A Crop Weather Loss Adaptation Index for Directing Investment in Climate Resilience

Mitchell Roznik[1]

Ashok K. Mishra[2]

[1]Postdoctoral Fellow, Morrison School of Agribusiness
[2]Kemper and Ethel Marley Foundation Chair, Morrison School of Agribusiness

Arizona State University

Sponsored by **USDA National Institute of Food and Agriculture (NIFA) 2021-67023-33818**

Introduction and Objectives

Introduction

- Future weather events may become more frequent and severe due to expected changes in climate (Walthall et al., 2012, Hatfield et al., 2014).
- Average temperatures may also continue to increase resulting in more temperature anomalies in growing regions (Hansen et al., 2010).
- How will climate change affect crop production and crop risk?

Problem

Assuming current practices, weather changes may increase crop production risk (D'Agostino and Schlenker, 2016; Liu et al., 2016; Lobell et al., 2011; Tack et al., 2015) **and increase government outlays for the U.S. crop insurance program** (Tack et al., 2018)**.**

The effect of weather changes on crop production risk is uncertain, due to the unknown effects of adaptation (D'Agostino and Schlenker, 2016) **such as changes in:**

- **planting timing,**
- **crop yield genetics,**
- **alteration of inputs and**
- **crop switching.**

Need for crop risk index decoupled from weather.

Objective

- Develop a weather-related crop loss index for monitoring the weather-related crop risk that accounts for adaptation.
  - Examine any trends in the index by crop type.

- The index may be useful for:
  - policymakers directing resources for encouraging adaptation to potential changes in climate, and
  - outreach services reaching out to producers to encourage adaptation.

Data

Data: Overview

- Summary of Business Cause of Loss insurance data from 2001 to 2020 filtered by weather related cause of loss.
- Data is reported at the county level and segmented by cause of loss including, indemnity, liability, net planted acres, total premium, year of loss, and loss ratio.

Table 1: Weather related cause of loss		
Drought	Wind/Excess Wind	Tornado
Excess moisture	Flood	Hot wind
Cold winter	Heat	Fire
Excess sun	Hurricane	Hail
Frost	Cold wet weather	Tornado
Freeze	Cyclone	Storm surge
Earthquake	Tidal wave	Other (snow, lightning, etc.)
Note: This table shows the cause of loss designated as weather related		

Data: Challenges, Limitations and Solutions

Challenges

- Total indemnities are trending due to more insured acres over time and changes in commodity prices.
- The data exhibits annual variation depending on growing conditions.

Limitations

- Data quality is higher from 2001 to present compared to previous periods.
- Establishing trends over a short time frame is not robust.

Solution

- Normalization and smoothing may be needed to make the data useful for the analysis of weather-related crop production risk.
- As more data is collected trend analysis will become more valuable.

Methods

Method

- Create a weather-related crop loss index that is insensitive to commodity prices and annual production variability.

- Examine trends in the index and test for trend significance by crop type.

Normalization Methods Used in Previous Studies

Measure	Formula
1) Relative fraction of indemnities (Lobell et al., 2011; Reyes and Elias, 2019; Reyes et al., 2020)	$rel\_indem_{t,col} = \frac{indem_{t,col}}{indem_t}$
2) Loss cost ratio by cause of loss (Reyes and Elisa, 2019)	$loss\ cost_{t,col} = \frac{indem_{t,col}}{liabilities_{t,col}}$
3) Adjusted indemnities by inflation and PPI (Barthel et al., 2012)	$adjusted\ indem_{t,col}^{base\ year} = indem_{t,col} x \frac{GDPdef_{base\ year}}{GDPdef_t} x \frac{premia_{base\ year,col}}{premia_{t,col}}$

Proposed Normalization and Smoothing Method: Adjusted Indemnity per Acre

Measure	Formula
Adjusted indemnities by acre and a commodity price index	$adjusted\ indem\ acre_{t,col}^{base\ year} = indem_{t,col} x \frac{1}{net\ planted\ acres_t} x \frac{com\ price\ index_{base\ year}}{com\ price\ index_t}$
Simple moving average of the adjusted indemnity per acre	$sma\ adjusted\ indem\ acre_t = \frac{1}{n}\sum_{t-n}^{t-1} adjusted\ indem\ acre_t$

Preliminary Results

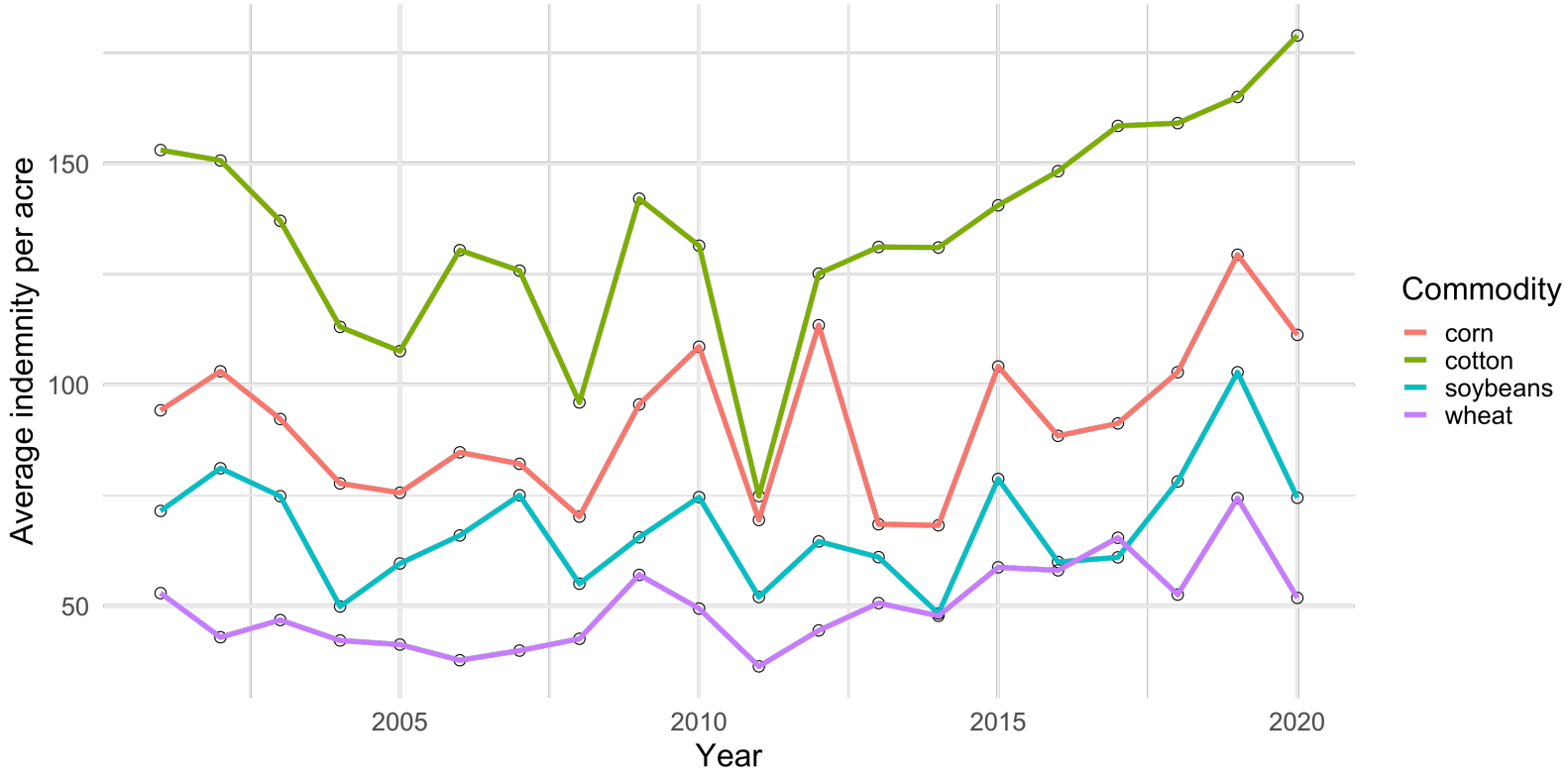
Results

The adjusted indemnity per acre measure was proposed for monitoring weather-related crop loss.

An examination of the adjusted indemnity per acre for four crops (corn, soybeans, cotton, and wheat) showed statistically significant annual trends for cotton and wheat.

Assuming trends continue, total indemnities adjusted for commodity prices (2016 base year) are expected to increase by $11 million each year for cotton, and $7 million for wheat.

Average Adjusted Indemnity per Acre by Commodity Type



Note: Average indemnity appears to be increasing over time. The annual variability is high due to growing season conditions.

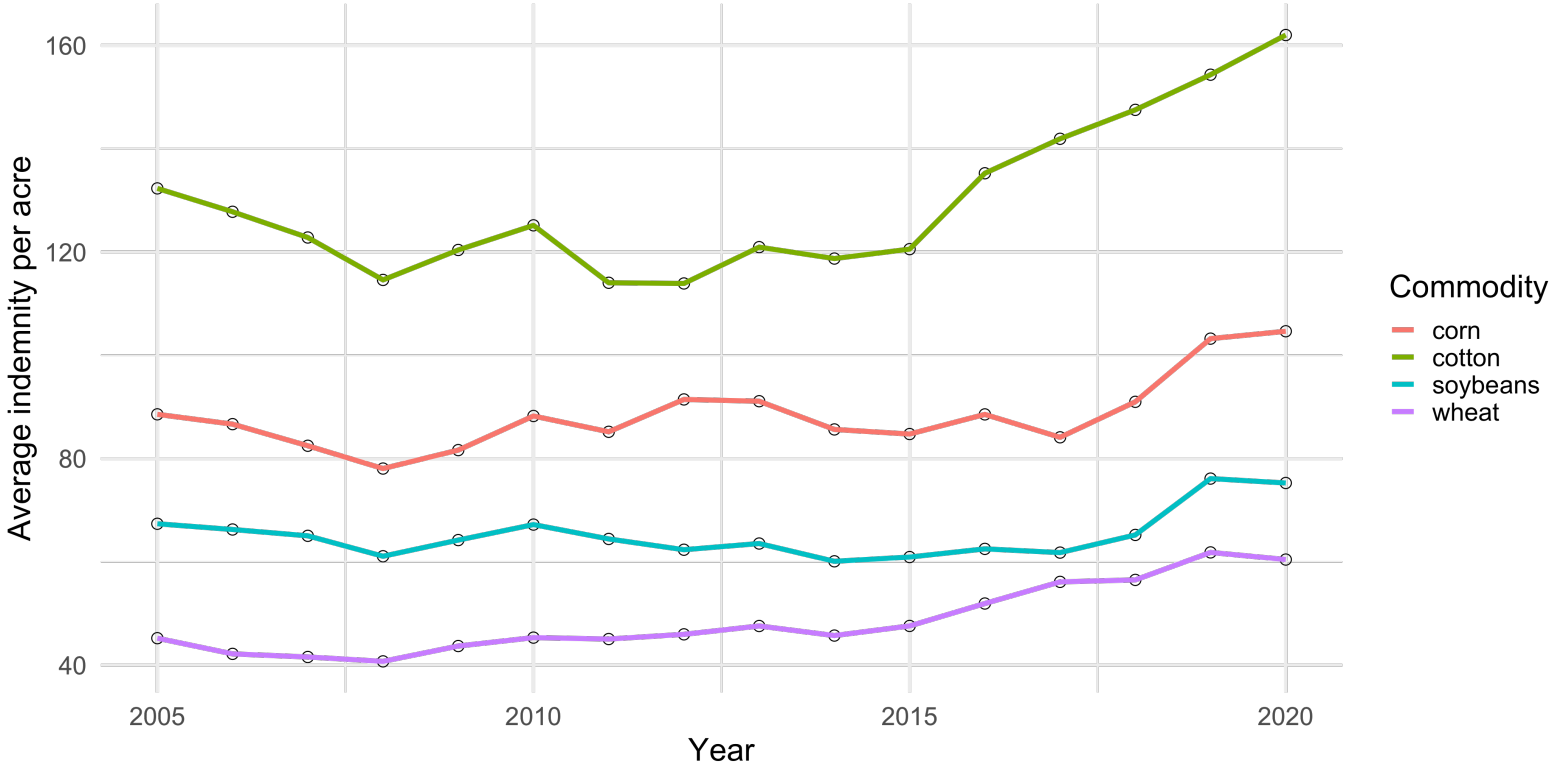
Testing for Trends in Indemnity per Acre

Table 2: Trend results

	Dependent Variable:			
	Corn	Soybeans	Cotton	Wheat
Year index	1.002	0.418	1.731*	0.993***
	(0.645)	(0.507)	(0.888)	(0.305)
Constant	81.036***	63.309***	116.830***	39.227***
	(7.727)	(6.070)	(10.634)	(3.648)
Observations	20	20	20	20
R^2	0.118	0.036	0.174	0.371
Adjusted R^2	0.069	-0.017	0.128	0.336
Residual Std. Error (df=18)	16.635	13.067	22.891	7.854
F Statistic (df=1; 18)	2.411**	0.682	3.801	10.629***

Note: Regression results indicate there is a significant positive trend for cotton indemnity per acre and Wheat indemnity per acre. In 2020 there was a total of 6.23 million acres of insured cotton. If the trend continues cotton total indemnity (adjusted for commodity prices) may increase by $11 million annually. *p<0.1; **p<0.05; ***p<0.01

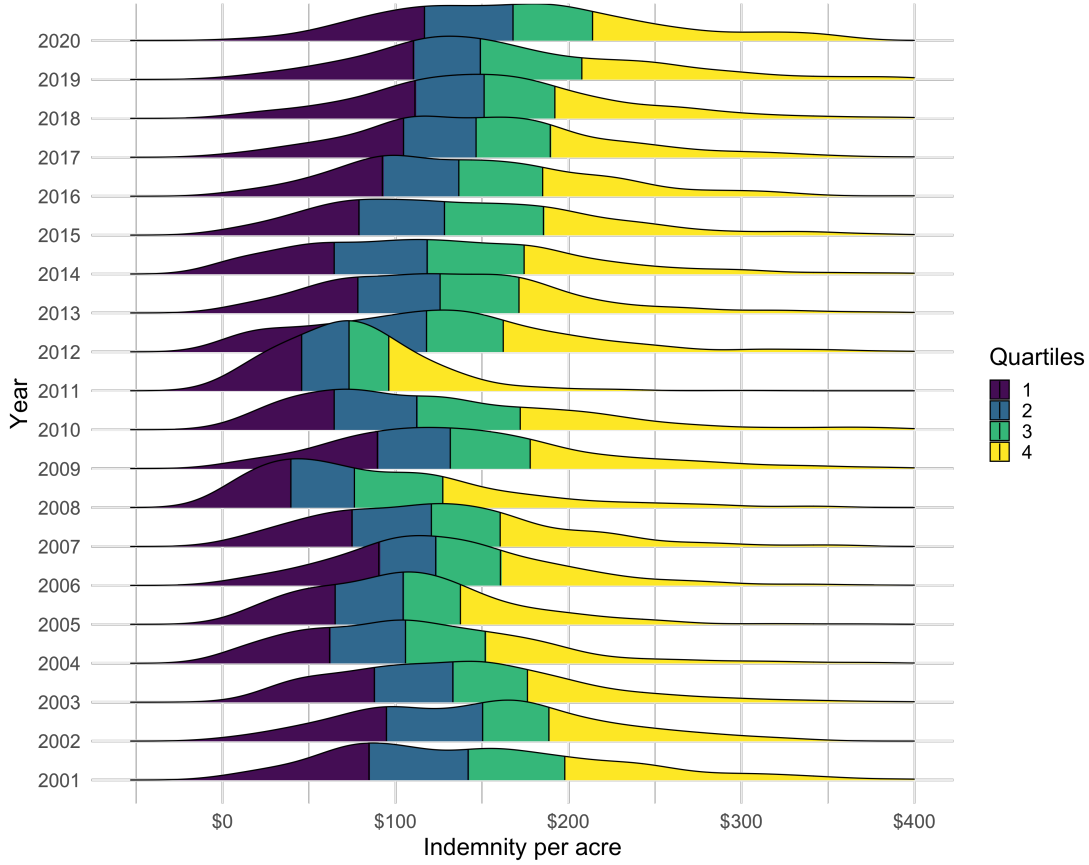
Five-year Simple Moving Average of Adjusted Indemnity per Acre



Note: Average indemnity appears to be increasing over time. The accelerating trend in cotton is concerning and could indicate higher weather-related losses in the future.

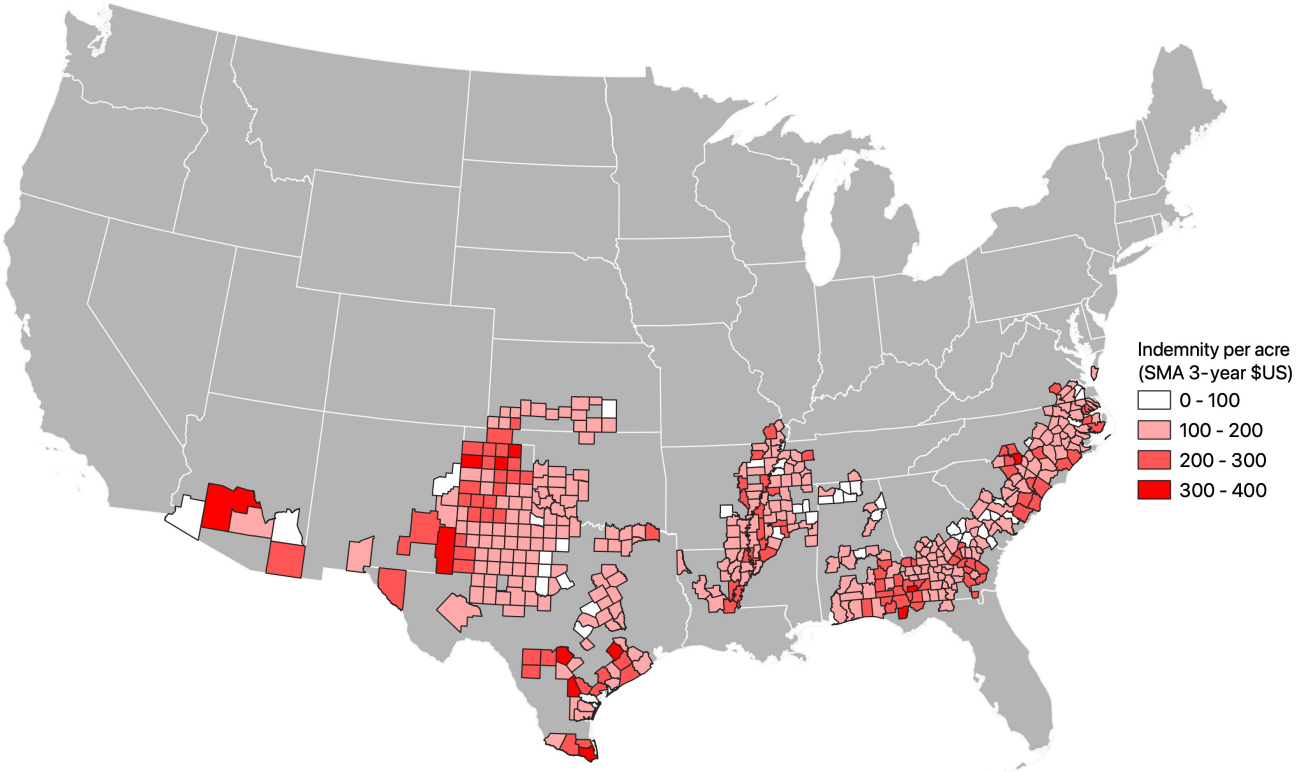
Cotton at a Closer Look

- Cotton adjusted indemnity per acre for 196 counties from 2001 to 2020.
- After 2011 the distributions appears to become flatter and broader.



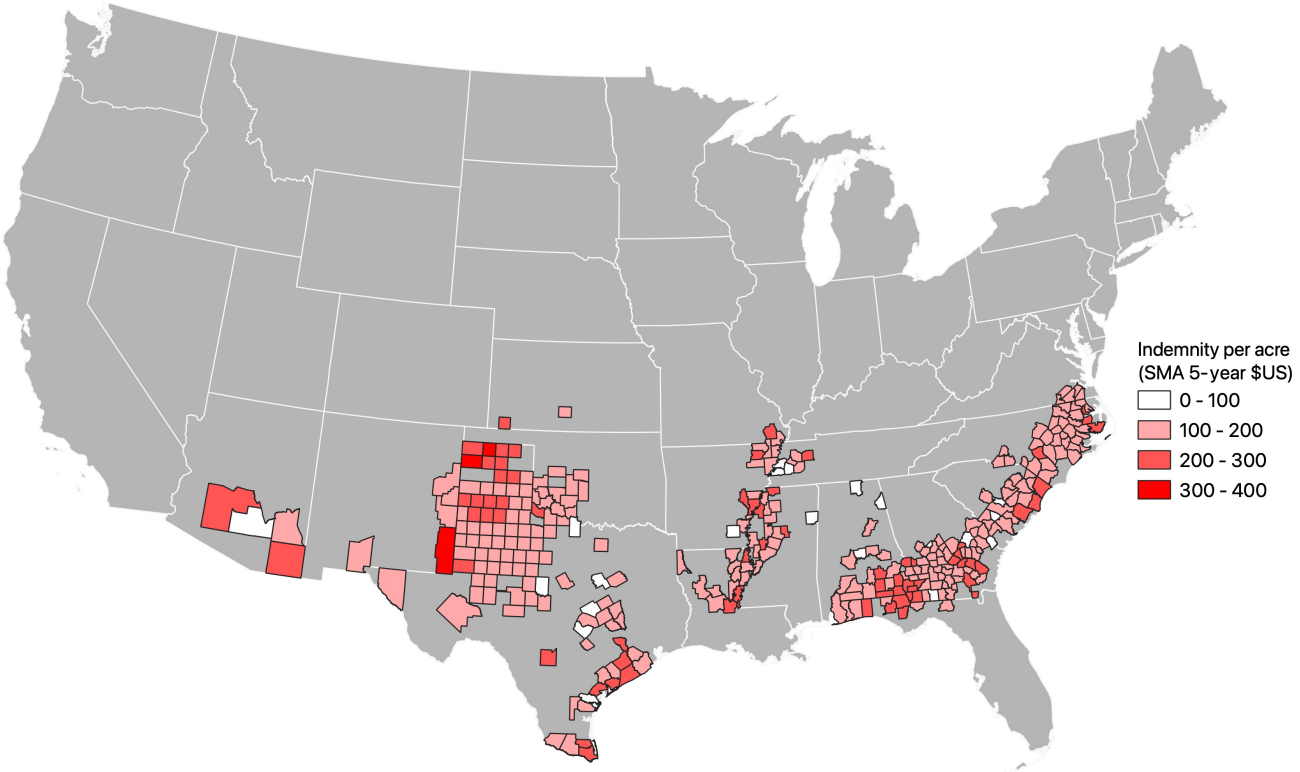
Cotton: a Closer Look

- Three-year simple moving average by county.
- Indemnities higher in Texas and New Mexico.



Cotton: a Closer Look

- Five-year simple moving average by county.
- Similar geographic pattern.



Summary

We developed a commodity weather-related loss index for monitoring the change in weather related crop yield risk that accounts for adaptation. Then examined trends in the index.

Cotton and wheat showed statistically significant annual trends. The economic impact assuming trends continue is an increase in total adjusted indemnity of $11 million annually for cotton and $7 million for wheat.

Future Directions

Examine % changes in the index for crops over time.

Investigate additional moments of the adjusted indemnity per acre distribution.

Create a process to improve data quality from 1989 to 2001.

Correlation analysis between weather changes and index changes.

Investigate the potential for using the index as a predictor for future climate impact on crop production.

Thank you!

Mitchell Roznik, PhD
mitchell.roznik@asu.edu