Agricultural Decision Making Under Climate Uncertainty

Risk & Decision Analysis Applied to Climate Adaptation

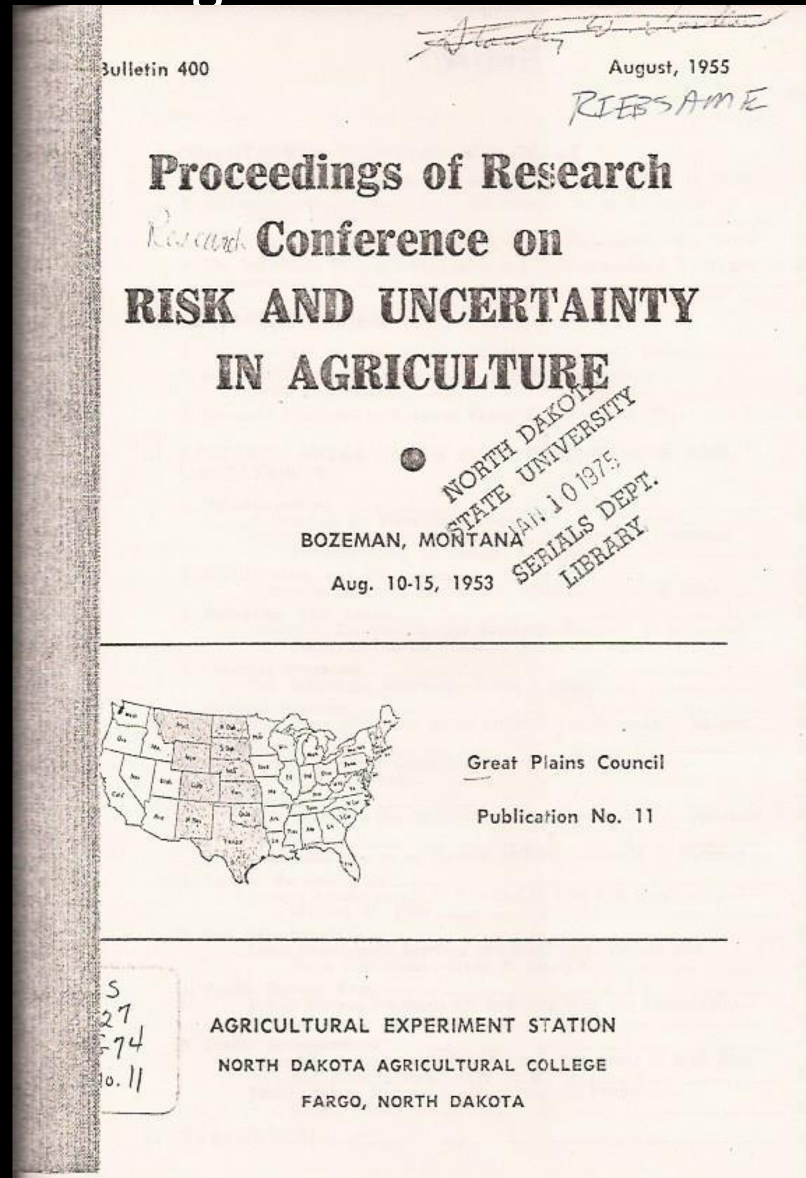
William R. Travis
Department of Geography
and
Institute of Behavioral Science
University of Colorado - Boulder

Key Points:

- Agriculture is risky business, especially due to markets and climate
- Risk pervades the whole structure of agriculture, from the producer to the trader, and is often addressed by government policy which plays a big role in ag worldwide.
  - Price supports
  - Marketing assistance
  - Insurance
  - Disaster aid
- Systems to manage risk within ag are well-developed:
  - Adaptive, flexible production methods often with intelligence gathering
  - Farm finance management (e.g., from family savings to alternative income)
  - Marketing strategies (on-farm storage; forward contracts, etc.)

Formal risk and decision analysis has been applied to agriculture for a long time:

Different from traditional ag-economic approaches, but generally compatible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FARGO, NORTH DAKOTA

Attend to: Risk, uncertainty, decision making, and decision support

Climate Change Impacts in the United States

CHAPTER 26
DECISION SUPPORT
CONNECTING SCIENCE, RISK PERCEPTION, AND DECISIONS

Convening Lead Authors

Richard Moss, Joint Global Change Research Institute, Pacific Northwest National Laboratory, University of Maryland

P. Lynn Scarlett, The Nature Conservancy

Lead Authors

Melissa A. Kenney, University of Maryland

Howard Kunreuther, University of Pennsylvania

Robert Lempert, RAND Corporation

Jay Manning, Cascadia Law Group

B. Ken Williams, The Wildlife Society

Contributing Authors

James W. Boyd, Resources for the Future

Emily T. Cloyd, University Corporation for Atmospheric Research

Laurna Kaatz, Denver Water

Lindene Patton, Zurich North America

Some aspects of ag risk

- Large uncertainty, but very adaptable system, mostly short-term, repetitive "bets" with lots of learning
- Some long-term investments (e.g., irrigation), so some dimensions of long-term risk do matter
- Risk aversion vs. regret aversion (mini-max, maxi-min, etc.)
- Deal with full statistical distribution, and explicitly with extreme events and catastrophic loss
- RDA should lead to decision support (RDA does not yield decisions but can provide decision support)
- Incremental vs. transformational responses (adaptation)

Enterprise Decision Structuring

- What's the goal of the DM'er? What outcomes matter (utilities), what options, sequences, range of outcomes, etc.
  - What to plant, when to plant, manage for pest, manage fertility, when to harvest, how to market, how to hedge
- What utility function?
  - risk aversion posture (e.g., maximum yield, maximized expected utility, avoid complete loss; trade-off with average gain, etc.).

Risk analysis and risk management and decision-support emerging as important planning tools

Risk

R=p*c

Expected utility of a decision

$$EU(di) = \sum_{j=1}^{N} \mathrm{P(sj)\ U\ (di, sj)}$$

d_i = alternative decisions i = 1, 2….
N = number of possible future states (s_j)
P (s_j) = probability of state j

Risk and regret aversion

If S is a state, and P a policy choice, let P*(S) be the best policy choice conditional on S being the state, and V(S,P) the value of choosing policy P if the outcome is S. Then the goal is:

$$\mathrm{Min}_p \mathrm{Max}_S\ [V(S,P^*(S)) - V(S,P)]$$

FISHERMAN'S CHOICE

A. EXPECTED UTILITY: COMPLETE UNCERTAINTY

ALTERNATIVE ACTIONS	STATES OF NATURE	
	E_1 Hurricane	E_2 No. hurricane
A_1 Evacuate	Equipment intact Pay for evacuation (+1)	Equipment intact Pay for evacuation (+1)
A_2 Remain	Lose equipment (0)	Equipment intact (+2)

B. EXPECTED UTILITY: KNOWN PROBABILITY

ALTERNATIVE ACTIONS	STATES OF NATURE		
	E_1 Hurricane	E_2 No. hurricane	Expected utility
A_1 Evacuate	Equipment intact Pay for evacuation .4(+1) = .4	Equipment intact Pay for evacuation .6(+1) = .6	1.0
A_2 Remain	Lose equipment .4(0) = 0	Equipment intact .6(+2) = 1.2	1.2

C. EXPECTED UTILITY: SUBJECTIVE PROBABILITIES

ALTERNATIVE ACTIONS	STATES OF NATURE		
	E_1 Hurricane	E_2 No. hurricane	Expected utility
A_1 Evacuate	Equipment intact Pay for evacuation .9(+2) = 1.8	Equipment intact Pay for evacuation .1(+2) = .2	2.0
A_2 Remain	Lose equipment .9(0) = 0	Equipment intact .1(+4) = .4	.4

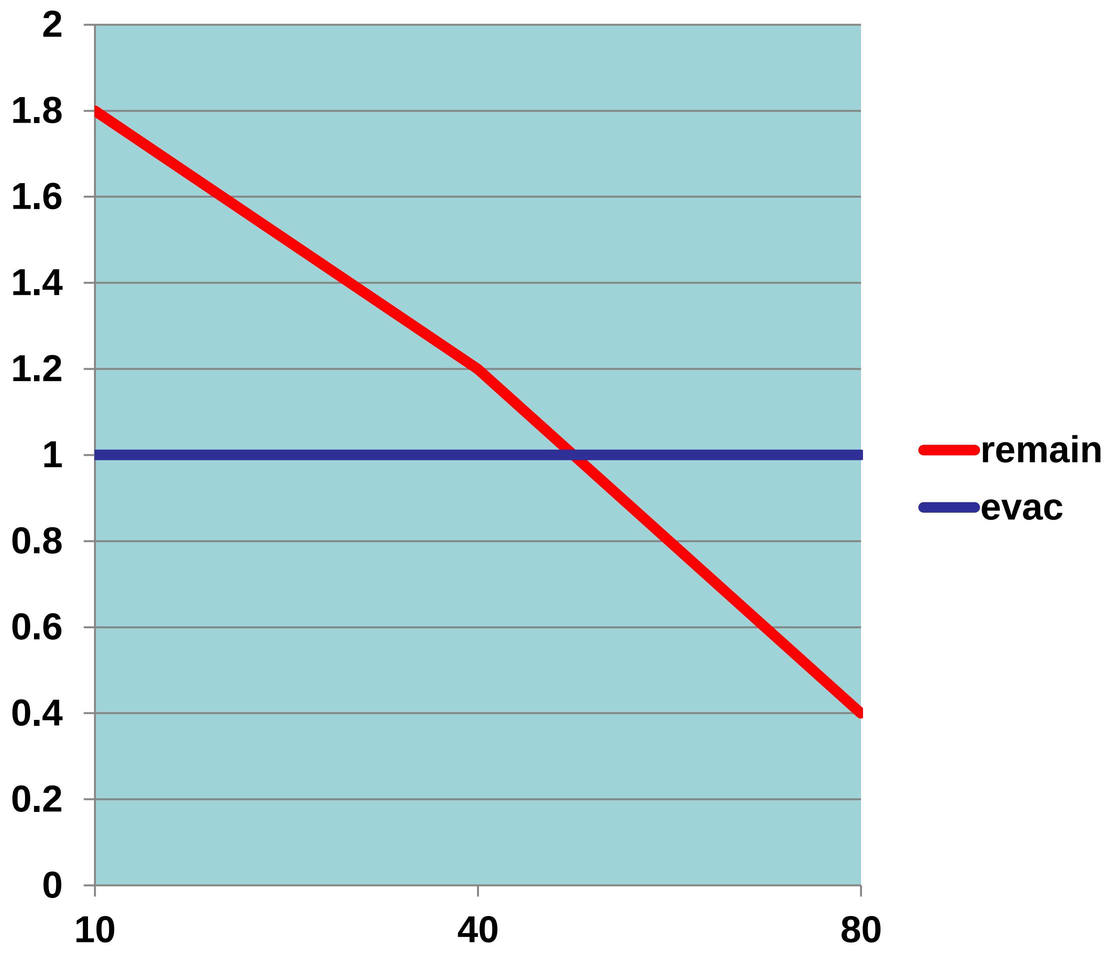
D. EXPECTED UTILITY: MINIMIZE REGRET

ALTERNATIVE ACTIONS	STATES OF NATURE	
	E_1 Hurricane	E_2 No. hurricane
A_1 Evacuate	Equipment intact Pay for evacuation −1	Equipment intact Pay for evacuation −1
A_2 Remain	Lose equipment −2	Equipment intact 0

FIGURE 2.8—PAY-OFF MATRICES FOR EQUIPMENT EVACUATION ON TROPICAL CYCLONE WARNING
In trying to decide whether to evacuate the boat with his equipment or to "sit it out" in the face of a tropical cyclone warning, a "rational" fisherman might analyze his choices in many ways depending on his knowledge, beliefs, and values.

Chance of Hurricane = 20%		Hurricane	No Hurricane	
	Evacuate	-1	-1	EU=(.2*-1)+(.8*-1)=-1
	Remain	-3	0	EU-(.2*-3)+(.8*0)=-0.6
30% chance		Hurricane	No Hurricane	
	Evacuate	-1	-1	EU=(.3*-1)+(.7*-1)=-1
	Remain	-3	0	EU=(.3*-3)+(.7*0)=-0.9

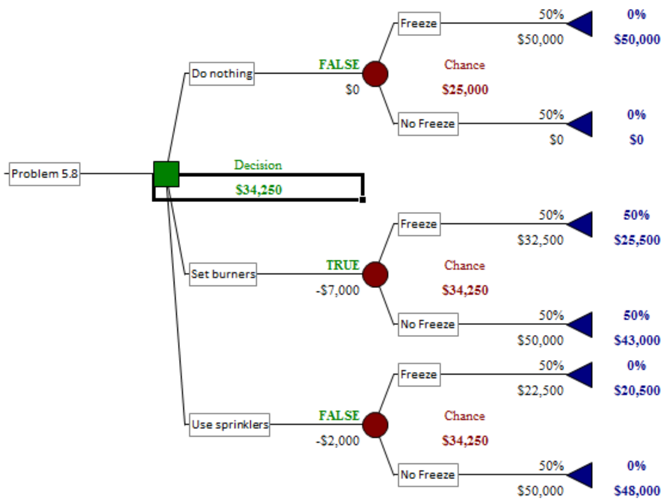
50% Chance hurricane		Hurricane	No Hurricane	
	Evacuate	1	1	1
	Remain	0	2	1
60% Chance hurricane		Hurricane	No Hurricane	
	Evacuate	1	1	1
	Remain	0	2	0.8


2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10
40
80
remain
evac

Problem 5.8 - Excel Solution

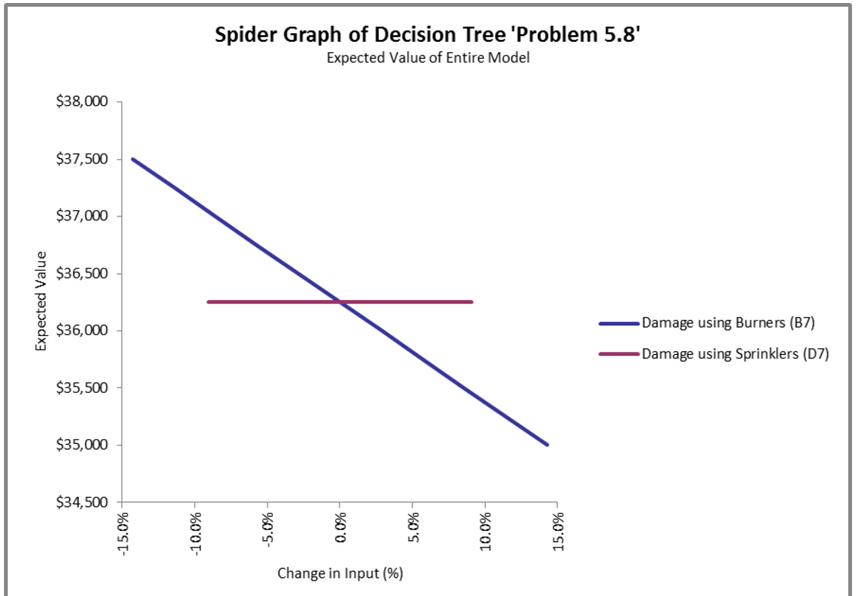
Making Hard Decisions with DecisionTools, 3rd ed., Clemen & Reilly

Cost of Burners	$7,000	Cost of Sprinklers	$2,000	Value of crop	$50,000
Damage using Burners		Damage using Sprinklers		Probability of Freeze	50%
Low	$15,000	Low	$25,000		
Best Guess	$17,500	Best Guess	$27,500		
High	$20,000	High	$30,000		



Results found by varying losses in the tree and determining the expected loss:

Alternative	Min Exected Crop Value	Max Expected Crop Value
Do nothing	$25,000	$25,000
Set burners	$35,000	$37,500
Use sprinklers	$33,000	$35,500



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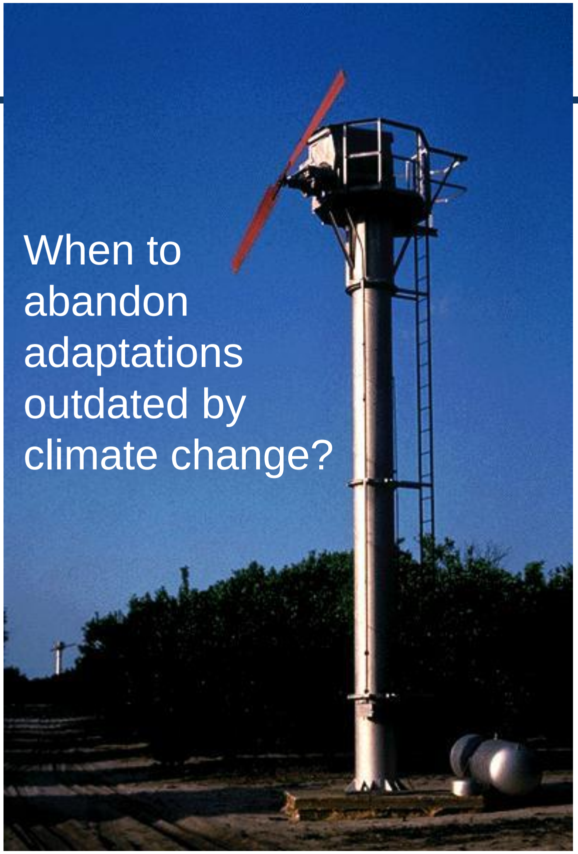
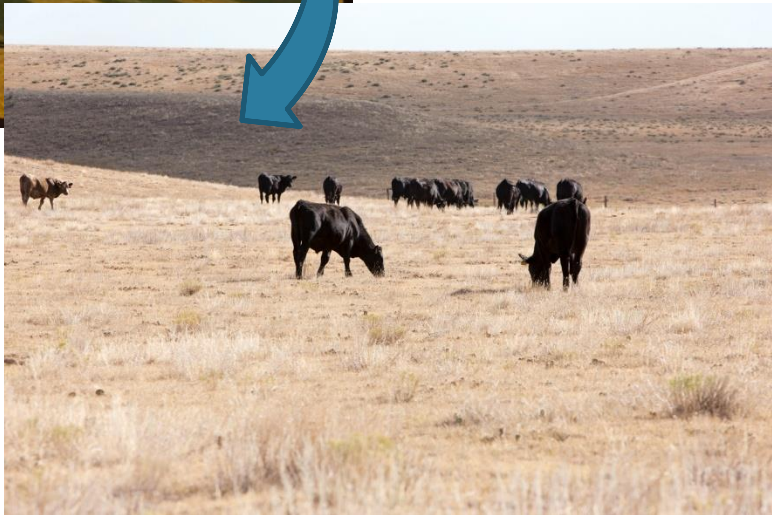
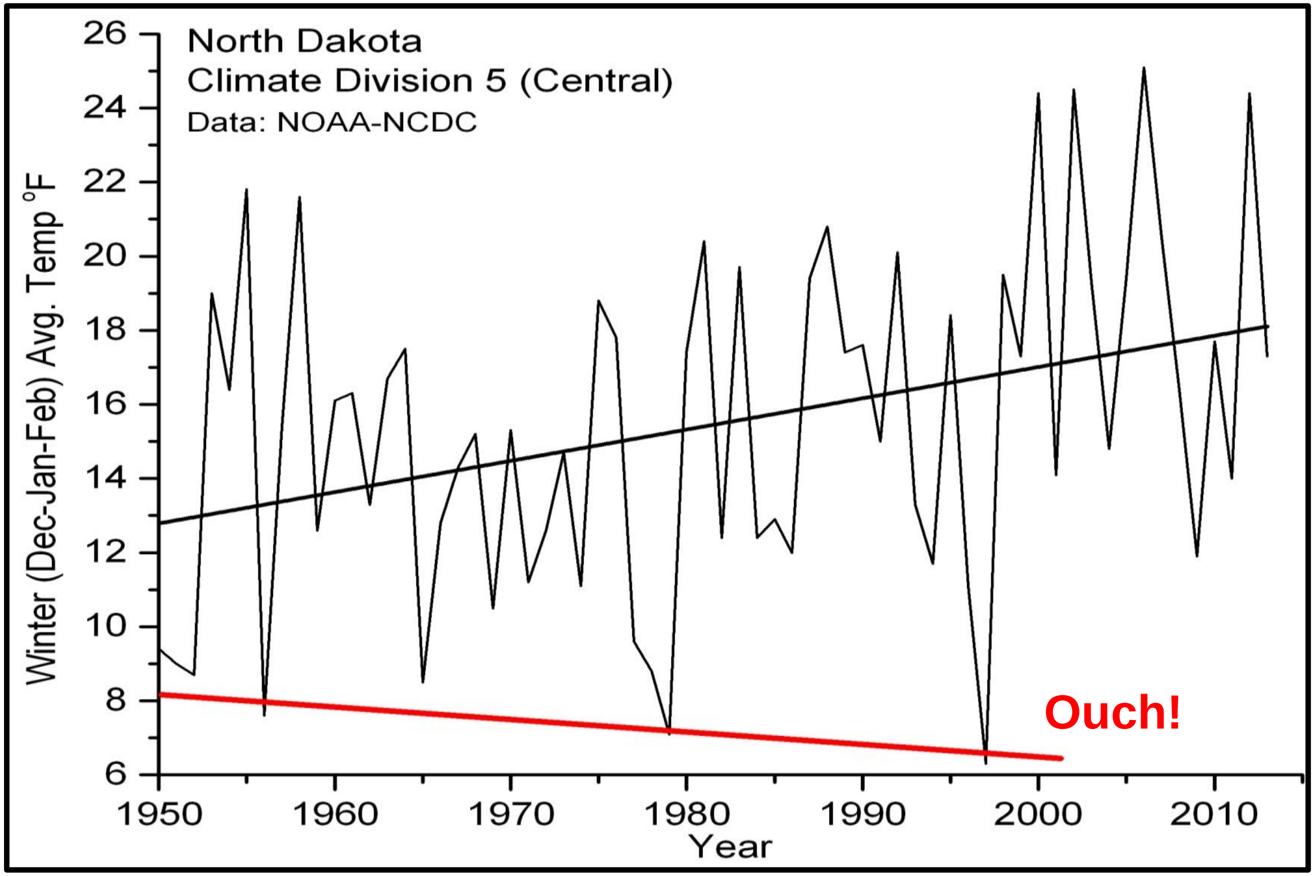




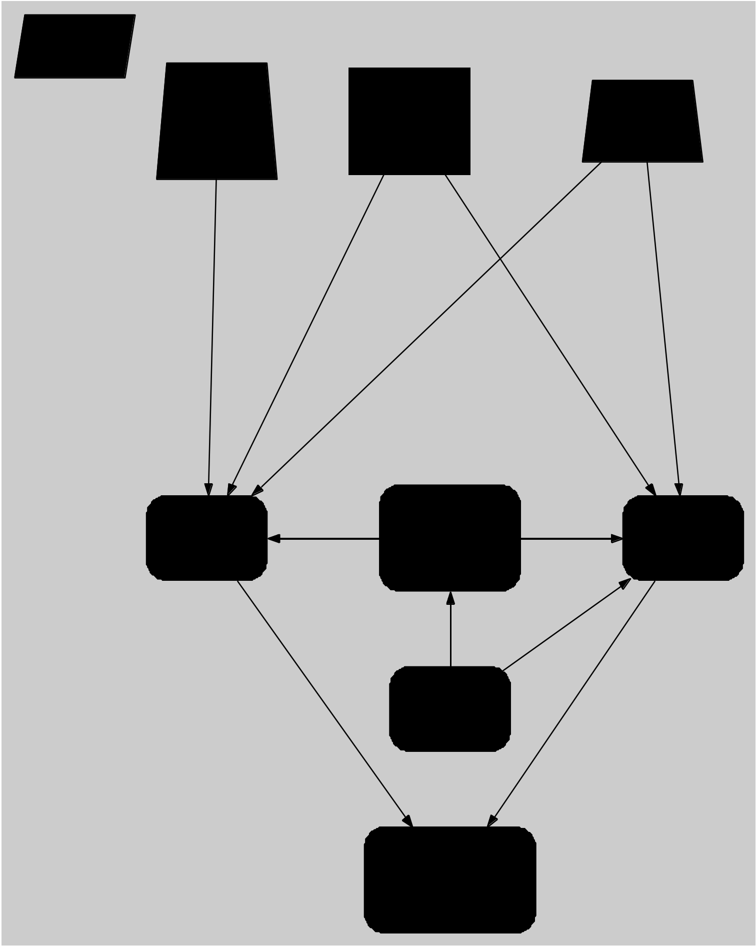
Less work yet on when and how to adapt to climate change

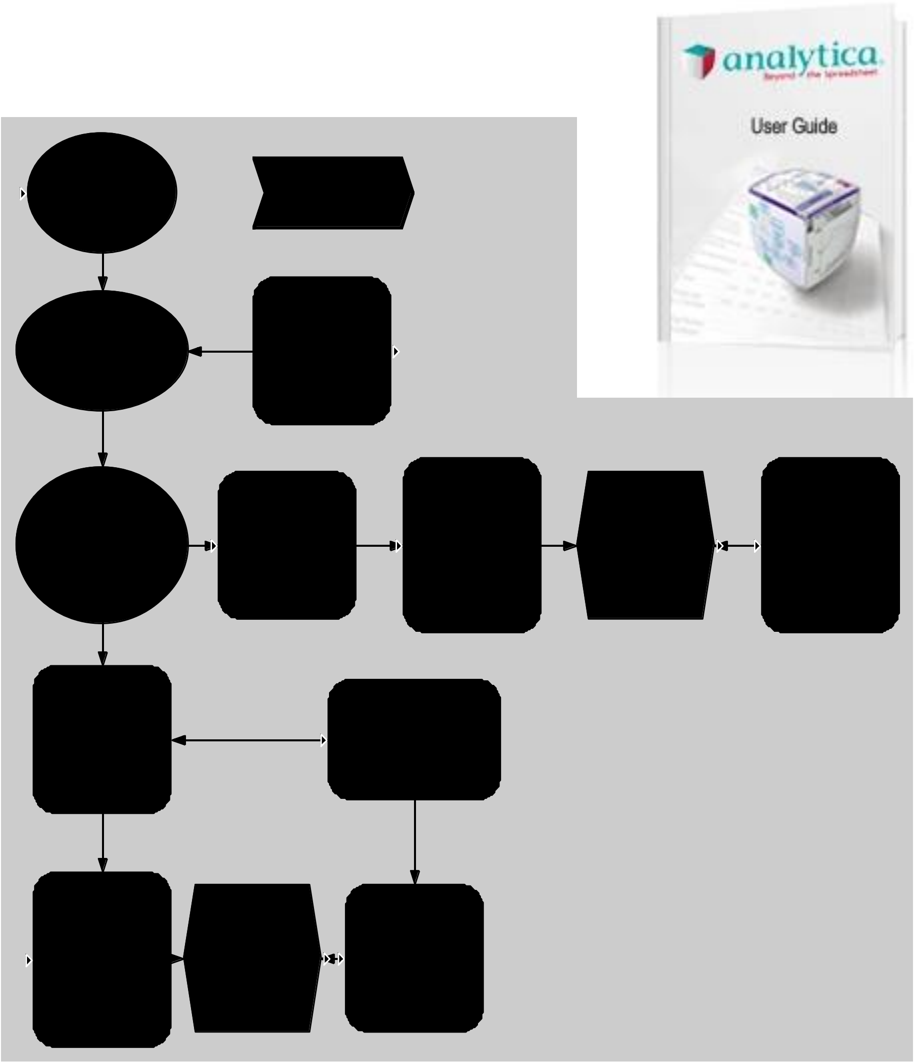
Farmers and other decision-makers face real conundrums:

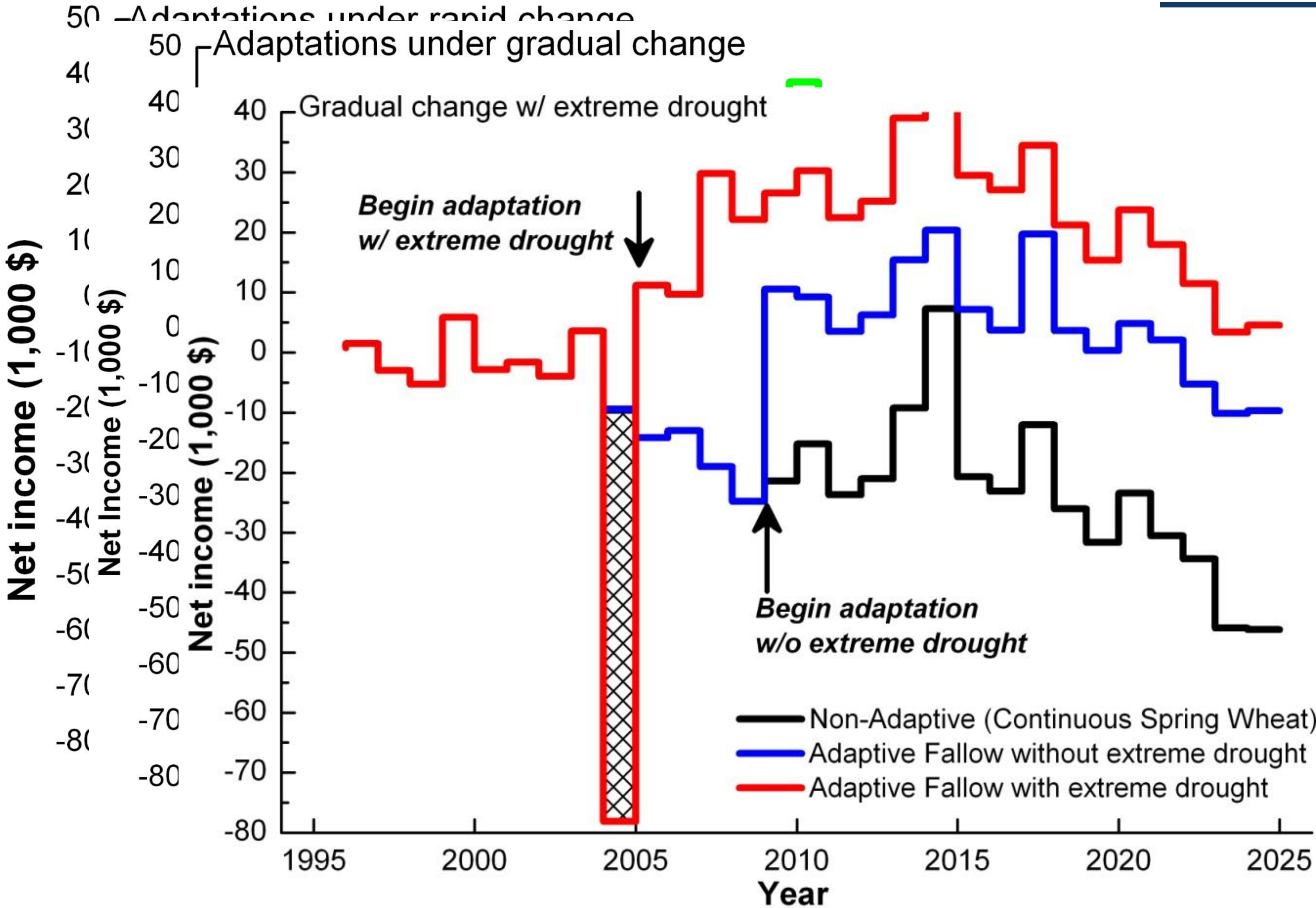
- Adapt to what trend?
- When to adapt?
- What adaptation?



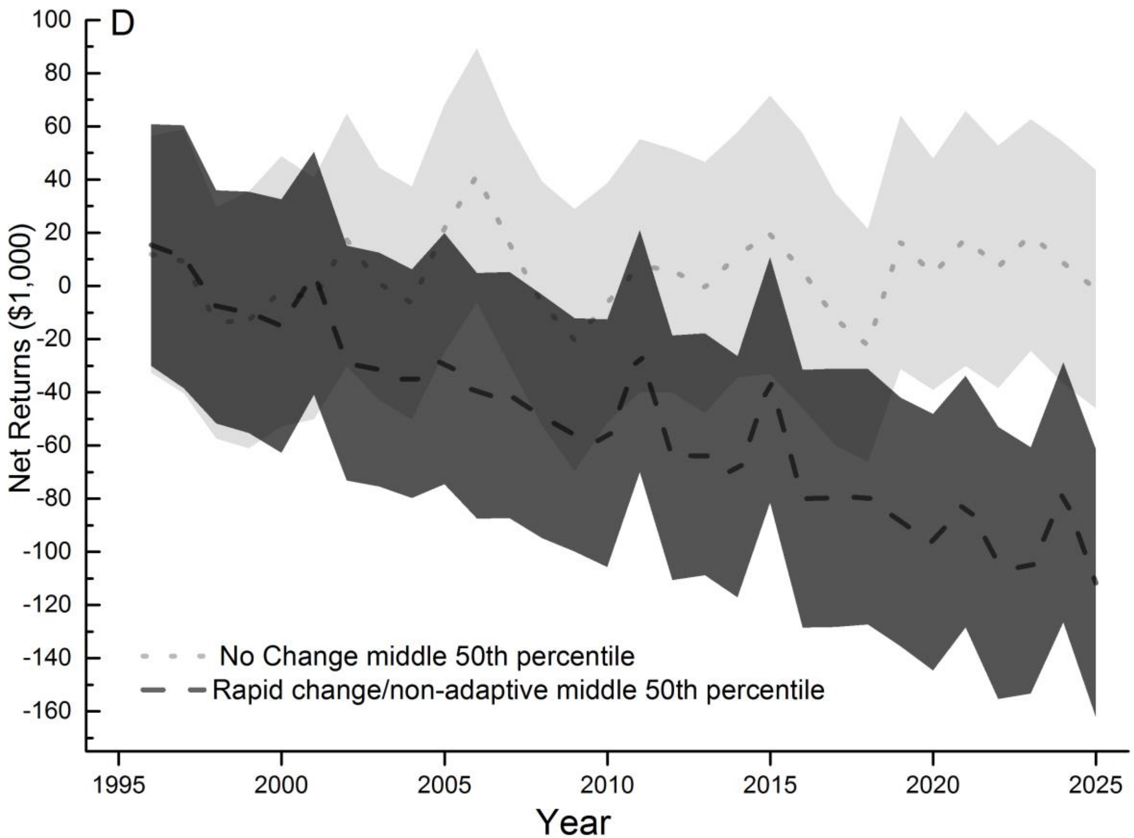
FarmAdap: Great Plains Dryland Wheat Farm Model

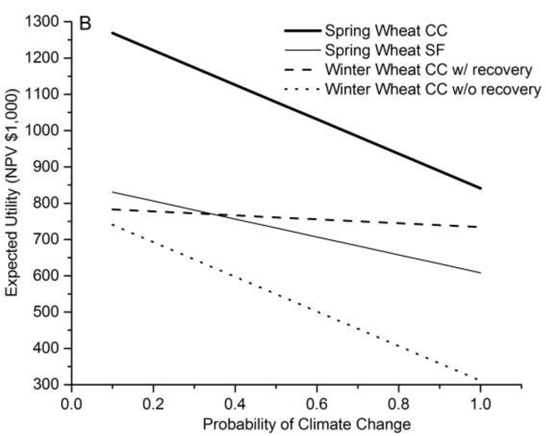


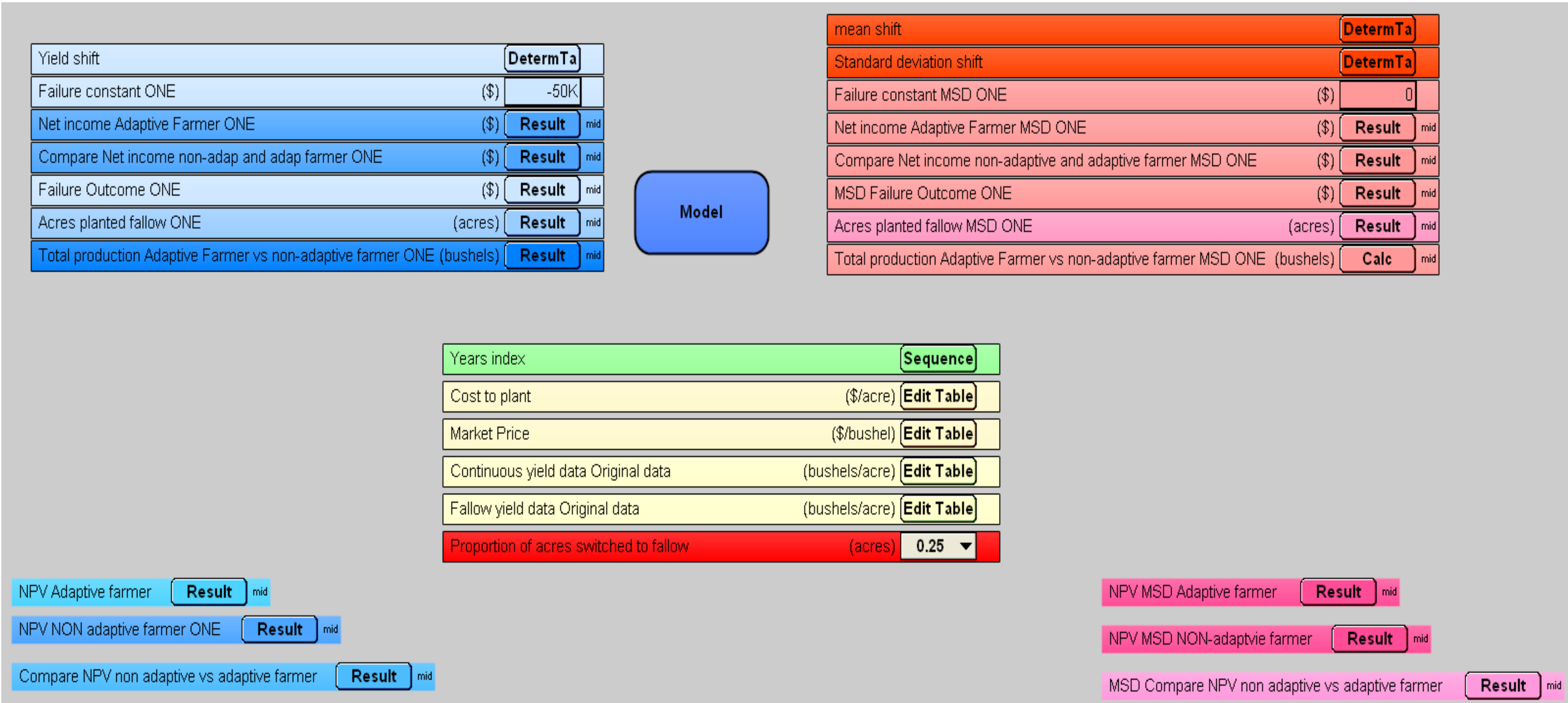




When to Adapt?


D
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
Net Returns ($1,000)
No Change middle 50th percentile
Rapid change/non-adaptive middle 50th percentile
1995
2000
2005
2010
2015
2020
2025
Year


B
1300
1200
1100
1000
900
800
700
600
500
400
300
Expected Utility (NPV $1,000)
Spring Wheat CC
Spring Wheat SF
Winter Wheat CC w/ recovery
Winter Wheat CC w/o recovery
0.0
0.2
0.4
0.6
0.8
1.0
Probability of Climate Change



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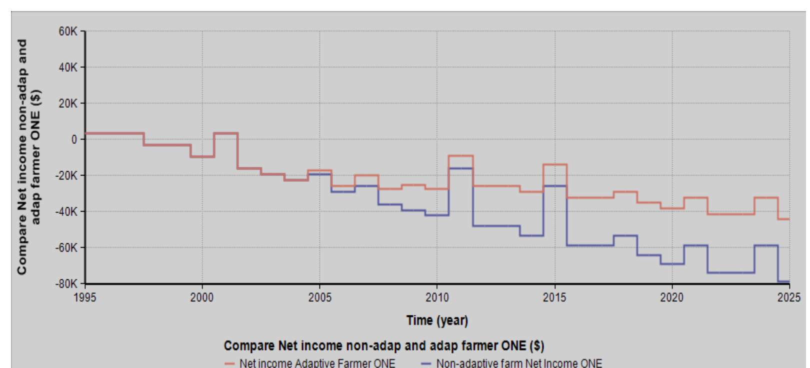


Much work to do in ag risk and climate:

- Extremes and complete loss
- Alternative risk transfer instruments
- Game theory: how to choose when choice by others affects your utility.
- Value (+/-) of additional information (e.g., seasonal to decadal forecasts)

Farmers in central North Dakota are growing more Winter Wheat as winters warm and cold-hardy varieties become available. But watch out for those cold extremes! Is it time to switch yet?

•Adapt to

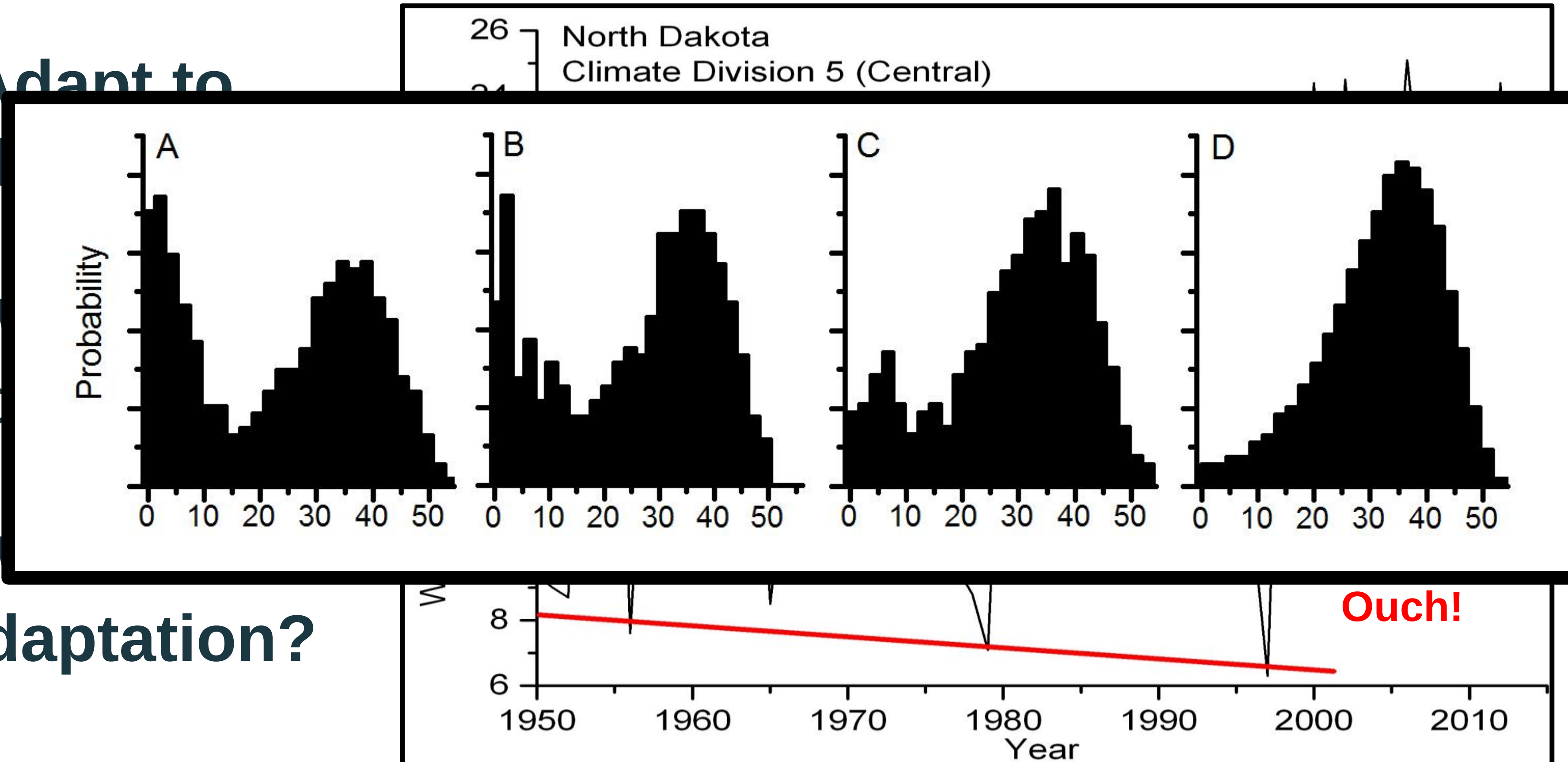
wh

•W

ac

•W

adaptation?



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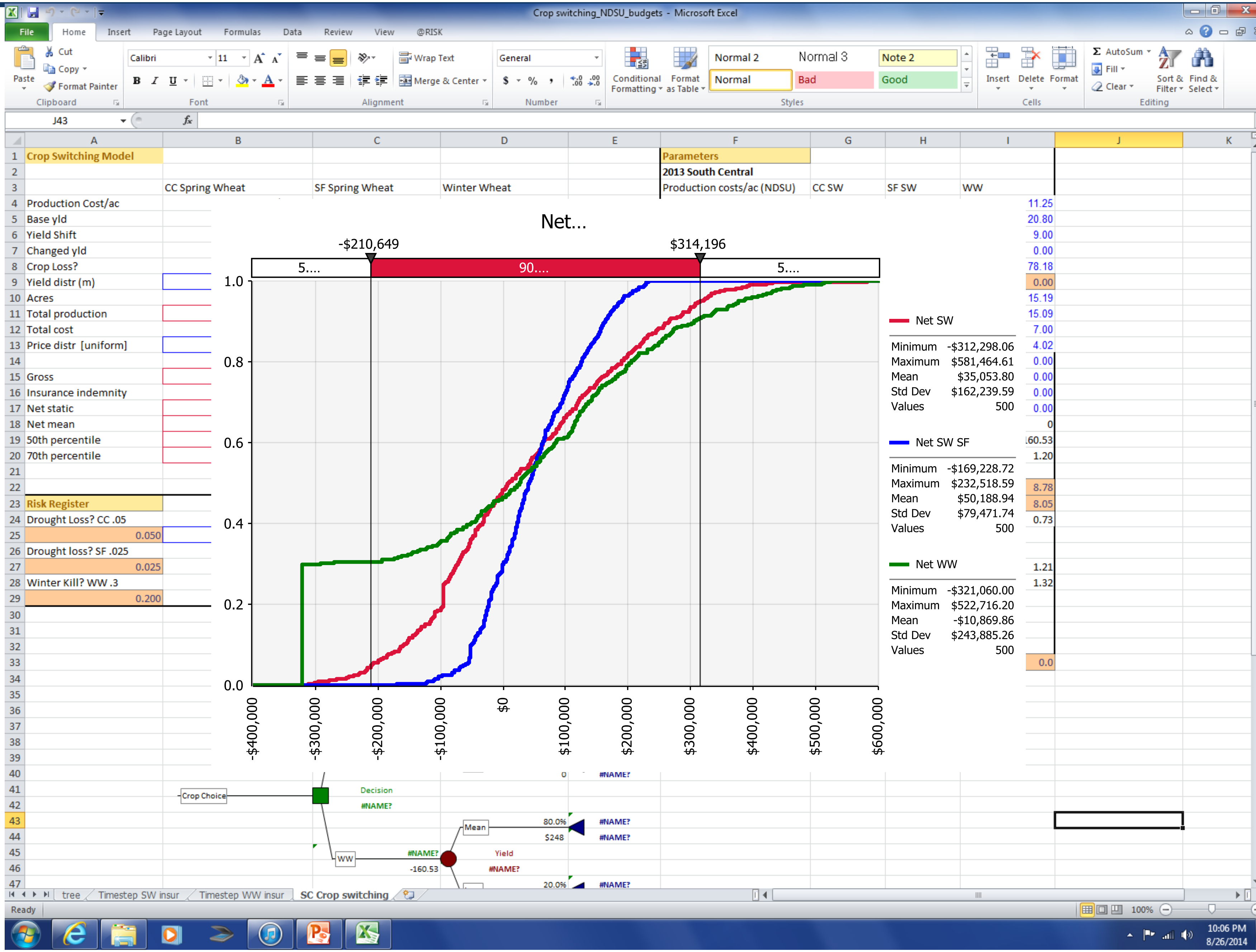
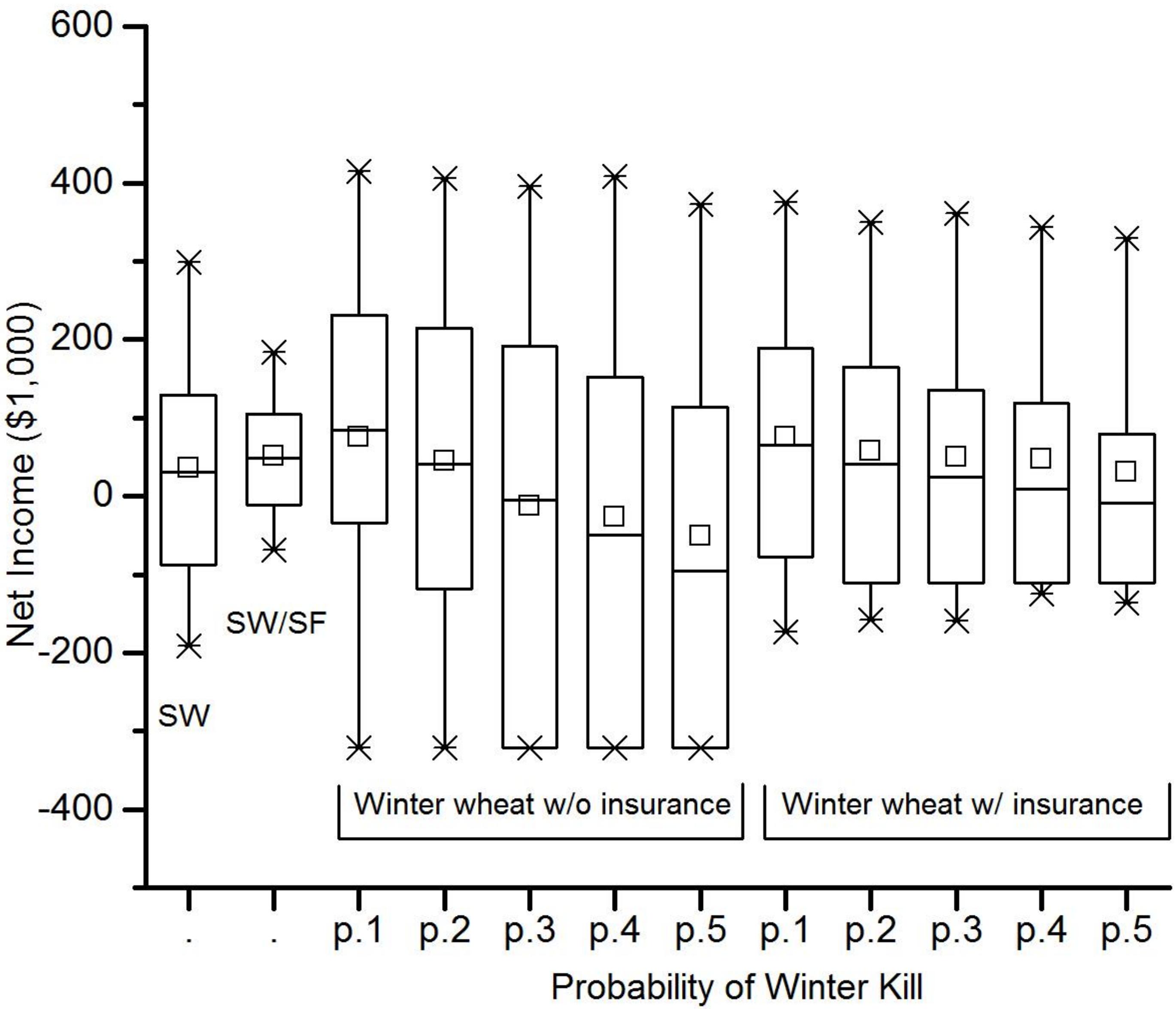
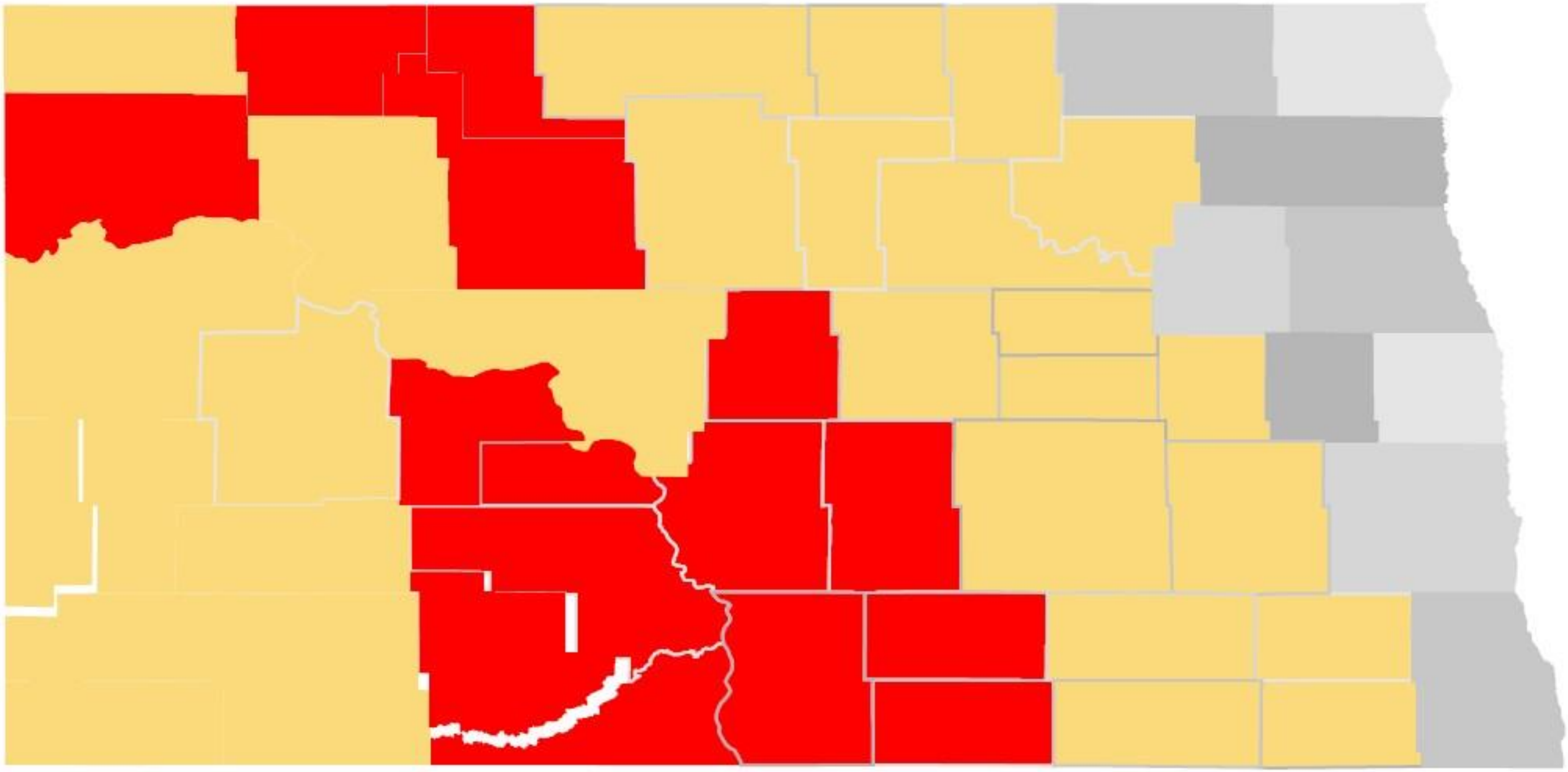
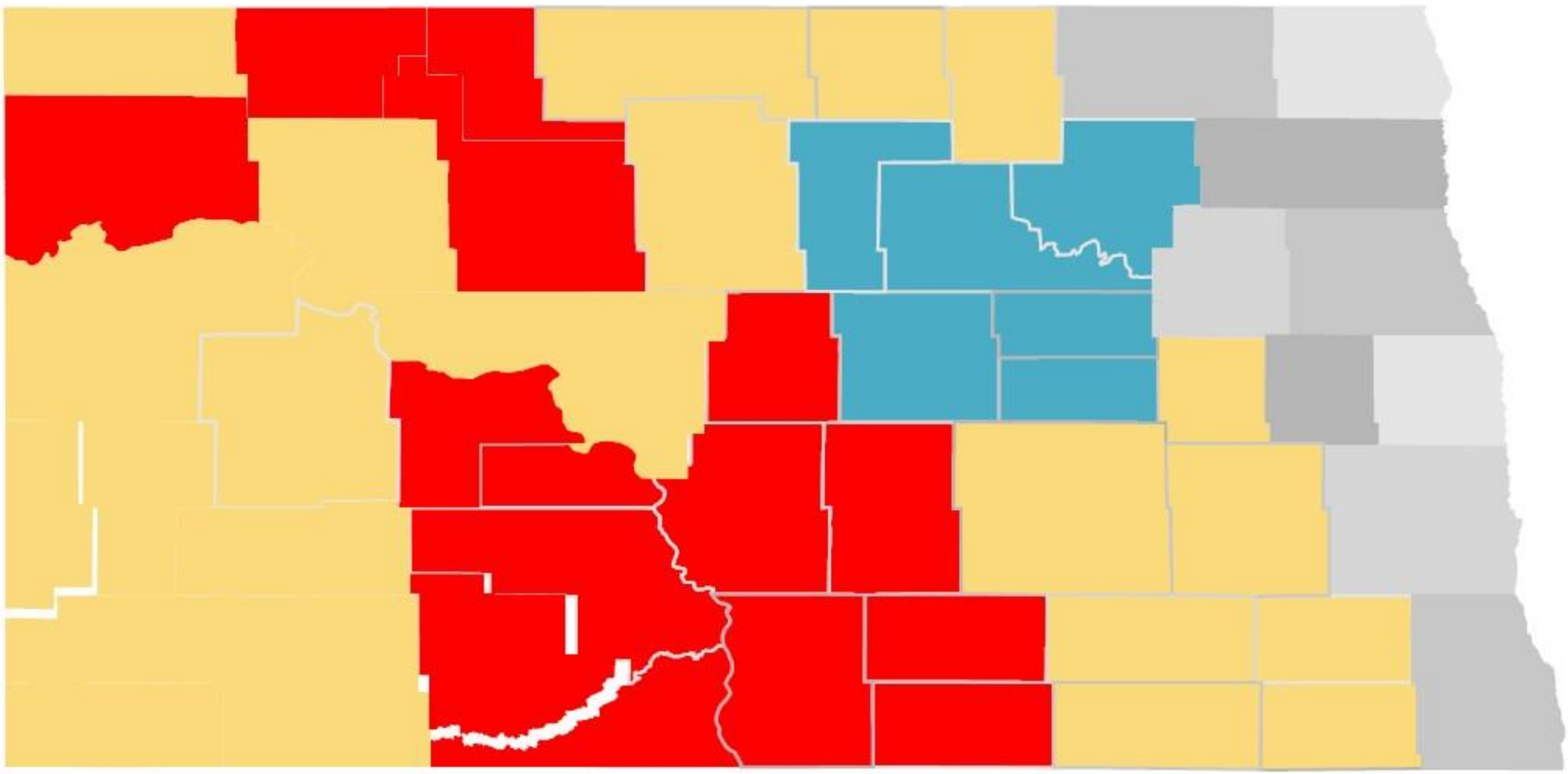



600
400
200
0
-200
-400
Net Income ($1,000)
SW
SW/SF
Winter wheat w/o insurance
Winter wheat w/ insurance
.
.
p.1
p.2
p.3
p.4
p.5
p.1
p.2
p.3
p.4
p.5
Probability of Winter Kill

North Dakota base

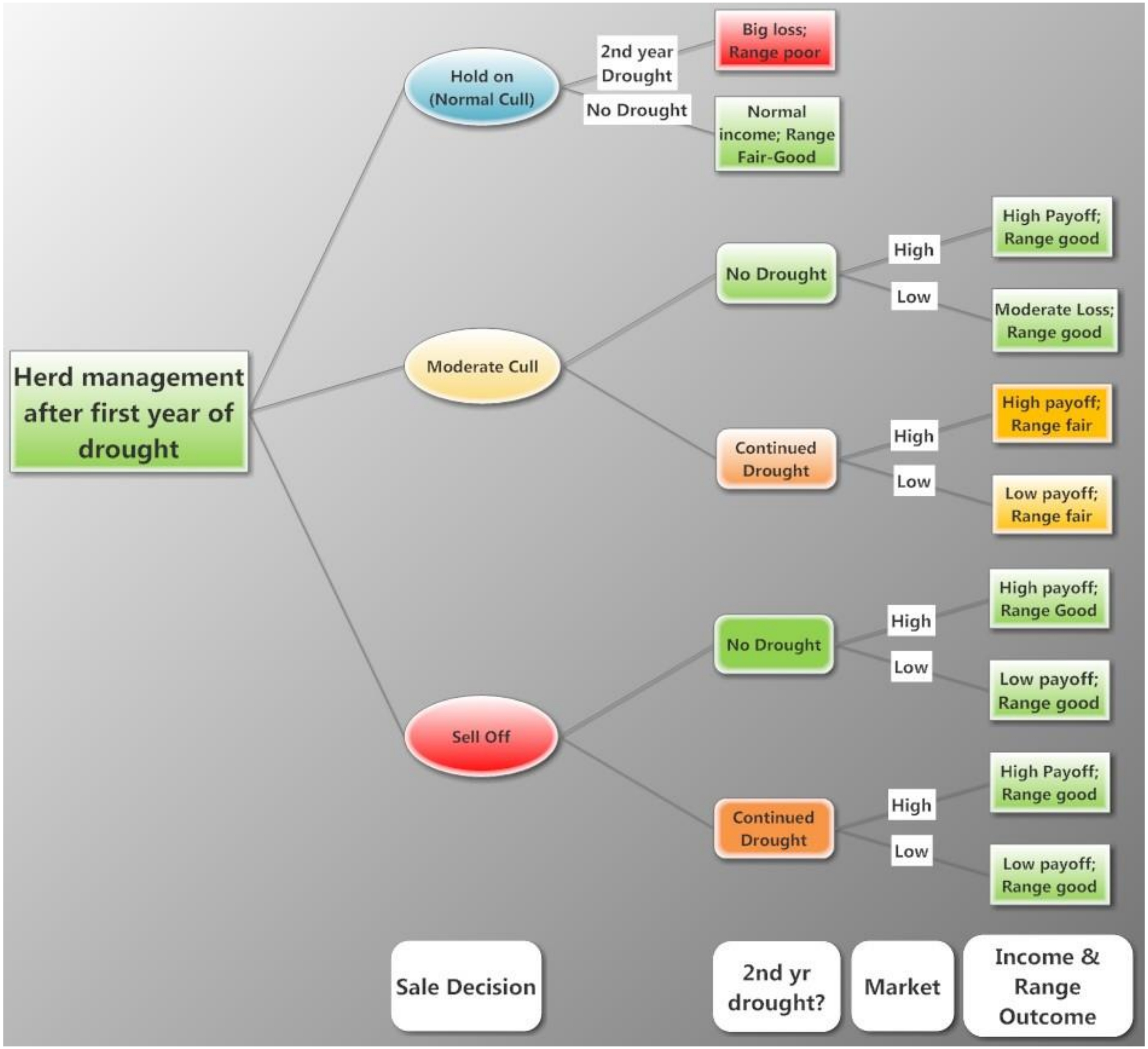


North Dakota Step 2

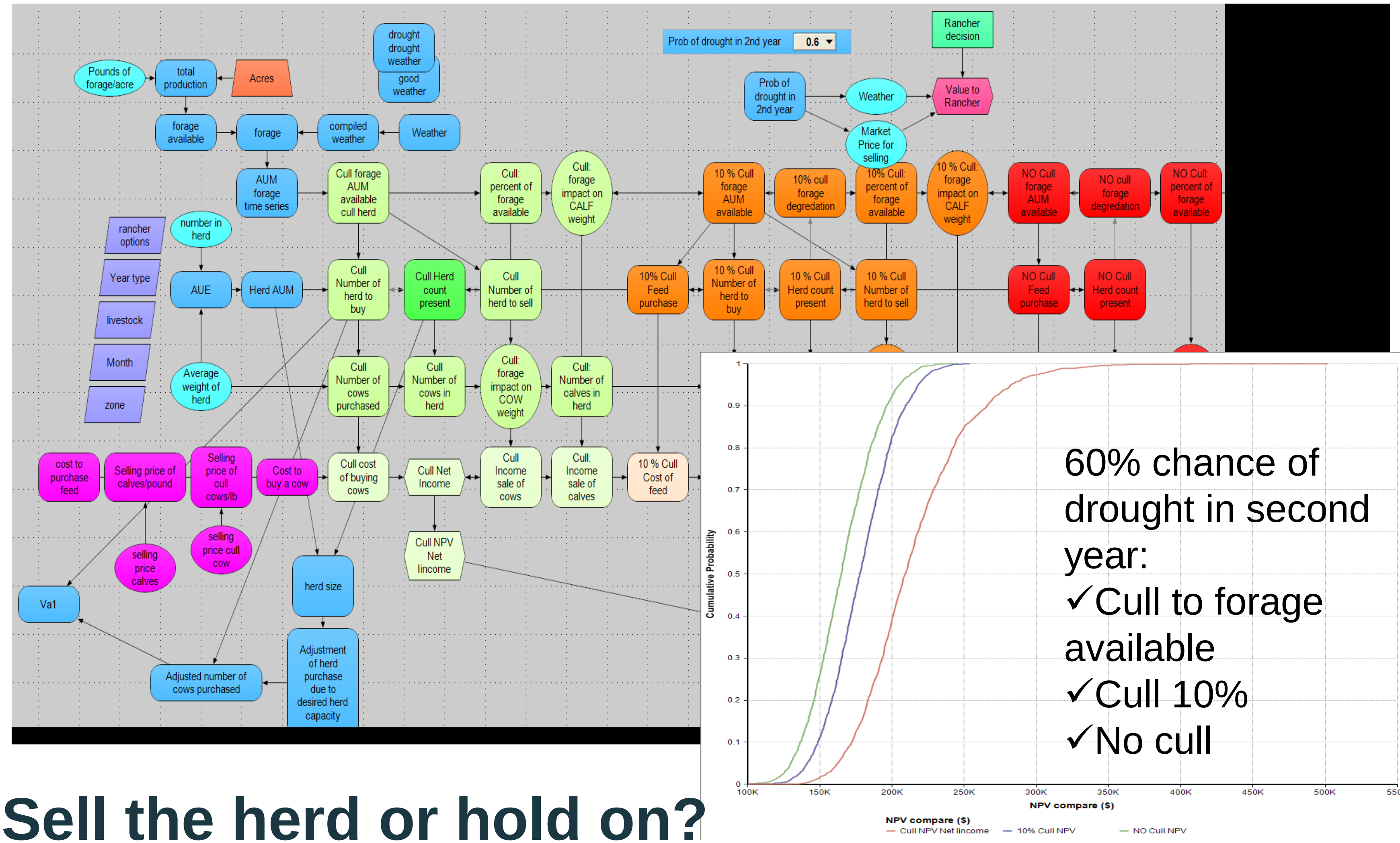


Insurance Instruments

- Yield deficiency
- Income protection
- Index insurance (often rainfall, but maybe range condition, even NVDI)
  - Is insurance adaptive?
  - Can insurance schemes keep up with climate and technological change?
  - Might it incentivize risky behaviors and non-adaptation (worries from the flood insurance program in the US)?


Herd management after first year of drought
Hold on (Normal Cull)
2nd year Drought
Big loss; Range poor
No Drought
Normal income; Range Fair-Good
Moderate Cull
No Drought
High
High Payoff; Range good
Low
Moderate Loss; Range good
Continued Drought
High
High payoff; Range fair
Low
Low payoff; Range fair
Sell Off
No Drought
High
High payoff; Range Good
Low
Low payoff; Range good
Continued Drought
High
High Payoff; Range good
Low
Low payoff; Range good
Sale Decision
2nd yr drought?
Market
Income & Range Outcome

Ranching drought decision-making model



60% chance of drought in second year:

✓Cull to forage available

✓Cull 10%

✓No cull

Sell the herd or hold on?