The effects of climate change on the production costs of the dairy industry in the U.S.

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Introduction

The dairy industry has great economic and cultural significance in the United States today. Dairy is considered part of a balanced diet and the fourth largest agricultural commodity in America. Dairy farmers operate in all fifty states and produced over 192 billion pounds of milk in 2010. Operating on slim profit margins, dairy farmers are vulnerable to fluctuations in production costs and the market price of milk.

Climate change is expected to greatly impact dairy farmers. Crop yields will change due to variations in climate, affecting feed costs to farmers. In addition, climate change will affect energy and electricity costs. Working together with the Innovation Center for U.S. Dairy, we developed a model to quantify how climate change will impact the production costs of milk in the future, so that dairy farmers can prepare for these changes.

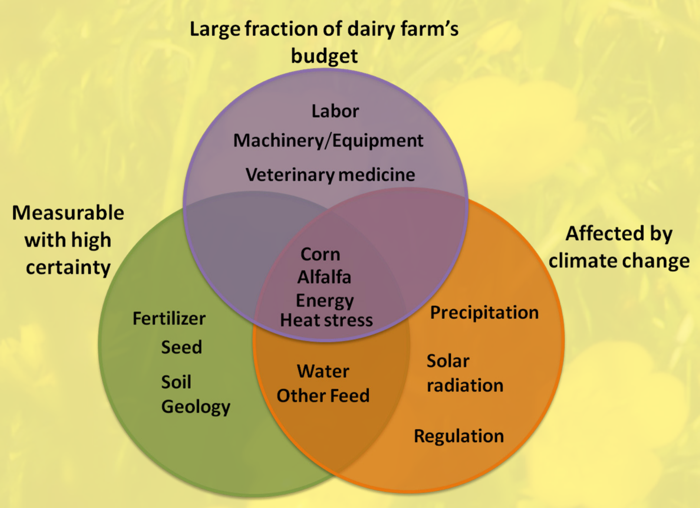
Objectives:

- Identify how climate change affects the critical inputs of the dairy industry.
- Quantify the climate change impacts on production costs.
- Model the change in total cost to farmers.

Regions

We divided the U.S. into five regions to better represent the regional differences of dairy farms and to account for climate change effects. We used the A2 climate change scenario by the IPCC, which predicts a 75ppm increase in CO_2 concentration and an average 2°C temperature increase across the country. Regional temperature variations were incorporated into the model.

Inputs and climate change response



We used three evaluation criteria to determine the inputs included in the model:

- Large fraction of a dairy farm's budget
- Measurable with high certainty
- Affected by climate change

The selected inputs are corn, alfalfa, energy, and heat stress. To build the model we estimated how each input responds to climate change.

Researchers predict **corn yields** to decrease nationally by 8% under the A2 scenario. Warmer temperatures during the summer shorten the growth cycle of corn, resulting in lower yields.

Climate change is likely to cause **alfalfa yields** to increase nationally by 4% because alfalfa benefits from higher CO_2 concentrations and temperatures.

Energy costs, including both electricity and fuel, are expected to increase due to climate change. Overall, we expect a 43% increase in the farmers' energy costs due to climate change by 2050.

Higher temperatures will cause **heat stress** in dairy cows. Heat stress reduces the milk yield per cow for the same amount of feed. In addition, heat stress lowers the protein and fat content of the milk. By 2050, we expect a 3.32% decrease in milk yield across all regions.

Scenarios

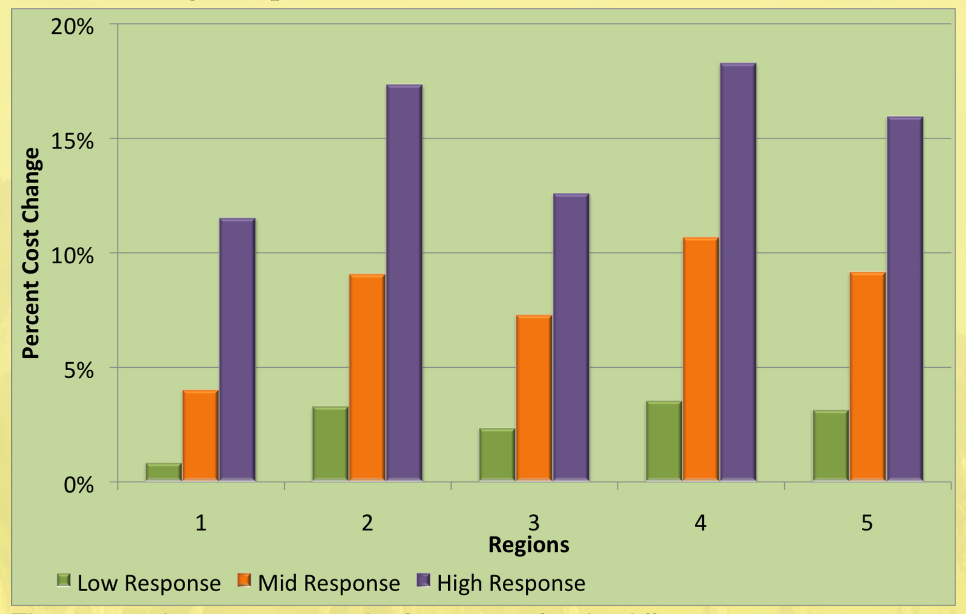
Our literature review revealed that there is a wide range of estimates for future changes in many of the model's inputs, such as the predicted crop yields and corresponding market prices. For this reason, we ran our model for three scenarios:

The **low-response scenario** used values from the lower bounds of the published value ranges, predicting the least change in the model's inputs. Thus, it produced the smallest change in production costs.

The **mid-level scenario** used moderate responses to climate change. The values were taken from the middle of the published range in values. We expect this scenario to be the most likely one.

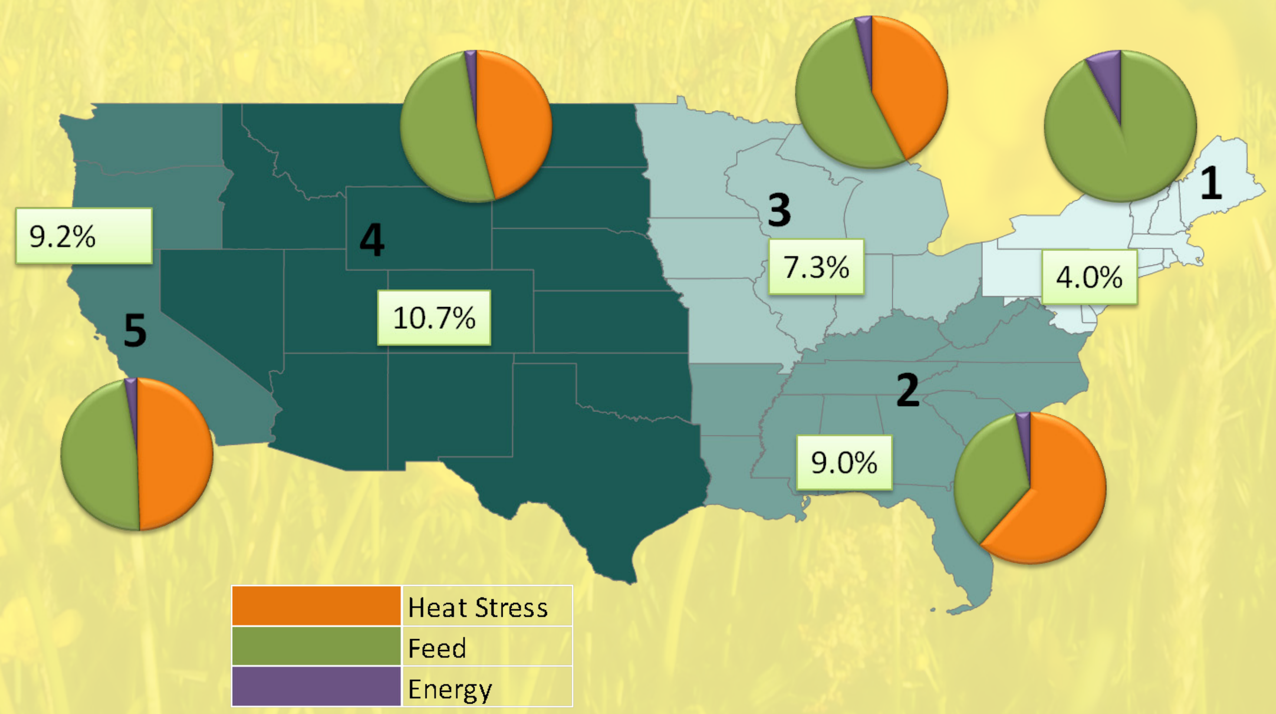
The **high-response scenario** used values from the extreme, most negative, end of the estimated range of values to model a high-impact situation.

Using this approach, we were able to estimate varying levels of expected changes to the production costs due to climate change. The graph shows the results of our model calculated for the three scenarios in different regions with the x-axis representing the regions and the y-axis showing the percent production cost changes.



The climate change impacts in the five regions for the different scenarios.

Results

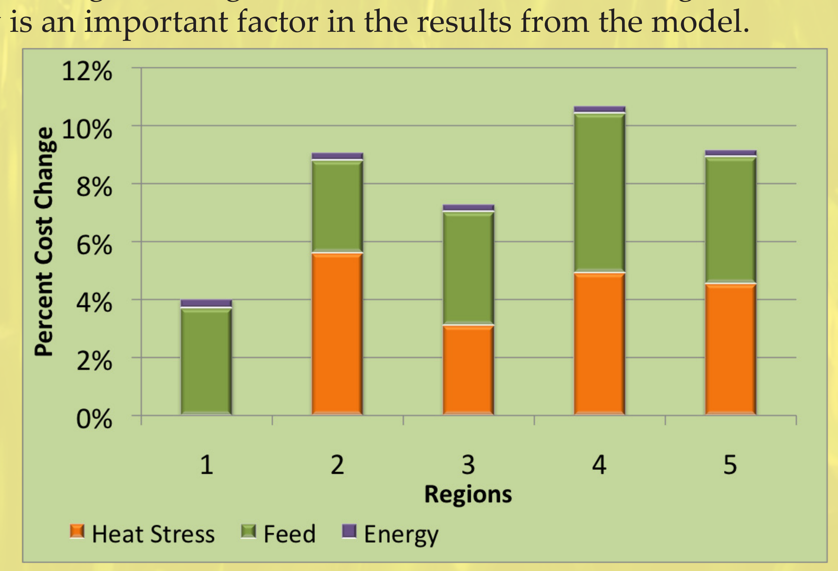


In this graph the percentages indicate the increase in production costs in each region.
The pie charts reflect the relative contribution of each factor to this increase.

The model indicates that production costs will generally increase in all five regions of the U.S. However, the increase varies from region to region and the variables with the greatest influence do so as well. Regionality is an important factor in the results from the model.

Furthermore, it becomes clear, that changes in feed costs will be a significant contributor to rising production costs in all regions.

With the exception of region 1, that does not experience heat stress, heat stress is the second major contributor to the cost changes, while the impact of increasing energy prices is almost negligible in all regions.



Comparison of the climate change impacts between regions.

Model

We designed the model to estimate how climate change will affect the costs in milk production to a dairy farmer. To determine the total change in dairy production costs, we quantified how changes in the critical inputs affect the overall production budget.

Changes in operational costs = (Changes in feed costs + Changes in energy costs + Changes in other costs) X Heat stress factor

Feed Costs

To calculate the total change in feed costs, we summed the cost change in homegrown feed to the cost change in purchased feed cost. In order to determine a change in crop price, we used the elasticity of supply to find the relationship between yield and price for each crop. Using the change in crop prices, budget weights, and feed composition, we determined the total change in feed costs.

Energy Costs

The change in energy costs is a function of the change in fuel and electricity prices. The price changes were weighted according to their contribution to a farm's energy budget. For our analysis, we assumed a 1:1 ratio for fuel and electricity.

Heat Stress

We used the Berry et al. (1964) heat stress equation to determine the loss in milk yield due to heat stress. This equation is a function of initial production levels of milk and the temperature humidity index. Heat stress is a decrease in milk yield per cow given the same monetary inputs, thus effectively increasing production costs.

Final Equation

The overall equation for the total price cost change (TPPC) includes the changes in feed costs, energy costs, and heat stress on the total production costs of a dairy farm due to climate change:

$$\boldsymbol{TPCC} = \frac{(FBC \cdot W_f) + (E_c \cdot W_e) + (O_c \cdot W_o) + 1}{1 + HS_x} - 1$$

Discussion and next steps

Our results suggest that climate change will increase the production costs of dairy farmers. Even though our model can be improved, it is an important first step toward designing a tool that helps farmers estimate the challenges they will face due to climate change. This understanding will help farmers plan their business for the future. The results provide the dairy industry with information about how they might be impacted. In addition, our model highlights areas for further research.

Future improvements to the model include the following:

- Additional research concerning the response of feed crops to climate change and the related price changes
- Improved research on the predicted changes in energy costs
- Adaptation and mitigation strategies that help farmers adapt to climate change and alleviate its adverse impacts
- Feed substitution effects that show how farmers can reduce feed costs by switching feed sources

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Selected Sources

Hatfield, J., et al. 2008. Agriculture. In: The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States. Synthesis and Assessment Product 4.3. U.S. Department of Agriculture, Washington, DC, 21-74

Tubiello FN, Soussana J-F, Howden SM. 2007. Crop and pasture response to climate change. Proceedings of the National Academy of Sciences, USA 104, 19686–19690

Wilbanks, T. J., et al. 2008. Effects of Climate Change on Energy Production and Distribution in the United States. In: The Effects of Climate Change on Energy Production and Use in the United States. Synthesis and Assessment Product 4.5. U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Washington, DC, p. 29-48