Changing climate could worsen foods’ nutrition

Evidence builds for lessening of certain micronutrients, protein in plants

BY SUSAN MILIUS 3:07PM, MARCH 13, 2017 Science News

CROP FUTURES Experiments using circles of white pipes blowing extra carbon dioxide over crops suggest that certain nutrients may dwindle in crops grown in a carbon-enhanced future atmosphere. Here, researchers in Arizona measure the growth of wheat.

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A dinner plate piled high with food from plants might not deliver the same nutrition toward the end of this century as it does today. Climate change could shrink the mineral and protein content of wheat, rice and other staple crops, mounting evidence suggests.

Selenium, a trace element essential for human health, already falls short in diets of one in seven people worldwide. Studies link low selenium with such troubles as weak immune systems and cognitive decline. And in severely selenium-starved spots in China, children’s bones don’t grow to normal size or shape. This vital element could become sparser in soils of major agricultural regions as the climate changes, an international research group announced online February 21 in *Proceedings of the National Academy of Sciences*.

Likewise, zinc and iron deficiencies could grow as micronutrients dwindle in major crops worldwide, Harvard University colleagues Samuel Myers and Peter Huybers and collaborators warned in a paper published online January 6 in the *Annual Review of Public Health*. Futuristic field experiments on wheat and other major crops predict that more people will slip into nutritional deficits late in this century because of dips in protein content, Myers reported February 16 at the Climate and Health Meeting held in Atlanta.

“If we’d sat down 10 years ago and tried to think what the effects of anthropogenic carbon dioxide emissions might be on human health, none of us would have anticipated that one effect would be to make our food less nutritious,” Myers said. “But we can’t fundamentally disrupt and reconfigure most of the natural systems around our planet without encountering unintended consequences.”

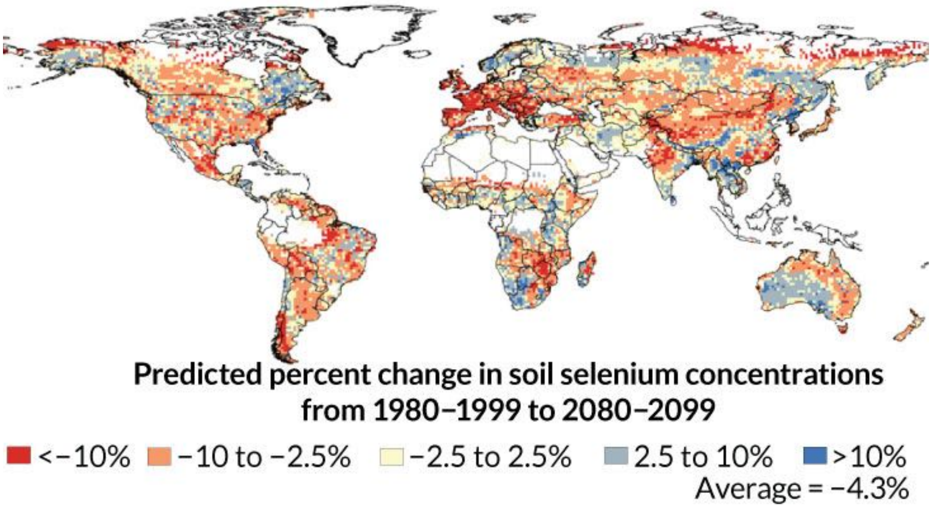
Figuring out those unintended nutrient consequences isn’t easy. For selenium, scientists have only a rough idea of the element’s global movements. It’s unclear what proportions erode out of rocks or waft onto land from sea, says biogeochemist Lenny Winkel of ETH Zurich and the Swiss aquatic research group Eawag in Dübendorf. She was the principal investigator for the selenium in soils project in the new *Proceedings* paper. As far as she knows, it presents the first global look at selenium concentrations in soils and what basic factors influence what’s there. This scale, she says, was “a bit bold.”

Starting with more than 33,000 data points from other sources, Winkel and colleagues pieced together a map of selenium concentrations in soils across much of the globe. Climate popped out as one of the more important predictors of selenium content in soil, a link that hadn’t shown up in small studies. Places where climate turns land arid generally have lower selenium, but soil character matters, too. Places with high organic carbon, as in a woodland rich with fallen leaves, as well as places with abundant clay, tend to do better at retaining selenium.

Story continues after map

Selenium slump

Soil concentrations of the element selenium, essential for human life, could change by the end of the 21st century, according to computer simulations based on an intermediate scenario for climate change (a scenario that the Intergovernmental Panel on Climate Change labels RCP6.0). The analysis identified what influences soil selenium now — including precipitation and concentrations of organic carbon in soil — and predicted future concentrations based on those influences.



G.D. JONES *ET AL/PNAS* 2017

By the end of the century, about two-thirds of heavily cultivated agricultural land would probably lose selenium under an intermediate scenario of climate change, Winkel and colleagues conclude. With a projected average end-century warming of 2.2 degrees Celsius compared with 1986 to 2005, selenium drops in breadbasket regions in the study by an average of 8.7 percent. Only 19 percent of croplands seem likely to gain selenium.

The new map "is worrisome," says plant physiologist Philip White of the James Hutton Institute in Invergowrie, Scotland. White, who studies agricultural plants, has published on selenium but was not part of the new study. As a rule of thumb, he says, natural selenium concentrations in soil "are directly related to the selenium available in plants."

That may be a rule of thumb. But Winkel says that to refine predictions, scientists need to consider how plant species vary in building up selenium in their tissues. Brazil nuts, for instance, accumulate so much selenium that extreme and persistent fans can develop signs of overdosing. One sign of excess: otherwise unexplained garlic breath.

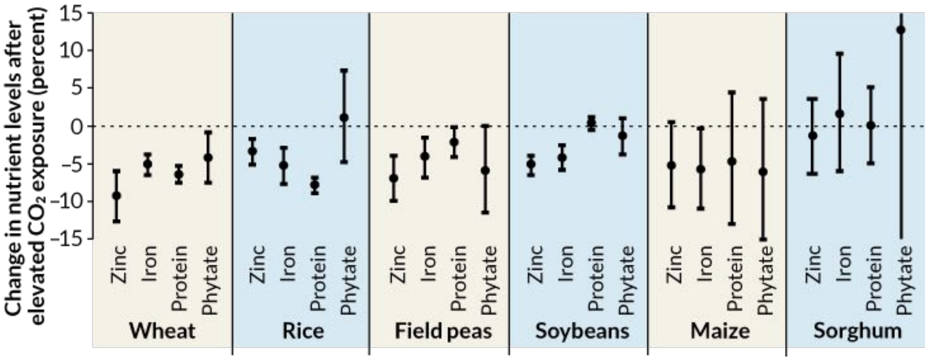
Excess can be an issue because the healthful ranges of selenium are narrow. "You can quickly get too much or too little," Winkel says. This Goldilocks problem complicates planning for what to do about shortages: What boosts health among the nutrient-poor might not be so good for well-fed people with varied sources of selenium.

Zinc and iron concentrations in crops, too, will probably shift as climate changes, Myers and colleagues reported in *Nature* in 2014. They analyzed harvest samples from a total of 41 cultivated varieties of major crops (wheat, rice, field peas, soybeans, maize and sorghum) grown with the expensive and elaborate experimental protocol known as FACE, for Free-Air CO_2 Enrichment. In Australia, Japan and the United States, test crops grew in outdoor fields within futuristic Stonehenge circles of skinny ducts blowing extra carbon dioxide to mimic mid- to late-century atmospheres. Sites varied, but at the time, researchers reported their baseline CO_2 as 363 to 386 parts per million and pushed their pipes to deliver 546 to 586 ppm.

Story continues after graph

Nutrient drop

Multiple varieties of major crops showed some nutrient changes when grown outdoors with extra carbon dioxide blown over them (ranging from 546 to 586 ppm) in seven spots scattered across Australia, Japan and the United States. Sorghum and maize, plants capturing carbon with what's called a C_4 pathway, may be better at preserving nutrients in a future carbon-enriched atmosphere than most crops. Phytate, not a nutrient but a compound that can sabotage zinc uptake in humans, decreased only in wheat. The phytate dip might help compensate for declining zinc, but researchers note that zinc decreased even more than phytate content did. Just what these declines mean depends on how many people draw a substantial part of particular nutrients from a particular crop, a calculation later papers are starting to address.



S.S. MYERS *ET AL/NATURE* 2014

Based on samples from these far-flung experiments, the researchers found iron concentrations in wheat dropped an average of 5 percent. Zinc levels fell 9 percent. Most other crops showed a tendency toward declines too, although maize and sorghum, which use what's called the C_4 pathway for carbon capture, showed signs of possible resilience.

Then Myers asked: "So what?"

Figuring that out wasn't easy. A major plant source of the minerals for Ethiopia might not matter much for England with its meat-rich diet. Myers and colleagues put together an epic database of how much of 95 foods people eat in 188 countries around the world, and then calculated where the relatively modest downturns of zinc would put people at risk in the future. Nutrient changes by 2050 would push about 138 million more people into zinc deficiency, the researchers reported in 2015. And for more than 2 billion people already zinc deficient, future crop declines could make their health problems even worse.

The shortfall could be especially hard on women and children. Too little zinc raises pregnant women's risks of premature delivery and can doom children to poor weight gain and growth. A robust immune system needs adequate zinc, and public health specialists blame 100,000 child deaths a year on immune responses so enfeebled by skimpy zinc that children couldn't fight off pneumonia or diarrhea.

Livestock also may have to contend with plant nutrition changes. There will be complex interactions among CO_2, temperature and water, which we don't fully understand yet, says Jerry Hatfield. He's a plant physiologist at the U.S. Department of Agriculture's National Laboratory for Agriculture and the Environment in Ames, Iowa. Some of the best evidence so far for effects of CO_2 enhancement comes from FACE experiments in rangeland grasses, he says. Rising CO_2 spurred rapid growth but weakened the grasses' ability to take up nitrogen. Grass short on nitrogen didn't have the raw materials for the usual protein content of livestock forage.

Just how the soaring CO_2 lowers nutrient content remains under debate. The prevailing hypothesis has been that extra carbon in the atmosphere lets plants bulk up with carbohydrates, in a sense diluting anything that isn't a carbohydrate, plant micronutrients included.

Not so, says plant physiologist Arnold Bloom of the University of California, Davis, a coauthor of the 2014 paper in *Nature*. A wide range of experimental results show that although most nutrients go down, some do not and some even go up. That doesn't fit with a general pattern of low, "diluted" concentrations, concentrations of the various noncarbohydrates scattered all over the place.

With nutrient concentrations going down, it might seem that people could solve the problem just by eating more. But there may not be more. Early studies raised hopes that extra CO_2 might give plants' carbon-trapping machinery extra raw material for growth spurts and bonanza yields. But sustained growth now looks elusive. Experiments tracking growth over years suggest that plants may not sustain initial surges, and theoretical predictions that build in such nonminor details as pests and water supplies are not encouraging. The 2014 report from the Intergovernmental Panel on Climate Change notes that crop yields are more likely to decrease than soar and agriculture will have to change to try to compensate.

"Global demand for food is rising more steeply than ever before in human history," Myers said in Atlanta. In 40 years, agriculture will have to produce 70 percent more food than it does today just to keep even as Earth's population grows by several billion people. Yet in this time of growing need, human activities are transforming the climate in ways that could make farming even more of a challenge.

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Worries grow that climate change will quietly steal nutrients from major food crops

Increasing carbon dioxide tinkers with plant chemistry in ways not well understood

BY **SUSAN MILIUS** 8:27AM, DECEMBER 13, 2017

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2017 was a good year for worrying about nutrient losses that might come with a changing climate.

The idea that surging carbon dioxide levels could stealthily render some major crops less nutritious has long been percolating in plant research circles. "It's literally a 25-year story, but it has come to a head in the last year or so," says Lewis Ziska, a plant physiologist with the U.S. Agricultural Research Service in Beltsville, Md.

Concerns are growing that wheat, rice and some other staple crops could, pound for pound, deliver less of some minerals and protein in decades to come than those crops do today. In 2017, three reports highlighted what changes in those crops could mean for global health. Also this year, an ambitious analysis made an almost-global assessment of sources of selenium, a trace element crucial for health, and warned of regions where climate change might cut the element's availability (*SN: 4/1/17, p. 14*).

Crop responses to rising CO_2 might affect nutrition and health for billions of people, Ziska says, but the idea has been difficult to convey to nonspecialists. One complication is that though plants certainly need CO_2 to grow, providing more of it doesn't mean that all aspects of plant biology change in sync. In hoping for a farming bonus, Ziska warns, people often overlook the disproportionate zest of weeds. An outdoor experiment wafting extra CO_2 through a forest has already shown, for example, that poison ivy grew faster than the trees.

In the 2017 *Annual Review of Public Health*, Samuel Myers of Harvard University and colleagues wrote that global shortfalls in human nutrition are already "staggering." More than a billion people aren't getting enough zinc now, raising risks of premature birth, stunted childhood growth and weak immune systems. To estimate future shortfalls, Myers and colleagues turned to nutrient data they published in 2014 in *Nature*.

That report compared staple crops grown in various outdoor setups on three continents at either ambient or enhanced atmospheric CO_2 concentrations. Fancy research piping boosted ambient levels of 363 to 386 parts per million to 546 and 584 ppm. (A moderate scenario puts late-century levels at 580 to 720 ppm.)

Nutrient tracker

Major crops showed some nutrient changes when grown in experimental plots with extra carbon dioxide blown over plants (ranging from 546 to 584 parts per million). Wheat, rice and soybeans (below) showed drops in zinc and iron content, with wheat and rice also having less available protein. But nutrient drops were not universal. Results suggest that sorghum and maize may better preserve nutrients as atmospheric CO_2 increases. And concentrations of phytate, which can interfere with zinc uptake, decreased only in wheat.

Decreases in zinc concentrations, including in rice and wheat, could plunge an additional 150 million to 200 million people into zinc deficiency, the researchers calculate. Likewise, predicted declines in iron content in some grains and legumes look worrisome for countries with anemia rates already higher than 20 percent, such as India and Algeria, Myers and colleagues reported in August in *GeoHealth*. Such high-anemia nations have a lot of people especially at risk, including 1.4 billion young children and women of childbearing age.

An expanded set of experiments suggested that protein content in rice and wheat could sink by roughly 8 percent, Myers and colleagues wrote in the August *Environmental Health Perspectives*. Thus, rising CO_2could add some 148 million people worldwide to the roughly 1.4 billion expected to be short of protein by 2050.

Also this year, grazing cattle joined the list of animals facing a protein downturn in their food. (Ziska and colleagues raised the issue for bees in 2016.) For cattle, 22 years and more than 36,000 fecal measurements suggest that plants on U.S. grazing lands have grown poorer in protein, ecologist Joseph Craine of Jonah Ventures, in Boulder, Colo., and colleagues reported April 10 in *Environmental Research Letters*. For every kilogram of plants that cattle ate in 2015, there were 10.6 grams less protein than there had been 22 years before. The yearly loss is equivalent to the protein available in $1.9 billion worth of soy meal — and rising CO_2 is a possible culprit.

Plant reactions will be varied and complex, Ziska points out. An *Artemisia* plant's anti-malarial compound, artemisinin, can get more concentrated as CO_2 increases, possibly good news for plant-based medicine. But the mix of urushiols, oils that put the itch in poison ivy, can become more allergy-provoking when exposed to extra CO_2, a test suggested. Ziska is now looking into how much caffeine will turbocharge future coffee beans.

Whatever the changes, concern is growing, says mathematical biologist Irakli Loladze of Bryan College of Health Sciences in Lincoln, Neb. He, Ziska and nine coauthors included nutritional erosion in the 2016 U.S. scientific assessment of the impacts of climate change on human health. To raise the public profile of the issue, though, Myers says, "We have a ways to go."

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