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Implications of Climate Change on Regional Livestock Production in the United States

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This study used a partial equilibrium model focusing on U.S. agriculture to investigate the climate change implications for U.S. livestock production. Climate change impacts on crop productivity, grazing land productivity, and livestock animals' biophysical growth were factored into the model to examine the market equilibrium changes under alternative climate change scenarios. Results suggest that the U.S. livestock sector would be negatively influenced by climate change, with meat and milk prices increasing and exports decreasing. Livestock producers would expand the use of grazing and raise more animals to meet market demand given reduced productivity per head. Profit margins for meat and milk production would however decline due to increases in input prices than more than outweigh the gains from higher output prices.



1. Introduction

Climate Change (CC) can affect livestock productivity directly - such as imposing greater or ameliorated heat stress on beef and dairy cattle, causing changes in their weight gain, milk production, and reproductive performance (St-Pierre et al. 2003; Mader et al. 2009). CC can also result in input market effects on livestock production – such as altering feed crop yields and thus potentially the regional pattern of feed availability and feed prices, as well as the productivity and availability of grazing land (Mu et al. 2012). A less recognized impact is the output market effects for animal products, namely the potential for changes in export demand and international price for animal products. For the U.S. on average, the challenges that CC presents to livestock and crop production are projected to be increasing (USGCRP 2009), including increased heat and water stress. From an economic perspective, these changes could imply reduction in livestock productivity, rising feed costs, greater limits on water availability and greater need for labor and/or management effort. Consequently CC may affect the market dynamics of beef and dairy products for domestic consumption, export as well as the beef and dairy market prices, and even consumption patterns.

The implications are not isolated to U.S. producers and consumers alone. The consumption of animal products has been trending upward in emerging markets with large populations, particularly in Asia where rising per capita incomes, among other factors, are resulting in growing per capita meat consumption (Westcott and Trostle, 2013). These demand factors, along with increased market access since the mid-1990s as a result of the World Trade Organization formation and increased participation by individual trade partners in bilateral free trade agreements, have resulted in a trend of increased amounts of U.S. animal products going to export markets. CC will affect many facets of U.S. animal product dynamics, as well as the production dynamics of other countries. An improved understanding of how CC would affect the performance of the U.S. livestock sector, and consequently its ability to take advantage of growing export market potential, is thus interesting and an important contribution.

2. Literature Review

The structure of the U.S. beef and dairy cattle industry makes it vulnerable to the consequences of CC. The beef cattle industry in North America involves heavy use of grazing land in cow-calf and stocker operations and grain and high-energy feed usage in animal feeding (Galyean et al. 2011). The U.S. cow-calf industry is extensive, made up of many small operations that often utilize forage land less suitable for crops or public rangeland. Under CC, forage productivity in some regions could increase as a result of increases in CO₂ and precipitation levels (Izaurrealde et al. 2011). Baker et al. (1993) simulated ecosystem responses and cattle production in a CC regime and their results show increased biomass production in most of the Great Plains region – thus the grazing supply could increase under CC. In addition, CC will affect hay production, a critical factor in winter cattle maintenance and feeding regimes as cattle require certain proportions of roughage to maintain digestive health. In Beach et al. (2010a), the Environmental Policy Integrated Climate (EPIC) crop modeling results show that the rain-fed hay yields will increase in most places across the U.S. under CC, thus implicitly suggesting that the grazing supply per acre of rangeland or pasture land would increase. Thereupon CC may generally result in positive impacts for the extensive grazing cattle operations in the U.S.

The impacts of CC on the intensive feeding of market animals, dependent on the availability and price of feed grains, are however mixed (see Beach et al. 2010a). Crop selection, regions, and irrigation status can influence the production efficiency of different cropping enterprises and hence their relative economic competitiveness in a broader market. In turn, these changes may affect the downstream livestock sector, because the economic viability of livestock production, namely the animal finishing stage of production, can be heavily dependent on feed supply and costs. On the other hand, an expanding or shrinking livestock sector can influence the economic returns to feed cropping enterprises also, by presenting increasing or decreasing demand for feed crops. Given the interdependencies, and competition as well, between crop production, grazing land, and livestock production, a market equilibrium model covering all these phases would be then an ideal tool to provide analyses from a systems perspective.

Factors that contribute to cycles of expansion and contraction in the livestock production sector may include the direct physiological impacts of climate on animal performance and forage



availability as well as the indirect market forces. These impacts would include regional differences, such as distance to major feed grain production areas. CC effects on beef, dairy and swine production in the Great Plains, for example, have been simulated to exhibit a northwest to southeast gradient in general, with the most negative impacts occurring on the east side (Mader et al. 2009). In the Northeastern U.S., Wolfe et al. (2008) found that heat stress can indicate a substantial negative impact on milk production. The annual economic losses due to heat stress, using animal response models and 5-year average economic factors, are estimated to be \$1.69 –\$2.36 billion (St. Pierre et al. 2003). However, this did not consider the market mediations that factor in reduced supply and rising supply costs induced by heat stress in livestock industries. Adams et al. (1999) found that the responses of U.S. livestock production and market prices to future CC are relatively mild.

In sum, impacts of CC on livestock productivity through changes in animal performance, forage/grazing productivity and feed grain availability have been examined using various approaches (Mader et al. 2009; Baker et al. 1993). The economic or welfare evaluations have been limited in scope (St-Pierre et al. 2003; Adams et al. 1999). This study contributes to the literature in two ways: first, it considers three facets of CC impacts relevant to livestock production, including the biophysical changes in crop and livestock productivity, changes in input markets, as well as feedbacks from output markets. Second, it not only examines CC impacts at national level, but also investigates the regional breakdown to provide a closer look at the regional distribution of effects.

3. Methodology

3.1. Model

To take into account the mutually influencing effects that crop and livestock sectors place on each other and considering that the direction and magnitude of those effects may change under CC, the agricultural component of the Forest and Agricultural Sector Optimization Model with Greenhouse Gases (hence forth ASM, see Adams et al. (2005) and Beach et al. (2010b) for model documentation) is employed for this study.

The ASM is a dynamic, price-endogenous, and nonlinear optimization model simulating the U.S. agricultural sector and its most relevant export markets. Covering a broad range of cropping and livestock production and processing activities, the ASM optimizes the land use allocation within the U.S. agricultural sector maximizing total agricultural consumer and producer welfare.

This study will extend the research done by Adams et al. (1999), McCarl (2006), and Beach et al. (2010a) by updating and synthesizing data on CC scenarios and policy regimes. It will try to answer how the market equilibriums would look with CC after factoring in the changes in per unit livestock yields and the changes in crop and grazing yields.

3.2. Scenario Development

To examine the CC effects, a baseline scenario without any CC impacts included, and two CC scenarios were used in this study. CC effects on livestock yield – including beef, pork, milk, and lamb – as well as the number of animal units that can be supported by forage provided by an acre of grazing land are considered under CC scenarios. In addition, CC effects on crop yield and irrigation water usage and availability, pesticide usage, and grain supply from the rest of the world are included following Adams et al. (1999) and McCarl (2006). Comparisons of livestock production at the national and regional level, feed use, as well as the feed crop and livestock market prices between scenarios would then show the CC impacts on the U.S. livestock sector and their implications for U.S. livestock product exports.

Note that for different livestock enterprises, the indirect effects of CC are assumed to be manifested in different ways. For example, for cow-calf and dairy cattle production, the indirect effects include changes in the carrying capacity of rangeland and pastureland, as well as supplemental feed supply and costs. For feedlot and swine operations, the indirect effects largely imply changes in “intensive” feed supply and costs.

In addition to the aforementioned CC effects, the U.S. biofuel policy regime, Renewable Fuel Standards (RFS2), is incorporated in the base and CC scenarios also. Taheripour et al. (2010) examined the implications of U.S. biofuel mandates and found that the by-products of biofuels production could play an important role in providing substitute feeds for ruminants and thus the biofuel mandates do not necessarily curtail those livestock industries. In this study, the

by-product of U.S. biofuels production – dried distillers grains (DDG) and gluten feed – substitute feeds in the model. The mandate volumes of U.S. biofuels production were incorporated in accordance with the RFS2 specifications following Beach and McCarl (2010), and the technical RFS2 and climate change scenario modeling set up follows Zhang and McCarl (2013). Future projections for U.S. agricultural production technological progress rates, as well as the domestic and exports markets demand, were included in all scenarios using the assumptions in Beach and McCarl (2010).

Table 1 presents the scenarios used in this study. Two CC scenarios – CGCM31 (Coupled Global Climate Model 3.1, developed by the Canadian Centre for Climate Modeling and Analysis, Canada) and GFDL20 (GFDL-CM 2.0, developed by the Geophysical Fluid Dynamics Laboratory, USA) from Beach et al. (2010a) – are used here. In general, the temperature rises relative to the base scenario (no CC) by 2050 are milder under CGCM31 than under GFDL20. Also, the precipitation would increase under CGCM31 whereas it would decrease under GFDL20. Thereupon the GFDL20 climate is “hotter and drier” than the CGCM31 climate.

[Table 1 about here]

In order to make the CC scenario components (crop and livestock) as consistent as possible, the tripling ($3\times$ CO_2) Hadley results from Mader et al. (2009) were used for the CGCM31 scenario and the tripling CGCMI results were matched with the GFDL20 scenario. Such an arrangement is done because the projected temperature increases under the tripling scenarios in Mader et al. (2009) fall closer to the range of EPIC modeling temperature changes used in Beach et al. (2010a).

Moreover, since the ASM is an inter-temporal model and the data on CC scenarios were available for the period 2050 only, we assumed a linearly increasing manifestation of the 2050 CC for periods 2015 to 2045 in the model – thus by 2030 the CC effects would reach 50% of the 2050 CC effects. The data on CC effects on crop/grazing yields and livestock yields are specified in the next section.

4. Data

The CC data on crop yields – including corn and hay – and irrigation water usage by ASM sub-region are from Beach et al. (2010a). The CC effects on dryland hay yields were used as proxy estimates for the CC effects on the animal units of grazing land (grazing productivity). To save space, the CC data aggregated at regional level are presented below in Tables 2 and 3.

[Table 2 about here]

[Table 3 about here]

Table 2 and 3 show simulated percentage changes in corn and hay yields at regional level respectively. In general, both corn and hay (grazing) yields would increase in the Pacific Northwest Eastside region and decrease in the Southwest region. Compared to hay (grazing) yields, corn yields would see negative effects in the Southeast and deeper declines in the Southwest region. Also, the “hotter and drier” GFDL20 climate tends to impose noticeably larger negative or smaller positive effects on corn yields, compared to the more uniform CC impacts on hay yields across the scenarios.

The data on CC effects on livestock productivity were derived from Mader et al. (2009). Specifically, for beef and pork industries, the percentage changes in growing days for swine and beef cattle finishing were translated to decreases in productivity for use in this study. The magnitude of the CC shocks was also capped at 10%, based on information in Adams et al. (1999). The CC data on milk production did not need such translating process.

Since the animal production response projections in Mader et al. (2009) covered 15 points in the Great Plains region only, region proxy mapping was used to extrapolate the data for non-Great Plains regions, based on spatial proximity and latitude.

Table 4 presents the assumed percentage changes in livestock yields at regional level under CC by 2050. For beef cattle production, the GFDL20 scenario shows a larger regional variance in weight gain changes and a more obvious northwest to southeast gradient than the CGCM31 scenario. For dairy cattle milk production, the reductions in milk output per cow are shown to be much greater under GFDL20 than under CGCM31. Moreover, the regional disparity in milk output changes under CC are relatively small compared to that of beef cattle production.

For swine production, the decreases in weight gains are shown to be much larger than beef cattle production under CC scenarios, especially in the South regions.

[Table 4 about here]

The rest of the data such as the CC effects on pesticide usage, irrigation water availability, and grain supply in the rest of the world are from Adams et al. (1999) and McCarl (2006).

5. Results and Discussion

5.1. Input Production and Market Impacts

Figures 1 to 3 present how corn production, in terms of acreage by ASM sub-region, would be affected by CC. Under the base scenario, by 2050 the majority of the corn plantation would occur in the Corn Belt, the northern Great Plains, and the Lake States regions. Under CC scenarios, however, corn production in the Lake States will decrease. The CGCM31 climate will decrease corn production in part of the Great Plains and Southern regions in general, whereas the GFDL20 climate would negatively affect the Corn Belt and much of the Southwest region. Broadly speaking, the GFDL20 climate imposes larger negative impacts on corn production than the CGCM31 climate as it hits the Corn Belt region. Nonetheless, compared to the GCCM31 scenario, the GFDL20 scenario induces greater corn production in the Great Plains and the Southeast regions, making the corn production more evenly spread out.

[Figure 1 about here]

[Figure 2 about here]

[Figure 3 about here]

Regarding the feed use, under the base scenario, corn is the primary feedstock for livestock production on weight basis, accounting for 42% of the total feed consumption (Figure 4). Corn accounts for almost half of livestock feed on weight basis, when the corn processing co-products DDG and gluten feed are included. Other grains like sorghum, wheat, barley, and oats – in order of declining weight shares – account for over 7% of the feed. Hay and silage are another

major two feedstocks contributing to almost 40% of the consumption. Soybean meal, an important protein feed, provides about 3% of the feed on weight basis.

Under CC, the total feed consumption would increase as shown in Table 5. The CGCM31 scenario in particular exhibits an increase of corn feed consumption by about 3% in 2050, as well as noteworthy increases in hay and silage consumption. Other small feed grains and soybean meal also show increased use for livestock production. These increases suggest overall the CGCM31 climate has positive effects on crop production at the market-mediated national level. Under the GFDL20 scenario, the consumption of corn for feed use would decrease slightly, though the decrease would get compensated by a remarkable increase in use of corn's processing co-product gluten feed. Small grains would still see increases in feed use, however not as much as under the CGCM31 scenario. In sum, the total feed consumption would increase under CC scenarios, with the CGCM31 inducing larger increases than the relatively "hotter and drier" GFDL20.

[Table 5 about here]

While the total feed consumed by livestock industries increase under both CC scenarios, the outputs of the livestock industries do not necessarily increase because the CC effects on per unit livestock yields may outweigh the effects on overall feed production.

Input prices for livestock would rise in general under CC scenarios, as presented in Table 6. Corn, the largest feed component, sees price increases, especially under the relatively more severe GFDL20 scenario. Calf prices for the beef and dairy industry would experience substantial increases under both CC scenarios. On the contrary to changes in corn prices, calf prices see larger price increases under the relatively milder CGCM31 scenario, as a result of complex interplay between crops and grazing resources.

[Table 6 about here]

Prices for feeder pigs would decline under CC scenarios. This price decrease is primarily driven by the comparatively beneficial impacts of CC that the swine industry receives.

5.2. Output Market

Compared with the base scenario, beef production would decrease under CC scenarios, and prices increase – especially under the GFDL20 scenario (Table 7). Pork and milk production,

however, would remain close to the base levels and could even expand under the CGCM31 scenario, even though the CC effects are in general negative on their per unit meat/milk yields. The market clearing prices of pork and milk would correspondingly decrease under the CGCM31 scenario, benefitting domestic consumers and/or export markets. Considering that the total feed consumed by the livestock sector are projected to increase under CC, the decreases in beef outputs and increases in pork and milk outputs would then suggest that the U.S. livestock sector would reallocate more feed toward dairy and pork production under CC, resulting in increased supply and reduced prices (under CGCM31). Specifically, livestock producers would elect to raise more dairy cattle and expand swine populations. The exception is that under the more severe GFDL20 scenario, milk production would decline as well. This implies that cattle production that needs both “intensive” feed and “extensive” land could be materially challenged under CC. Moreover, compared with the input price changes shown in Table 6, the output price changes are generally milder. This indicates a narrowing profit margin for livestock production under CC scenarios, especially for the dairy industry.

[Table 7 about here]

Table 8 shows that the export volumes of corn and beef would decrease whereas pork would increase or remain unaffected under CC scenarios, corresponding to the changes in their domestic production levels.

[Table 8 about here]

5.3. Regional Production

For livestock production, the regional patterns of animal population would also change under CC scenarios, with the regional shifts of feed production contributing to the changes.

Under the base scenario, as the population grows and the absolute demand for meat products increases, by 2050 the feedlot beef cattle population would expand and get further concentrated in major feed producing regions, namely the Great Plains and Corn Belt, and completely shift out of the Lake States. Meanwhile the Southwest and Pacific Northwest Eastside would see declines, compared with the current conditions.

Under CC scenarios, the aforementioned tendency of concentrating and declining varied by region would be ameliorated (Table 9). For example, the beef cattle population would in

general undergo noticeable downsize in the Great Plains and Corn Belt and incur remarkable expansion in the Southwest and Pacific Northwest Eastside regions. The exception is that the Southwest would experience a decrease in feedlot cattle population under the GFDL20 scenario, due to substantial feed production decreases. Note that the reduction in beef cattle population is particularly pronounced under the CGCM31 scenario that actually sees increases in total feed consumption. This phenomenon implies that the increased feed consumption is not originating from the feedlot beef industry but other livestock industries. As will be detailed later, the swine industry expansion induced by the relatively positive CC effects on swine growth explains the decline in feedlot beef cattle population.

[Table 9 about here]

Under the base scenario, cow-calf operations would incur similar patterns of regional shifts as feedlot cattle, though the total size of population would decrease. A focused analysis on the changes in distribution of the cow-calf population, by region, is presented in Table 10. Opposite to the overall changes in feedlot beef cattle, the cow-calf population would get enlarged under CC scenarios, with substantial proportions of the increases taking place in the South and Pacific Northwest Eastside regions. Again, this shows that the presence of CC would counteract the baseline evolution.

[Table 10 about here]

Taking into consideration the CC impacts on crops and pastures, the cow-calf expansions reflect the enhanced relative competitiveness of raising livestock over growing crops in those regions. For example, in the Southwest region where the hay and pasture productivities are assumed to increase and the corn productivity is assumed to decrease, livestock producers would tend to increase cow-calf production. Furthermore, comparing the CGCM31 scenario with the GFDL20 scenario, one can find that the feedlot beef industry in the Southwest can benefit from the feed crop production increases in the Corn Belt under CGCM31, experiencing expansions.

A closer examination of the regional distribution of cow-calf and feedlot beef cattle populations also suggests that the beef sector may increase cow-calf operations that utilize more pasture land and/or decrease the population of intensively grain fed cattle, to respond to the potentially challenging feed conditions under CC. While the baseline evolution in this result corresponds to Galyean et al. (2011) in the sense that beef production in North America may

(eventually) focus more on the intensive, grain/energy feeds-based production than the “extensive, forage-based” production, unfolding CC may present a force counteracting this trend of beef production.

Regarding the dairy sector, by 2050, as the per cow milk yields increase over time (substantially), based on projections used in Beach and McCarl (2010), the dairy cattle population would decline over time and experience noteworthy changes in regional distribution. In particular, the dairy production would shift out of the Northeast region and get concentrated in the Pacific Southwest, Rocky Mountain, and Southeast regions. Against that future baseline picture, the presence of CC would increase the dairy cattle population (Table 11) – again, counteracting the baseline evolvement. The Pacific Northwest Eastside, Rocky Mountain and South regions – where per cow milk yields are assumed to be most negatively affected under CC (Table 4), would incur those population increases. This counterintuitive result suggests that, to meet the market demand, the U.S. livestock sector would reallocate more dairy production to its major traditional places, given the competition between livestock alternatives and the regionally varied feed and grazing conditions.

[Table 11 about here]

As for the pork industry, under the base scenario, the swine population would expand over time and experience similar changes in regional distribution as feedlot cattle – shifting from the Lake States and South regions to the Great Plains and Corn Belt. Table 12 shows that under CC scenarios, the shifting to the Great Plains region would be further intensified, largely due to the assumed increases in per pig pork yields (Table 4). The swine population increase in the Southwest is then more a story of the supporting market demand forces, though it also implies that shifting to the Southwest would improve the production efficiency at the national level. Compared with the projected increases in cow-calf and dairy cattle populations that represent a trend toward more “extensive, forage-based” production under CC, the swine population expansion corresponds to the declines in “feeds-intensive” feedlot beef cattle population, and the regional shifts under CC resemble those for feedlot cattle except for the Great Plains region.

[Table 12 about here]

5.4. Land Use

Table 13 presents the major land use changes with respect to the base scenario, at the region level, under CC scenarios. Intuitively, the increases in cow-calf and dairy cattle population and the decreases in feedlot cattle population suggest that there would be more grazing land being utilized and thus an expansion of high quality grazing land, such as cropland pasture, may occur. The model results however suggest that the trend toward more “extensive, forage-based” production does not necessarily lead to an expansion of high quality pasture acres. For example, in the Rocky Mountain region, the cow-calf population is projected to increase, potentially increasing the amount of grazing land. However, the model results show that the pasture land area in the Rocky Mountain region would decrease while cropland increases. Similarly, in the Great Plains region, broadly speaking, cow-calf and dairy populations are projected to decrease and thus less grazing land would be needed. In contrast, the model results suggest that cropland pasture (high quality pasture land) would increase and cropland would decrease. The South Central and the Southwest regions, on the other hand, could expect simultaneous pasture land expansions and cow-calf and/or dairy cattle population increases.

[Table 13 about here]

The phenomena above suggest that for regions that are either major feed production regions (such as the Great Plains) or having abundant grazing land resources in addition to the high quality cropland pasture (such as the Rocky Mountain region), land conversion would be largely driven by crop production profitability, whereas for regions that are otherwise, land conversion would be largely propelled by livestock production changes.

6. Conclusions

CC can negatively influence the supply of U.S. livestock products. Under CC scenarios with relatively mild impacts on crop and livestock production, the U.S. livestock sector may be able to maintain a production level close to baseline quantities (e.g., under the less “hotter and drier” CGCM31 climate) – however this is at the expense of using more high quality grazing land and having to raise more animals. In general, meat and milk prices would increase under the relatively severe CC, improving the income levels for livestock producers. However, the

increases in input prices would outweigh the increases in gross revenue, narrowing the profit margins of livestock production.

In general, the amount of crops used for livestock consumption would increase at national level under CC, even though CC can have regionally varied negative impacts on feed crop yields. The increased feed consumption is mainly attributed to non-beef production activities because the beef production would take advantage of increasing grazing productivity and be more “extensive, forage-based.” For future research, a sensitivity analysis on different levels of international demand for U.S. livestock products, as well as how CC influences livestock production in other countries may be needed to gain a better understanding of the relative competitiveness of U.S. livestock production under CC.

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Table 1. Scenarios Used*

Scenario	Change Maximum Temperature (°C)	Change Minimum Temperature (°C)	Change Precipitation (%)	Change Crop Yields/ Grazing Supply	Change Livestock Yields
Base	-	-	-	-	-
cgcm31	2.45 (spring) 2.27 (summer)	2.41 (spring) 2.17 (summer)	2.1 (spring) 0.7 (summer)	CGCM3.1 EPIC results in Beach et al. (2010a)	Hadley and 3X CO ₂ results in Mader et al. (2009)
gfdl20	2.78 (spring) 4.34 (summer)	2.41 (spring) 3.44 (summer)	-7.4 (spring) -8.5 (summer)	GFDL-CM2.0 EPIC results in Beach et al. (2010a)	CGCMI and 3X CO ₂ results in Mader et al. (2009)

*CC data for crop yields are from Appendix B “Percentage Changes in Crop Yields Incorporated into FASOM” in Beach et al. (2010a). CC data for livestock yields are based on “3x CO₂” results in Tables 1 – 3 in Mader et al. (2009).

Table 2. Percentage Changes in Corn Yields under CC, 2050

	Dryland		Irrigated	
	cgcm31	gfdl20	cgcm31	gfdl20
Corn Belt	-0.92	-9.48		
Great Plains	5.08	-2.63	0.85	-4.26
Lake States	-0.22	-5.37		
Northeast	1.68	-0.62		
Pacific Northwest Eastside	26.08	13.04	4.94	1.08
Pacific Southwest			3.19	-9.42
Rocky Mountain			1.99	-11.27
South Central	0.65	-6.04	-2.03	9.39
Southeast	-1.01	-1.5		
Southwest	-5.69	-8.24	-3.02	-5.89

Data Source: Beach et al. (2010a).

Table 3. Percentage Changes in Hay (Grazing Productivity) Yields under CC, 2050

	Dryland		Irrigated	
	cgcm31	gfdl20	cgcm31	gfdl20
Corn Belt	2.17	-1.35		
Great Plains	6.89	6.13	4.66	7.45
Lake States	5.98	1.09		
Northeast	5.96	7.31		
Pacific Northwest Eastside	16.89	25.55	10.62	15.44
Pacific Southwest	18.9	17.05		
Rocky Mountain	3.65	-2.28		
South Central	-1.99	-0.84		
Southeast	3.36	7.42		
Southwest	-2.26	-2.41		

Data Source: Beach et al. (2010a)

Table 4. Percentage Changes in Livestock Yields under CC, 2050

	Beef Cattle (Weight Gain)		Dairy Cattle (Milk Output)		Fed Hogs (Weight Gain)	
	cgcm31	gfdl20	cgcm31	gfdl20	cgcm31	gfdl20
Corn Belt	-3.84	-8.77	-4.43	-6.73	-10	-10
Great Plains	-3.9	-6.15	-4.51	-5.79	1.54	2.69
Lake States	-3.2	-3.2	-4	-6.2	-1.7	1.7
Northeast	-3.64	-6.81	-4.18	-6.43	-9.89	-9.84
Pacific Northwest Eastside	-3.79	0.7	-4.25	-7.13	-0.84	5.13
Pacific Southwest	-3.2	-3.9	-3.8	-7.5	-3.3	-1.7
Rocky Mountain	-3.8	2.5	-4.77	-6.58	-1.45	5.37
South Central	-3.68	-7.37	-4.18	-6.03	-10	-10
Southeast	-3.8	-7.94	-4.21	-6.82	-10	-10
Southwest	-3.1	-9.99	-3.89	-3.9	-10	-10

Data Source: Mader et al. (2009)

Table 5. Changes in Feed Use by Feedstock under CC Scenarios, 2050 (million pounds)

	2050			vs. base	
	base	cgcm31	gfdl20	cgcm31	gfdl20
Corn	412,430	423,739	411,655	2.74%	-0.19%
Sorghum	40,594	42,559	41,237	4.84%	1.58%
Oats	4,036	4,280	4,252	6.06%	5.35%
Barley	5,295	5,854	5,556	10.55%	4.93%
Wheat	18,715	20,919	20,608	11.78%	10.11%
Silage	183,262	205,501	192,678	12.14%	5.14%
Hay	208,279	216,217	209,466	3.81%	0.57%
Soybean Meal	27,831	28,534	27,828	2.53%	-0.01%
Gluten Feed	4,581	4,587	5,709	0.13%	24.62%
DDG	78,351	78,366	78,394	0.02%	0.05%
Total	983,374	1,030,556	997,382	4.80%	1.42%

Table 6. Input Prices for Livestock Production under CC Scenarios, 2050

	Unit	2050			vs. base	
		base	cgcm31	gfdl20	cgcm31	gfdl20
Corn	<i>\$ per bushel</i>	2.57	2.58	2.73	0.47%	6.46%
Calf, Heifer	<i>\$ per cwt</i>	177.12	193.59	188.74	9.30%	6.56%
Calf, Steer	<i>\$ per cwt</i>	170.93	185.94	181.59	8.78%	6.23%
Calf, Stocked	<i>\$ per cwt</i>	135.47	147.33	143.80	8.75%	6.15%
Yearling, Stocked	<i>\$ per cwt</i>	124.15	132.31	131.60	6.57%	6.00%
Calf, Dairy	<i>\$ per cwt</i>	167.01	182.24	177.56	9.12%	6.32%
Feeder Pig	<i>\$ per cwt</i>	174.97	164.48	166.38	-6.00%	-4.91%

Table 7. Beef, Pork, and Milk Production and Prices under CC Scenarios, 2050

	Unit	2050	vs. base				
			base	cgcm31	gfdl20	cgcm31	gfdl20
Beef	Production	<i>million cwt</i>	494	485	469	-1.82%	- 5.06%
	Price	<i>\$ per cwt</i>	72.50	74.03	77.22	2.11%	6.51%
Pork	Production	<i>million cwt</i>	506	510	506	0.79%	0.00%
	Price	<i>\$ per cwt</i>	40.56	39.68	40.56	-2.17%	0.00%
Milk	Production	<i>million cwt</i>	2592	2606	2534	0.54%	- 2.24%
	Price	<i>\$ per cwt</i>	15.20	14.93	15.72	-1.78%	3.42%

Table 8. Corn, Beef, and Pork Exports under CC Scenarios, 2050

	Unit	2050	vs. base			
			base	cgcm31	gfdl20	cgcm31
corn	<i>million bu</i>	3,671	3,627	3,291	-1.20%	-10.37%
beef	<i>million cwt</i>	37.54	37.18	36.11	-0.95%	-3.81%
pork	<i>million cwt</i>	52.43	53.39	52.43	1.82%	0.00%

Table 9. Regional Distribution of Feedlot Beef Cattle Population (1000 Head) under CC Scenarios, 2050

	2050			vs. base	
	base	cgcm31	gfdl20	cgcm31	gfdl20
Corn Belt	2,268	2,109	2,116	-159	-152
Great Plains	15,340	13,525	15,261	-1,815	-79
Lake States	0	0	0	0	0
Northeast	0	0	0	0	0
Pacific Northwest Eastside	573	656	648	83	75
Pacific Southwest	1,698	1,636	1,636	-62	-62
Rocky Mountain	4,669	4,767	4,404	98	-266
South Central	146	174	196	28	50
Southeast	729	764	745	35	16
Southwest	5,672	6,695	5,414	1,023	-258
Total	31,096	30,327	30,419	-769	-676

Table 10. Regional Distribution of Cow-Calf Population (1000 Head) under CC Scenarios, 2050

	2050			vs. base	
	base	cgcm31	gfdl20	cgcm31	gfdl20
Corn Belt	2,869	2,668	2,677	-201	-193
Great Plains	6,699	6,253	6,783	-445	84
Lake States	0	0	0	0	0
Northeast	0	0	0	0	0
Pacific Northwest Eastside	842	965	952	122	110
Pacific Southwest	796	767	767	-29	-29
Rocky Mountain	4,401	4,658	4,319	256	-82
South Central	2,512	2,986	3,280	474	768
Southeast	2,424	2,528	2,513	104	89
Southwest	5,401	6,513	6,525	1,112	1,125
Total	25,945	27,337	27,816	1,393	1,871

Table 11. Regional Distribution of Dairy Cattle Population (1000 Head) under CC Scenarios, 2050

	2050			vs. base	
	base	cgcm31	gfdl20	cgcm31	gfdl20
Corn Belt	670	623	625	-47	-45
Great Plains	360	336	365	-24	5
Lake States	0	0	0	0	0
Northeast	0	0	0	0	0
Pacific Northwest Eastside	256	294	290	37	33
Pacific Southwest	763	735	735	-28	-28
Rocky Mountain	503	564	526	61	23
South Central	290	412	465	121	175
Southeast	549	579	566	30	17
Southwest	291	348	325	57	34
Total	3,682	3,890	3,896	208	214

Table 12. Regional Distribution of Swine Population (1000 Head) under CC Scenarios, 2050

	2050			vs. base	
	base	cgcm31	gfdl20	cgcm31	gfdl20
Corn Belt	38,248	35,575	35,690	-2,672	-2,557
Great Plains	75,008	81,128	78,189	6,120	3,181
Lake States	0	0	0	0	0
Northeast	0	0	0	0	0
Pacific Northwest East	707	810	799	102	92
Pacific Southwest	1,610	1,551	1,551	-59	-59
Rocky Mountain	832	685	616	-147	-216
South Central	2,939	4,002	4,501	1,062	1,562
Southeast	6,357	6,605	6,741	248	384
Southwest	2,703	3,176	1,939	474	-763
Total	128,405	133,533	130,028	5,128	1,624

Table 13. Levels of and Changes in Land Use (1000 Acres) under CC Scenarios, 2050

	Cropland			Cropland Pasture		
	base	<i>vs. base</i>		base	<i>vs. base</i>	
		cgcm31	gfdl20		cgcm31	gfdl20
Corn Belt	75,600	111	84	8,928	-323	-309
Great Plains	62,288	-2,640	-4,949	15,107	2,605	5,204
Lake States	32,342	-204	-204	2,838	7	7
Northeast	10,905	-33	105	1,854	33	-43
Pacific Northwest East	19,521	637	2,797	8,402	-469	-1,924
Pacific Southwest	7,349	17	17	159	-17	-17
Rocky Mountain	7,266	-110	-146	825	110	146
South Central	29,265	-2,323	-754	7,503	2,131	520
Southeast	10,281	-426	676	6,885	361	-701
Southwest	21,583	-2,365	-1,799	19,018	2,109	1,561
Total	276,398	-7,337	-4,173	71,518	6,547	4,443

Figure 1. Corn Acres under Base Scenario, 2050

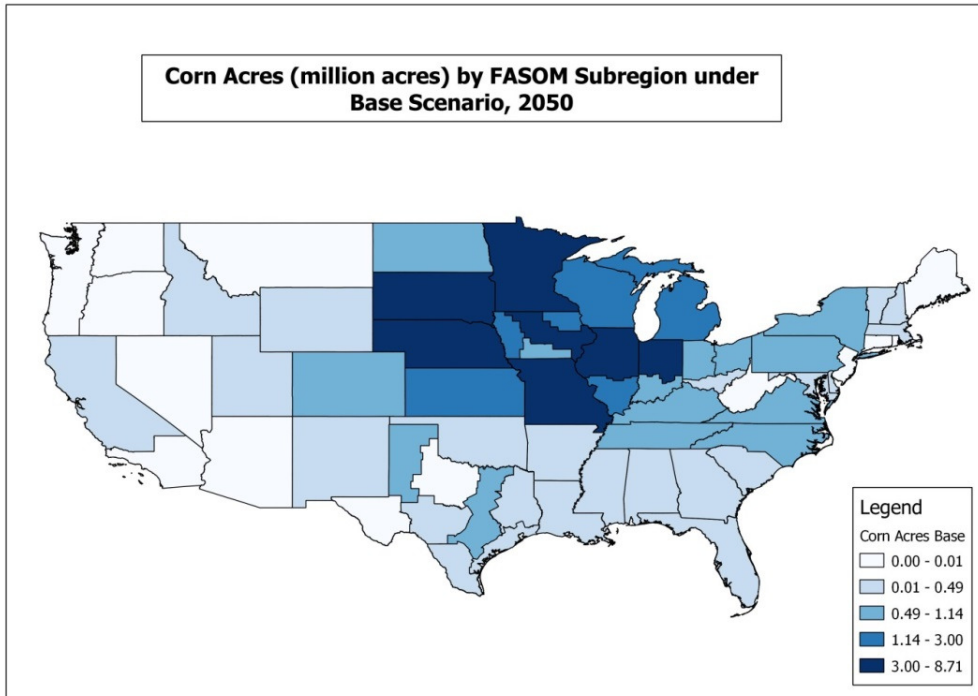


Figure 2. Changes in Corn Acres under CGCM31 Scenario, 2050

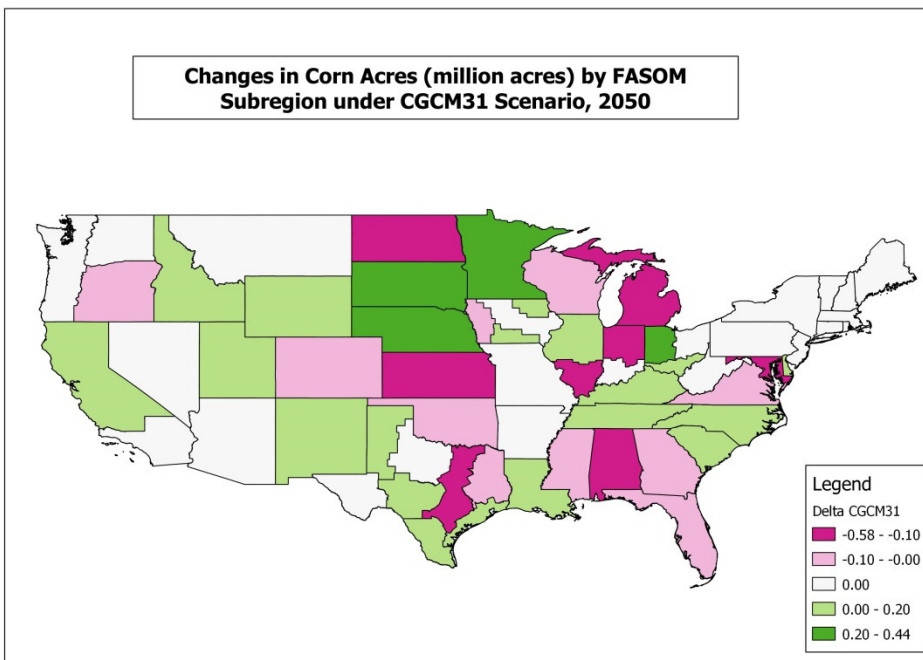


Figure 3. Changes in Corn Acres under GFDL20 Scenario, 2050

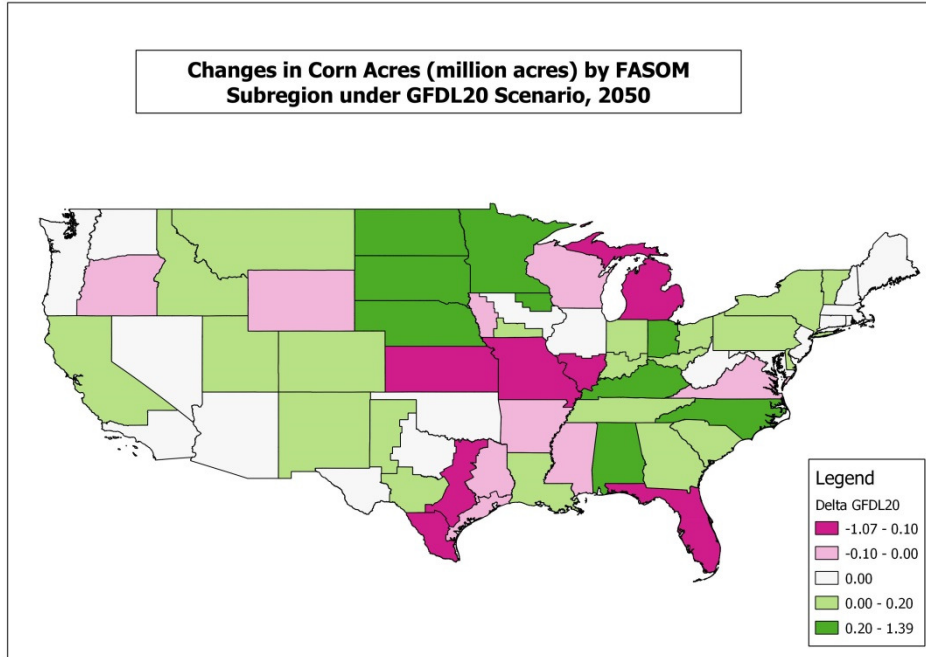


Figure 4. Livestock Feed Consumption by Feedstock on Weight Basis, 2050

