RESEARCH HIGHLIGHTS

Adaptation Only Partially Offsets Dairy Losses from Extreme Heat

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How does extreme heat affect dairy productivity, and can farmers adapt?

Context

Many studies have predicted climate change's impact on crops, but less is known about its effects on livestock. Dairy cows in particular have been shown to be vulnerable to heat, which can affect milk production. This could have widespread implications both nutritionally and economically, with about 150 million households engaged in milk production globally. While global milk production is projected to increase faster than most other main agricultural commodities to meet rising demand, it's uncertain how much climate change could slow growth. Adding to the uncertainty, over the next 10 years, more than half of the growth in milk production is expected to occur in South Asia, where heatwaves are projected to be more intense and frequent. The researchers analyze the effect of heat on milk production, and the potential for cost-effective adaptation.

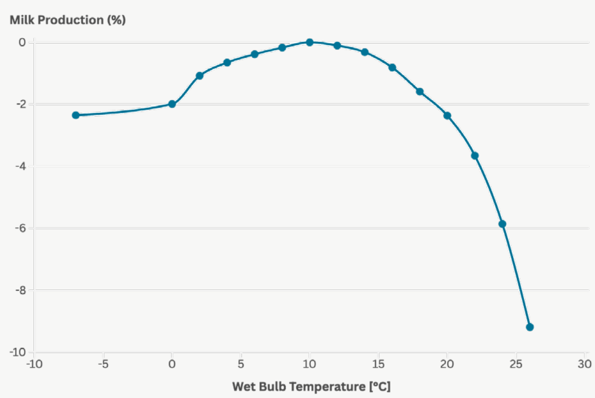
Research Design

The researchers study the dairy industry in Israel, which has several unique attributes that make it a good testbed: the dairy farms scattered throughout its region experience a wide range of temperatures and humidity that represent conditions for top milk producing countries; prices are centrally controlled; and virtually all farms have adopted technologies to reduce heat stress. Given these representative features, the researchers analyze highly local weather data on wet-bulb temperature records—measuring humid heat—and more than 320 million daily milk production observations over 12 years, representing records from more than 130,000 Israeli dairy cows. They then survey 306 dairy farm managers, asking whether farmers have taken steps to adapt through cooling technologies (mostly ventilation and spraying systems), shifting of calving periods, and adjusting feeding practices. This information allows them to estimate the effect of humid heat on milk production and the degree to which adaptation strategies can help.

Findings

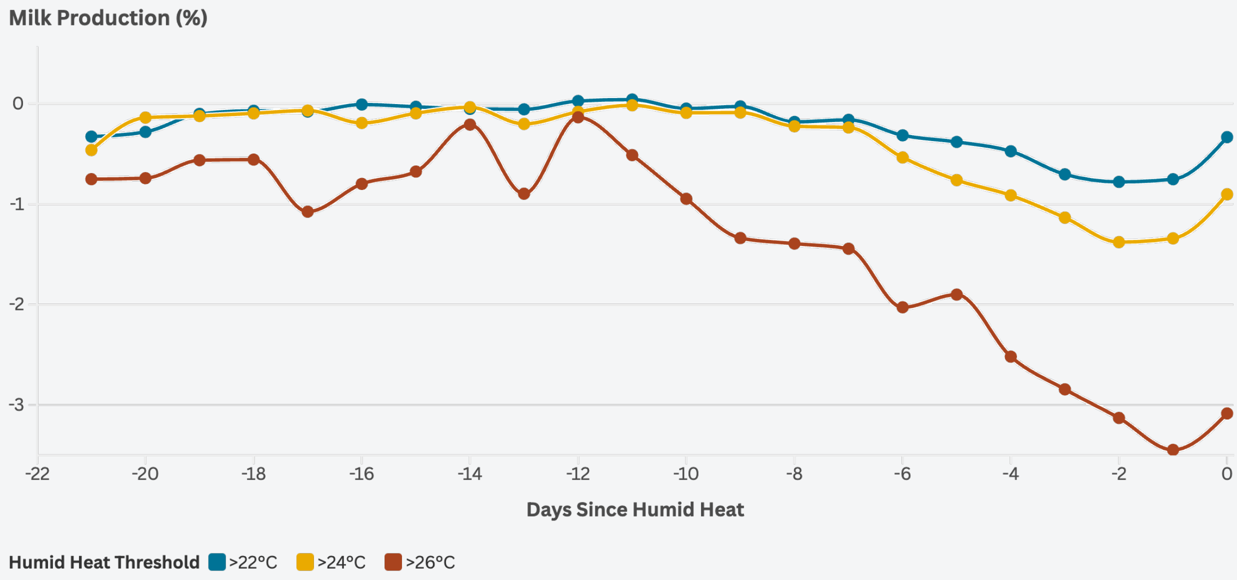
Extreme heat reduces milk output by up to 10 percent. Milk output declined significantly on hot days—by up to 10 percent when daily wet-bulb temperatures exceeded 26°C. One additional hour of wet-bulb temperature above 26°C relative to the 10-12°C range reduces daily milk yield by 0.5 percent.

Figure 1 · Response to the Daily Mean Temperature



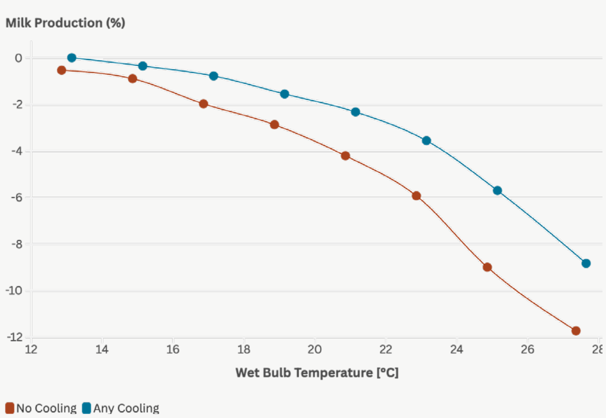
The effects from extreme heat exposure last for more than 10 days. The researchers also observed a prolonged effect to humid heat exposure, with milk production seeing negative impacts for more than 10 days after exposure. This suggests a more sustained impact of extreme heat than previously recognized. In fact, a period of 10 consecutive days of extreme heat leads to a 25.9 percent reduction in output (on day 11). The cumulative milk production declines only moderately when exposure rises from 22°C to 24°C, but increases sharply when exposure rises to 26°C.

Figure 2 · Prolonged Impact of Heat on Milk Production



Adaptation strategies mitigate at most about half of the effects of extreme heat. While shading is already the norm in virtually all farms, different systems capable of either cooling the cow directly or cooling the surrounding environment can be employed, such as ventilation, sprinklers, or evaporative cooling systems. In the context of Israel, such cooling infrastructure had been widely adopted over the preceding two decades. But the researchers found these strategies only partially mitigate the losses from extreme heat. And, the hotter it gets, the less helpful these cooling systems are. On moderately hot days with average wet-bulb temperatures between 18-20°C days, the impact of heat is reduced by only half. But on days above 24°C, cooling stops less than 40 percent of the impact. Overall, even in a high-tech, well-resourced setting like Israel, adaptation could not fully offset the damages.

Figure 3 · Effects of Cooling Equipment



The benefits that come with adapting quickly outweigh costs. The researchers conduct a cost-benefit analysis to assess the economic returns of adopting cooling technologies for the typical dairy farm. They estimate the annual avoided loss in milk production associated with cooling and monetize those estimates using yearly milk prices, finding that the average annual gain in milk output from 2009 to 2020 is equivalent to $22,538 USD. Compared with a one-time fixed cost of $30,804 USD for cooling equipment, the investment breaks even in about a year and a half, not taking into account operation and maintenance costs.

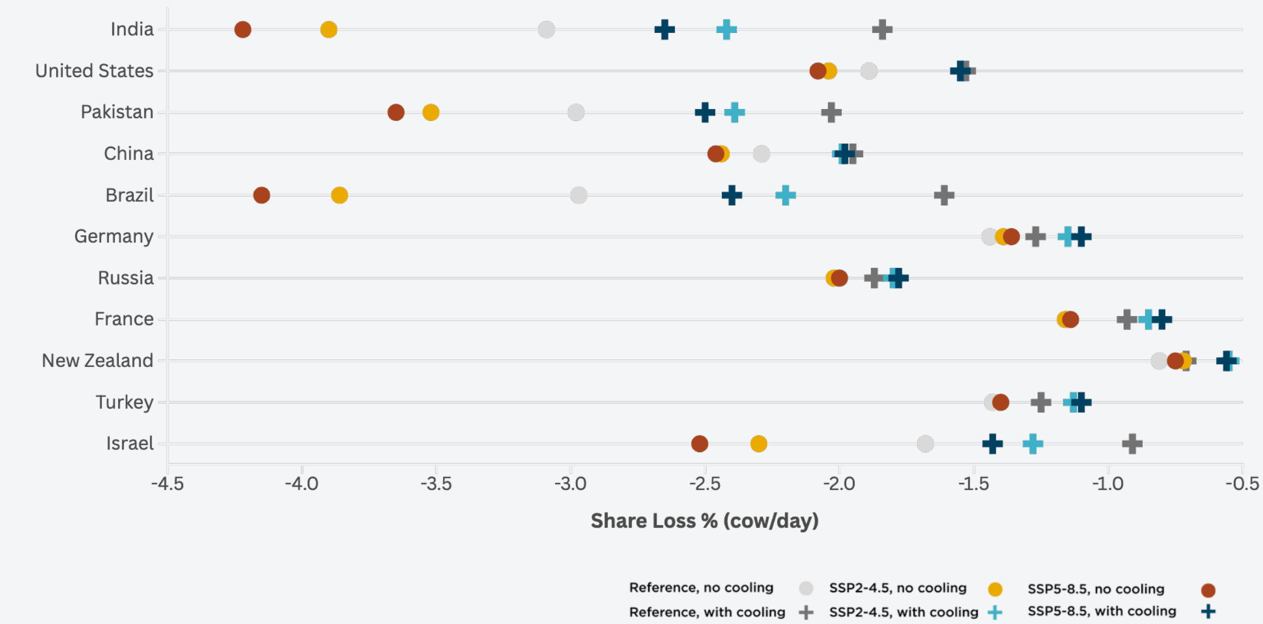
Future projections show significant losses across key dairy regions. The researchers use their estimates in Israel to show how climate change by mid-century is going to affect milk production, and which countries have a bigger potential for adaptation. Using climate forecasts for 2050 and taking into account the location and density of cattle, the researchers calculate expected reductions in daily milk production per cow, both with and without cooling technologies, for the top 10 milk-producing countries, plus Israel. They find that, without adaptation, heat stress could reduce the average daily milk output by 4 percent in some of the main dairy-producing countries by mid-century, with notable regional variation. Countries already experiencing high heat exposure are most helped by cooling technologies.

There is a trade-off between productivity and resilience. The researchers find that cows are substantially more sensitive to heat during the times when they would ordinarily produce more milk (early lactation). Cows that have had more calves are also known to produce more milk, but these cows are also more sensitive to heat. The percentage decline in milk output due to heat stress is more than twice as high for cows who have had two or more calves. This shows that cows that produce more milk—either due to lactation stage or parity—are also more vulnerable to heat stress.

Figure 4 · Annual hot days (SSP5–8.5) & Average Daily Milk Loss

Country	22°C	24°C	26°C
India (213 Mt)	132	82	36
United States (103 Mt)	22	7.7	1.3
Pakistan (62 Mt)	102	77	47
China (42 Mt)	27	14	5.2
Brazil (37 Mt)	135	43	3
Germany (34 Mt)	1.7	0.3	0

Country	22°C	24°C	26°C
Russia (33 Mt)	2.2	0.3	0
France (25 Mt)	4.2	0.7	0
New Zealand (21 Mt)	0	0	0
Turkey (20 Mt)	2.9	0.5	0.1
Israel (1.5 Mt)	70	22	2.6



CLOSING TAKE-AWAY

This study offers one of the most comprehensive assessments of heat's impacts on livestock, and specifically dairy cows. It finds that even in an advanced dairy system with widespread adaptation, extreme heat leads to significant and lasting losses in milk output. The most innovative adaptation strategies may be insufficient to address climate change damages to the dairy industry—with cooling technologies offsetting, at best, only half of the productivity losses from hot days. This underscores both the value and the limitations of current adaptation measures. Moving forward, policymakers should support research into a broader range of strategies to reduce stressors in dairy systems, particularly in regions with growing heat exposure and expanding dairy sectors. Reducing heat exposure through fully enclosed housing may introduce new stressors—like confinement—that undermine welfare and productivity. As an alternative, dairy farmers could alleviate other stressors, such as confinement or cow-calf separation, to reduce the compound effect on cow sensitivity and build resilience.