

What do we know about **THE FUTURE OF CROP PESTS AND DISEASES IN RELATION TO FOOD SYSTEMS?**

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Key messages

- Crop pests and diseases (P&D) can cause substantial yield losses and pose a threat to global food security. Losses at a regional level can even exceed 40 percent for crops like maize and rice.
- Most studies show that a warmer climate creates a conducive, albeit spatially variable, environment for P&D spread. However, existing foresight research is largely biophysical in nature and focuses on individual pathosystems, examined mostly at the national level. As such, projections of the magnitude of economic impacts of changing patterns of P&D are missing.
- Global assessment of model-based historical and future P&D impacts on food systems remains constrained by the small number of available models that can estimate yield losses under contrasting climate and agroecological conditions.
- Efforts are needed to improve data accessibility, model versatility, and simulation platforms and to establish international observation and modeling networks. Artificial intelligence (AI) and related methods can assist in the development of robust and adaptable models to capture the impacts of P&D on food systems.

RECENT TRENDS AND CHALLENGES

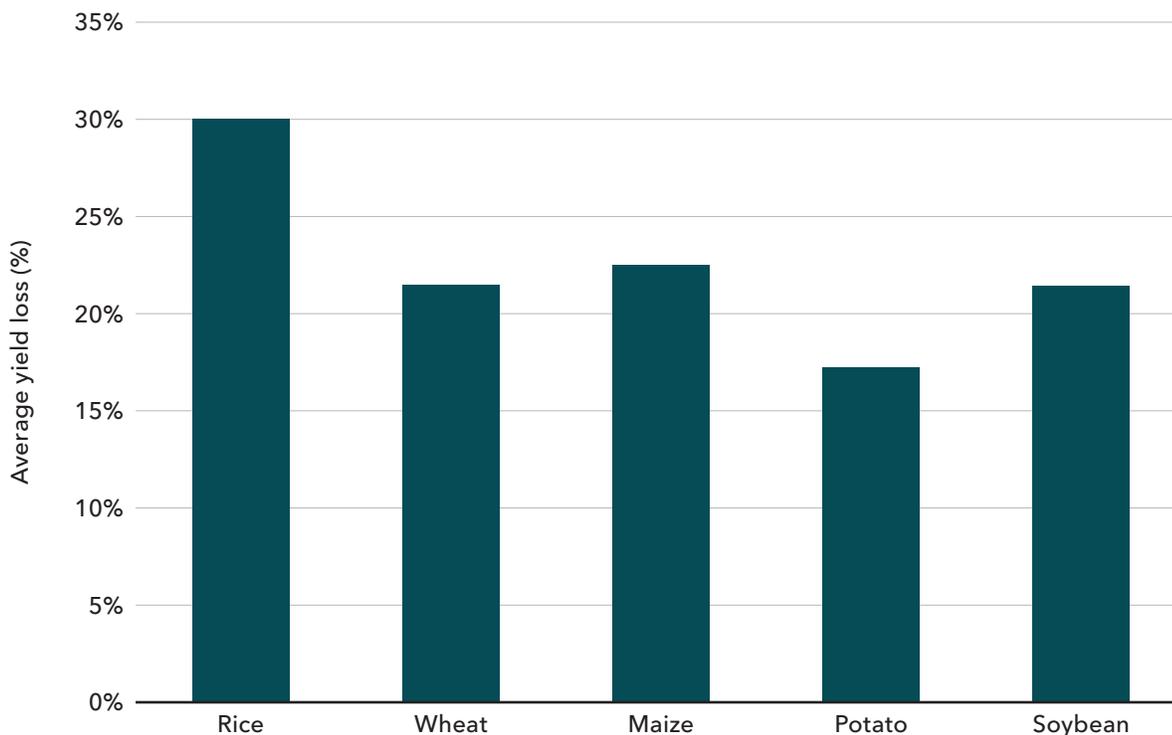
Pests and diseases (P&D) present a major threat to global food security and have led to several famine events in human history, like the infamous Irish potato famine in the mid-19th century. Latest estimates suggest that current average losses to P&D for wheat, maize, rice, potatoes, and soybeans are in the range of 17–30 percent globally (Figure 1). Losses for maize and rice in the Indo-Gangetic Plains in India even exceed 40 percent (Savary et al. 2019). Without use of pest and disease control, these losses could double (OECD/FAO 2012).

Recent P&D outbreaks and emergencies have put the spotlight on P&D, leading the United Nations to declare 2020 the International Year of Plant Health. Examples of such incidents are abundant: the “Panama” disease, which almost caused a collapse of banana trade in the mid-1900s, is once again threatening banana production worldwide, leading Colombia to declare a national

emergency in 2019 and prompting concern about the possible “near-death” of [banana cultivation](#). The recent desert locust outbreak in the Horn of Africa triggered international concerns about food security in the region. Similar concerns are even shared by developed countries that have witnessed a reemergence of the wheat stem rust disease after almost 60 years (Lewis et al. 2018).

Climate is one of the most important factors mediating the impact of P&D on food systems. Climate change is thus expected to affect existing pathosystems, leading to epidemiological and distributional changes in existing P&D (Bebber, Castillo, and Gurr 2016; Garrett et al. 2006). It can also facilitate the establishment of new pathogens, especially when combined with increased trade between countries, as happened recently in the case of the wheat blast disease, introduced to Bangladesh in 2016 via international wheat trade. The disease is now threatening wheat production in South Asia, especially those regions where climate conditions are most suitable for its development (Montes, Hussain, and Krupnik 2022; Pequeno et al. 2024).

FIGURE 1 Estimated global yield losses to pests and diseases based on expert opinion, average over 2010–2014



Source: Data drawn from Savary et al. (2019).

LATEST FORESIGHT RESEARCH

Many studies have assessed the potential impacts of climate change on future threats associated with P&D, often examining one pathosystem at a time and at varying spatial scales. Juroszek et al. (2022) reviewed 143 studies performing model-based projections of potential disease infection risks for 30 different crops. The review reveals that more than 60 percent of them project an increase of infection risks in the future, but results are associated with high uncertainty and exhibit considerable spatial variability.

Chaloner, Gurr, and Bebbber (2021) found that projections (to the late 21st century) of climate-induced yield changes for 12 crops exhibited positive spatial correlations with infection risks from 80 crop pathogens. These results suggest that while climate may become more suitable for crop growth over some areas in the future, it will also be conducive to pathogen development. Their analysis reveals that the number of pathogens developing under suitable climate conditions (pathogen richness) will likely increase in higher latitudes for most crops except rice, for which an increase in pathogens is projected across all latitudes. For instance, Europe, China, and Peru are expected to face the greatest overall pressure from P&D in the future because of increased pathogen richness and large changes in the composition of pathogen assemblages.

Deutsch et al. (2018) studied the global impact of increasing temperatures on grain losses from insect pests by 2050. Their analysis shows that a warmer climate can lead to up to 25 percent higher yield losses globally per degree of temperature increase. The United States, China, and Europe are likely to face the largest increase in yield losses for wheat (>60 percent) and maize (>40 percent), whereas China and South Asia are expected to register up to almost 30 percent higher losses for rice.

Several authors (Liu and Van der Fels-Klerx 2021; Moretti, Pascale, and Logrieco 2019) highlight the increased risks of aflatoxin contamination with climate change and the expansion of current risk areas (mainly in tropical and subtropical zones) to Europe, the United States, and southern latitude countries like Argentina and Australia. Increased CO₂, elevated temperatures, drought, and the combination of these factors are expected to increase crops' susceptibility to pathogens. Among the major staples, maize

has been found to be more susceptible to infection, with aflatoxin-producing pathogens leading to high aflatoxin levels when grown under very dry and warm conditions in combination with drought. These climate conditions are expected to be more frequent in the future. Forecasting models have been developed in combination with crop phenology models to calculate the aflatoxin risk index (ARI) under current and future conditions to determine critical levels of infection (Alvito and Assunção 2021). Given the increasing high risk of aflatoxin contamination for humans and livestock, especially in tropical areas, more forward-looking analyses are required to inform policy decisions and assess the economic viability of potential long-term agroecological solutions for aflatoxin biocontrol, such as Aflasafe (Atehnkeng et al. 2022).

KEY GAPS AND OPPORTUNITIES FOR FORESIGHT RESEARCH

Quantifying the future pressure of P&D on food systems remains a challenge. The difficulty in modeling P&D stems from the complexity of simulating the various processes related to P&D dynamics, which is exacerbated by the existence of multiple pathosystems, the uncertainty related to model parameterization, and the limited availability of the data needed for model validation and calibration.

Among existing P&D models, only a few have been implemented at the regional or global scale, considering long-term climate trends (Juroszek et al. 2022). The number of models that quantify the impact of P&D on yields is equally small, and mostly focused on the main grain crops such as wheat, maize, and rice (for example, Batchelor et al. 2020; Willocquet et al. 2002, 2022).

The difficulty in quantifying losses to P&D and in accounting for socioeconomic conditions currently presents a major obstacle in linking P&D models with existing integrated foresight modeling frameworks to assess potential P&D pressures on food production systems and food security in the future. As such, current foresight work largely focuses on how climate change affects biophysical processes for specific P&D, and future changes in risk of infection. However, the link to crop yield responses and to food security is missing. Attempts to combine P&D with

economic models to address food security issues are still at an embryonic stage, with current research limited to “what if” analyses of the economic impacts from potential epidemics of specific crop diseases (Godfray, Mason-D’Croz, and Robinson 2016; Petsakos et al. 2023).

The need to link epidemiological and crop simulation models to quantify the impacts of P&D on crop development and yield has long been considered one of the priorities for P&D modeling, but also an important challenge (Cunniffe et al. 2015; Donatelli et al. 2017). Recent research on coupling crop modeling with generic P&D modeling (Batchelor et al. 2020; Pequeno et al. 2024), along with the expressed need to create multidisciplinary communities of practice, reveals opportunities for improving existing tools and enhancing our understanding of the future impacts of P&D on food systems.

Given the complexity of agronomic system interactions, AI techniques offer a promising alternative and complement to traditional crop and P&D modeling approaches. AI-driven methods, particularly machine learning and deep learning algorithms, excel at identifying nonlinear patterns and relationships that may elude conventional modeling techniques. AI has the potential to overcome existing modeling limitations by integrating cause-and-effect relationships from diverse and complex data sources, including satellite imagery, sensor data, and historical records. This integration could not only improve model accuracy but also expand applicability across various agricultural scenarios. By leveraging these capabilities, researchers can develop more robust and adaptable models that capture the intricate dynamics of P&D impacts on crops and can be easily used to inform integrated foresight modeling frameworks.

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Related chapters on the future of food system drivers and impacts, regional and national perspectives, food commodities, and foresight tools are available in our [Table of Contents](#).

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References

- Alvito, P., and R. Assunção. 2021. "Climate Change and the Impact on Aflatoxin Contamination in Foods: Where Are We and What Should be Expected?": In K.R. Hakeem, C. A. F. Oliveira, & A. Ismail, eds., *Aflatoxins in Food. A Recent Perspective*, 275-288. Springer. <https://doi.org/10.1007/978-3-030-85762-2>
- Atehnkeng, J., P.S. Ojiambo, A. Ortega-Beltran, J. Augusto, P.J. Cotty, and R. Bandyopadhyay. 2022. "Impact of Frequency of Application on the Long-Term Efficacy of the Biocontrol Product Aflasafe in Reducing Aflatoxin Contamination in Maize." *Frontiers in Microbiology* 13. <https://doi.org/10.3389/fmicb.2022.1049013>
- Batchelor, W.D., L.M. Suresh, X. Zhen, Y. Beyene, M. Wilson, G. Kruseman, and B. Prasanna. 2020. "Simulation of Maize Lethal Necrosis (MLN) Damage Using the CERES-Maize Model." *Agronomy* 10 (5): 710. <https://doi.org/10.3390/agronomy10050710>
- Bebber, D.P., A.D. Castillo, and S.J. Gurr. 2016. "Modelling Coffee Leaf Rust Risk in Colombia with Climate Reanalysis Data." *Philosophical Transactions of the Royal Society B: Biological Sciences* 371 (1709): 20150458. <https://doi.org/10.1098/rstb.2015.0458>
- Chaloner, T.M., S.J. Gurr, and D.P. Bebbber. 2021. "Plant Pathogen Infection Risk Tracks Global Crop Yields under Climate Change." *Nature Climate Change* 11 (8): 710-715. <https://doi.org/10.1038/s41558-021-01104-8>
- Cunniffe, N.J., B. Koskella, C.J.E. Metcalf, S. Parnell, T.R. Gottwald, and C.A. Gilligan. 2015. "Thirteen Challenges in Modelling Plant Diseases." *Epidemics* 10: 6-10. <https://doi.org/10.1016/j.epidem.2014.06.002>
- Deutsch, C.A., J.J. Tewksbury, M. Tigchelaar, D.S. Battisti, S.C. Merrill, R.B. Huey, and R.L. Naylor. 2018. "Increase in Crop Losses to Insect Pests in a Warming Climate." *Science* 361 (6405): 916-919. <https://doi.org/10.1126/science.aat3466>
- Donatelli, M., R.D. Magarey, S. Bregaglio, L. Willocquet, J.P.M. Whish, and S. Savary. 2017. "Modelling the Impacts of Pests and Diseases on Agricultural Systems." *Agricultural Systems* 155: 213-224. <https://doi.org/10.1016/j.agry.2017.01.019>
- Garrett, K.A., S.P. Dendy, E.E. Frank, M.N. Rouse, and S.E. Travers. 2006. "Climate Change Effects on Plant Disease: Genomes to Ecosystems." *Annual Review of Phytopathology* 44 (1): 489-509. <https://doi.org/10.1146/annurev.phyto.44.070505.143420>
- Godfray, H.C.J., D. Mason-D'Croz, and S. Robinson. 2016. "Food System Consequences of a Fungal Disease Epidemic in a Major Crop." *Philosophical Transactions of the Royal Society B: Biological Sciences* 371 (1709): 20150467. <https://doi.org/10.1098/rstb.2015.0467>
- Juroszek, P., Bartsch, L., Fontaine, J. F., Racca, P., & Kleinhenz, B. (2022). Summary of the worldwide available crop disease risk simulation studies that were driven by climate change scenarios and published during the past 20 years. *Plant Pathology*, 71 (9): 1815-1838. <https://doi.org/10.1111/ppa.13634>
- Lewis, C.M., A. Persoons, D.P. Bebbber et al. 2018. "Potential for Re-emergence of Wheat Stem Rust in the United Kingdom." *Communications Biology* 1 (1): 13. <https://doi.org/10.1038/s42003-018-0013-y>
- Liu, C., and H.J. Van der Fels-Klerx. 2021. "Quantitative Modeling of Climate Change Impacts on Mycotoxins in Cereals: A Review." *Toxins* 13 (4): 276. <https://doi.org/10.3390/toxins13040276>
- Montes, C., Sk.G. Hussain, and T.J. Krupnik. 2022. "Variable Climate Suitability For Wheat Blast (*Magnaporthe oryzae* pathotype Triticum) in Asia: Results from a Continental-Scale Modeling Approach." *International Journal of Biometeorology* 66 (11): 2237-2249. <https://doi.org/10.1007/s00484-022-02352-9>
- Moretti, A., M. Pascale, and A.F. Logrieco. 2019. "Mycotoxin Risks under a Climate Change Scenario in Europe." *Trends in Food Science & Technology* 84: 38-40. <https://doi.org/10.1016/j.tifs.2018.03.008>
- OECD/FAO (Organisation for Economic Co-operation and Development/Food and Agriculture Organization of the United Nations). (2012). *OECD-FAO Agricultural Outlook 2012-2021*. OECD Publishing. https://doi.org/10.1787/agr_outlook-2012-en
- Pequeno, D.N.L., T.B. Ferreira, J.M.C. Fernandes et al. 2024. "Production Vulnerability to Wheat Blast Disease under Climate Change." *Nature Climate Change* (February). <https://doi.org/10.1038/s41558-023-01902-2>
- Petsakos, A., M. Kozicka, G. Blomme, J.N. Nakakawa, W. Ocimati, and E. Gotor. 2023. "The Potential Impact of Banana Xanthomonas Wilt on Food Systems in Africa: Modeling Scenarios of Policy Response and Disease Control Measures." *Frontiers in Sustainable Food Systems* 7. <https://doi.org/10.3389/fsufs.2023.1207913>
- Savary, S., L. Willocquet, S.J. Pethybridge, P. Esker, N. McRoberts, and A. Nelson. 2019. "The Global Burden of Pathogens and Pests on Major Food Crops." *Nature Ecology & Evolution* 3: 430-439. <https://doi.org/10.1038/s41559-018-0793-y>
- Willocquet, L., V. Rossi, and S. Savary. 2022. "Simulation Modelling of Yield Losses Caused by Wheat Stem Rust." *Plant Pathology* 71 (3): 544-555. <https://doi.org/10.1111/ppa.13488>
- Willocquet, L., S. Savary, L. Fernandez et al. 2002. "Structure and Validation of RICEPEST, a Production Situation-Driven, Crop Growth Model Simulating Rice Yield Response to Multiple Pest Injuries for Tropical Asia." *Ecological Modelling* 153 (3): 247-268. [https://doi.org/10.1016/S0304-3800\(02\)00014-5](https://doi.org/10.1016/S0304-3800(02)00014-5)

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