

Climate change effects on livestock in the Northeast US and strategies for adaptation

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NE states included in the analysis

CONNECTICUT
DELAWARE
MAINE
MARYLAND
MASSACHUSETTS
NEW HAMPSHIRE
NEW JERSEY
NEW YORK
PENNSYLVANIA
RHODE ISLAND
VERMONT
WEST VIRGINIA

Structure of the livestock industries in the NE US

- Dairy is the main livestock industry. Total milk and dairy product sales in the region exceeded $7.5 billion in 2014
  - Sales of dairy products represented 32% of all farm receipts
- Poultry production in the NE includes broiler chicken, egg, and turkey operations, providing $4.50 billion in cash receipts in 2015
  - Poultry and egg production in the region represents 9.4% of the total value produced in the USA
- Beef animals in the NE represent 3.7% of the national cattle inventory
  - 2% of the national cattle and calf farm receipts, at $1.69 billion in 2014
- The NE horse industry is an important segment of animal agriculture; the total value of horses in the NE is between $1.4 and $4.3 billion
  - The GDP impact of the region's horse industry is estimated at $7.5 billion, which is about 7.4% of the national impact of $101 billion in 2005
- Sheep, goats, and pigs are additional livestock sectors in the NE
  - The swine industry had a $362.5 million production value in the NE in 2013

The NE dairy industry

- Vermont (68.1% of the total farm receipts); New York (NY; 54.6%); Pennsylvania (PA; 33.0%)
- Current NE milk production is 13.8 billion kg/year, or 14.6% of the U.S. total
  - About 20% of the organic milk produced in the U.S. comes from the NE
- Dairy farms in the region employ approximately 55,000 workers
- In 2015, there were 13,720 dairy farms in the region with about half located in PA and 35% in NY
- The dairy cow population in the NE totaled 1.4 million with 80% on PA and NY dairies
- Farm size varied with 1.5% of herds having less than 30 cows, 26% at 500 or more and a median herd size of about 200 cows

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Poultry industry in the NE

- Poultry operations in the NE are medium and large concentrated animal feeding operations (CAFO) with environmentally-controlled housing systems
- Broiler farms with 100,000 birds or more in annual sales contribute about 98.6% of total broiler production and represent 30% of broiler farms in the NE
- There are 235 medium and large layer farms with 20,000 layers or more representing less than 1% of layer operations in the NE, but producing 84% of the layer inventory
  - In 2012, Sussex, DE and Lancaster, PA were ranked first and fourth counties in the nation for poultry and egg sales with $658 and $469 million, respectively
- Broiler production in the region was 780 million birds per year, mainly in Maryland (MD), DE, PA, and West Virginia (WV)
- Pennsylvania leads in egg production with about 64% of the layer inventory (40 million birds) and 86% of the total egg production in the NE
- Pennsylvania and WV account for 96% of all turkey production (14 million birds) in the NE

Equine industry in the NE

- The estimated number of horses in the NE range from a low of 370,000 (NASS 2012) to a high of 965,000 (AHCF 2005)
  - 716,000 horse population was estimated for this analysis using equine specific state surveys
- The region represents approximately 5.6% of the total land in the U.S., but the equine population represents 10-11% of the national population
- The primary disciplines in which horses are involved and approximate percentages are:
  - recreation (40%), showing (30%), and racing (10%)
- In terms of total national horse population, states in the NE range in overall ranking from 9th (PA) to 50th (Rhode Island)
  - Pennsylvania, NY, MD, and WV represent 73% of the horses

Summary of climate trends in the NE

- More extremely warm nights (minimum temperature >21°C)
- Fewer extremely cold and cold nights (<−18°C and <0°C)
- Warmer average winter and summer temperatures
- More days with heavy rain (generally >5.0 to 7.6 cm events)
- Higher annual precipitation

Kunkel et al. (2013)

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Climate change effects on forage production

Table S2. Potential changes in forage crop productivity and quality associated with climate change. Projected changes will have both positive and negative effects		
Change in climate	Change in forage productivity	Change in forage quality
Elevated air temperature	**Perennial cool-season forages** will begin growth earlier in the spring and go dormant later in the fall **Increase productivity of annual and perennial forages** with longer growing season **Favorable for warm-season forage species because of longer growing season** and greater photosynthetic efficiency at temperatures > 29°C **"Summer slump"** associated with cool-season forages will be more pronounced	**Reduced digestibility associated with increased lignin deposition** in plant cell wall and lower leaf:stem ratios **Decrease in crude protein content** of forage
Decreased winter soil temperature (due to less snow cover)	**Increased winter damage to sensitive perennial forage species**. Result in possible species shift or stand loss, especially in northern areas of the region, and reduced production	

Climate change effects on forage production

Table S2. Potential changes in forage crop productivity and quality associated with climate change. Projected changes will have both positive and negative effects		
Change in climate	Change in forage productivity	Change in forage quality
Less frequent but more intense precipitation	**Warm-season forage and weed species have competitive advantage** over cool-season species during long periods with limited soil moisture **Cool-season forages have competitive advantage** during wet and cool periods **Increased challenge to successful forage establishment** and early access of grazing animals to wet fields	**Warm-season weed encroachment** reduces forage quality **Reduced quality associated with "rained on" forage while drying** **Postponed harvest** may decrease forage quality
Elevated CO_2	**Increased productivity of cool-season (+30%) and warm-season (+10%) forage species**	**Elevated plant nonstructural carbohydrates, decrease in crude protein content, but no effect on forage digestibility**

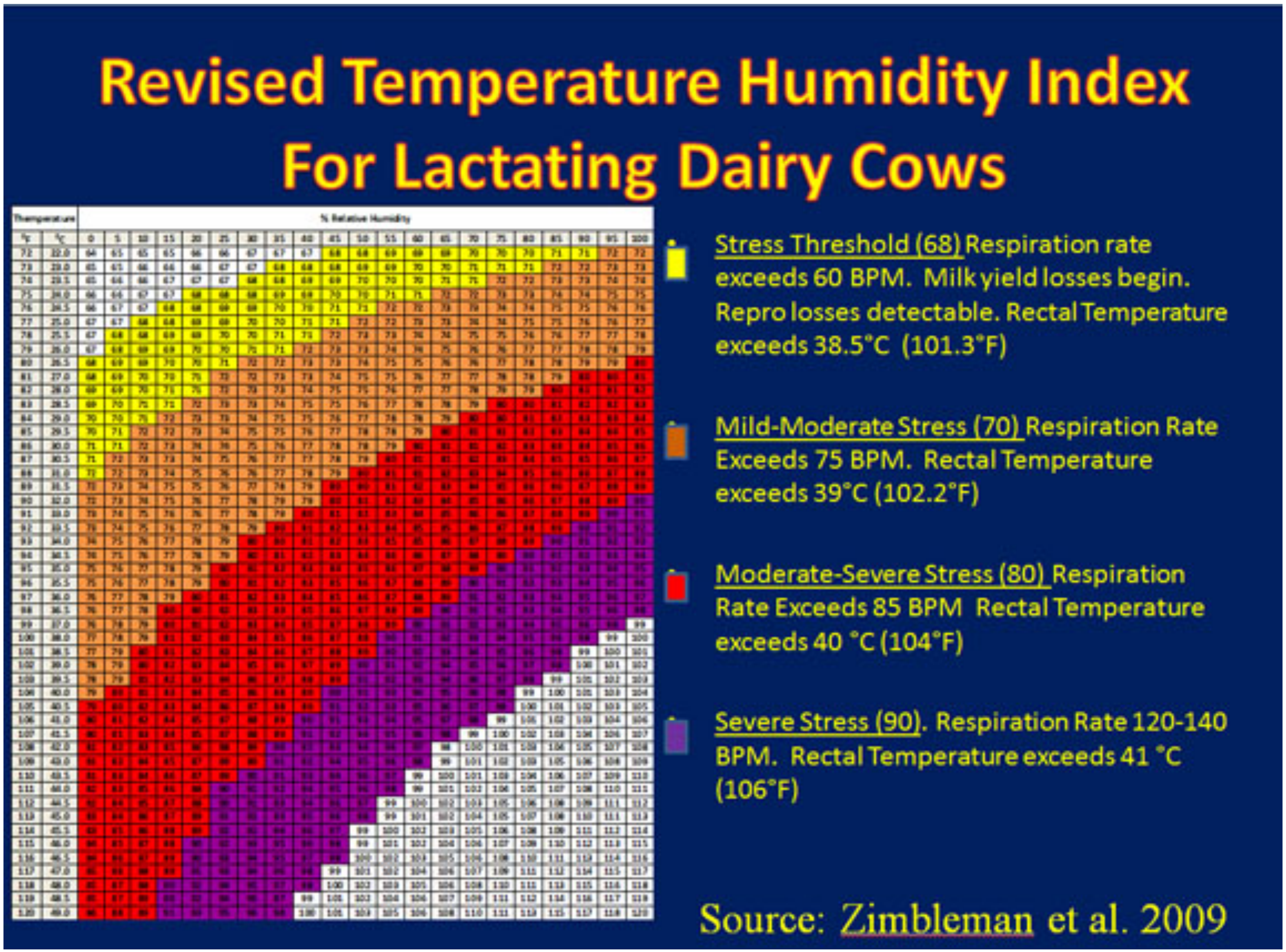
Forage production summary

- Reduced snow cover could increase exposure to extremely cold temperatures by reducing the insulating effect of snow
- Impacts of climate change on the predominant annual forages such as whole-crop corn and small grains should generally be positive
- Forage yields of small grain crops should increase due to elevated atmospheric CO_2 levels and air temperatures
  - Modeling a central NY dairy farm: yields of alfalfa, corn silage, wheat grain, and wheat straw were projected to increase by 12, 22, 5, and 32%, respectively (Rotz et al., 2016)
- A trend toward warmer temperatures may allow better success with no-till and cover crop establishment in northern portions of the region

Effects on livestock

- Animals have a Thermo-Neutral Zone (TNZ)
  - as an example, for dairy/beef cattle TNZ is between 5 and 25°C
- Below the TNZ, animals will require extra energy to maintain body functions and have to increase feed intake
- Above the TNZ, animals are under heat stress of various severity
  - **A major effect of heat stress is decreased DMI**

Temperature-humidity index



Effect of heat stress on DMI (dairy)

- DMI loss estimation:
  - $DMI_{Loss} = 0.0345 \times (THI_{max} - THI_{threshold})^2 \times D$

- THI_{max}:
  - THI_{max} = 0.8 × maximum ambient temperature in °C + [(minimum humidity ÷ 100) × (maximum ambient temperature in °C - 14.3)] + 46.4

St-Pierre et al. (2003)

Other potential effects of heat stress in dairy cattle

- Studies have shown decreased milk protein yield
- Increased mortality, increased incidences of diseases, decreased reproductive performance, and decreased heifer feed intake and daily gain
  - Heat stress reduces fertility by affecting the ovaries, uterus, and the hormones regulating their function
- The physiological responses to heat stress in dairy cattle include altered hormonal status, reduction in rumination and nutrient absorption, suboptimal immune function, and increased maintenance requirements

Effects of heat stress on reproduction in dairy cattle

- The most extreme predicted temperature increases from current models (6.5 °C) are expected to reduce fertility in dairy cattle in the NE
  - A reduction in pregnancy rates from the current 20% in the NE to 15% would result in >$50 million in lost income per year
- This loss includes losses due to lower milk production, increased culling of non-pregnant cows, and increased costs of repeated inseminations
- To minimize the impact of warmer temperatures, dairy producers will likely respond:
  - Adopting additional heat abatement strategies and hormonal synchronization protocols
  - Use genetic selection strategies that include greater emphasis on fertility traits and disease resistance; selection for resistance to heat stress
- Thus, it is likely that smaller or more financially-leveraged dairies will exit the industry at a greater rate, which would accelerate consolidation of the industry toward fewer and larger dairy operations

Summary of effect in the dairy sector

- Predicted changes in climate will likely result in reduced production efficiency in dairy cattle, stemming from reduced feed intake, reduced feed efficiency, and increased incidence of metabolic stress
- This will result in increased incidence of diseases and lowered fertility and, as indicated earlier, will likely accelerate consolidation of dairy cows onto fewer and larger farms

Effects on the dairy industry

Table S3. Historical and projected average maximum temperature and minimum humidity and projected additional milk and economic losses due to increased risk of heat stress for the Northeast dairy industry[1]

Item	Historical	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5
Temperature (April-October), °C					
Average maximum	24.3	28.2	28.9	28.6	30.8
Relative average humidity, %					
Average minimum	48.7	47.8	46.8	47.5	45.9
Days with average maximum temperature ≥ 25°C	67	102	111	112	130
Additional milk loss, t/year	-	75,258	111,740	105,124	286,041
As % of projected milk production[2]	-	0.38	0.40	0.53	1.02
Additional economic loss,[3] $1,000/year	-	33,113	49,166	46,255	125,858
Economic loss, $/cow/year	-	23	35	33	88

[1]Projections for Years 2050 and 2100 and Representative Concentration Pathway (RCP) 4.5 and 8.5. For temperature and relative humidity data see ***Climate projection data*** above.
[2]Based on average, projected milk production per cow for PA and NY of 13,809 and 19,646 kg/year, 2050 and 2100, respectively (projections based on 1990-2015 trends, i.e., increase of about 94 and 140 kg/cow/year, PA and NY, respectively).
[3]Estimated based on 1,423,400 cows (2015 data) in the region and $20/cwt (approximately $0.44/kg) milk price.

Effects on the dairy industry: Lancaster County

Table S4. Historical and projected maximum temperature and minimum humidity and projected additional milk and economic losses due to increased risk of heat stress (with no or only minimal animal heat abatement) for the dairy industry in Lancaster County, PA (ranked eighth in dairy production among U.S. counties)[1]

		2050		2100	
Item	**Historical**	**RCP4.5**	**RCP8.5**	**RCP4.5**	**RCP8.5**
Temperature (April-October), °C					
Average maximum	28.4	29.9	30.6	30.4	32.1
Relative average humidity, %					
Average minimum	45.6	44.6	43.6	44.3	42.8
Days with average maximum temperature ≥ 25°C	115	150	157	157	182
Additional milk loss, t/year	-	12,344	17,685	16,434	37,615
As % of projected milk production[2]	-	0.88	0.92	1.17	1.96
Additional economic loss[3], $1,000/year	-	5,431	7,781	7,231	16,551
Economic loss, $/cow/year	-	49	70	65	149

[1]Projections for Years 2050 and 2100 and Representative Concentration Pathway (RCP) 4.5 and 8.5. For temperature and relative humidity data see ***Climate projection data*** above.
[2]Based on average, projected milk production per cow for PA of 12,660 and 17,357 kg/year, 2050 and 2100, respectively (projections based on 1990-2015 trends, i.e., an increase of about 94 kg/cow/year).
[3]Estimated based on 110,805 cows (2015 data) in Lancaster County, PA and $20/cwt (approximately $0.44/kg) milk price.

Climate change effects in the poultry industry

- The potential challenges posed by climate change on broiler production are twofold:
  - increased energy cost to maintain an optimum environment (to prevent heat stress)
  - potential impaired productivity from heat stress
- Projections in the NE for warmer winter and summer temperatures and fewer extreme cold nights would benefit broiler production by reducing fuel usage and disease challenges through better ventilation and an improved housing environment
- Future housing will most likely require greater insulation and greater ventilation fan capacity to offset warmer temperatures
  - Some of the added cost (i.e., increased ventilation and cooling) will be offset by energy savings during warmer winters

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Climate change effects in the poultry industry

- Warming ambient temperatures will reduce the cost of fuel needed to heat the brooding barns and maintain desirable temperatures
- Heat stress, however, can reduce pullet growth, egg production, and the quality of eggs
  - Heat stress also reduces shell thickness leading to a greater percentage of cracked or broken eggs and economic loss
- Overall, providing adequate housing and ventilation equipment to offset climate changes will increase the price of eggs as these costs are already a significant cost of production

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Climate change effects in the beef industry

- Overall, based upon average temperature increases ranging from 3.9 to 6.5°C, impact of climate change on beef cattle and beef production losses in the NE should be minimal
- Increased moisture in the region may have an impact on beef cattle grazing operations
  - Housing is not generally considered necessary for grazing cattle; however, increased winter precipitation may reduce pasture stocking rates and increase housing needs for grazing beef

Climate change effects in the equine industry

- Overall, predicted climate changes for the NE are likely to have an economic impact on the horse industry through:
  - additional management of land and forage resources
  - building of shelters
  - climate monitoring and heat abatement at equine events
- The horse industry is composed of a great diversity of operations making any realistic estimate of an economic impact due to climate change beyond the scope of this report

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Climate change effects in the small ruminants industries

- Sheep, including lambs, total 304,456 head in the NE
  - PA and NY make up 30.9% and 26.2% of the NE total
  - 12% of sheep operations are certified organic, making the organic sector a much larger segment of the sheep industry than the beef industry in the NE
- There are a total of 162,242 goats in the NE
- Sheep and goats are predominantly raised on pastures
- Both species are more affected by heat stress, and, thus, more likely to reduce their feed intake, than cattle
- Parasite loads in warming climates may be the greatest issue
  - Sheep and goats are extremely susceptible to internal parasites, and those internal parasites that afflict sheep and goats are becoming increasingly resistant to anthelmintics
- Most of the effects of climate change on sheep and goats will be related to changes in parasite load

Climate change effects on manure management

- Using current manure handling methods, projected climate changes in the NE may increase ammonia losses 20% by midcentury and up to 39% by 2100
  - Longer growing season and increased temperatures will increase plant uptake and evapotranspiration, thus reducing the potential for manure nitrates leaching to groundwater
- With wetter and warmer conditions, nitrous oxide emissions are projected to increase about 12% by midcentury and 24% by 2100 on NE dairy farms
- Increases in precipitation and storm intensity are projected to increase P losses as much as 40% by midcentury and 87% by 2100
- Projected climate changes may increase methane emissions from manure management by about 4% by midcentury and 8% by 2100
- Warmer temperatures and a longer growing season may allow more time for manure handling, tillage, and planting of crops
- Thus, the net effect of climate change on these operations may be minor or difficult to predict

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Climate change effects on emerging pathogens and diseases

- Climate warming may create broadening ecotones (areas of contact) and interfaces for exchange of pathogens among domestic animals, wildlife, and people.
  - The potential costs for animal and human health of these changes may exceed several billion dollars
- Under a regime of accelerating climate change, threats to security, reliability, availability, and safety for food and water resources are expected to expand
- Monitoring and targeted surveillance of pathogens at broad geographic scales will be critical to address climate change challenges

Ammonia & GHG mitigation options

- Animal nutrition
  - Feeding protein close to requirements can alleviate some of increase in N losses and ammonia volatilization caused by climate change; this can also have a significant impact on manure ammonia and nitrous oxide emissions
  - There are mitigation options for decreasing enteric methane emissions; effectiveness of some of these has been proven but they have to be applied in practice and on a large scale to have an impact
- Manure management
  - Manure covers are effective for reducing gaseous emissions and the resulting odor
  - Anaerobic digesters can be used to enhance methane production (increased temperatures will have a positive effect on biogas production)
  - Injecting manure below the soil surface can reduce ammonia emission by 80% and runoff losses by 50%
  - Modified cropping systems (cover crops, double cropping) can also improve utilization of the manure nutrients and reduce ammonia and GHG emissions

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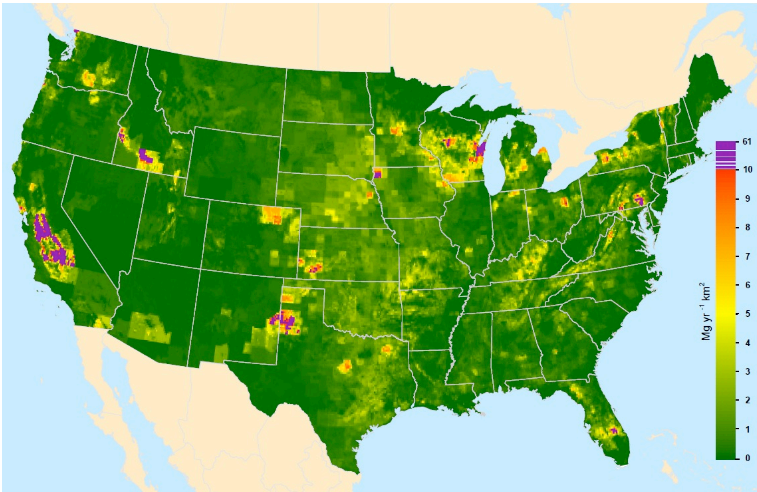
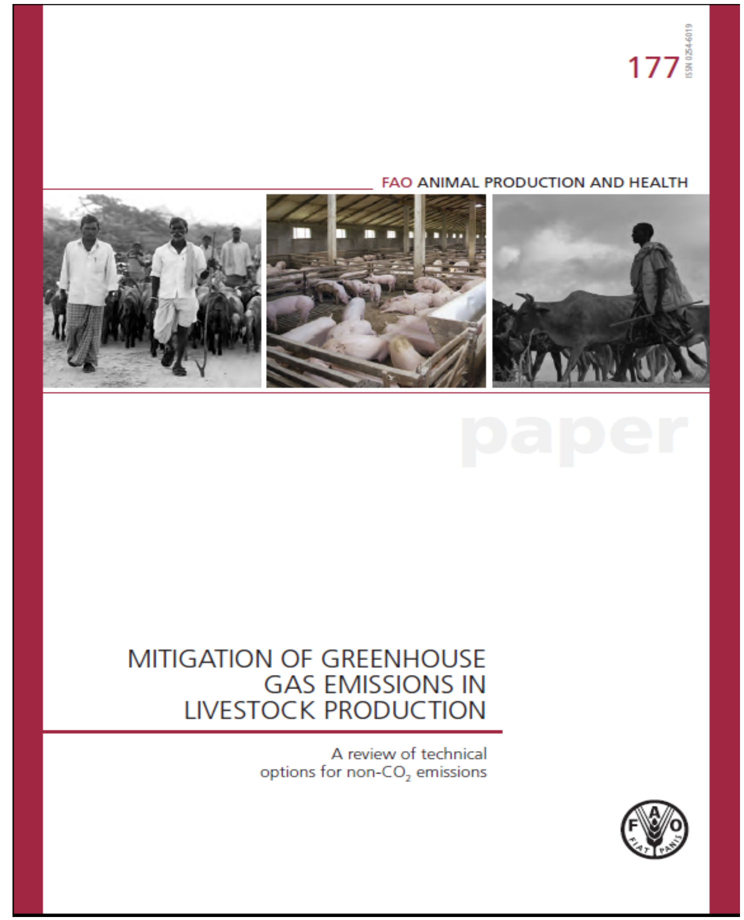




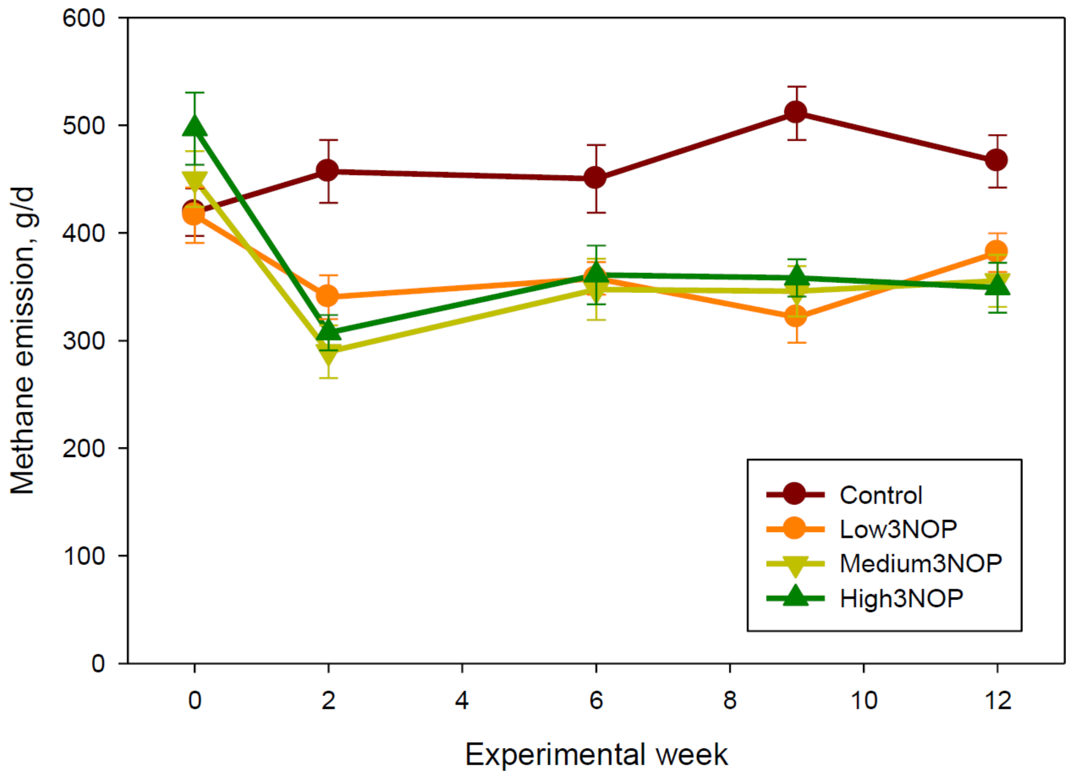
GHG Mitigation Options for the Livestock Industries

FAO, 2013

Hristov et al., 2015

Effect of 3NOP on methane emission

29% lower; Means: 481, 363, 333, and 329 g/cow/d; SEM = 15.9; $P_L < 0.001$



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Summary/Conclusions

- Overall, increased average maximum temperatures, days with temperatures exceeding 25°C, higher annual precipitation in the NE, and increased atmospheric CO_2 concentration are expected to either increase or decrease forage productivity depending on the crop, and may decrease protein content and forage digestibility
  - These changes may cause winter damage to sensitive forage species
- In the dairy sector, additional loss in milk production due to decreased feed intake is estimated to be up to 1% of the projected annual milk production through 2100
- Increased temperatures may reduce fertility in dairy cattle and heat stress-induced inflammation may limit energy available for productive functions
- The effects of climate change on the beef industry in the NE are expected to be minimal
- Broiler production in the region may benefit from warmer winter and summer temperatures
  - Providing adequate housing and ventilation to offset climate changes will be important for both the broiler and layer industries and may increase the price of eggs
- Climate change is expected to have an economic impact on the horse industry
- Increased temperatures and more intense storms will likely increase nutrient losses and gaseous emissions from animal manure
- Continued animal health monitoring is necessary to address responses of host animals, pathogens, and disease vectors to climate change


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2134
Control
1940
Control
2082
2026
1997
1845
1831
QUESTIONS?