OreCal

a policy research collaboration

Center for Agricultural & Environmental Policy at Oregon State University

University of California Agricultural Issues Center

Impacts of Changes in Federal Crop Insurance Programs on Land Use and Environmental Quality

Roger Claassen[a], Christian Langpap[b], Jeffrey Savage[a], and JunJie Wu[b]

[a] *USDA Economic Research Service*

[b] *Oregon State University*

Presented in

Crop Insurance and the 2014 Farm Bill: Implementing Change in U.S. Agricultural Policy

October 8-9, Louisville, Kentucky

Introduction

- The focus of federal agricultural policy has shifted from direct payments to risk management.
- Federal crop insurance has become the central component of agricultural support in the U.S.

Introduction

- More than 265 million acres were enrolled in the crop insurance program in 2011, with $114 billion in estimated total liability.
- The corresponding costs to the federal government were over $11 billion.
- The Congressional Budget Office projects expenditures exceeding $90 billion over the next decade

Introduction

- Crop insurance alters producers' incentives in two broad ways.
  - Premium subsidies add to expected revenue for crop production, which may create incentives for farmers to expand crop production to marginal lands.
  - Crop insurance reduces the risk of growing covered crops relative to other crops, thus potentially affecting farmers' crop mix and input use.

Introduction

- Changes in land use and crop mix may have unforeseen secondary effects on environmental quality.
  - Soil erosion
  - Water quality
  - Wildlife habitat
  - Carbon sequestration

Objectives

- To evaluate the effects of crop insurance on land use in the Corn Belt:
  - conversions of non-cropland to crop production
  - changes in crop mix and crop rotation

- To estimate the potential effects of land use changes under crop insurance on environmental quality
  - soil erosion
  - nitrate runoff
  - nitrate percolation
  - soil organic carbon loss

Literature

- Effects of crop insurance on crop mix:
  - Wu (1999)
  - Wu and Adams (2001),
  - Young et al. (2001)
  - Glauber (2004)
  - Goodwin et al. (2004)
  - Goodwin and Smith (2013)
- Effects of crop insurance on input use:
  - Horowitz and Lichtenberg (1993)
  - Smith and Goodwin (1996)
  - Babcock and Hennessy (1996)
- Effect of crop insurance on soil erosion:
  - Goodwin and Smith (2003)
  - Walters et al. (2012)

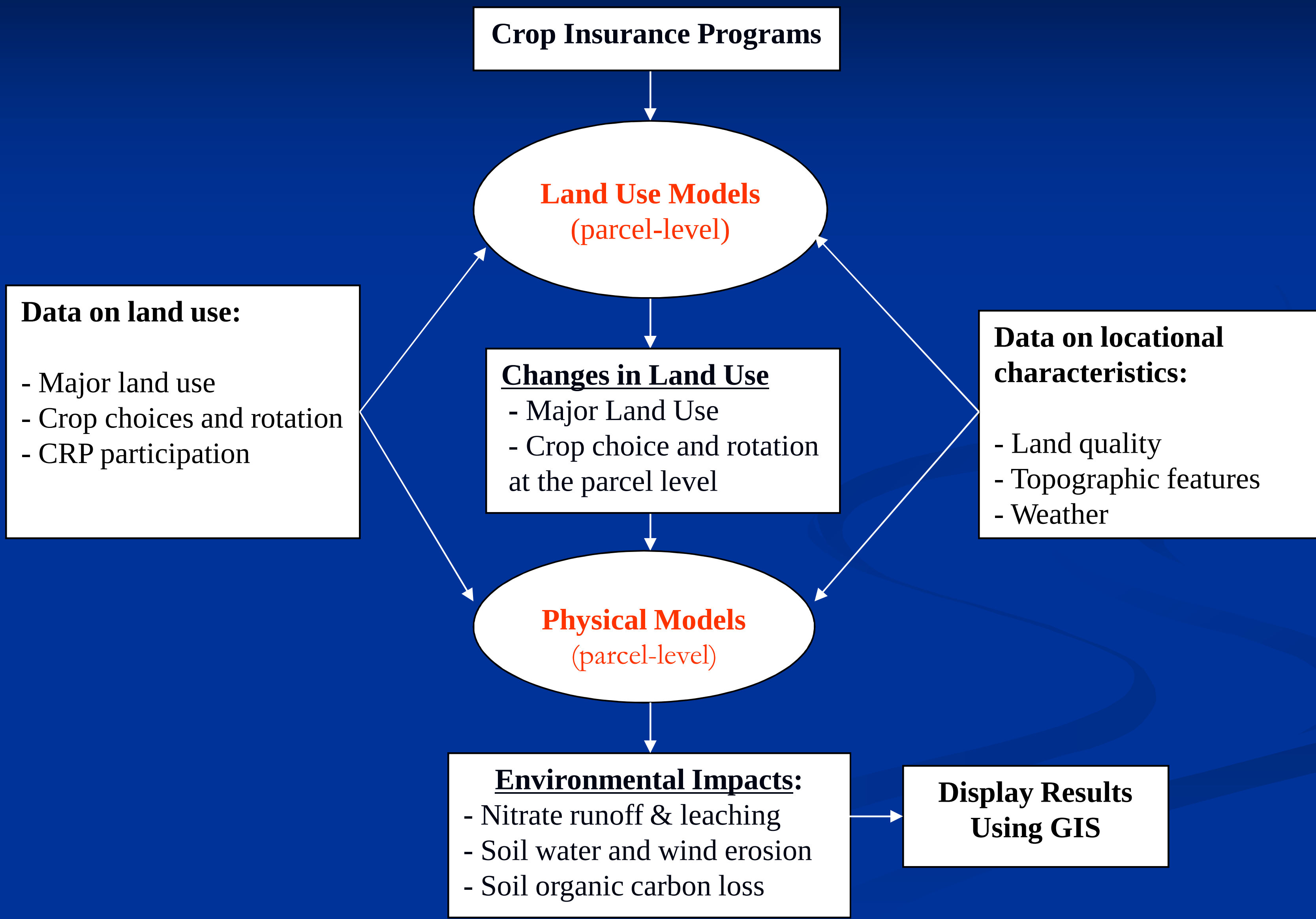
Approach

- Theoretical Model
  - Purpose: To better understand how risks affect farmers' planting decisions.
  - Key insight: The share of land allocated to a crop depends on the mean, variance, and covariance of net returns for all crops:

$$s_i^* = s_i\left(E\pi_0,...,E\pi_N;V(\pi_0),...,V(\pi_N);Cov(\pi_0,\pi_1),...,Cov(\pi_0,\pi_N),...,Cov(\pi_{N-1},\pi_N)\right)$$

$i = 1, 2, \ldots, N.$

Empirical Framework



The Land Use Models

A set of logit models to predict at the parcel level:

a) major land use (crop vs. non-crop):

$$P_j = P(major\ \ land\ \ use\ \ j) = \frac{e^{X'_j\beta_j}}{\sum_{k=0}^{N} e^{X'_k\beta_k}},\ \ j = 1, 2$$

a) crop choice (corn, soybeans, wheat, hay, others):

$$P_i = P(i\,|\,crop)\cdot P(crop) = \frac{e^{X'_i\beta_i}}{\sum_{k=1}^{N} e^{X'_k\beta_k}} \cdot \frac{\sum_{k=1}^{N} e^{X'_k\beta_k}}{\sum_{k=0}^{N} e^{X'_k\beta_k}},\ \ i = 1,\ldots,N$$

Based on

- expected revenue for alternative crops
- variance and covariance of revenues
- cost variables
- land quality
- weather conditions
- land use in previous year on the parcel

Economic Models: Data

- Land use/crop choice data
  - National Resources Inventories (NRIs)
  - NRIs collect information at 800,000 sample sites
  - At each NRI site, information on 200 attributes is collected
  - 1982, 1987, 1992, 1997, 1998-2002 NRIs
- Land quality
  - Topographical features and soil characteristics at each NRI site were collected by linking NRI to the SOIL-5 database
- Weather
  - The Midwestern Climate Center
  - Mean and variance of max and min daily temperatures and precipitation during corn, soybean and wheat growing seasons
- Output and input prices
- Government commodity program provisions

Physical Models

- Consists of a set of environmental productions functions, which link land use and crop management practices to a set of selected environmental indicators.
- The environmental production functions are estimated using a metamodeling approach.
- The specific method used to develop the environmental production functions can be found in Mitchell at al. (1998) and Wu and Babcock (1999).
- The environmental production functions have been applied in several previous studies (Wu et al. 2004; Langpap and Wu 2013).

Simulating the Effects of Crop Insurance

- Consider a county ARC policy that guarantees a minimum revenue:

$$R^I = \begin{cases} \alpha \bar{R} & \text{if } R < \alpha \bar{R} \\ R & \text{if } R \geq \alpha \bar{R} \end{cases}$$

where

$\bar{R}$ is the ARC county guarantee
α is the coverage level

Simulating the Effects of Crop Insurance

- The expected revenue and variance of revenue for the crop under the insurance equal:

$$E(R^I) = E(R) + V(R)^{1/2}[\phi(h) + h\Phi(h)] + S - C$$

$$V(R^I) = V(R)\{1 - \Phi(h) + h\phi(h) + h^2\Phi(h) - [\phi(h) - h\Phi(h)]^2\}$$

where

$$h = (\alpha\bar{R} - E(R)) / V(R)^{1/2}$$

$\phi(.)$ *and* $\Phi(.)$ are the pdf and cdf of the standard normal dis.

S is the per-acre government subsidy for insurance premium

C is the insurance premium per acre

Simulating the Effects of Crop Insurance

- Substituting the expected revenues and variances of revenues into the land use models, we can predict the land use and crop choices at each NRI site under the crop insurance.
- Feeding land use information and corresponding nitrogen application rate into the environmental production functions, we estimate N runoff, N leaching, soil water erosion, soil wind erosion, and soil organic carbon loss.
- Comparing the predictions under the crop insurance with the baseline results, we estimate the effects of crop insurance on land use and environmental quality.

Results

- Results on Land Use Models
- Results on the Effects of Insurance on Land Use
- Results on the Effect of Insurance on Environmental Quality

Table 1. Major Land Use Choice Model - Elasticities of the Probability of Allocating a Parcel to Cropland

Variable	
Expected revenue for corn	0.494***
	(0.003)
Variance of revenue for corn	-0.024***
	(0.001)
Expected revenue for wheat	0.056***
	(0.002)
Variance of revenue for wheat	-0.054***
	(0.001)
ARP rate for corn	0.059***
	(0.001)
ARP rate for wheat	-0.005***
	(0.001)
Price of hay in previous year	-0.007***
	(0.002)
Good land	0.022***
	(0.001)
Bad land	-0.005***
	(0.0001)
Slope	-0.073***
	(0.0004)
Mean precipitation corn season	-0.189***
	(0.007)
Std. Deviation precipitation corn season	0.084***
	(0.008)
Mean maximum temperature corn season	-0.540***
	(0.015)
Mean precipitation wheat season	0.010***
	(0.001)
Std. Deviation precipitation wheat season	-0.059***
	(0.003)
Observations	964,387

Note: Std. errors in parentheses.
*, **, *** denote statistical significance at α = 10%, 5%, and 1%.
All elasticities are evaluated at the sample means of variables.

Results – The Major Land Use Model

Table 1. Elasticities of the Probability of Allocating a Parcel to Cropland with Respect to Selected Variables

Variable	1982-1997	1997-2010
Expected revenue for corn	0.494***	0.227***
Variance of revenue for corn	-0.024***	-0.049***
Expected revenue for wheat	0.056***	0.104***
Variance of revenue for wheat	-0.054***	-0.031
Good land	0.022***	0.041***
Slope	-0.073***	-0.137***

Note: *, **, *** denote statistical significance at α = 10%, 5%, and 1%.
All elasticities are evaluated at the sample means of variables.

Results – The Crop Choice Model

Table 2. Elasticities of Probabilities of Choosing Corn and Soybeans with Respect to Selected Variable

Variable	1982-1997		1997-2010	
	Corn	Soybeans	Corn	Soybeans
Expected revenue for corn	0.430***	-0.312***	1.484***	-1.166***
Variance of revenue for corn	-0.072***	0.150***	-0.219***	0.167***
Land Characteristics				
Good land	0.034***	-0.037***	0.053***	-0.033***
Slope	0.059***	-0.142***	-0.016	-0.079***

Note: *, **, *** denote statistical significance at α = 10%, 5%, and 1%.
All elasticities are evaluated at the sample means of variables.

Model Validation

Table 3– Predicted vs. Actual Acres of Land Uses (1000 acres)

	Actual 1997 (NASS)	Predicted	Mean Actual 2009-2012 (NASS)	Predicted
Acres of cropland	85,626	83,308	83,837	87,118
Acres of Corn	35,950	32,291	39,113	40,676
Acres of Soybeans	35,350	32,490	33,950	28,123
Acres of Other Crops	14,326	18,527	10,774	18,319

Table 2. Crop Choice Model - Elasticities of Probabilities of Choosing Alternative Crops

Variable	Corn	Soybeans	Wheat	Hay	Other
Revenue, Price, and Policy Variables					
Expected revenue for corn	0.430***	-0.312***	-1.071***	-1.071***	-1.071***
	(0.015)	(0.022)	(0.036)	(0.036)	(0.036)
Variance of revenue for corn	-0.072***	0.150***	-0.149***	-0.149***	-0.149***
	(0.009)	(0.012)	(0.027)	(0.027)	(0.027)
Expected revenue for wheat	-0.009***	-0.009***	0.226***	-0.009***	-0.009***
	(0.001)	(0.001)	(0.027)	(0.001)	(0.001)
Variance of revenue for wheat	0.035***	0.035***	-0.831***	0.035***	0.035***
	(0.002)	(0.002)	(0.039)	(0.002)	(0.002)
Variance correlation corn-soybeans	0.061***	-0.076***	-0.288***	-0.142***	0.234***
	(0.011)	(0.015)	(0.043)	(0.045)	(0.041)
Variance correlation corn-wheat	0.047***	-0.109***	0.647***	0.422***	-0.484***
	(0.009)	(0.012)	(0.068)	(0.030)	(0.028)
Expected price for hay	0.0003	0.0003	0.0003	-0.014	0.0003
	(0.001)	(0.001)	(0.001)	(0.043)	(0.001)
ARP rate for corn	0.067***	-0.106***	0.026***	0.026***	0.026***
	(0.003)	(0.004)	(0.008)	(0.008)	(0.008)
ARP rate for wheat	0.009***	0.009***	-0.207***	0.009***	0.009***
	(0.0004)	(0.0004)	(0.008)	(0.0004)	(0.0004)
Fuel price	0.008	-0.424***	1.479***	0.095	1.999***
	(0.027)	(0.038)	(0.092)	(0.126)	(0.106)
Wage rate	0.065*	0.258***	-3.706***	0.571***	0.149
	(0.037)	(0.053)	(0.137)	(0.173)	(0.143)
Land Characteristics					
Good land	0.034***	-0.037***	0.016*	-0.042***	-0.094***
	(0.002)	(0.003)	(0.008)	(0.011)	(0.009)
Bad land	-0.001***	0.002***	-0.001	-0.0003	0.003***
	(0.0003)	(0.0004)	(0.001)	(0.0009)	(0.001)
Slope	0.059***	-0.142***	0.180***	0.233***	0.162***
	(0.002)	(0.003)	(0.007)	(0.007)	(0.006)
Available water capacity	-0.001	0.119***	-0.258***	-0.471***	-0.480***
	(0.016)	(0.023)	(0.055)	(0.070)	(0.057)
Organic matter	0.015***	-0.019***	-0.101***	0.013*	0.059***
	(0.001)	(0.002)	(0.011)	(0.008)	(0.005)
Soil pH	0.308***	-0.166***	-0.910***	-0.935***	-1.019***
	(0.025)	(0.035)	(0.090)	(0.122)	(0.091)
Coarse-textured soil	0.002***	-0.003***	0.0002	-0.002	0.003***
	(0.0003)	(0.0004)	(0.001)	(0.001)	(0.001)
Fine-textured soil	-0.007***	0.012***	0.006***	-0.017***	-0.010***
	(0.0004)	(0.0006)	(0.001)	(0.002)	(0.002)
Weather Conditions during Corn or Wheat Growing Season					
Mean maximum temperature corn season	-2.355***	3.001***	1.518***	1.518***	1.518***
	(0.065)	(0.094)	(0.161)	(0.161)	(0.161)
Mean precipitation corn season	0.184***	-0.127***	-0.482***	-0.482***	-0.482***
	(0.028)	(0.040)	(0.072)	(0.072)	(0.072)

Results–Effect of Crop Insurance on Land Use

Consider three coverage levels of insurance for corn, soybeans and wheat:

- Insures 50% of revenue
- Insures 75% of revenue
- Insures 90% of revenue.

Results–Effect of Crop Insurance on Land Use

- As the level of insurance coverage goes up, expected revenue increases for all crops.

- But the changes are small;
  - expected revenue for corn, soybeans, and wheat increases 1.2%, 0.4%, and 0.4%, respectively, at the highest level of coverage ($\alpha = 90\%$).

Results–Effect of Crop Insurance on Land Use

- The impacts on the variance of revenues are significant.
- For the highest level of coverage ($\alpha = 90\%$) the variances decrease by – 27%, -13%, and -7% for corn, soybeans, and wheat, respectively.
- Revenue insurance can significantly decrease the risk of growing covered crops.

Results–Effect of Crop Insurance on Land Use

Table 4. Estimated Impacts of Crop Insurance on Land Use

	Baseline (1000 acres)	% Change from the baseline under different coverage levels		
		α = 50%	α = 75%	α = 90%
Acres of cropland	66,116	0.2%	0.8%	2.0%
Acres of non-cropland	15,728	-0. 7%	-3.4%	-8.3%
Acres of Corn	26,755	16.3%	17.2%	18.3%
Acres of Soybeans	24,056	8.2%	7.5%	5.8%
Acres of Other Crops	15,305	-62.2%	-60.3%	-59.8%

Results–Effect of Crop Insurance on Land Use

Table 4. Effects of Crop Insurance on Cropping Systems

	Baseline (1000 acres)	% Change from the baseline under different coverage levels		
		α = 50 %	α = 75%	α = 90%
Continuous corn	15,832	17.5%	19.3%	22.3%
Continuous soybeans	11,639	6.4%	5.5%	2.3%
Continuous wheat	971	-41.8%	-37.6%	-15.9%
Corn-Soybeans	20,885	12.2%	11.4%	9.5%
Corn-Corn-Soybeans	827	53.6%	58.3%	61.1%
Corn-Soybeans-Wheat	130	32.5%	29.9%	36.9%
Soybeans-Soybeans-Corn	243	4.0%	5.0%	6.3%
Wheat-Soybeans	940	-15.5%	-13.1%	5.8%
Corn-Corn-Hay	5,657	-11.3%	-8.6%	-4.0%

Results–Effects on Environmental Quality

Table 5. Effects of Crop Insurance on Environmental Quality

Indicator	Baseline	% Change from the baseline under different coverage levels		
		α = 50%	α = 75%	α = 90%
Nitrogen Runoff (1000s lbs.)	729,471	6.4%	6.4%	6.4%
Nitrogen Percolation (1000s lbs)	486,762	3.7%	4.1%	5.1%
Loss of Soil Organic Carbon (1000s metric tons)	8,830	1.0%	1.8%	3.6%
Wind Erosion (1000s tons)	149,884	24.5%	22.4%	16.3%
Water Erosion (1000s tons)	375,296	0.4%	0.9%	6.4%

Conclusions (tentative)

- A crop insurance plan based on historical revenues will not results in significant conversions of non-cropland to cropland in the Corn Belt.
- The more meaningful impact of revenue insurance will be on crop choice and crop rotation.
- The changes in land use and cropping systems will have small to moderate effects on agricultural runoff and environmental quality.

Conclusions

- Higher commodity prices, however, can have much larger effects on land use and environmental quality (Langpap and Wu, 2013).
- Eighty-two percent of the region's pasture and range land will be converted to cropland with $8 corn.
- Rising commodity prices will also result in large changes in crop mix and rotation systems in the Midwest.
- With $8 corn, the total acreage of corn will increase by 37% in the Corn Belt, with a significant increase in continuous corn.

Conclusions

- The changes in land use will have a large impacts on the environment.
- Wildlife habitat will be lost when pasture and range lands are converted to cropland.
- Nitrogen leaching and wind erosion will increase, in most cases by more than a third, with $8 corn.
- Some of the environmental impacts could be mitigated through adoption of conservation tillage, or conservation compliance measures such as a ban on converting highly erodible land to crop production, but only to be certain extent.

Ongoing Extensions

- Exploring alternative approaches to estimating the land use models (e.g., latent class models)
- Using the updated land use models to examine the environmental impacts of crop insurance.