U.S. Livestock Production under Climate Change

Implications for International Trade*

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*The views presented in this presentation are those of the authors and not necessarily those of the U.S. Department of Agriculture.

Outline

- Introduction/Literature Review
- Method/Scenarios Used
- Data on Crop and Livestock Productivity under Climate Change
- Model Results
- Conclusion and Discussion

Introduction

- Heat stress was estimated to result in estimated annual economic losses in the U.S. of $1.69 billion to $2.36 billion in 2000, including $0.9-$1.5 billion for dairy, $370 million for the beef industry, $299-$316 million for swine, and $128-$165 million for poultry (St-Pierre et al. 2003). Rising temperatures may further increase these impacts.

- Livestock production is potentially sensitive to climate change (Parry et al. 2004).

- Implications of Climate Change on U.S. livestock sector and markets?

Literature Review

- Mader et al. (2009)
  - Regional differences in climate change impacts on U.S. livestock would be apparent, potentially with gradient of increasing impacts moving from the Northwest to the Southeast.
- Baker et al. (1993)
  - Future climate change can increase the above-ground biomass production in most regions.
  - Animal production in the northern regions would increase
  - Changes in animal production in the southern regions are less certain, however.
- Adams et al. (1999)
  - Overall, at national level, the future climate change impacts on livestock production (quantities and prices) are moderate.

Method

- The Forest and Agricultural Sector Optimization Model (FASOM) is employed to explore the climate change impacts on U.S. livestock production and the associated implications for U.S. livestock product export markets.

- FASOM is an intertemporal partial equilibrium economic model that simulates the allocation of land over time to competing activities in the U.S. forest and agricultural sectors and the associated commodity markets (Adams et al. 2005).
  - Has been used for a broad range of policy applications
    - Climate change impacts and mitigation, biofuels, farm policy

Scenarios Used

- Three scenarios are used:
  - *Base* – no climate change;
  - *CGCM31* - assuming climate change projected by the Coupled Global Climate Model (CGCM) 3.1 [developed by the Canadian Centre for Climate Modeling and Analysis, Canada];
  - *GFDL20* – assuming climate change projected by the GFDL-CM2.0 model [developed by the Geophysical Fluid Dynamics Laboratory (GFDL), USA].
- CGCM31 and GFDL20 related data are from Beach et al. (2010).

Scenarios Used

- Compared with CGCM31 that shows moderate changes, GFDL20 scenario exhibits greater changes in (summer) temperature and precipitation.

Table 2-3. Changes in Temperature and Precipitation under GCMs Modeled, 2045-2055 Relative to 1990-2000 Climate Baseline

Model	Season	Change Max Temp (°C)	Change Min Temp (°C)	Change in Precipitation (%)
GFDL-CM2.0	MAM	2.78	2.41	-7.4
GFDL-CM2.0	JJA	4.34	3.44	-8.5
GFDL-CM2.1	MAM	1.66	1.72	0.6
GFDL-CM2.1	JJA	4.03	3.45	-16.5
CGCM3.1	MAM	2.45	2.41	2.1
CGCM3.1	JJA	2.27	2.17	0.7
MRI-CGCM2.2	MAM	1.23	1.37	9.5
MRI-CGCM2.2	JJA	1.28	1.57	8.7

*Table Source: Beach et al. (2010)

Data: Updates since Adams et al. (1999)

- Climate change effects on crop yields and irrigation water demand
  - EPIC simulation results from Beach et al. (2010) are used.
  - Rain-fed hay data are used to adjust grazing productivity on pasture and range land under climate change.

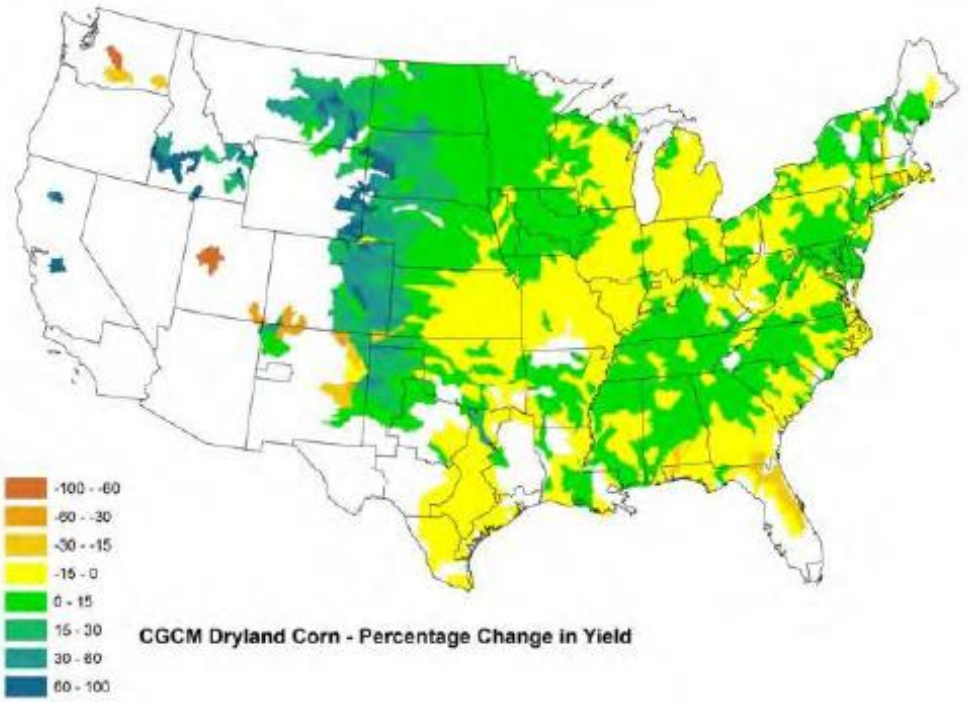
- Climate change effects on livestock productivity:
  - The animal production-response (APR) model simulation results from Mader et al. (2009) are used.
  - The APR models focus on voluntary feed intake, weight gain, and ambient temperature.

Data

- Rain-fed corn yields see decreases in the Midwest, the major corn production region, especially under GFDL20 scenario.

Percentage Changes in Yields

	CGCM31	*GFDL20*
CB	-0.92	-9.48
GP	5.08	-2.63
LS	-0.22	-5.37
NE	1.68	-0.62
RM	26.08	13.04
SC	0.65	-6.04
SE	-1.01	-1.5
SW	-5.69	-8.24



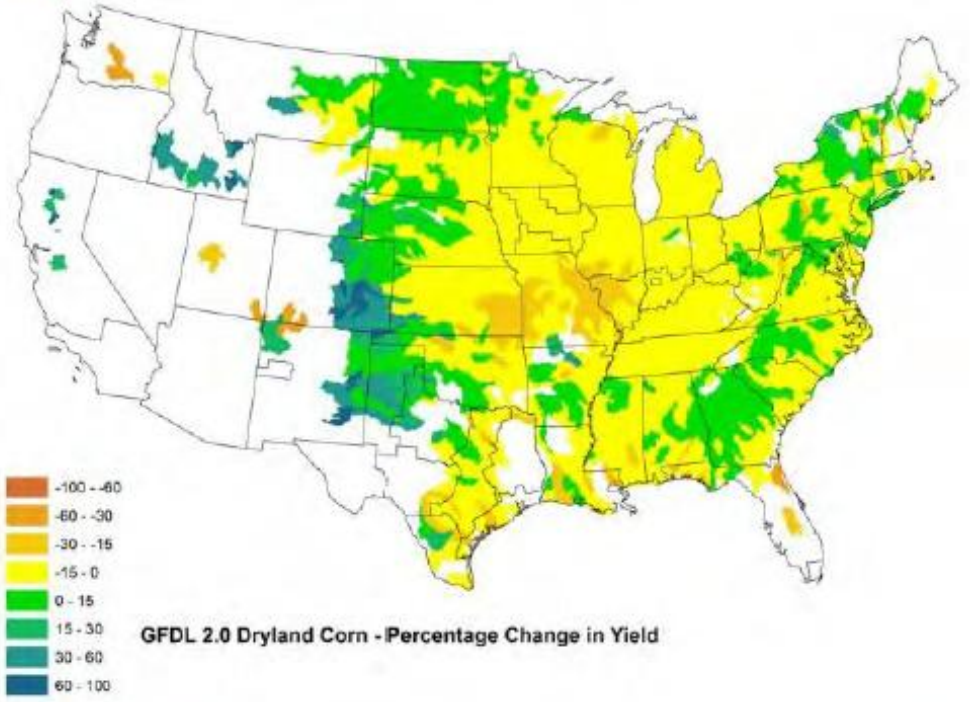


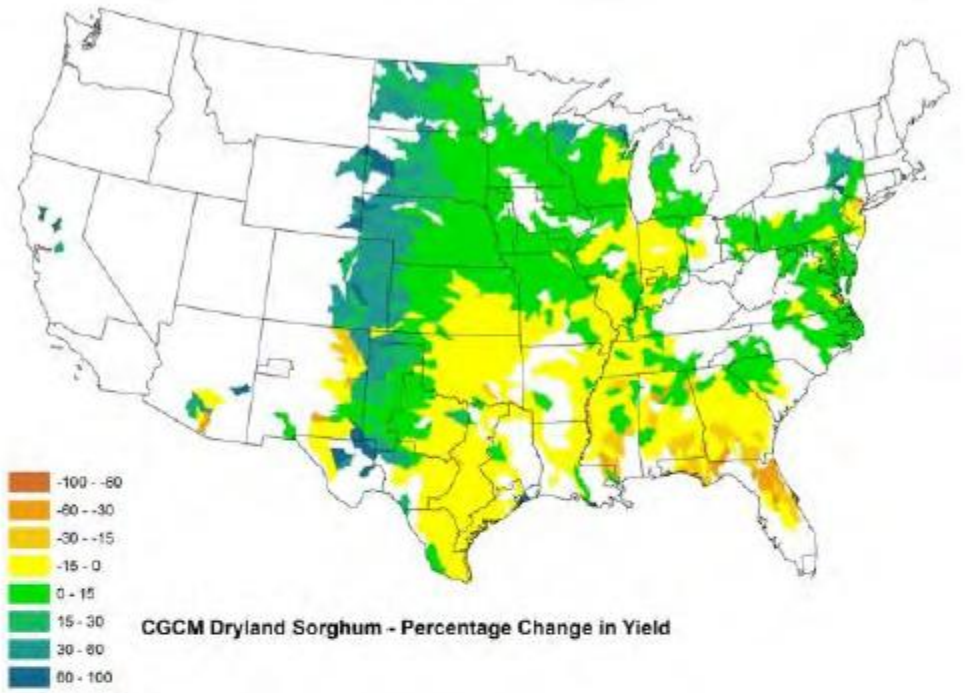
Figure Source: Beach et al. (2010)

Data

- Rain-fed sorghum yields show increases in the Southwest and the Rocky Mountain regions.

Percentage Changes in Yields

	CGCM31	*GFDL20*
CB	-0.28	-10.01
GP	1.62	-3.66
NE	2.87	17.38
RM	11.61	40.34
PSW	122.76	87.7
SC	-5.44	-12.32
SE	-3.35	-0.57
SW	2.52	7.09



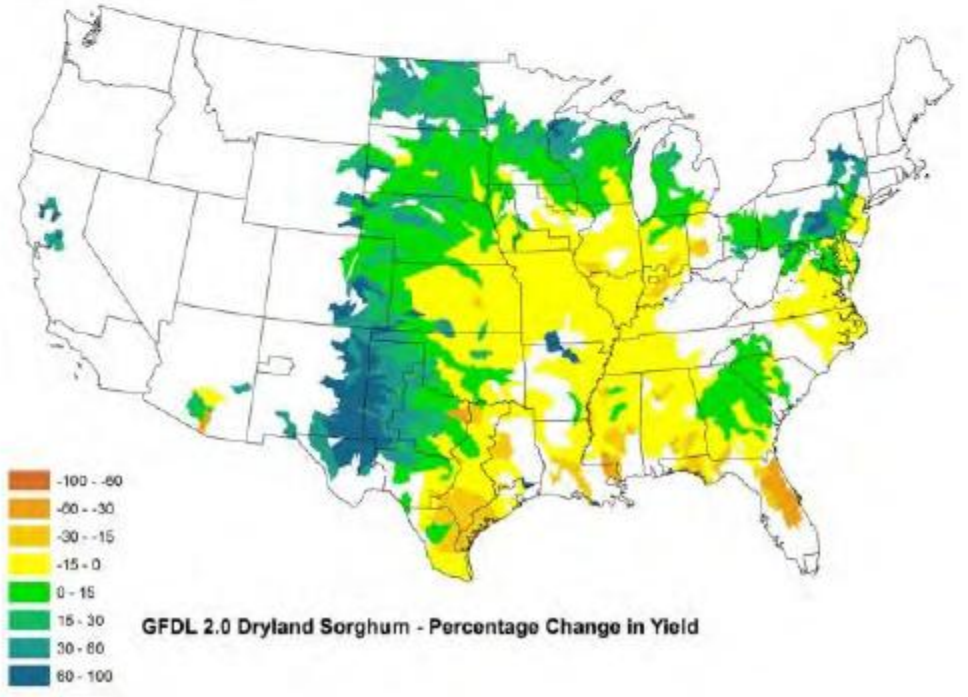


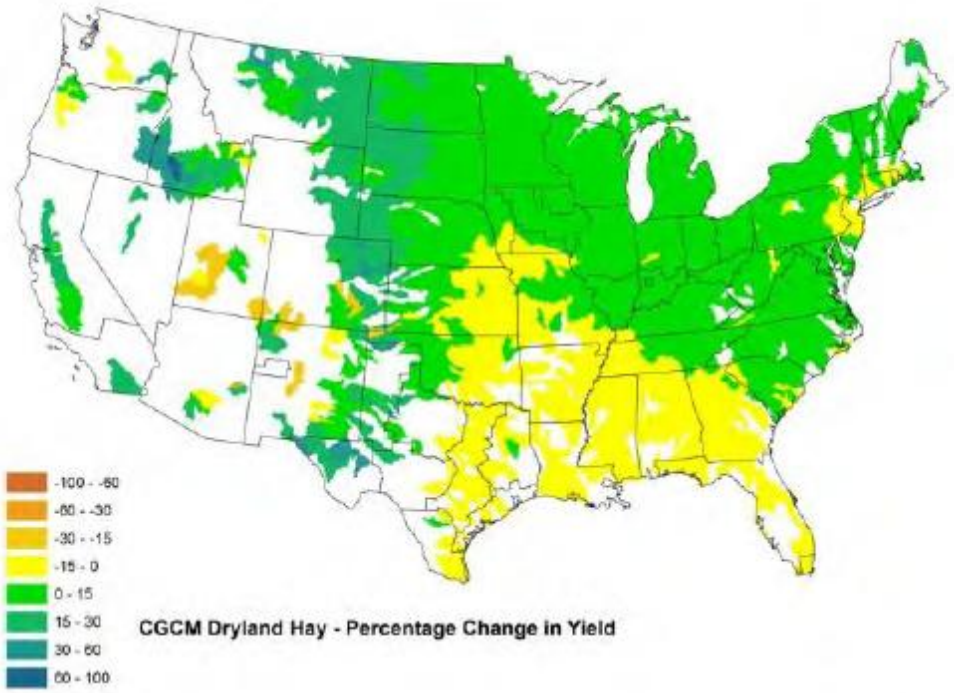
Figure Source: Beach et al. (2010)

Data

- Hay yields (grazing productivity) show increases in most regions; decreases in some Southern regions.

Percentage Changes in Yields

	CGCM31	*GFDL20*
CB	2.17	-1.35
GP	6.89	6.13
LS	5.98	1.09
NE	5.96	7.31
RM	16.89	25.55
PSW	18.9	17.05
PNWE	3.65	-2.28
SC	-1.99	-0.84
SE	3.36	7.42
SW	-2.26	-2.41



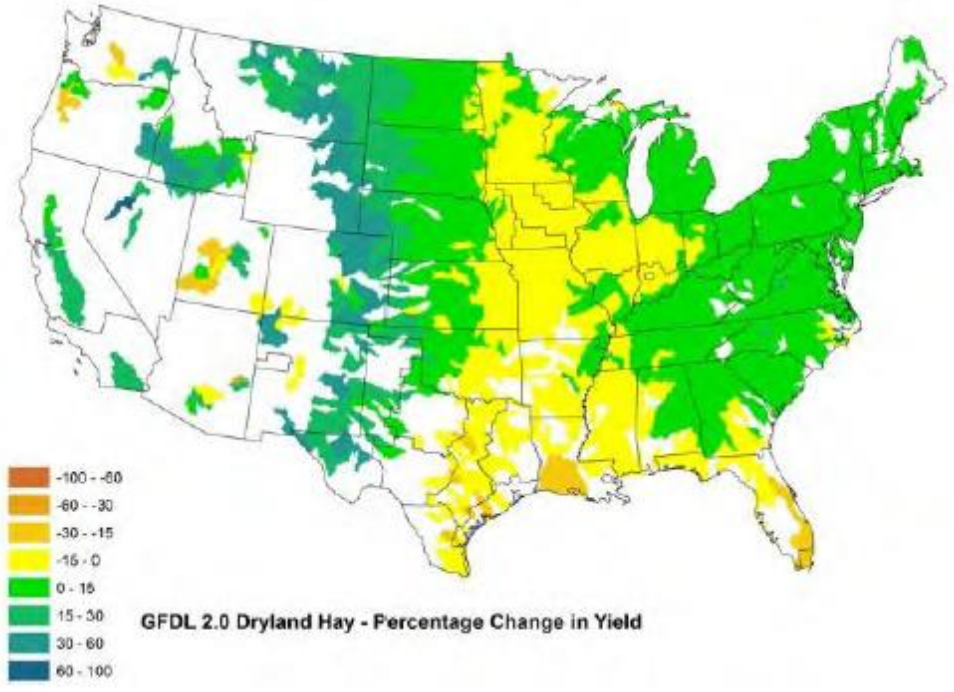


Figure Source: Beach et al. (2010)

Data on Livestock

- Data on beef cattle, swine, and dairy cattle milk output from Mader et al. (2009) are utilized for this study.

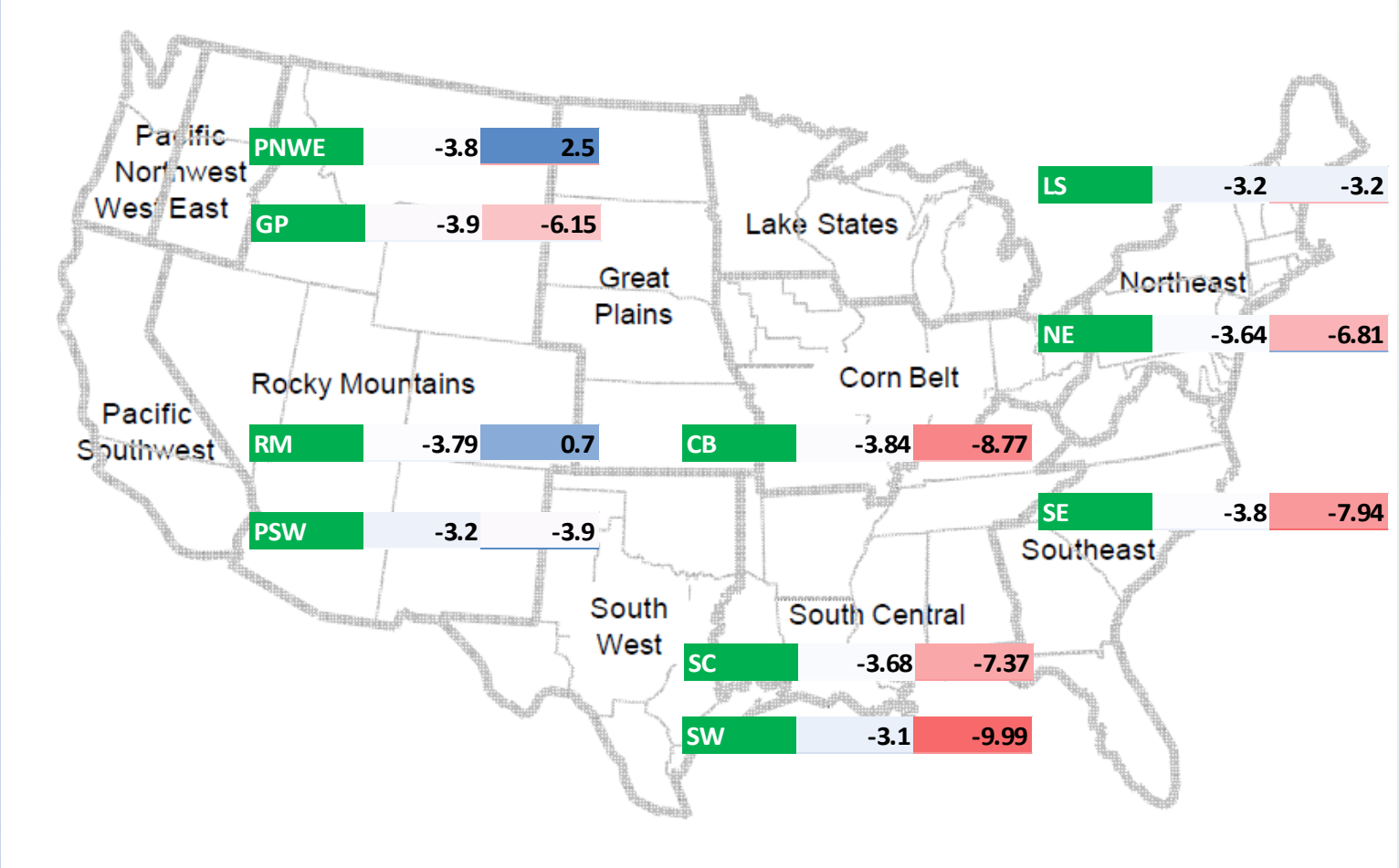
- The results for changes in growing days of beef cattle and swine production are translated to changes in livestock productivity in this study.
  - For example, if 4% more days are needed for finishing under climate change, then a 3.8% reduction in productivity is implied.

- Hadley data are matched to CGCM31 scenario; CGCMI data are matched to GFDL20 scenario.
  - In Mader et al. (2009), the results used from the Hadley model involve smaller changes in global temperatures than those in the CGCMI model.

Data on Livestock

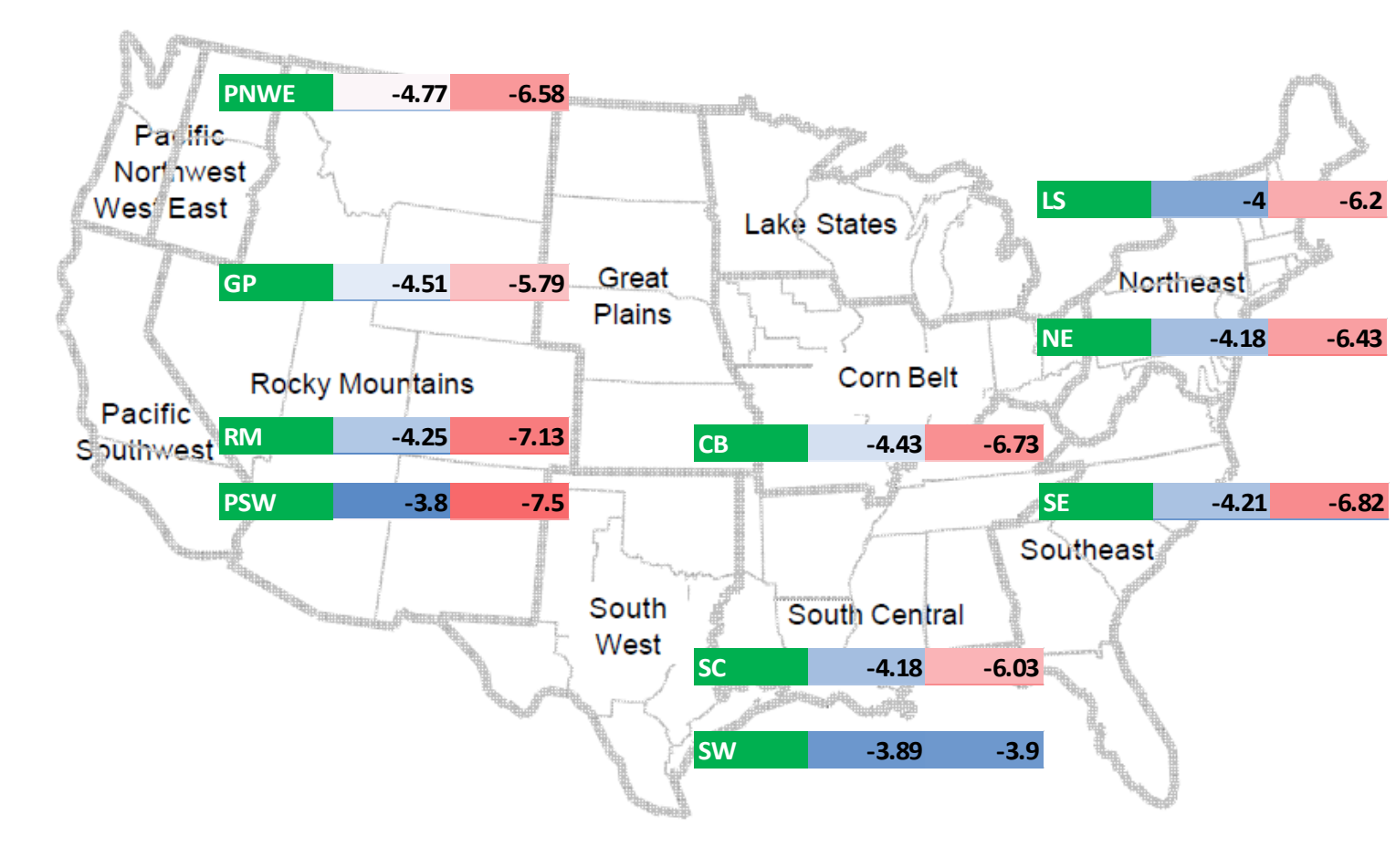
- Beef Cattle
  - The GFDL20 scenario shows a larger variance in climate change induced weight gain effects across regions, CGCM31 exhibits a more even distribution.
- Dairy Cattle
  - Milk production per cow shows a greater reduction under GFDL20 than under CGCM31.
- Fed Hog weights
  - Compared with beef cattle, fed hogs show larger decreases in weight gain under climate change, especially in the South.

Livestock: Beef Cattle Weight Gain



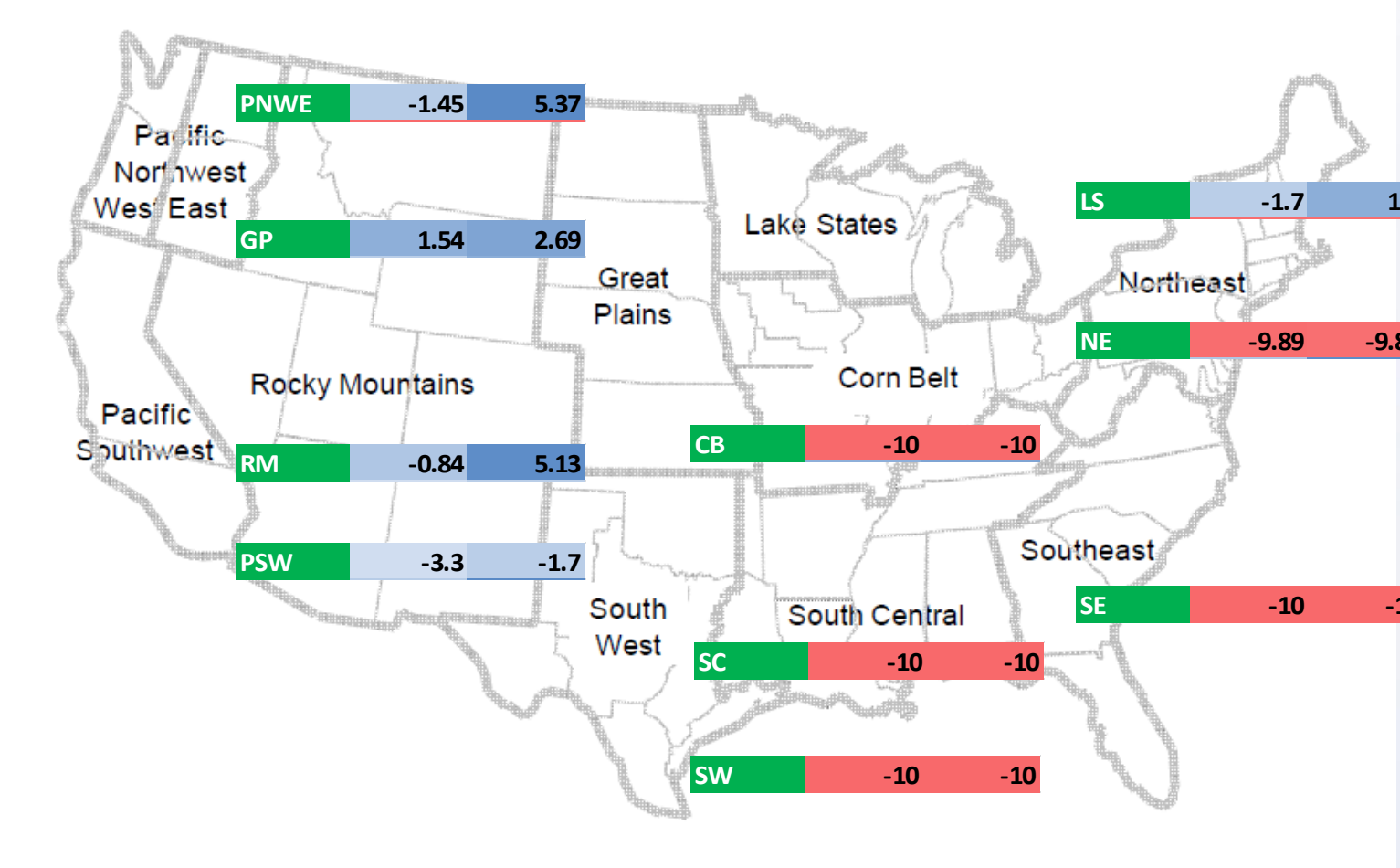
*Percentage Changes in Weight Gain w.r.t. Base. Left: CGCM31; Right: GFDL20.

Livestock: Dairy Cattle Milk Production



*Percentage Changes in Milk Output w.r.t. Base. Left: CGCM31; Right: GFDL20.

Livestock: Fed Hog Weight gain



*Percentage Changes in Weight Gain w.r.t. Base. Left: CGCM31; Right: GFDL20.

Model Results

- The FASOMGHG model results on Climate change impacts on U.S. livestock sector are summarized for:
  - Beef, pork, and milk commodity markets
  - Total herd size for fed beef cattle, dairy cattle, and fed hogs
  - Regional distribution of animal populations

Livestock Product Market under Climate Change

- Percentage changes in market parameters, w.r.t. "non-climate change" base:

	CGCM31		GFDL20	
	2030	*2050*	*2030*	*2050*
Beef, Fed				
Domestic Consumption	-1.58	0.00	-4.42	-3.52
Export Volume	-0.95	0.00	-3.81	-3.85
Price	2.03	0.32	5.58	4.37
Production	-1.51	0.00	-4.35	-3.56
Fluid Milk				
Domestic Consumption	0.00	0.00	0.00	0.00
Price	-0.31	0.01	0.07	0.30
Production	0.00	0.00	0.00	0.00
Pork				
Domestic Consumption	0.00	-3.70	0.00	-3.70
Export Volume	0.00	-3.70	-1.69	-7.41
Import Volume	-0.52	0.00	2.69	7.69
Price	-1.03	3.92	0.70	7.34
Production	0.02	-3.80	-0.28	-4.50

Livestock Sector under Climate Change

- Percentage changes in animal numbers under climate change scenarios w.r.t. base:

	CGCM31		GFDL20	
	2030	*2050*	*2030*	*2050*
Livestock				
Feedlot Beef Calves	0.51	3.95	-0.33	-3.71
Dairy Cattle	3.32	4.37	3.10	4.46
Fed Hogs	2.70	2.30	2.06	1.43

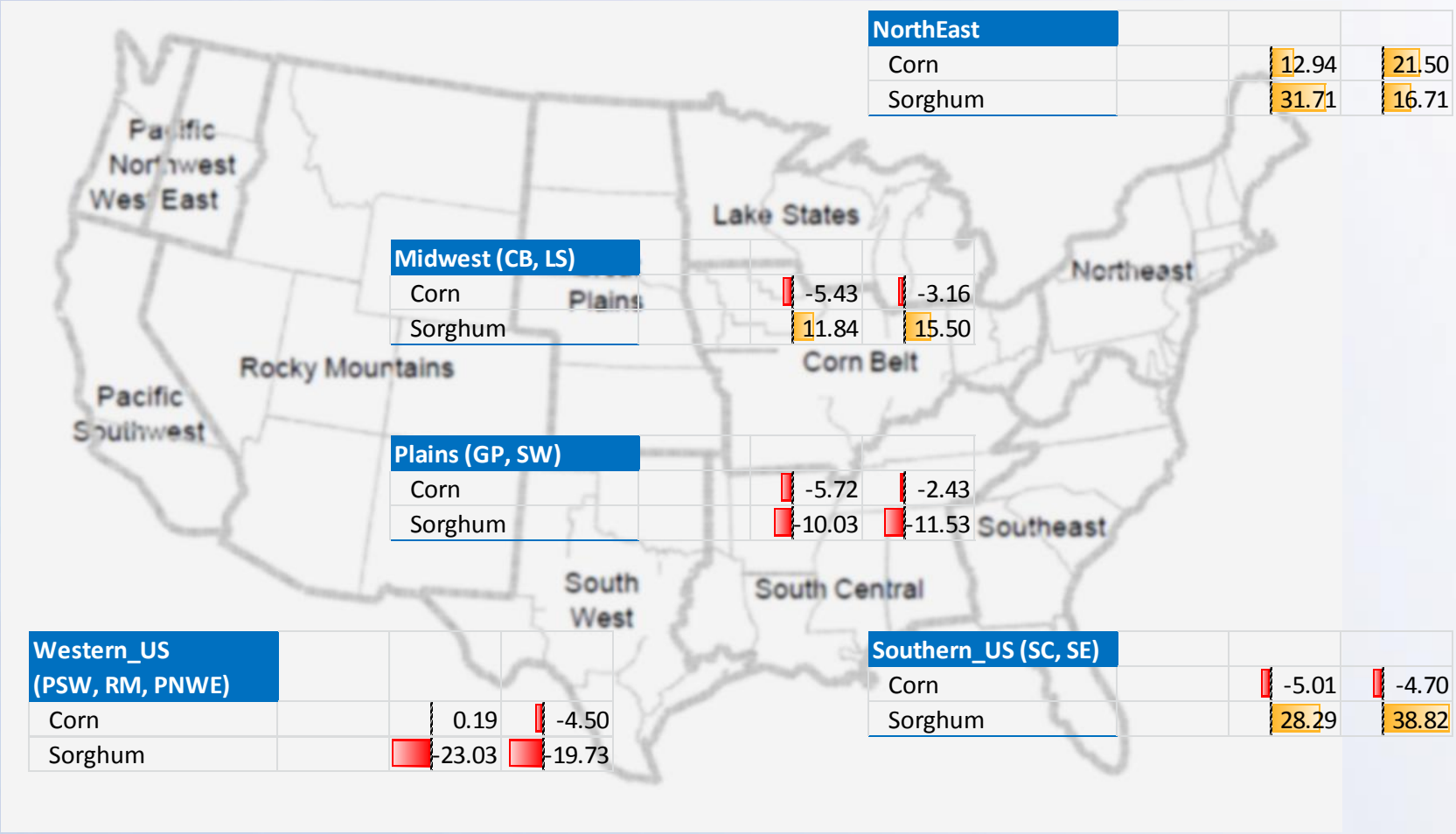
- Except for feedlot beef cattle under the more severe climate change scenario, livestock populations are projected to increase as productivity declines in order to meet the market demand.

Regional Distribution of Animal Population

- Dairy cattle population increased significantly in the Northeast region under climate change.
- Feedlot Beef Cattle increased in the Midwest (CB and LS) and decreased in the Western area (PSW, RM, PNWE).
- Fed Hog population increased in all regions except the Western area.

	CGCM31	GFDL20
Dairy Cattle	**3.32**	**3.10**
Midwest	3.70	5.51
NorthEast	112.50	232.21
Plains	0.53	1.76
Southern_US	7.03	4.19
Western_US	2.01	0.21
Feedlot Beef Calves	**0.51**	**-0.33**
Midwest	6.82	26.17
NorthEast	0.38	0.80
Plains	0.50	-1.85
Southern_US	8.15	4.99
Western_US	-2.41	-5.41
Fed Hogs	**2.70**	**2.06**
Midwest	2.41	4.30
NorthEast	1.63	3.36
Plains	3.37	1.66
Southern_US	2.03	0.59
Western_US	-2.84	-14.09
***2030 Projections**		

Regional Corn and Sorghum Production



NorthEast		
Corn	12.94	21.50
Sorghum	31.71	16.71

Midwest (CB, LS)		
Corn	-5.43	-3.16
Sorghum	11.84	15.50

Plains (GP, SW)		
Corn	-5.72	-2.43
Sorghum	-10.03	-11.53

Western_US (PSW, RM, PNWE)		
Corn	0.19	-4.50
Sorghum	-23.03	-19.73

Southern_US (SC, SE)		
Corn	-5.01	-4.70
Sorghum	28.29	38.82

*Left: CGCM31; Right: GFDL20. Estimates of 2030 Percentage Changes w.r.t. Base.

Conclusion

- Compared with dairy production, U.S. beef and pork production are more sensitive to climate change – production and export volumes decrease; prices increase.
  - Impacts are greater over the long term
- Livestock producers increase animal populations to counter the per unit productivity losses under climate change.
- Livestock production shifts to the major feed crop production regions, such as the Midwest, as corn and sorghum yields are decreasing in the more southern or drier traditional regions.

Discussion

- Breed adaptation not considered:
  Adapting breeds may ameliorate the productivity losses under climate change.
  - Zhang et al. (2011) found that breeders do respond to summer heat stress when selecting cattle breeds.

- Schedule adjustment not considered:
  Lengthened feeding period (albeit more costly) may reduce productivity losses.

- Climate change impacts on livestock in the rest of the world is likely to have major implications for U.S. trade

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