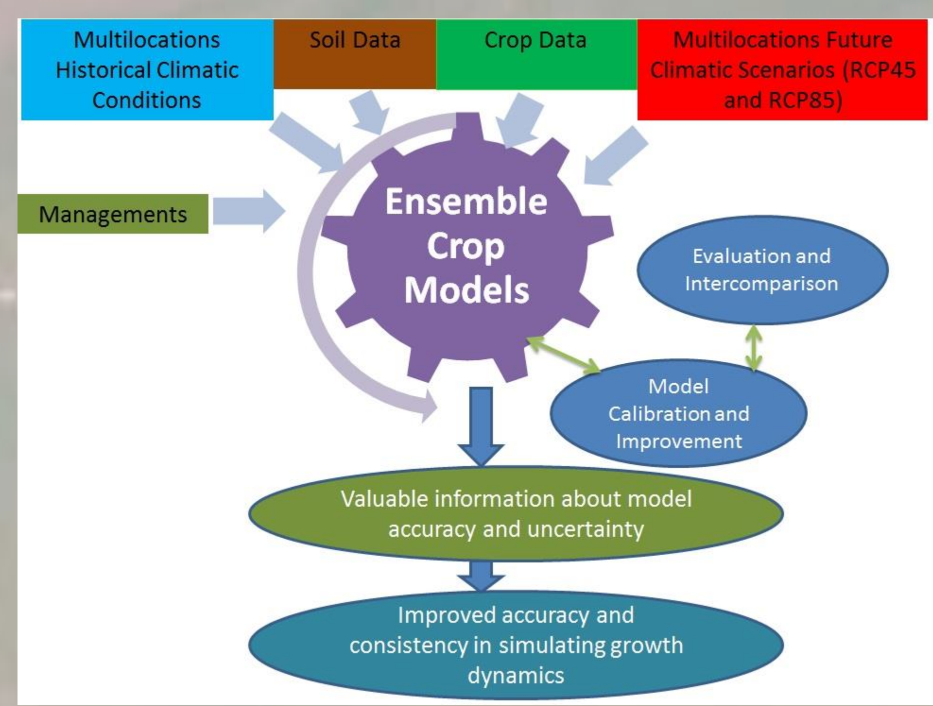
1. Whitman County
2. Fremont County

Irrigated

1. Grant County

Models Calibration

The observed data of wheat LAI, flowering time, biological yield (t ha^{-1}) and grain yield (t ha^{-1}) from three study sites in Washington i.e. Cook Agronomic Farm, Lind and Moses lake (Irrigated) were used to Calibrate all ensemble wheat based models. For calibration the cultivar coefficients were obtained step by step first for phenological development and then for grain development. The manual trial and error method was used to determine genetic coefficients as described by Godwin and Singh (1998).



Results

- Table shows the historical (1979-2010) means of WW anthesis, maturity date, LAI, drymatter (t ha^{-1}), grain yield (t ha^{-1}) and harvest index at three variables sites of PNW.
- RMSE confirms the close agreement between observed and simulated values.
- Future winter wheat (WW) growth dynamics and yield using 14 GCMs to baseline (historical) growth and yield is available for APSIM wheat and Ceres-Wheat while for other models its in progress.

Crop Models	Parameters	High rainfall			Low rainfall			Irrigated		
		Cook			Lind			Moses Lake		
		Observed	Simulated	RMSE	Observed	Simulated	RMSE	Observed	Simulated	RMSE
Ceres-Wheat	Anthesis date (DOY)	160	159.27	6.83	145	145.67	8.82	145	138.43	9.69
APSIM-Wheat			160.00	5.24		147.87	9.42		142.23	7.04
Ceres-Wheat	Maturity date (DOY)	210	199.53	5.00	191	190.00	3.03	200	174.47	24.90
APSIM-Wheat			210.48	4.90		188.10	3.93		187.81	12.01
Ceres-Wheat	Leaf area index	8	6.73	2.42	3	2.63	2.44	8	7.17	1.51
APSIM-Wheat			7.50	1.80		3.00	3.10		8.00	1.45
Ceres-Wheat	Drymatter (t ha^{-1})	20.57	19.86	4.94	6.7	6.16	3.13	20.57	25.64	5.74
APSIM-Wheat			19.42	3.99		8.48	3.08		20.88	1.77
Ceres-Wheat	Grain yield (t ha^{-1})	8.29	8.79	1.38	2.9	3.16	1.57	9.68	10.33	2.32
APSIM-Wheat			8.82	1.65		2.81	1.07		8.39	1.27
Ceres-Wheat	Harvest index	0.45	0.45	0.06	0.45	0.52	0.12	0.48	0.40	0.05
APSIM-Wheat			0.45	0.04		0.32	0.10		0.40	0.06

Concluding Remarks

In general, the accuracy of simulation model results is a major concern. Evaluating results from an ensemble of crop models may elucidate model accuracy, sensitivity and uncertainty. Multimodal ensembles can be used to create new estimators with improved accuracy and consistency in simulating wheat growth and yield.