Adding Dynamic Social-Economic Factors to Crop Simulations to Improve Acreage and Yield Predictions

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Introduction:
A Changing Landscape

Over the past decade the crop landscape of North Dakota has witnessed a large swing in acreage of corn, soybeans, and wheat driven by the individual farmer decision-making process. This has transpired into an increase in soybean and corn acreage by over 300% and a smaller decrease in wheat acreage over the same timeframe.

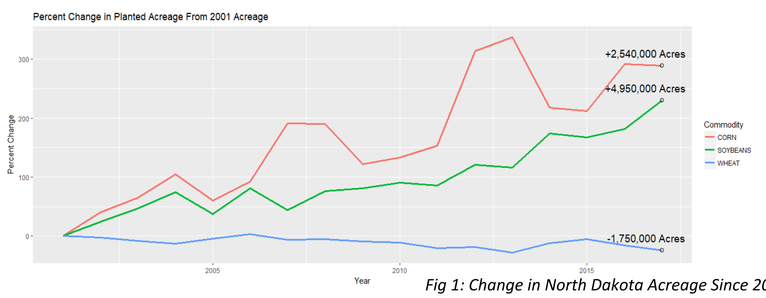

Fig 1: Change in North Dakota Acreage Since 2001
Source: NASS Quickstats

Simulation Models:
Limitations in Landscape Modeling

To understand these changes more completely and to aid with future farmer decision-making, crop simulation models such as the Agricultural Land Management Alternative with Numerical Assessment Criteria (ALMANAC) model, are used to simulate crop growth. These models work at a point-scale basis, taking as inputs field managements, weather, and soil characteristics and simulating biomass growth and plant stage development. These are often taken into the future via coupling with global climate simulations.

However, these models have the limitation of relying on static rotation scenarios, which inherently adds an unrealistic aspect to simulation models. In this study we add human factors to the crop planting decision logic to mimic real world decision-making at a localized scale across the entire Prairie Pothole Region of North Dakota.

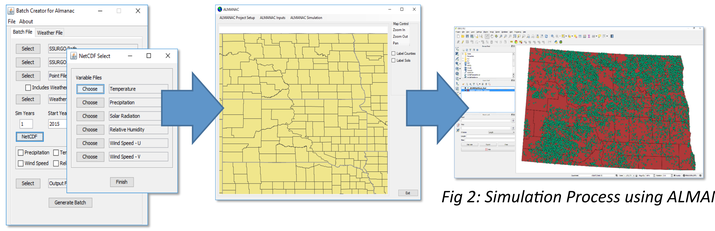

Fig 2: Simulation Process using ALMANAC

Methodology:

To incorporate the decision-making process into the ALMANAC crop simulation model we combined a economic model with the crop simulations at a annual timestep as follows:

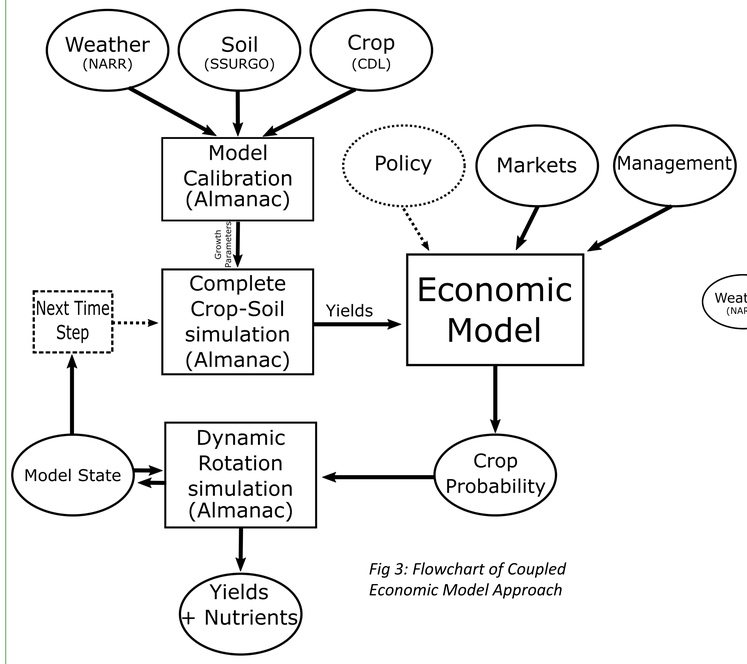

Fig 3: Flowchart of Coupled Economic Model Approach

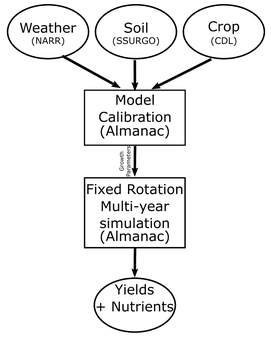

Fig 4: Flowchart of historic rotation approach

Tools and Datasets

- **Crop Simulation Model:** For the crop simulations the ALMANAC crop model was used, this simulates crop growth at a daily timestep for a point based location.
- **Economic Model:** To add local level decision-making a spatially-explicit land-use model was incorporated directly into the decision making logic of the crop model management.
- **Soils:** The Soil Survey Geographic Database (SSURGO) was used for soil profile information.
- **Weather:** The North American Regional Reanalysis (NARR) was utilized, daily timestep for local weather conditions.
- **Crop History:** For historic crop locations and crop calibration the Cropland Data Layer was used.

The study was broken into two regimes to determine planting acreage and locations:

- **Historic Approach:** Using the historic crop information from 2001-2013 acreage and location of each planted crop was selected by the percentage each crop had been seen historically by soil type.
- **Coupled Economic Model Approach:** The economic model was given 2013 yield data from ALMANAC and setup to mimic conditions going into the 2014 growing season. The economic model provided crop probabilities which were then used to select the most probable by soil type.

Results:

When comparing to the standard historic rotation based system overall the following results were found

- **Acreage estimations** of corn and soybean were improved by 13% and 11% respectively.
  - However wheat projections saw little improvement
  - Adjustments were made to account for non-agricultural land and non-study crops.
- **Yield predictions** for corn were improved by 14% for the study area due to the proper simulation of the location of the fields.
- **Soil health** change was simulated and noted, but no definitive results were found.

Table 1: Total Acreage Results by Agricultural District

Crop	Ag. District	Economic Model	Adj. Economic	Historic	Actual	Adj. Model %	Historic %
Maize	Central	89,117	83,096	72,599	164,308	51%	44%
	East Central	172,420	165,709	165,885	227,441	73%	73%
	North Central	127,919	117,347	27,052	65,966	178%	41%
	Northeast	119,967	104,019	55,124	84,987	122%	65%
	Northwest	60,259	43,535	6,638	17,402	250%	38%
	Southeast	190,336	182,128	253,399	341,567	53%	74%
	Maize Total	**760,019**	**695,835**	**580,697**	**901,672**	**77%**	**64%**
Soybean	Central	298,574	278,402	253,997	443,551	63%	57%
	East Central	766,977	737,124	484,874	577,507	128%	84%
	North Central	607,156	556,977	100,468	224,204	248%	45%
	Northeast	546,992	474,277	253,535	390,536	121%	65%
	Northwest	231,273	167,087	28,615	75,679	221%	38%
	Southeast	599,398	573,550	403,110	564,152	102%	71%
	Soybean Total	**3,050,371**	**2,787,417**	**1,524,599**	**2,275,628**	**122%**	**67%**
Wheat	Central	103,033	96,072	222,862	192,233	50%	116%
	East Central	216,957	208,513	243,080	137,598	152%	177%
	North Central	363,243	333,222	247,324	271,554	123%	91%
	Northeast	597,384	517,970	533,669	534,204	97%	100%
	Northwest	458,044	330,921	214,394	418,865	79%	51%
	Southeast	150,776	144,274	162,107	111,293	130%	146%
	Wheat Total	**1,889,437**	**1,630,972**	**1,623,436**	**1,665,745**	**98%**	**97%**

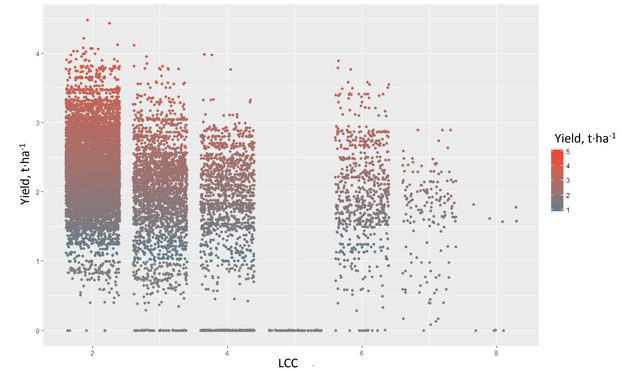

Fig 5: Simulated Wheat yields by Land Capability Class

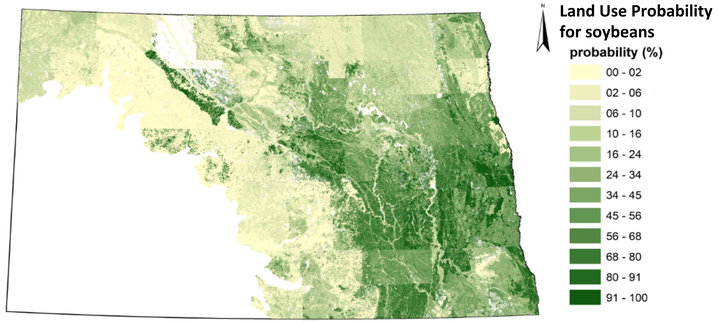

Fig 6: Simulated land use probability for soybeans in 2014

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