

Assessing the Impacts of Global Climate Change on Nutrient Availability in Latin America

Global climate change has already been impacting agricultural production and is projected to have considerably larger impacts in the future. There have been a number of studies assessing potential impacts on food security, but these assessments tend to focus only on changes in production of major grains and oilseeds due to productivity shocks. There has been growing interest in moving beyond a focus on the implications of climate change for agricultural production to an examination of the effects on health and nutrition as well. In addition, there have been several studies providing evidence that increasing concentrations of atmospheric CO₂ results in crops that contain a higher proportion of carbon in their tissues and a reduced proportion of certain key macro- and micronutrients (e.g., Myers et al., 2014; Taub, Miller, and Allen, 2008; Loladze, 2014). This change in plant tissue composition would tend to make foods less nutritious and further contributes to the concerns surrounding nutrition and health effects under future climate projections. A shift towards less nutritious food also potentially contributes to the global double burden of malnutrition, which includes both undernutrition and obesity.

In this study, we incorporate both impacts on crop productivity as well as effects of elevated atmospheric carbon dioxide (CO₂) concentrations on nutrient content to explore the implications of alternative future climate scenarios for nutrient availability. We focus our assessment on Latin America, but include impacts on the rest of the world in order to capture trade effects associated with changes in relative competitiveness of Latin America given changes in productivity experienced across the globe under climate change. We incorporate climate scenarios consistent with the IPCC Fifth Assessment Report (AR5) representative concentration pathways (RCPs) as implemented in multiple global circulation models (GCMs) such as the MIROC, GFDL, and HADGEM models, using a set of RCP-GCM combinations that provides a range of possible climate futures.

In order to model the economic responses to changes in agricultural productivity, we incorporate changes in yields by crop and region relative to baseline projections. These adjustments differ across crop-region combinations, resulting in changes in the relative profitability of individual crop production across regions. This results in adjustments in which commodities are produced in which parts of the world and impacts on regional and global production, consumption, and prices. As a result, consumers' alter their consumption baskets in response to changing prices. In addition to changes in the quantities of different food commodities that are consumed, these foods are expected to experience changes in nutrient content due to elevated CO₂ levels. We account for these effects through post-processing adjustments consistent with the Loladze (2014) and Myers et al. (2014) estimates to calculate changes in nutrient content per kg for different food commodities. We also make use of data from the GEnuS dataset at Harvard to disaggregate the sources of key nutrients consistent with baseline diets across different regions of the world.

We focus on iron and zinc for this assessment due to the substantial global impacts of deficiencies in those nutrients. Iron and zinc are available from a number of different types of commodities, including both livestock and crop products. However, the bioavailability of these nutrients varies across regions based on the allocation of nutrient sources in the diet. Thus, we make use of estimated recommended nutrient intake (RNI) data provided by Matthew Smith to approximate the daily requirements for nutrient intake across different regions of the world and assess availability relative to those RNIs.

The model used for this analysis is the Applied Dynamic Analysis of the Global Economy (ADAGE) model, a recursive dynamic, multi-region, and multi-sector CGE model. ADAGE follows the classical Arrow-Debreu general equilibrium framework covering all aspects of the economy, including production, consumption, trade, and investment. Households can distinguish between domestic or imported consumption goods, including personal and purchased transportation services. Producers maximize profits subject to technology constraints in a nested constant elasticity of substitution (CES) structure. The dynamics in ADAGE are represented by: (i) growth in the available effective labor supply from population

growth and changes in labor productivity, (ii) capital accumulation through savings and investment, (iii) changes in stocks of natural resources, and (iv) technological change from improvements in manufacturing, energy efficiency and land productivity. ADAGE is simulated for the period 2010-2050 with a five-year time step.

The key underlying database used in ADAGE is the Global Trade Analysis Project (GTAP) database version 7.1 (Narayanan and Walmsley, Ed., 2008), which was updated from 2004 to the baseline year 2010 using secondary data from World Energy Outlook (WEO, 2010) and International Energy Outlook (IEO 2010) and Food and Agricultural Organization. The model has rich details in energy and electricity generation, agriculture, biofuel, and land. ADAGE also has full GHG accounting where baseline data for GHGs (carbon dioxide, CO₂; methane, CH₄; nitrous oxide, N₂O; hydrofluorocarbons, HFCs; perfluorocarbons, PFCs; and sulphur hexafluoride, SF₆) are from U.S. EPA historical inventory data and projections. ADAGE has been undergoing continuous enhancement since 2009 and has been applied for various economic, energy, and environmental policies analyses, including renewable fuel policy analysis, evaluation of climate change impacts, and food, energy and climate mitigation analysis.

Our findings suggest that climate change is likely to have important effects on nutrient availability in Latin America as global climate impacts affect the relative competitiveness of agricultural production in Latin America and lead to shifting production patterns over time. This leads to changes in the mix of food commodities consumed and tends to reduce availability of iron and zinc over time. The effects of elevated atmospheric CO₂ levels tends to have an even larger effect on nutrient availability than climate change. Our primary GCM scenarios include CO₂ fertilization, which offsets much of the negative impact of climate change on yields in our primary climate scenarios. Scenarios assuming no CO₂ fertilization suggest considerably more negative effects on nutrient availability, with yields declining for all major crops globally and contributing to reductions in iron and zinc availability of around 5-10%.

This study provides important insights into the potential combined effects of climate change on nutrient availability through both effects on crop productivity and nutrient content per kg of output. This information is important for considering appropriate mitigation and adaptation policies to reduce negative impacts on nutrient availability and associated effects on health outcomes. We find one of the key effects of climate change is likely to be a reduction in global progress towards nutrition targets identified by the sustainable development goals and other major global efforts.

References

- Loladze, I. (2014). Hidden shift of the ionome of plants exposed to elevated CO₂ depletes minerals at the base of human nutrition. *eLife* 3:e03356. doi:10.7554/eLife.02245
- Myers, S.S., et al. (2014). Increasing CO₂ threatens human nutrition. *Nature* 510:139-142. doi:10.1038/nature13179
- Taub, D.R., B. Miller, and H. Allen. (2008). Effects of elevated CO₂ on the protein concentration of food crops: A meta-analysis. *Global Change Biology* 14: 565-575. doi:10.1111/j.1365-2486.2007.01511.x