Climate Warming and Crop-switching in the Northern Great Plains Dryland System

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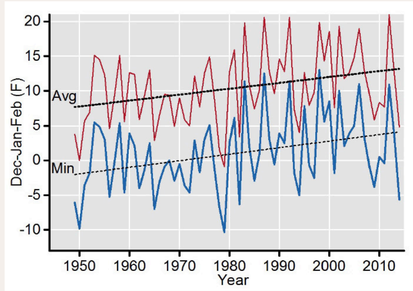
A RISK AND DECISION ANALYSIS APPROACH TO CLIMATE ADAPTATION

Increased calls for risk approaches and decision-oriented research in climate adaptation (e.g., in IPCC AR5 Jones et al. 2015; U.S. National Assessment, Moss et al. 2014), but few studies take a formal risk and decision analysis approach. We apply formal risk and decision analysis to test adaptation in dryland wheat production, including these steps:

1. Decision structuring: Identify decision settings, decision-makers, and their options
2. Risk analysis: estimate probability and consequence of harmful outcomes
3. Build a simulation model: Parameterize an expected utility model of the relevant decisions
4. Examine the sensitivity analysis
5. Test for effects of risk aversion and risk management tools like insurance

THE DECISION SETTING

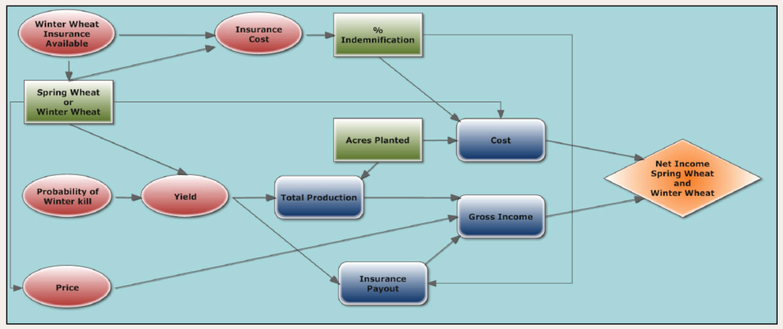
A warming climate in the Northern Great Plains creates the opportunity to switch from spring wheat to winter wheat, which has several advantages, but suffers the risk of complete crop loss from winter kill. Spring wheat farmers must consider the changing probability of winter kill in considering making the switch, which can provide 10% greater net income.



THE QUESTION

When does it make sense to switch crops as the relative advantages and risks of different production systems change with changing climate?

THE MODEL: "CROPSWITCH"



CropSwitch simulates net income of a 2,000-acre dryland wheat farm in North Dakota based on North Dakota State University (NDSU) extension service budgets and using the following parameters:

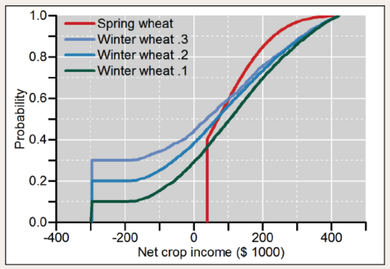
- **Probability of Winter Kill for Winter Wheat-**Because so little winter wheat has been grown in North Dakota the rate of winter kill is unknown, historically it has ranged from 10-30%. CropSwitch starts with 30% and decreases the rate of winterkill over 30 years.
- **Insurance-**Traditionally crop insurance is not available for winter wheat in ND we simulate several emerging insurance schemes. Mechanics are based on USDA yield protection insurance at 75% indemnification.
- **Yield-**Cropswitch generates yield using a probability density function (PDF) based on previous wheat yields.

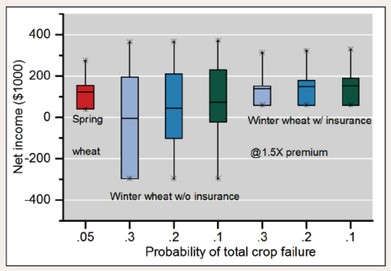
RESULTS

Results include simulations comparing spring and winter wheat outcomes based on 2014 crop production budgets for different rates of winter kill, followed by runs over a 30-year simulation to test the pace of adaptation, and finally sensitivity runs to test insurance instruments and the role of risk aversion and risk premiums in adaptation decision-making.

SPRING VS. WINTER WHEAT

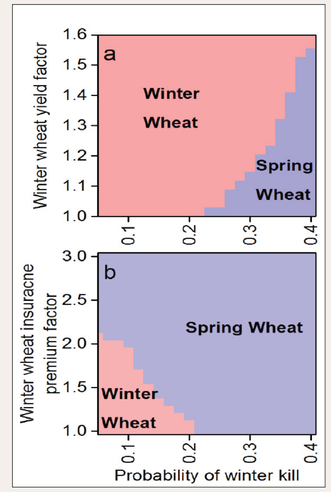
- Winter wheat out-performs spring wheat only at low (e.g., .1 to .2) probabilities of winterkill.
- In only about 40% of the time could winter wheat be expected to equal or exceed the net returns of spring wheat.
- A 30% chance of winter kill creates a large downside risk that would comport with the historical fact that winter wheat was not grown in North Dakota
- Winter wheat outcomes range widely compared to spring wheat (lower right) due both to higher probability of complete crop loss but also lack of insurance coverage.
- **Without insurance,** the downside risk of winter wheat is large deterring risk adverse farmers.
- **With insurance** (right-hand plots) using a premium price of 1.5x spring wheat the downside risk is similar to spring wheat.



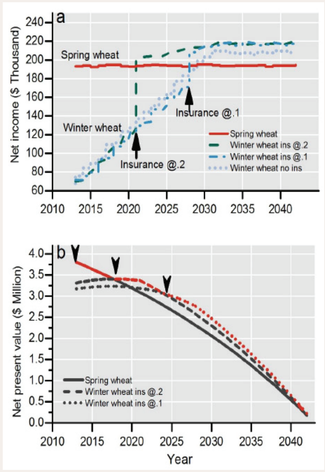


WHERE WINTER WHEAT PAYS OFF

Sensitivity analysis (right) shows where winter wheat makes sense for a range of winter kill probabilities and its yield benefit compared to spring wheat (top heat map) and compared to the premium that must be paid over spring wheat insurance costs (bottom heat map).



WHEN TO SWITCH?



In a 30 year simulation (left) with warming climate reducing winter kill risk to something close to spring wheat (*p.1* to p.05 crop loss) it eventually out-performs spring wheat. Insurance offered at .2, even with premium rates 1.5 to 2 times spring wheat rates, advances that point almost a decade.

Spring wheat exhibits the largest NPV at the start of all scenarios, given the *p.3* winter wheat loss, but winter wheat NPV exceeds spring wheat in about 5 years if insurance kicks in at a *p.2* loss rate, and in about 12 years if insurance emerges at a *p.1* loss probability.