Weniger Mais durch Erderwärmung | TREIBHAUSFOLGEN

Geht es mit der Erderwärmung so weiter wie bisher, sinkt der Maisertrag bis 2070 global um bis zu 24%. Das berechnete das Laxenburger IIASA zusammen mit der NASA und dem Potsdamer Institut für Klimafolgenforschung. Mais ist in ärmeren Ländern neben Reis eines der wichtigsten Grundnahrungsmittel. Steigende Temperaturen, geänderte Niederschlagsmuster und höhere bodennahe CO2-Werte setzen dem Mais vor allem im tropischen Anbaugebiet zu.

Im Gegenzug wird der Weizenertrag bis 2050 um 17 Prozent steigen. Weizen gedeiht vor allem in gemäßigten Breiten. Durch die globale Erwärmung kann er sich Richtung Norden ausbreiten.

Hauptautor Jonas Jägermeyr von der NASA war selbst überrascht von den Ergebnissen der Simulation. Verglichen mit Berechnungen von 2014 zeigten sich jetzt viel stärkere Effekte der Klimaveränderung. »Sogar unter optimistischen Klima-Szenarien, in denen sich die Staaten für ambitionierte Klimaschutzmaßnahmen entscheiden, muss sich die globale Landwirtschaft einer neuen Klima-Realität stellen«, so Jägermeyr.

01112021 | IIASA | Global climate change impacts on crops expected within 10 years

https://iiasa.ac.at/web/home/about/211101-climate-change-impacts-on-crops_.html

Climate change may affect the production of maize (corn) and wheat by 2030 if current trends continue, according to a new international study that included researchers from IIASA, NASA, and the Potsdam Institute for Climate Impact Research (PIK). Maize crop yields are projected to decline by 24%, while wheat could potentially see growth of about 17%.

Using advanced climate and agricultural models, scientists found that the change in yields is due to projected increases in temperature, shifts in rainfall patterns, and elevated surface carbon dioxide concentrations from human-caused greenhouse gas emissions. These changes would make it more difficult to grow maize in the tropics, but could expand wheat's growing range.

“We did not expect to see such a fundamental shift, as compared to crop yield projections from the previous generation of climate and crop models conducted in 2014,” said lead author Jonas Jägermeyr, a crop modeler and climate scientist at NASA's Goddard Institute for Space Studies (GISS) and The Earth Institute at Columbia University in New York City. The projected maize response was surprisingly large and negative, he said. “A 20% decrease from current production levels could have severe implications worldwide.”

To arrive at their projections, the research team used two sets of models. First, they used climate model simulations from the international Climate Model Intercomparison Project-Phase 6 (CMIP6), followed by an ensemble of biophysical crop growth models to estimate yield implications of the changing climate. Each of the five CMIP6 climate models used for this study runs its own unique response of Earth's atmosphere to greenhouse gas emission scenarios through to 2100. These responses differ somewhat due to variations in their representations of the Earth's climate system.

The research team then used the climate model simulations as inputs for 12 state-of-the-art global crop models that are part of the Agricultural Model Intercomparison and Improvement Project (AgMIP), an international partnership coordinated by Columbia University. IIASA involvement in the study was twofold: first, on the climate data acquisition and processing side, researchers from the Advancing Systems Analysis and Biodiversity and Natural Resources programs, carried out the data transformation from the original format to the format suitable for feeding the institute's Environmental Policy Integrated Model (EPIC), which contributed crop growth modeling data to the study. Second, and most importantly, the IIASA teams also carried out biophysical simulations informing (among other variables) the yield projections corresponding to the CMIP6 data.

The crop models provide large-scale simulations of how crops grow and respond to environmental conditions such as temperature, rainfall, and atmospheric carbon dioxide, which are provided by the climate models. Each crop species' behavior is based on their real life biological responses studied in indoor and outdoor lab experiments. In the end, the team created about 240 global climate-crop model simulations for each crop. Using multiple climate and crop models in various combinations, increased the team's confidence in their results.

The study focused on climate change impacts. The models used do not address economic incentives, changing farming practices, and adaptations such as breeding hardier crop varieties, although that is an area of active research. The research team plans to look at these angles in follow-up work, since these factors will also determine the fate of agricultural yields in the future as people respond to climate-driven changes.

The team looked at changes to long-term average crop yields and introduced a new estimate for when climate change impacts "emerge" as a discernible signal from the usual, historically known variability in crop yields. Soybean and rice projections showed a stronger decline in their regional change patterns than previously expected, but at the global scale, the different models still disagree on the overall impacts from climate change. For maize and wheat, the climate effect was much clearer, with most of the model results pointing in the same direction.

"Apart from more pronounced production losses projected for maize by the new model ensemble, the emergence of adverse climate change impacts – the point of time when historic extreme years become the new norm – also occurs substantially earlier for this crop and the model agreement is more robust. This suggests that less time may be left to adapt related crop production systems to the changing climate than indicated by earlier ensemble studies," says coauthor and IIASA researcher Christian Folberth.

Maize, or corn, is grown all over the world, and large quantities are produced in countries nearer the equator. North and Central America, West Africa, Central Asia, Brazil, and China will potentially see their maize yields decline in the coming years and beyond as average temperatures rise across these breadbasket regions, putting more stress on the plants.

Wheat, which grows best in temperate climates, may see a broader area where it can be grown as temperatures rise, including the Northern United States and Canada, North China Plains, Central Asia, Southern Australia, and East Africa, but these gains may level off mid-century.

Temperature is not the only factor the models consider when simulating future crop yields. Higher levels of carbon dioxide in the atmosphere have a positive effect on photosynthesis and water retention, increasing crop yields, though often at a cost to the nutritional value of the crop. This effect happens more so for wheat than maize, which is accounted for better in the current generation of models. Rising global temperatures are also linked to changes in rainfall patterns, and the frequency and duration of heat waves and droughts, which can affect crop health and productivity. Higher temperatures also affect the length of growing seasons and accelerate crop maturity.

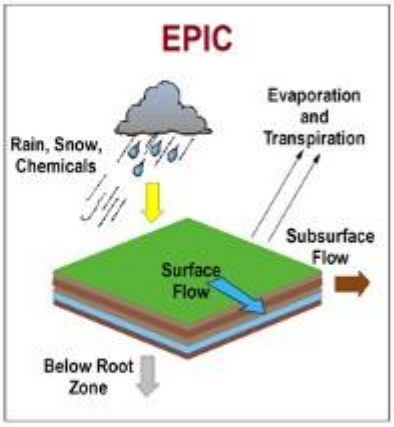
"Even under optimistic climate change scenarios, where societies enact ambitious efforts to limit global temperature rise, global agriculture is facing a new climate reality," Jägermeyr said. "And with the interconnectedness of the global food system, impacts in even one region's breadbasket will be felt worldwide."

Reference
Jägermeyr, J., Müller, C., Ruane, A.C., Elliott, J., Balkovic, J., Castillo, O., Faye, B., Foster, I., Folberth, C., et al. (2021). Climate impacts on global agriculture emerge earlier in new generation of climate and crop models. *Nature Food* DOI: 10.1038/s43016-021-00400-y

15032021 | IIASA | The Environmental Policy Integrated Model (EPIC)

https://iiasa.ac.at/web/home/research/researchPrograms/EcosystemsServicesandManagement/EPIC.en.html

A model assessing how land management affects the environment



EPIC Model

At IIASA, EPIC is used to assess the main global agricultural systems in response to management interventions such as cropping practices or fertilization and irrigation options, and changing environment, including climate change and soil degradation. Besides which EPIC is used to compare cropland management systems and their effects on environmental indicators like water availability, nitrogen and phosphorous levels in soil, and greenhouse gas emissions.

EPIC can analyze several crop types and their management under different weather, topographical, and soil conditions. It investigates the trade-offs between plant growth and yield on the one hand, and environmental impacts and sustainability on the other.

For example, EPIC can estimate—based on soil type and prevailing climatic conditions—the extent to which nutrients from fertilizer, such as Nitrogen (N) are leaching into nearby river and stream networks. This problem is of growing concern as globally, two-fifths of N used in agriculture is lost to ecosystems, with harmful environmental effects.

EPIC can analyse options of sustainable agriculture including soil erosion control, crop residue management, improving soil organic carbon stock and reducing GHG emissions. Global EPIC applications help informing on the potential of agricultural systems to contribute to meeting global climate and food security targets.

FAST FACTS

EPIC simulates agricultural activities and their interactions within ecosystems on a daily basis.

EPIC is widely used by scientists around the world. Research groups, like IIASA, can calibrate the model to meet their own analytical needs.

EPIC has accurately simulated agricultural conditions and practices for hundreds of years into the past. This makes it an excellent basis for projecting future trends in global change.

How the model works

EPIC, as used at IIASA, models a wide range of biophysical processes in the soil-plant-atmosphere system to consider alternative land uses where land is becoming degraded or is putting natural ecosystems at risk.

It includes a full water cycle, allowing quantifying water availability for plant growth, surface water runoff and percolation downwards to the groundwater system. It can simulate different weather patterns and events, such as the effects on crop production of heavy rainfall or prolonged drought, and it can estimate plant growth and yield based on the temperature or moisture content of the soil. The effects on crop productivity of natural processes, such as erosion and sedimentation, and of human activities, such as soil tillage, can also be fully demonstrated. The impacts of land use on carbon cycling, GHG emissions and soil functioning are among the main modeling focus.

Large-scale EPIC applications are based on the EPIC-IIASA Global Gridded Crop Modelling (GGCM) framework, integrating the site-scale EPIC model with globally available datasets on climate, soils, land cover and land use. A more detailed version of gridded EPIC is available for Europe (EU-EPIC).

Model applications

At IIASA, EPIC is part of the toolkit used to assess the economic and environmental effects on agricultural and forest lands of enhancing carbon sinks and GHG abatement measures. For example, the model has been recently used to quantify impacts and uncertainty of +2°C of global warming and soil degradation on European crop calorie supply, or to highlight the importance of soil data in global crop yield simulations.

EPIC plays a key role in IIASA’s current projects including VERIFY, COACCH, IMBALANCE-P, CIRCASA, and RESTORE+.

About the EPIC model

The EPIC model was developed by the United States Department of Agriculture to assess the status of U.S. soil and water resources and has been continuously expanded and refined to better analyze the exchange of GHG fluxes between terrestrial ecosystems and the atmosphere. It is used around the world by research groups, like IIASA, who calibrate EPIC to meet their own needs.

EPIC-IIASA and EU-EPIC large-scale gridded crop modelling frameworks are being developed by IIASA.

Verifying and updating the model

EPIC-IIASA is integrated into the GLOBIOM model, quantifying agricultural production as well as environmental externalities for a range of crop management systems at global scale.

We continue working on linking EPIC-IIASA with the BeWhere model, aiming to supply the model with information on availability of agricultural feedstock for bioenergy production.

EPIC-IIASA has been extensively evaluated as a part of the Inter-Sectoral Impact Model Intercomparison Project, the Agricultural Model Intercomparison and Improvement Project, and the Global Gridded Crop Model Intercomparison.

The future focus of the model at IIASA will be analysis of GHG emissions and carbon sequestration in the agricultural sector. EPIC already includes tools to analyze organic carbon and nitrogen in the soil, and a methane analysis module is under preparation. Links to IIASA's GAINS model are being strengthened.