Contact:
Laura Wonser, Senior Executive Assistant
GFSF/GIC Group
www.gicgroup.com
laura.wonser@gicgroup.com
GFSF: www.globalfoodsafetyforum.org

GFSF FOCUS 2026

A New Stage in Food Safety

Climate Change as a Driver of Food Safety Risk and Advancements in Technology

Content

- Climate Change as a Driver of Food Safety Risk and Advancements in Technology

By: Melike Celenk

Climate Change as a Driver of Food Safety Risk and Advancements in Technology

By: Melike Celenk

Introduction

The impacts of climate change on food security have been studied extensively. Yet food security is often reduced to a question of quantity: whether we produce enough food. The definition adopted at the 1996 World Food Summit asks for more. Food security exists when "all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (Food and Agriculture Organization of the United Nations [FAO], 1996). This piece focuses on the part of that definition that climate debates most often overlook: whether our food is safe to eat.

Climate change affects the planet in many ways. Its consequences include rising temperatures, warming oceans, intense droughts, water scarcity, severe wildfires, flooding, rising sea levels, melting polar ice, catastrophic storms, and declining biodiversity (Intergovernmental Panel on Climate Change [IPCC], 2022). This widespread disruption of nature affects billions of people in many ways, including through the food on their tables. As noted earlier, this piece will focus on the safety component of food. The stakes are high: the World Health Organization estimates that contaminated food sickens 600 million people and kills 420,000 every year (World Health Organization [WHO], 2015).

Growing scientific evidence supports the theory that climate-induced environmental changes will result in an increased net burden of food- and waterborne diseases (Carlton et al., 2016; European Centre for Disease Prevention and Control [ECDC], 2012; Smith & Fazil, 2019), caused by multiple hazards including bacteria, viruses, parasites, toxins and chemicals (WHO, 2015). These hazards rarely appear alone. Hazards that share the same "physical space" also interact with one another, and climate change shapes these interactions as well (FAO, 2020). Food safety risk, in other words, is more than the sum of individual hazards.

Climate Change and Food Safety Hazards

In its 2020 report *Climate Change: Unpacking the Burden on Food Safety*, FAO examines how climate change affects six major food safety hazards: foodborne pathogens and parasites, harmful algal blooms, heavy metals, methylmercury, pesticides and mycotoxins. Climate change affects us in many ways, but rising temperatures in particular pose a threat to food safety by affecting both our water and our soil.

Warmer water speeds the growth of harmful algae, and the effects are already visible. In a study of 71 lakes worldwide over three decades, peak summer blooms grew in 68% of them. In 2015, a patch of ocean about 3 °C warmer than normal triggered a massive *Pseudo-nitzschia* bloom stretching from central California almost to northern British Columbia. Fisheries had to close,

and the Dungeness crab industry alone lost USD 48.3 million. Rising temperatures are also thawing permafrost, which holds roughly ten times as much mercury as humans have released into the atmosphere to date. As it thaws, that mercury may end up in the fish on our tables (FAO, 2020).

Warmer soils, on the other hand, help plants absorb metals; rice is a key concern because it accumulates arsenic in the grain. One study projects that climate change combined with arsenic in paddy soils could double the arsenic content of rice and cut rice production by 39% by 2100, mostly in developing countries (Muehe et al., 2019, as cited in FAO, 2020).

Higher temperatures also make pesticides evaporate faster, which reduces how well they work. Combined with faster pest growth, this is likely to push farmers toward using more pesticides to protect their yields, which raises the risk of residues in food along with soil, water, and biodiversity damage (FAO, 2020).

Climate change is also bringing erratic rainfall and more frequent extreme weather, from floods and hurricanes to prolonged droughts, with serious consequences for our food systems (FAO, 2020). Heavy rain overwhelms water treatment systems, washes fertilizer, pesticides and heavy metals from the soil into waterways, and fuels harmful algal blooms, whereas drought concentrates contaminants in shrinking water supplies, compromises hygiene in food processing plants, and pushes farmers to irrigate with contaminated surface water.

Extreme weather has already left visible marks on food safety. Hurricanes Isabel (2003) and Gonu (2007) triggered massive algal blooms off Chesapeake Bay in the United States and in the Arabian Sea. In 2016, a strong El Niño contributed to Chile's "Godzilla" red tide, the largest farmed-fish die-off ever recorded, which cost USD 800 million in lost salmon exports. Across the Horn of Africa, cyclones and heavy rains in 2018–19 fuelled desert locust swarms that led to large-scale aerial pesticide spraying (FAO, 2020).

The pattern is clear: climate change is now a material risk to food safety, and the bill is already arriving. The FAO's 2020 report documents losses ranging from USD 48.3 million for a single marine heatwave's toll on the US crab industry to an estimated USD 170 billion a year from oxygen-starved coastal "dead zones."

From Reaction to Anticipation: The New Food Safety Toolkit

Technology has been central to how we manage food safety, and recent advances target the very hazards discussed above. Yet climate change has not been built into these tools as fully as it needs to be. The first step is data, and satellite data in particular. It can be used at two scales, macro and micro, and both matter.

At the macro scale, satellites track the large environmental shifts that create new hazards across whole seas and regions. In May 2026, NASA scientists unveiled an AI tool that fuses data from five space missions, including the new PACE satellite, to detect harmful algal blooms along entire coastlines (NASA Jet Propulsion Laboratory, 2026). In Europe, the ECDC's updated *Vibrio* tool uses satellite readings of sea temperature and salinity to give daily risk estimates and a five-day forecast across European waters (ECDC, 2026). Tools like these show authorities where to look before a problem reaches the food supply.

At the micro scale, satellite data zooms in on individual farms and fields. The European Space Agency supports a service called Crop Mycotoxin Management, which combines satellite images of wheat with ground data to estimate the in-field disease risk during vegetative growth and the risk of mycotoxin accumulation at harvest (European Space Agency, 2021.). Another service, BirdWatch, pairs satellite data with in-shed sensors to predict disease and welfare risks on individual poultry farms (European Space Agency, 2026). These tools help farmers decide when to harvest, where to test, and which batches to keep separate.

The two scales work best together. Macro data reveals where risk is shifting as the climate warms, and micro data shows which farms or harvests are actually affected. A 2026 review of mycotoxin monitoring in Central and Balkan Europe makes this point. It argues that combining regional climate projections with satellite data would move food safety from mapping past risk to forecasting future risk (Radócz et al., 2026).

The second step is what to do with the data. Satellites show what is happening now, but climate integration means predicting what comes next. Most food safety models learn from past conditions, so in a warming world they risk preparing us for a climate that no longer exists. The answer is to feed them forecasts and projections, and this works on two time horizons.

The first is the coming season. A 2026 study fed seasonal climate forecasts into AFLA-maize, a model that predicts aflatoxin in maize, so that risk could be flagged weeks before harvest (Balkova et al., 2026). US researchers have shown how much early signals matter. Their machine-learning models, trained on weather and satellite data, predicted mycotoxin contamination in Illinois corn with 94% accuracy, and some of the strongest predictors were weather conditions before the crop was even planted (Castano-Duque et al., 2022). A warning that arrives months before harvest gives farmers and buyers time to change planting dates, step up testing, or source elsewhere.

The second horizon is the coming decades. Here, models combine climate projections with other trends to show where hazards are heading. By linking *Vibrio* models to climate, population and socioeconomic projections, researchers estimated that up to 38,000 km of new coastline could become suitable for the bacteria by 2100 (Trinanes & Martinez-Urtaza, 2021). In China, a national analysis of peanut contamination projected that the volume exceeding regulatory limits could rise from about 478,400 metric tons in 2022 to 1.16 million metric tons by 2100 (Guo et

al., 2026). Projections like these tell governments and businesses where to build testing capacity, which suppliers to diversify away from, and which standards may soon need revisiting.

Seasonal forecasts support decisions for this year's harvest, and long-term projections guide investment for the decades ahead. Food safety needs both.

The third step is to catch problems faster where food is grown and stored. Forecasts show where risk is likely, and fast testing confirms it on the ground. Until recently that meant sending samples to a laboratory and waiting days for results. A new generation of portable tools is changing that.

Biosensors are leading the shift. Built from materials such as DNA aptamers, short strands of DNA that bind to a specific toxin, they offer high sensitivity, rapid response, and cost-effectiveness compared with conventional laboratory methods (Tong et al., 2025). Some no longer need equipment at all. In March 2026, researchers reported a hydrogel sensor that changes colour when *E. coli* is present, so contamination can be spotted with the naked eye (Food Safety Magazine, 2026a).

Storage is getting smarter too. Mould gives off gases before it produces toxins, and sensors can pick these up early. A 2026 review notes that such volatile signals often precede detectable toxin accumulation, which makes them useful early warnings (Okechukwu et al., 2026). In grain silos, the EU–China MyToolBox partnership used models of the carbon dioxide that stored grain gives off to design improved sensors for silo monitoring (Leslie et al., 2020).

The same tools offer a climate benefit. Researchers at the University of Connecticut developed a test that can detect eight different pathogenic and spoilage bacteria in milk in just two hours with more than 98 percent accuracy, and they are working to build similar sensors directly into food packaging (Food Safety Magazine, 2026b). Packaging that shows whether food has actually spoiled, rather than relying on a cautious date label, protects consumers and keeps safe food out of the bin. A 2026 review reaches the same conclusion, finding that electrochemical biosensors could cut food waste by detecting spoilage early (Pipliya et al., 2026). Since wasted food carries all the emissions used to produce it, faster detection supports both food safety and climate goals.

The most effective systems combine these tools. Rapid sensors screen widely and cheaply, and laboratory tests confirm what they flag. Linked to the forecasts described above, this creates a chain from satellite to sensor to safe plate.

Conclusion

Climate change is no longer just a question of how much food we can grow. It is changing whether that food is safe to sell. The hazards are already visible and each one carries a price, from a single season's lost crab harvest to the hundreds of millions wiped off salmon exports in

one red tide. The good news is that the tools to manage this risk are maturing fast. Satellites now track risk across whole coastlines and down to individual fields. Forecasting models flag contamination months before harvest, and long-term projections show which regions and suppliers are heading into trouble. On the ground, portable biosensors and smart storage catch problems in hours rather than days, and packaging that reads actual spoilage keeps safe food out of the bin.

The missing piece is putting it all together and planning around the climate we are heading into rather than the one we have left behind. Climate risk needs to be built into how hazards are assessed, how standards are set, and how testing and sourcing decisions are made across the supply chain. A food safety system built for yesterday's climate will keep paying for it. One that integrates climate and invests in the tools to match will be the one that keeps food safe, and keeps it on the shelf.

References

Balkova, D., Raj, R., Rieder, H. E., Camardo Leggieri, M., & Battilani, P. (2026). Predicting aflatoxin risk with seasonal meteorological forecast. *Environmental Research Letters, 21*(2), 024016. https://doi.org/10.1088/1748-9326/ae3629

Carlton, E. J., Woster, A. P., DeWitt, P., Goldstein, R. S., & Levy, K. (2016). A systematic review and meta-analysis of ambient temperature and diarrhoeal diseases. *International Journal of Epidemiology, 45*(1), 117–130. https://doi.org/10.1093/ije/dyv296

Castano-Duque, L., Vaughan, M., Lindsay, J., Barnett, K., & Rajasekaran, K. (2022). Gradient boosting and Bayesian network machine learning models predict aflatoxin and fumonisin contamination of maize in Illinois – First USA case study. *Frontiers in Microbiology, 13*, 1039947. https://doi.org/10.3389/fmicb.2022.1039947

European Centre for Disease Prevention and Control. (2012). *Assessing the potential impacts of climate change on food- and waterborne diseases in Europe*. ECDC.

European Centre for Disease Prevention and Control. (2026, July 7). *Amidst heatwave across Europe, ECDC launches improved tool for monitoring the risk of infection in coastal waters*. https://www.ecdc.europa.eu/en/news-events/amidst-heatwave-across-europe-ecdc-launches-improved-tool-monitoring-risk-infection

European Space Agency. (2021, July 28). *CMM*. ESA Business Applications. https://business.esa.int/projects/cmm

European Space Agency. (2026, February 25). *BirdWatch*. ESA Business Applications. https://business.esa.int/projects/birdwatch

Food and Agriculture Organization of the United Nations. (1996). *Rome declaration on world food security and World Food Summit plan of action*. FAO.

Food and Agriculture Organization of the United Nations. (2020). *Climate change: Unpacking the burden on food safety* (Food Safety and Quality Series No. 8). FAO. https://doi.org/10.4060/ca8185en

Food Safety Magazine. (2026a, March 13). Researchers develop colorimetric sensor that allows naked-eye E. coli detection in food. https://www.food-safety.com/articles/11224-researchers-develop-colorimetric-sensor-that-allows-naked-eye-e-coli-detection-in-food

Food Safety Magazine. (2026b, March 17). Novel test detects bacteria in milk with 98 percent accuracy using AI, sensor technology. https://www.food-safety.com/articles/11246-novel-test-detects-bacteria-in-milk-with-98-percent-accuracy-using-ai-sensor-technology

Guo, C., Zhao, Y., Liu, A., Wang, D., Wang, X., Yu, L., Ma, F., Wang, X., Fang, M., Ding, X., Logrieco, A. F., Li, P., & Zhang, L. (2026). Dynamic changes and early warning of peanuts aflatoxin B1 contamination in China in the context of climate change. *npj Science of Food, 10*, 47. https://doi.org/10.1038/s41538-025-00696-1

Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (H.-O. Pörtner et al., Eds.). Cambridge University Press. https://doi.org/10.1017/9781009325844

Leslie, J. F., Poschmaier, B., van Egmond, H., Malachová, A., de Nijs, M., Bagi, F., Zhou, J., Jin, Z., Wang, S., Suman, M., Schatzmayr, G., & Krska, R. (2020). The MyToolbox EU–China partnership—Progress and future directions in mycotoxin research and management. *Toxins, 12*(11), 712. https://doi.org/10.3390/toxins12110712

NASA Jet Propulsion Laboratory. (2026, May 20). *NASA-developed AI could help track harmful algae*. https://www.jpl.nasa.gov/news/nasa-developed-ai-could-help-track-harmful-algae/

Okechukwu, V. O., Adelusi, O. A., Fagbohun, T. R., Okonkwo, O. J., & Njobeh, P. B. (2026). Mycotoxin detection in food and feed: Bridging conventional analytical methods with emerging sensor-based technologies. *Mycotoxin Research, 42*(3), 47. https://doi.org/10.1007/s12550-026-00657-x

Pipliya, S., Kaur, J., Pal, A., Saha, D., Patel, J., Samadder, S., Gupta, R. K., Bhunia, K., & Srivastav, P. P. (2026). Electrochemical biosensors for food spoilage, quality monitoring, and food safety: Recent advances, sensor performance, and smart packaging integration. *Frontiers in Sustainable Food Systems, 10*, 1814448. https://doi.org/10.3389/fsufs.2026.1814448

Radócz, L., Nagy, A., Szőllősi, N., Kiss, N. É., Szabó, A., Tamás, J., & Nxumalo, G. S. (2026). AI-augmented systematic review of remote sensing and predictive modelling for mycotoxin risk monitoring in cereal crops across Central and Balkan Europe. *Remote Sensing, 18*(13), 2063. https://doi.org/10.3390/rs18132063

Smith, B. A., & Fazil, A. (2019). How will climate change impact microbial foodborne disease in Canada? *Canada Communicable Disease Report, 45*(4), 108–113. https://doi.org/10.14745/ccdr.v45i04a05

Tong, X., Chen, N., Wang, M., & Guo, X. (2025). Advanced biosensor technology for mycotoxin detection. *Frontiers in Nutrition, 12*, 1596690. https://doi.org/10.3389/fnut.2025.1596690

Trinanes, J., & Martinez-Urtaza, J. (2021). Future scenarios of risk of *Vibrio* infections in a warming planet: A global mapping study. *The Lancet Planetary Health, 5*(7), e426–e435. https://doi.org/10.1016/S2542-5196(21)00169-8

World Health Organization. (2015). *WHO estimates of the global burden of foodborne diseases: Foodborne Disease Burden Epidemiology Reference Group 2007–2015*. WHO.