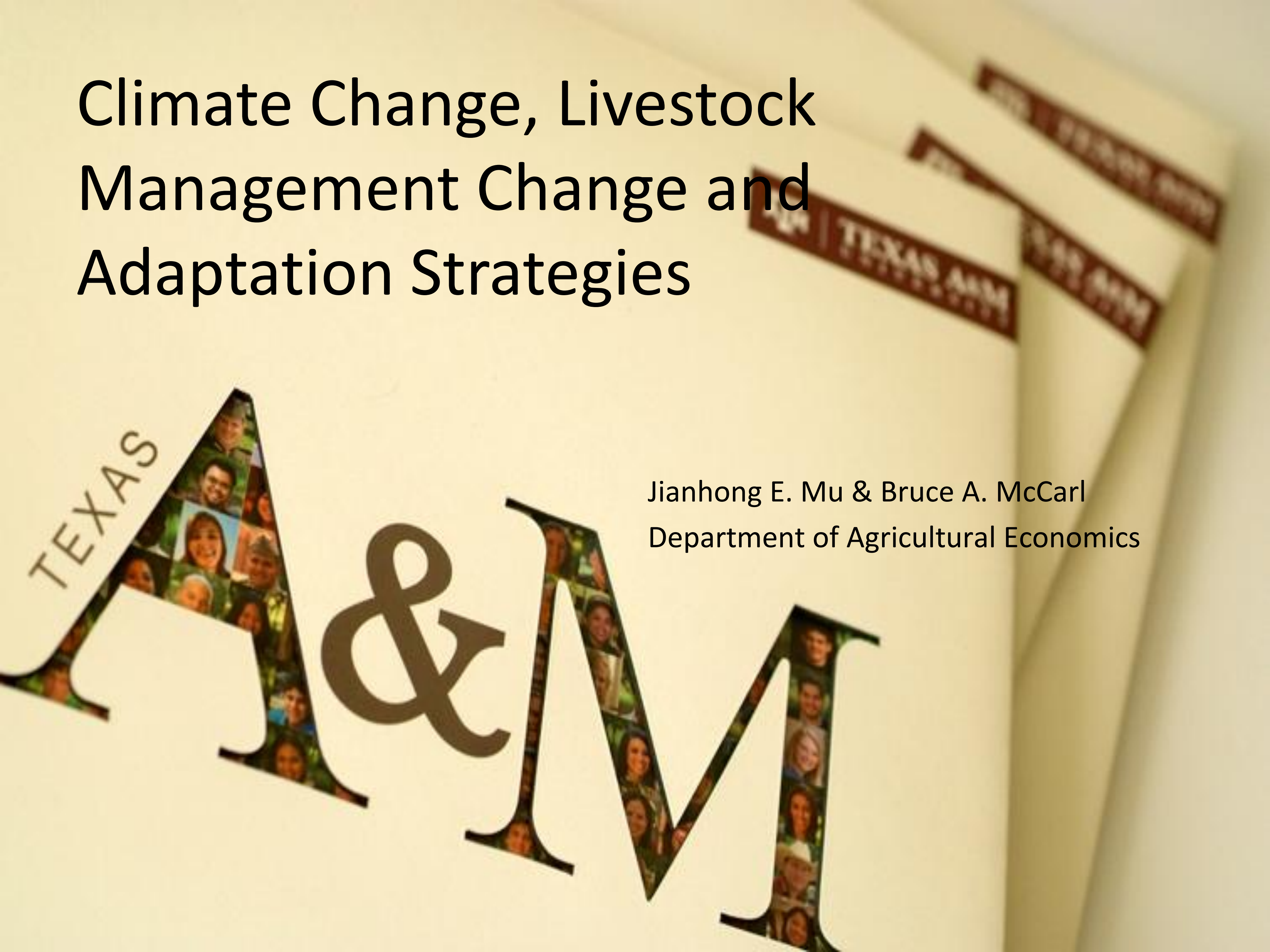
Climate Change, Livestock Management Change and Adaptation Strategies

Jianhong E. Mu & Bruce A. McCarl
Department of Agricultural Economics



Outlines

- ❑ Introduction
- ❑ Model and Data
- ❑ Results
- ❑ Conclusion and Discussion

Background

- Global warming
  - higher temperature
  - more intensity of precipitation
- What farmers could do?
  - “leave it”: do nothing
  - “live it”: adapt to it
- How?
  - switch crop land to pasture land or mix
  - lower cattle stocking rate (=animal/acre)

Literature Review

- Crop production shifts over space
  - McCarl and Reilly (2008)
  - Reilly et al. (2003)
- Livestock production loss
  - Mader et al. (2009)
- Land use changes among crops, livestock and forest
  - Seo (2010) etc.

Research Questions

- How do climatic factors impact livestock management?
  - land use allocation decisions between crop and livestock production
  - cattle stocking rate
- Under projected climate change, what are the directions and magnitudes of likely adaptation?

Random Utility Model

- Assume the net revenue from agriculture operation j can be written as,

$$\pi_j = U_j + \varepsilon_j$$

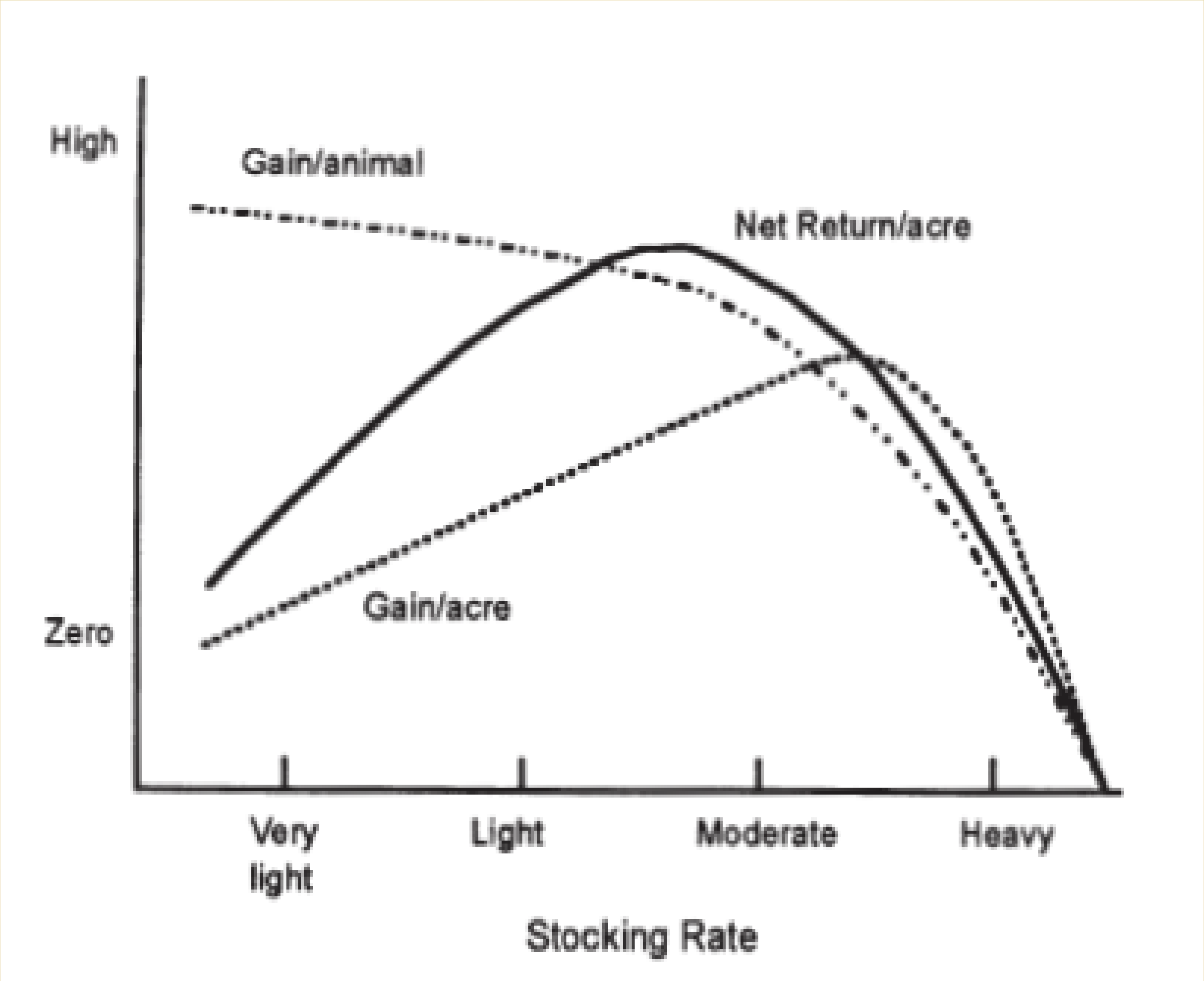
- The probability of choosing operation j is

$$P_{ij} = \frac{e^{U_{ij}\beta_j}}{\sum_{k=1}^{3} e^{U_{ik}\beta_k}} \qquad \forall j = 1, 2, 3$$

- Fractional Multinomial Logit estimation with

$$\sum_{j=1}^{3} P_{ij} = 1$$

Economics of Stocking Rate



Source: Redfearn and Bidwell

Data

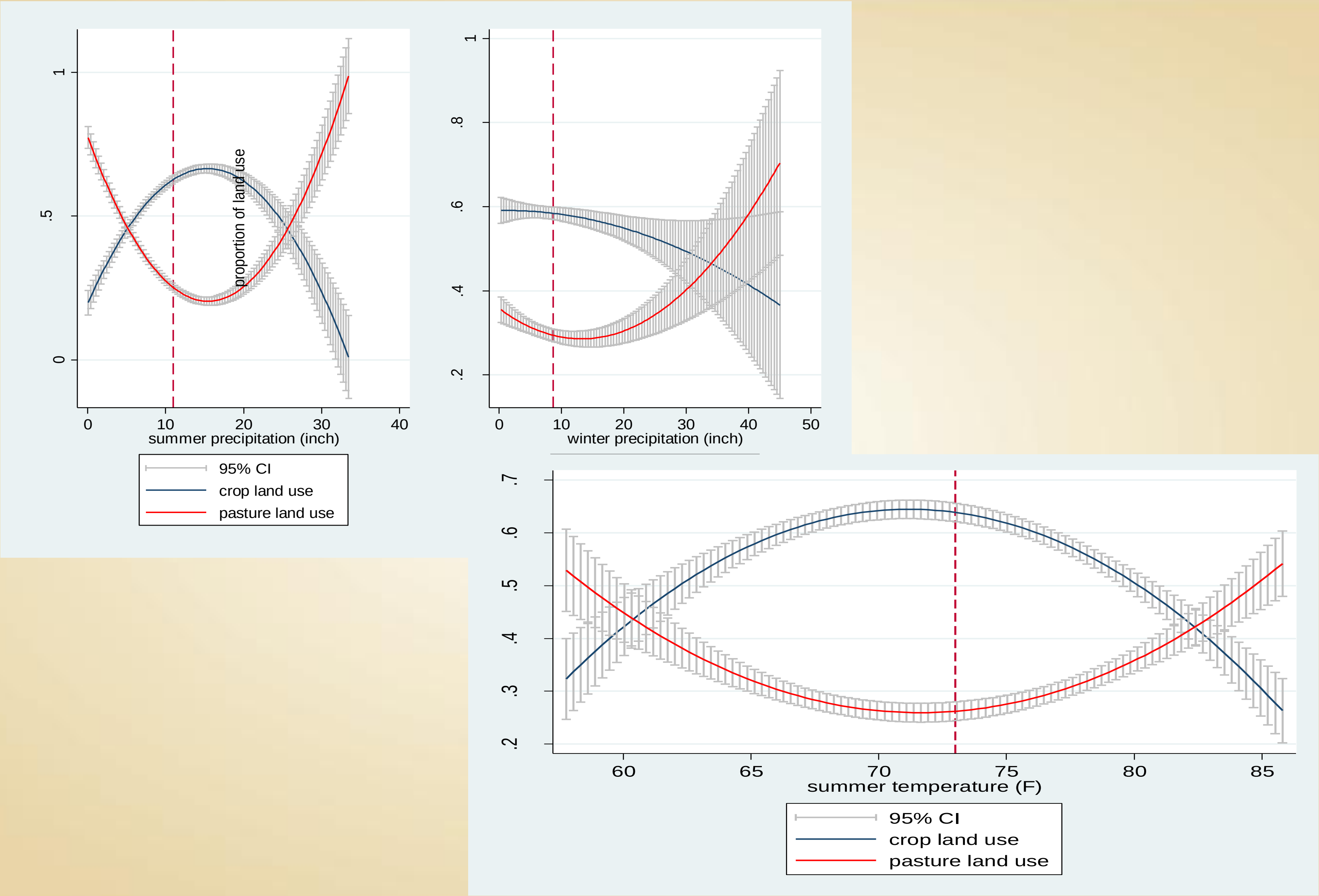
- Panel data
  - 5 agricultural census years
  - over 200 crop production districts
- Livestock management data
  - land use: crop land, pasture land, total land
  - cattle stocking rate
  - market value of crop and livestock products
- Climate data
  - temperature (F), precipitation (inch)
  - extreme hot days, Palmer drought index,…

Results1: climate effects

Variables	Crop land use		Pasture land use	
	APE	APE (w/o)	APE	APE (w/o)
Spring precipitation	**0.0150****	**0.0224*****	**-0.0107****	**-0.0194*****
	(0.0067)	**(0.0062)**	**(0.0064)**	**(0.0063)**
Squared spring precipitation	**-0.0004****	**-0.0005*****	**0.0004****	**0.0006*****
	(0.0002)	**(0.0002)**	**(0.0002)**	**(0.0002)**
Summer precipitation	**0.0252*****	**0.0352*****	**-0.0379*****	**-0.0543*****
	(0.0071)	**(0.0063)**	**(0.0079)**	**(0.0063)**
Squared summer precipitation	**-0.0007*****	**-0.0009*****	**0.0012*****	**0.0015*****
	(0.0002)	**(0.0003)**	**(0.0002)**	**(0.0002)**
Winter precipitation	**0.0170*****	**0.0136*****	**-0.0185*****	**-0.0188*****
	(0.0042)	**(0.0044)**	**(0.0046)**	**(0.0049)**
Squared winter precipitation	**-0.0003*****	**-0.0002****	**0.0003*****	**0.0004*****
	(0.0001)	**(0.0001)**	**(0.0001)**	**(0.0001)**
Spring temperature	0.0048	**-0.0240****	-0.0087	0.0107
	(0.0128)	**(0.0145)**	(0.0124)	(0.0153)
Squared spring temperature	-0.0002	0.0001	0.0003	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0002)
Summer temperature	**0.0924*****	**0.0811*****	**-0.1514*****	**-0.1600*****
	(0.0381)	**(0.0357)**	**(0.0373)**	**(0.0329)**
Squared summer temperature	**-0.0008*****	**-0.0007*****	**0.0012*****	**0.0013*****
	(0.0003)	**(0.0003)**	**(0.0003)**	**(0.0002)**
Winter temperature	-0.0003	0.0049	-0.0037	-0.0061
	(0.0048)	(0.0050)	(0.0052)	(0.0052)
Squared winter temperature	0.0000	-0.0002	0.0000	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)

Asterisk of ***, ** and * represents significance at 1%, 5% and 10% confidence level, respectively, and robust standard errors are in parentheses.

Nonlinear Climate Effects



Results1: other effects

Variables	Crop land use		Pasture land use	
	APE	APE (w/o)	APE	APE (w/o)
Spring Palmer drought index	-0.0024	0.0019	0.0023	-0.0084
	(0.0069)	(0.0073)	(0.0076)	(0.0077)
summer Palmer drought index	**-0.0218*** **	**-0.0366*** **	**0.0212*** **	**0.0433*** **
	(0.0067)	**(0.0055)**	**(0.0065)**	**(0.0058)**
Winter Palmer drought index	**0.0081***	**0.0150*** **	**-0.0106***	**-0.0145** **
	(0.0062)	**(0.0064)**	**(0.0070)**	**(0.0071)**
Precipitation intensity index	0.0077	**0.0833** **	0.0275	**-0.0763***
	(0.0401)	**(0.0455)**	(0.0416)	**(0.0474)**
Number of hot days with temp>32°C	**-0.0017*** **	**-0.0020*** **	**0.0016*** **	**0.0025*** **
	(0.0006)	**(0.0005)**	**(0.0006)**	**(0.0004)**
Log term of crop market value	**0.1153*** **	**0.1292*** **	**-0.1064*** **	**-0.1090*** **
	(0.0078)	**(0.0079)**	**(0.0075)**	**(0.0076)**
Log term of livestock market value	**-0.0205*** **	**-0.0327*** **	**0.0298*** **	**0.0352*** **
	(0.0083)	**(0.0084)**	**(0.0083)**	**(0.0077)**
Time dummy if year=1992	-0.0013	0.0210	0.0076	-0.0011
	(0.0323)	(0.0712)	(0.0253)	(0.0446)
Time dummy if year=1997	-0.0476	-0.0597	0.0223	0.0350
	(0.0594)	(0.0625)	(0.0724)	(0.0952)
Time dummy if year=2002	-0.1015	-0.1139	0.0323	0.0341
	(0.1553)	(0.2022)	(0.1503)	(0.2043)
Time dummy if year=2007	**-0.2280***	**-0.2393***	0.1263	0.1346
	(0.1398)	**(0.1535)**	(0.3435)	(0.3892)

Asterisk of ***, ** and * represents significance at 1%, 5% and 10% confidence level, respectively, and robust standard errors are in parentheses.

Results2: climate effects

Variable	OLS	Quantile Regression
Spring precipitation	-0.0017	0.0031
	(0.0042)	(0.0040)
Squared spring precipitation	0.0003	0.0000
	(0.0001)	(0.0001)
Summer precipitation	**0.0091***	**0.0123*****
	(0.0051)	**(0.0044)**
Squared summer precipitation	**-0.0003***	**-0.0003****
	(0.0002)	**(0.0001)**
Winter precipitation	**0.0210*****	**0.0126*****
	(0.0048)	**(0.0030)**
Squared winter precipitation	**-0.0004****	**-0.0002****
	(0.0002)	**(0.0001)**
Spring temperature	**0.0613*****	**0.0425*****
	(0.0145)	**(0.0133)**
Squared spring temperature	**-0.0009*****	**-0.0006*****
	(0.0002)	**(0.0002)**
Summer temperature	-0.0315	0.0131
	(0.0479)	(0.0418)
Squared summer temperature	0.0005	0.0000
	(0.0004)	(0.0004)
Winter temperature	0.0039	0.0010
	(0.0053)	(0.0038)
Squared winter temperature	0.0001	0.0001
	(0.0001)	(0.0001)

Asterisk of ***, ** and * represents significance at 1%, 5% and 10% confidence level, respectively, and robust standard errors are in parentheses.

Results2: other effects

Variable	OLS	Quantile Regression
Spring Palmer drought index	-0.0104	-0.0069
	(0.0072)	(0.0057)
summer Palmer drought index	0.0007	-0.0021
	(0.0061)	(0.0042)
Winter Palmer drought index	0.0066	0.0034
	(0.0079)	(0.0055)
Precipitation intensity index	**-0.1992*****	**-0.0900***
	(0.0619)	**(0.0473)**
Number of hot days with temp>32°C	**-0.0007****	**-0.0009*****
	(0.0004)	**(0.0003)**
Log term of livestock market value	**0.0502*****	**0.0415*****
	(0.0084)	**(0.0039)**
Spring THI index	**0.1627*****	**0.0918*****
	(0.0290)	**(0.0204)**
Summer THI index	-0.0590**	-0.0157
	(0.0258)	(0.0190)
Winter THI index	-0.0707	-0.0807*
	(0.0484)	(0.0444)
constant	-3.6922	-1.8639
	(3.4528)	(3.2979)
R-Square	0.3601	0.2631

Asterisk of ***, ** and * represents significance at 1%, 5% and 10% confidence level, respectively, and robust standard errors are in parentheses.

Projection of Adaptation

- Climate data
  - the third version of Hadley Center Coupled Model (HadCM3)
  - changes of temperature and precipitation
- Timelines
  - 2010-2039, 2040-2069, 2070-2099
- SRES scenarios
  - B1, A1B, A2

Adaptation Possibility

	Base	2010-2039	2040-2069	2070-2099
		HadCM3-B1 emission scenario		
Crop (proportion of crop land)	0.60	-0.20	-0.26	-0.31
Pasture (proportion of pasture land)	0.29	0.27	0.34	0.40
Other land use (proportion of other land)	0.11	-0.07	-0.08	-0.08
Cattle stocking rate (%)	0.25	-35	-42	-49
		HadCM3-A1B emission scenario		
Crop (proportion of crop land)	0.60	-0.29	-0.36	-0.41
Pasture (proportion of pasture land)	0.29	0.37	0.45	0.50
Other land use (proportion of other land)	0.11	-0.08	-0.09	-0.10
Cattle stocking rate (%)	0.25	-50	-58	-66
		HadCM3-A2 emission scenario		
Crop (proportion of crop land)	0.60	-0.26	-0.33	-0.43
Pasture (proportion of pasture land)	0.29	0.34	0.42	0.52
Other land use (proportion of other land)	0.11	-0.08	-0.09	-0.10
Cattle stocking rate (%)	0.25	-48	-55	-70

Conclusion

- Analysis over observed data suggest prior changes in climate have potentially caused current livestock management changes
- Projected climate is likely to play an even greater role in the future
- We expect less crop land, more pasture land and lower stocking rate under projected climate change
- Fractional Multinomial Logit (FMNL) Model lets us estimate the substitution effect between crop and pasture land use

Discussion

- Alternative adaptation strategies include changing livestock species, moisture, soil and water management, etc.
- Adaptation could in turn affect climate change, especially through land use changes, which could impact mitigation results
- Climate change policies should consider the interacted effect of adaptation and mitigation

Selected References

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Questions & Comments?

Thank You !

mujh1024@gmail.com