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

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. This project aims to identify and quantify the change in production costs for milk due to a changing climate.

Our client, the Innovation Center for U.S. Dairy, is a non-profit organization, representing all dairy farmers in the United States. They identify barriers to growth for the industry and discover new opportunities for innovation, helping the industry provide products that promote the health of people, communities, and the planet. Working together with the Innovation Center for U.S. Dairy, we quantified how climate change will impact the production cost of milk in the future, so that dairy farmers can prepare for these changes.

Objectives

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

Regions

For our study, we used the five regions identified by the Innovation Center for U.S. Dairy to account for the regional differences of dairy farms and climate change effects.

Dairy Facts

- California is the largest dairy producing state in the nation
- One fifth of milk produced in the U.S. comes from California
- The average herd size in California is 1,026 cows
- California produced 4.7 billion gallons of milk in 2010

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Climate Change

The Intergovernmental Panel on Climate Change (IPCC), an international group of scientists, uses global climate models to produce potential climate change scenarios. Our study utilized the IPCC's A2 scenario to find expected changes in temperature and CO_2 concentration by 2050.

The A2 scenario estimates an average temperature increase of 2ºC across the 5 studied dairy regions. In addition, we used regional temperature changes to predict changes in crop yields. CO_2 concentrations were assumed to increase evenly across all regions by 75 ppm.

Inputs to the Dairy Industry

We built a model to predict the effect of climate change on a farmer's production costs. Of the 15 factors initially identified, we determined which inputs to include in the model by applying three evaluation criteria (constitute a large fraction of a farm's budget, be measurable with high certainty, and be affected by climate change).

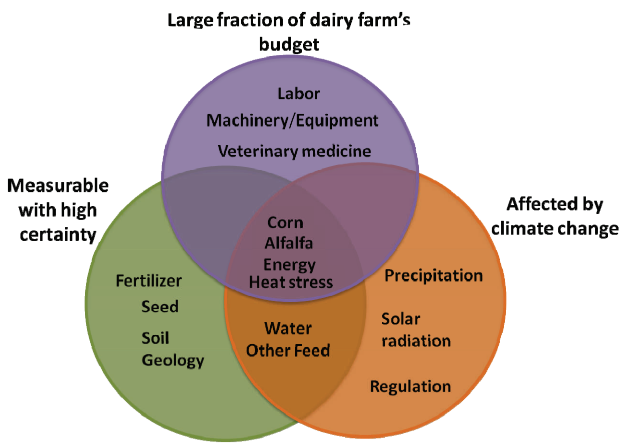


Fig.1: Selection criteria used to identify the model's inputs.

The selection process is illustrated in figure 1. Using our evaluation criteria, we selected corn, alfalfa, energy, and heat stress.

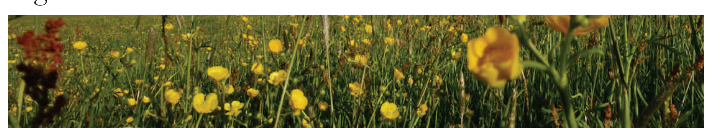
Response to Climate change

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. This effect cannot be offset by the slight biomass increase caused by elevated CO_2 levels. The lower yields will likely cause an increase in corn prices for dairy farmers.

Climate change is likely to cause **alfalfa yields** to increase nationally by 4% because alfalfa benefits from higher CO2 concentrations and temperatures. Our model expects alfalfa prices to decrease.

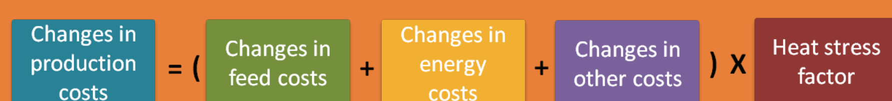
Energy costs, including both electricity and fuel, are expected to increase due to climate change. These increases are caused by a number of factors including: new energy policies, biofuel production, extreme climatic events, and new technological developments. Overall, we expect a 43% increase in the farmers' energy costs due to climate change by 2050.

Summer temperature will cause **heat stress** in dairy cows. Heat stress reduces the milk yield per cow (even when the amount of feed consumed remains constant), which effectively increases farmer's production costs. 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 due to heat stress.



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 needed to quantify how changes in the critical inputs affect the overall production budget.



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.

Final Equation

The overall equation used in the model is stated below. This equation includes the changes in feed costs, energy costs, and heat stress on the total production costs of a dairy farm due to climate change. It is important to note that heat stress is a decrease in milk yield per cow given the same monetary inputs, thus effectively increasing production costs.

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

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 different scenarios:

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

The mid-response scenario used moderate responses to climate change. These values were taken from the middle of the literature range in values. We determined 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. Figure 2 shows the results of our model calculated for the three scenarios in different regions. The low response scenario showed a modest 1-4%increase in production costs. The medium response scenario caused larger increases in production costs, between 4 and 11%. The high response scenario affected the farmers the most with an 12-18% increase in production costs.

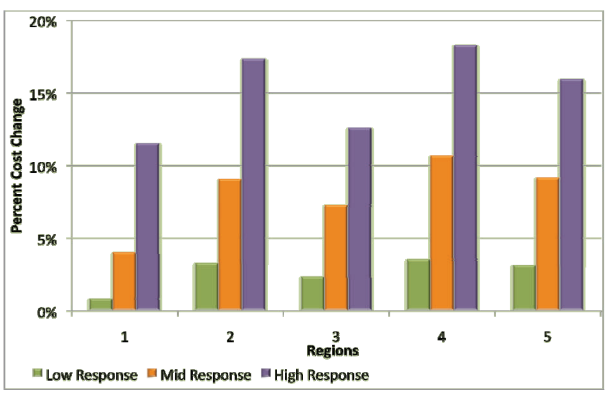


Fig. 2: The above graph shows the production cost changes in percent per region for all three scenarios.

Region 4 experienced the highest impact across all three scenarios, while region 1 is impacted the least. The changes in production costs are not linear. Comparing regions 2 and 5, region 2 has a higher cost increase for the high-response scenario, while region 5 has a higher cost increase for the mid-response scenario.

Results

Our results show that production costs will generally increase in all five regions of the U.S. due to climate change. However, the increase varies from region to region and the variables with the greatest influence do so as well. While heat stress was not a factor in region 1, it accounted for over half of the cost increase in region 2. Regionality, therefore, is an important factor in the results from the model. The model is most effective when used by a farmer to estimate the changes for an individual farm in a specific location. The exact input variables for feed composition, climate, and energy price could be used instead of aggregate values for the large, diverse regions.

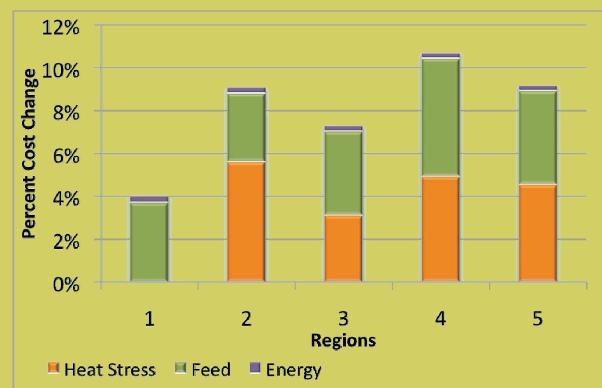


Fig. 3: The graph shows the contribution of each factor to the production cost increases in each region for the mid-level scenario.

Overall, the results indicate an increase in production costs for all regions no matter the response scenario. Since dairy farmers have slim profit margins the increase is a concern for the industry.

Our results show that heat stress and feed cost are the main contributors to the cost increase across all regions.

Changes in energy costs are negligible due to the fact that they only make up a small percentage of the overall dairy farm budget.

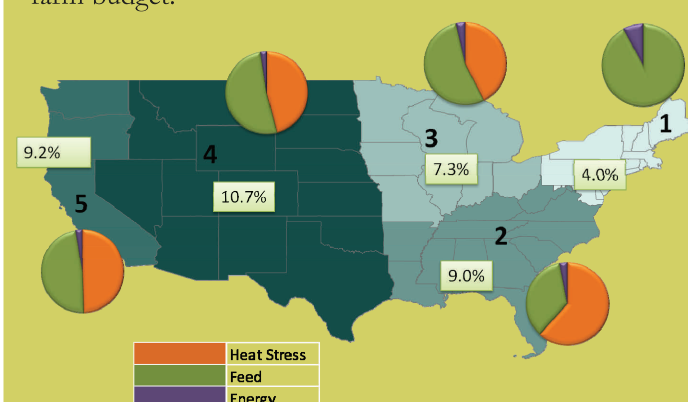


Fig.4: The percentage cost increase in each region for the mid-response scenario. The pie charts show the inputs' relative contribution

Photographs: Stephan Wittman. Frontpicture: istockphoto.com

Next Steps and Discussion

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. The results provide the dairy industry with information about how it might be impacted and help farmers plan for the future.

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 a farmer can reduce feed costs by switching to other feed sources.

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Case Study

We created a case study to illustrate how the proposed model can be used for an individual farm. For the case study, we ran the model with the values of the medium response scenario. In addition, we chose parameters that closely match a hypothetical farm in Fresno, CA., since the Central Valley has a large number of dairy farms.

We used the following parameters:

Parameters	Values
Milk Yield	22,000 lbs/(cow · year)
% of total budget for feed	58.8 %
Percentage of purchased feed	90 %
Feed Composition	Corn 40 %, Alfalfa 10 %, Other 50 %
% of total budget for energy	3.6 %
Energy price increase by 2050	21.4 %
Average daily summer temperature in 2050	31.3°C

Based on the parameters above, our model found a 10.3% increase in production costs to this farm. This increase is slightly larger than the average increase, 9.2%, for region 5 in the medium response scenario. The pie chart shows that the breakdown of inputs causing the greatest increase in production costs, are feed and heat-stress. The main factors contributing to the change in costs are a 22.2% increase in corn prices and a 4.2% decrease in milk yield due to heat stress.