Climate Impacts on Land Allocation in the Pacific Northwest: Weather Shocks and Climate Shifts

Jianhong E. Mu[1], John Antle[1] & John Abatzoglou[2]

[1] Oregon State University, Department of Agricultural and Resource Economics; [2] University of Idaho, Department of Geography

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Introduction

Climate is expected to change in Pacific Northwest (PNW) with increased mean annual temperature and reduced precipitation in summer. A substantial degree of this change is inevitable and is expected to affect agricultural production, which in term will shift land to uses that maximize the returns to land. Therefore, it is important to examine how land use among crop, pasture and forest is affected by climate conditions including a single year weather fluctuation and a long-term climatic shifts.

Farming decisions are not made for a single year alone, but with climate shifts. When making economic decisions of land use, a farmer can prepare for climate change but he/she can do little if a weather shock occurs. However, previous literature can only reveal the impacts of either one on agriculture production and land use changes (Schlenker and Roberts 2006; Fisher et al. 2012; Mu et al. 2012), rather than both.

Research Objectives

Using data from the PNW region, this paper contributes to the literature on climate change impacts on agriculture in several dimensions:

- Test the hypothesis that both random weather shocks and climate shifts may affect the land use allocation using the fractional multinomial logit model (FMLOGIT)
- Simulate how land use allocation changes under future climate scenarios
- Use recent down-scaled climate data for PNW from 14 Global Climate Models (GCMs) and 2 emission scenarios (RCP45 and RCP85) that are part of the fifth phase of the Coupled Model Inter-comparison Project (CMIP5) for the future prediction

Model Specification

Farmers' land-use decisions are based on the long-run equilibrium expected profit,

$$\underset{\delta_c,\delta_l}{Max}\,\pi = A\delta_c R(p_c, y_c(W,CC)) + A\delta_l R(p_l, y_l(W,CC)) + A(1-\delta_c-\delta_l)R(p_f, y_f(W,CC)) - TC(\delta_c,\delta_l)$$

where R is the revenue of crop, livestock and wood production, p_c, p_l, and p_f, and y_c, y_l, and y_f are the corresponding commodity prices and yields; yield is a function of random weather shocks W and climate shifts CC ; TC is the total costs which is a function of land use shares.

In an econometric context, the reduced-form model is written as,

$$\delta_{ij} = \delta_{ij}(W, CC, p_c, p_l, p_f) \quad j=1,2,\ldots,M \quad i=1,2,\ldots,N$$

Considering the property of the dependent variable, $\delta_{ij} \in [0,1]$, we estimate a FMLOGIT model,

$$E[\delta_{ij} \mid x_i] = \frac{\exp(x_i\beta_j)}{\sum_{m=1}^{M}\exp(x_i\beta_m)} \quad j=1,2,\ldots,M \quad i=1,2,\ldots,N$$

Data

We use county-level data from:

- Census of Agriculture from 1982 to 2007 for shares of land use, net returns of crop and livestock production, irrigation rate and percent of land enrolled in conservation programs
- The CMIP5 projections for historical and future climate variables including 10-year averaged and annual growing season degree days, total precipitation, their quadratic terms and precipitation intensity index
- The U.S. Bureau of Economic Analysis for population density and per capita income
- Deschenes and Greenstone (2012) and Fish et al. (2012) for soil characteristic variables, which is constant over time but vary across counties.

The growing season is defined from April to September. Thus, within the growing season, a single year climate is defined as annual random weather shocks and a 10-year averaged climate is defined as climate shifts.

Estimation Results

From the table below, we interpret results from Model 1:

- As more days with temperature between 8 and 32 °C, which is suitable for cropping, there is less land used for pasture. The elasticity of pastureland shares corresponding to the 10-year averaged degree-days is -0.71.
- Increase of 10-year averaged precipitation in growing seasons is likely to benefit crop production and reduce pasture land use, with elasticities of 0.52 and -0.53, respectively.
- More intense or frequency of rainfalls will cause soil loss and increase the risk of soil erosion, which is harmful for both crop and livestock production.
- When livestock production becomes more profitable relative to crop production, farmers move land to the use with high returns. In addition, cropland share is increasing with irrigation. With more irrigation, less land is used for pasture and more land is used for cropping
- Estimated results are consistent across model specifications and we do see different impacts from random weather shock and climate shift variables (Comparison between Model 3 and Model 4)

	Model 1				Model 2				Model 3				Model 4			
	Cropland share		Pastureland share		Cropland share		Pastureland share		Cropland share		Pastureland share		Cropland share		Pastureland share	
	APE	ELS	APE	ELS	APE	ELS	APE	ELS	APE	ELS	APE	ELS	APE	ELS	APE	ELS
nr_crop	0.0002	0.03	-0.0002	-0.02					0.0002	0.04	-0.0002	-0.03	0.0002	0.03	-0.0002	-0.03
	(0.0002)		(0.0002)						(0.0001)		(0.0001)		(0.0001)		(0.0001)	
nr_livestock	-0.0003	-0.03	0.0004*	0.03					-0.0003	-0.03	0.0004**	0.04	-0.0003	-0.03	0.0004*	0.04
	(0.0002)		(0.0002)						(0.0002)		(0.0002)		(0.0002)		(0.0002)	
pcinc	0.2093	0.06	0.1859	0.04	0.1824	0.06	0.1626	0.04	0.1513	0.05	0.0350	0.01	0.2389	0.07	0.1993	0.05
	(0.4728)		(0.4750)		(0.4893)		(0.4912)		(0.4779)		(0.4916)		(0.4422)		(0.4426)	
popden	0.0000	0.00	0.0001	0.01	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.01
	(0.0002)		(0.0002)		(0.0002)		(0.0002)		(0.0001)		(0.0002)		(0.0002)		(0.0002)	
irr	0.5762***	0.22	-0.5597***	-0.17	0.5734***	0.22	-0.5278***	-0.16	0.5889***	0.23	-0.5664***	-0.17	0.5707***	0.22	-0.5541***	-0.17
	(0.1157)		(0.1108)		(0.1170)		(0.1106)		(0.1115)		(0.1073)		(0.1149)		(0.1095)	
latitude	0.0205*	2.19	-0.0259**	-2.17	0.0236**	2.53	-0.0286**	-2.39	0.0222*	2.38	-0.0276**	-2.32	0.0204*	2.18	-0.0257**	-2.15
	(0.0119)		(0.0115)		(0.0117)		(0.0113)		(0.0115)		(0.0111)		(0.0120)		(0.0116)	
scrp	0.0712	0.01	0.0103	0.00	0.0870	0.01	-0.0118	0.00	0.0661	0.01	0.0317	0.00	0.0599	0.01	0.0162	0.00
	(0.1722)		(0.1728)		(0.1764)		(0.1764)		(0.1728)		(0.1736)		(0.1686)		(0.1698)	
yppt	0.0080**	0.52	-0.0103***	-0.53	0.0088**	0.57	-0.0111***	-0.56					0.0091***	0.59	-0.0120***	-0.61
	(0.0035)		(0.0035)		(0.0036)		(0.0035)						(0.0028)		(0.0029)	
yddays1_mid	0.2210	0.62	-0.3256*	-0.71	0.2590*	0.73	-0.3553**	-0.78					0.2473**	0.69	-0.3636***	-0.80
	(0.1644)		(0.1842)		(0.1569)		(0.1736)						(0.1166)		(0.1280)	
yp95r	-0.0077**	-0.41	-0.0096***	-0.40	-0.0079**	-0.42	-0.0099***	-0.41					-0.0063**	-0.33	-0.0083***	-0.34
	(0.0032)		(0.0031)		(0.0031)		(0.0031)						(0.0028)		(0.0028)	
lppt	0.0012	0.08	-0.0018	-0.09	0.0006	0.04	-0.0010	-0.05	0.0076***	0.49	-0.0099***	-0.51				
	(0.0018)		(0.0019)		(0.0018)		(0.0018)		(0.0022)		(0.0022)					
lddays1_mid	0.0326	0.09	-0.0465	-0.10	-0.0064	-0.02	-0.0135	-0.03	0.2084**	0.59	-0.2913***	-0.65				
	(0.1175)		(0.1276)		(0.1124)		(0.1204)		(0.1038)		(0.1100)					
lp95r	-0.0009	-0.06	0.0006	0.03	-0.0010	-0.06	0.0006	0.03	-0.0005	-0.03	-0.0002	-0.01				
	(0.0009)		(0.0009)		(0.0009)		(0.0010)		(0.0010)		(0.0010)					
Soil variables	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
MSE	0.0235		0.0235		0.0242		0.0239		0.0243		0.0252		0.0236		0.0236	
(within-sample)	(0.0292)		(0.0297)		(0.0307)		(0.0305)		(0.0303)		(0.0315)		(0.0295)		(0.0300)	
Log pseudo-likelihood	-423.33				-425.95				-425.84				-423.54			
Number of obs.	528				530				528				528			
Wald chi2(52)	1238.39															
Wald chi2(48)					1008.93											
Wald chi2(42)									1101.79				983.13			
Prob > chi2	0				0				0				0			

Note: Robust standard errors of average partial effects (APEs) are in parentheses; elasticities (ELS) are calculated at sample means using equation (3); * p<0.1, ** p<0.05, and *** p<0.01, respectively

Projection under Future Climate Change

For future projections, we aggregate future climate data into three time periods (2030, 2050 and 2090) for each GCM and emission scenario (RCP45 and RCP85), to represent the short-, medium- and long-term climate shifts in PNW, and predict land use shares by controlling all other variables constant. Comparing to the predicted land use shares using baseline climate data, we find that:

- From Fig.1 & Fig. 2, future cropland shares are slightly decreasing in the early period when projected climate change is not serious in PNW, and pastureland shares are slightly increasing in some cases by 2030. As time goes by, we expect a big change in temperature and precipitation in PNW. Correspondingly, we find cropland shares increase significantly, while pastureland shares decrease, and changes in land use is much larger under the worse emission scenario (i.e., RCP85)
- On average across all GCMs and emission scenarios, Fig.3 and Fig. 4 shows the changes in cropland and pastureland shares in each county, respectively, and there is large variation across counties and time periods

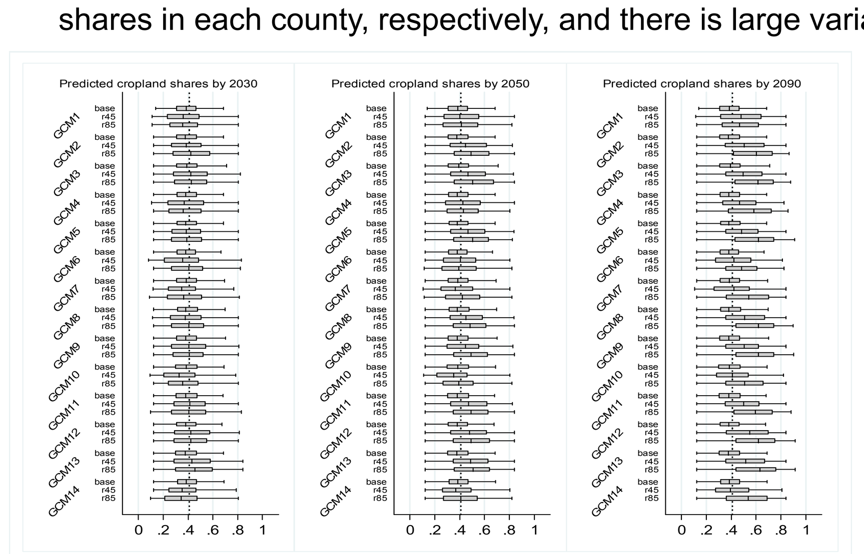

Fig.1 Cropland share changes under GCM projected climates

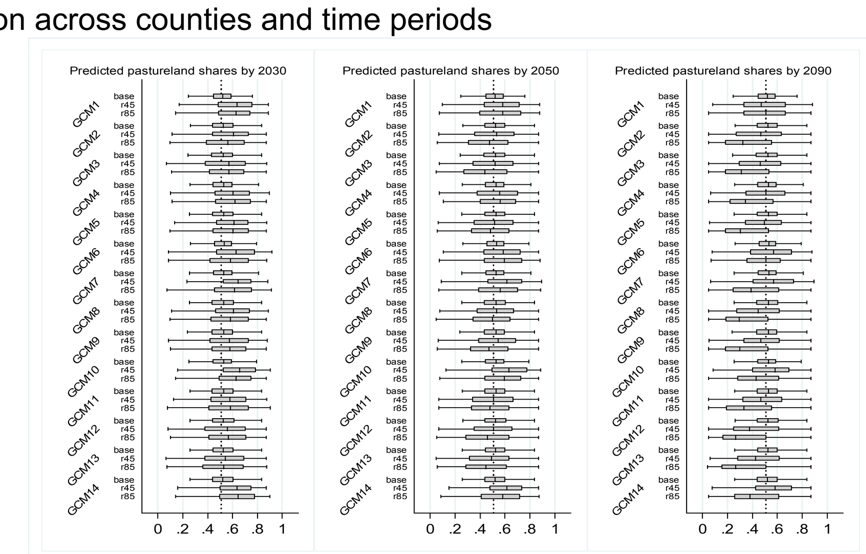

Fig.2 Pastureland share changes under GCM projected climates

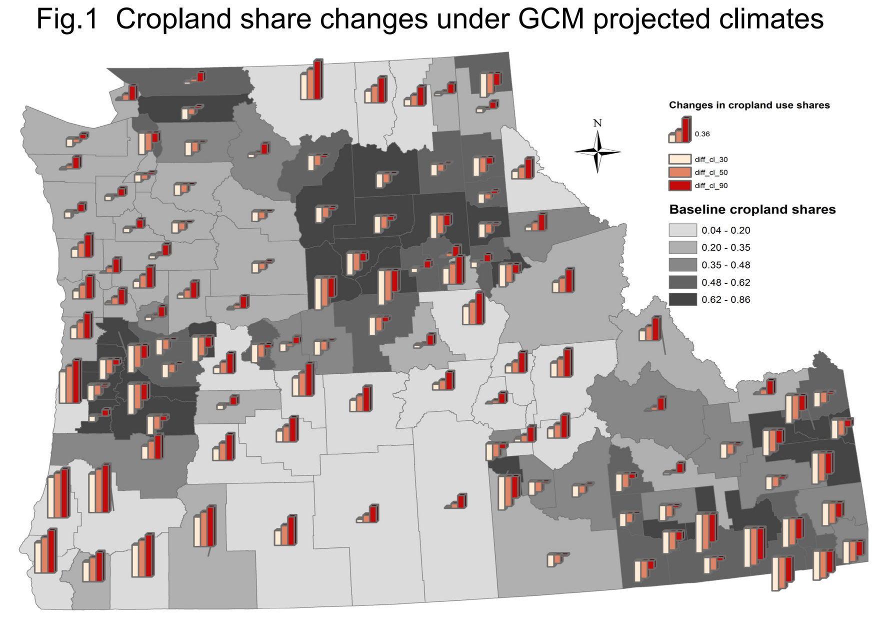

Fig.3 Averaged changes in cropland share under future climate

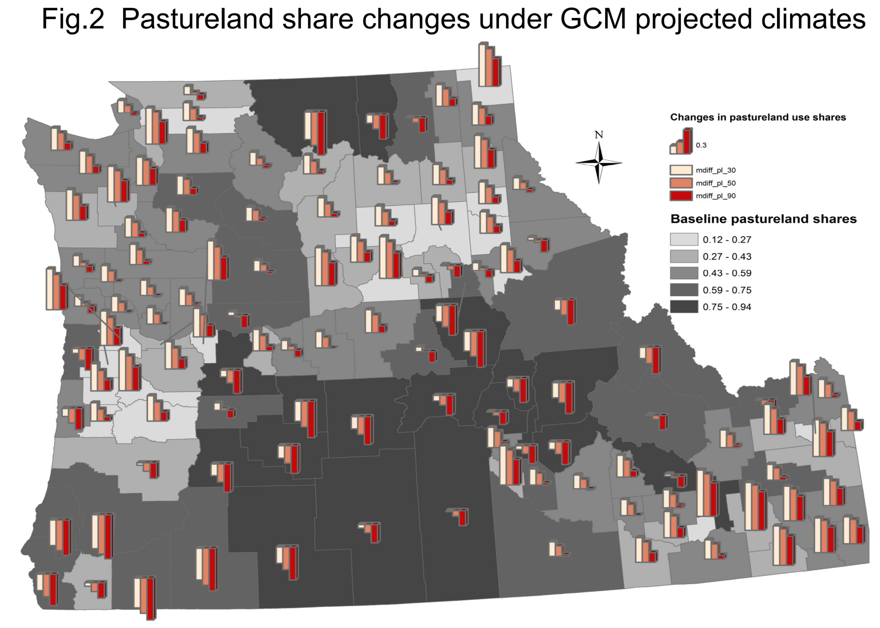

Fig.4 Averaged changes in pastureland share under future climate

Conclusions

In this paper, we first examine how historical climate conditions affect agricultural land use shares using a fractional multinomial logit model, and then predict how future climate change will shift land use using projected climate data from 14 GCMs and 2 emission scenarios.

Land use allocation between crops and livestock is substantially affected by 10-year climate shifts. Pastureland shares decline if there are more days with 10-year averaged temperature between 8 and 32 °C or decrease in 10-year averaged precipitation. Correspondingly, cropland shares increase. Higher precipitation intensity is harmful for both crop and livestock production.

When looking into the future, we find changes in cropland and pasture land shares are very small in the early period (i.e., 2030). Later in the century, the model projects a significant increase in cropland shares and a decline in pastureland shares.

The results vary by the climate model and emission scenario used as to generate inputs for the land use model. Due to the uncertainty of future climate change implied by the climate projections, it would also be useful to investigate the sensitivity of the results to different economic models, and thus evaluate the magnitude of the uncertainty associated with economic models as well as climate models.

References

Deschênes, O., and M.Greenstone. 2012. The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather: Reply. *American Economic Review* 102(7): 3761-73

Fisher, A.C., W. M. Hanemann, M. J. Roberts, and Wolfram Schlenker. 2012. The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather: Comment. *American Economic Review* 102(7): 3749-60

Mu, Jianhong, Bruce A. McCarl, and Anne Wein (2012):" Adaptation to climate change: changes in farmland use and stocking rate in the U.S.," *Mitigation and Adaptation Strategies for Global Change*, forthcoming.

Schlenker W,Hanemann WM, Fisher AC (2006) The Impact of Global Warming on U.S. Agriculture:An Econometric Analysis of Optimal Growing Conditions. *Review of Economics and Statistics* 88: 113-125

Questions & comments?

Please contact **Jianhong Mu** at jianhong.mu@oregonstate.edu