Assessing the Impacts of Climate Change on Global Nutrient Availability

Robert Beach and Yongxia Cai

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Overview

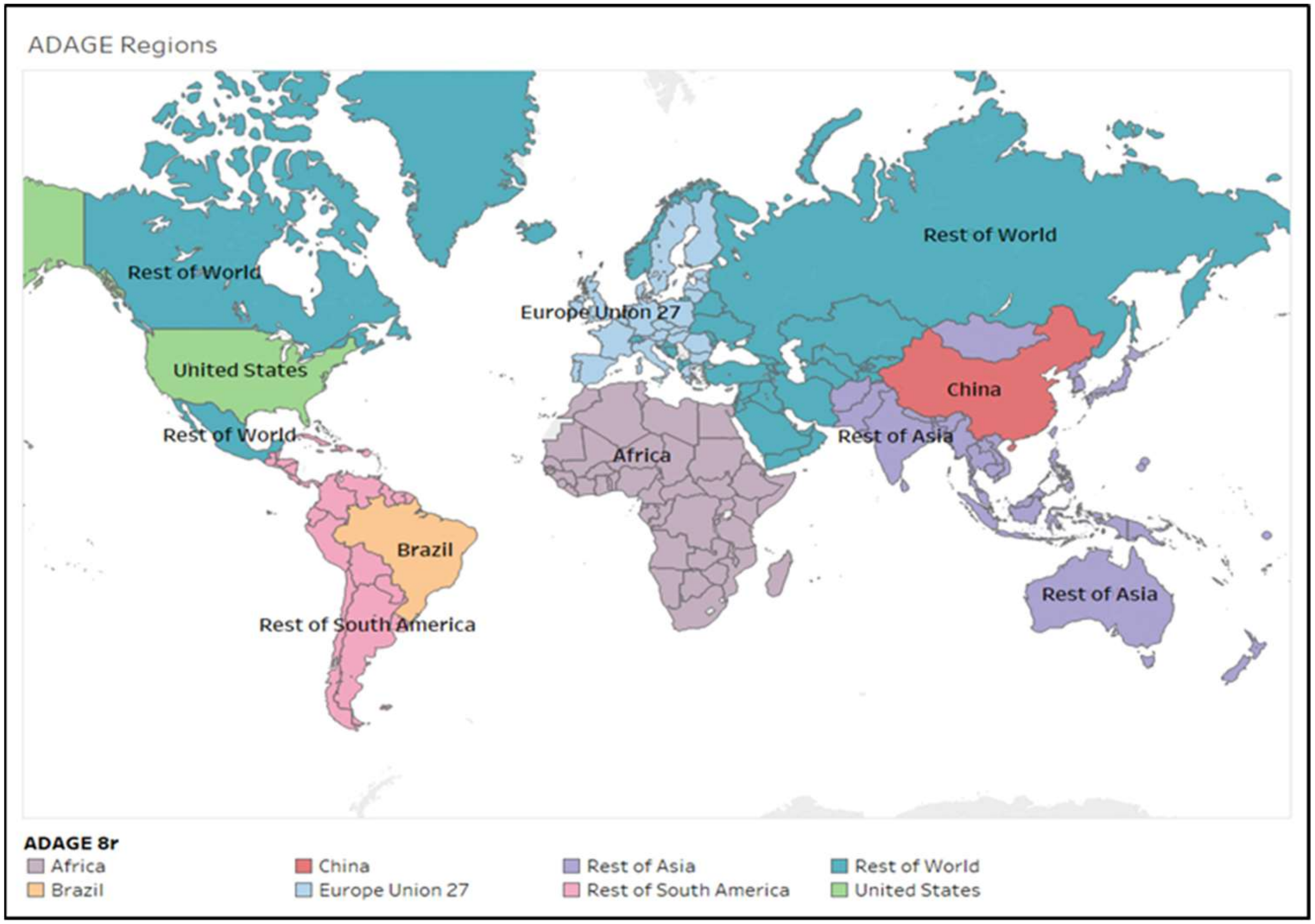
- Increases in atmospheric concentrations of greenhouse gases can potentially affect nutrient availability through multiple pathways
  - Contributions to climate change and associated impacts on agricultural productivity
  - There has recently been increasing recognition of the effects of rising CO_2 on nutrient content of food crops
- Few studies have examined these impacts simultaneously
  - Beach et al. (2019) applied partial equilibrium global model of the agricultural sector (IMPACT)
- In this study, we use a global CGE model with a detailed agricultural sector to project the impacts of alternative climate scenarios on future availability of protein, iron, and zinc accounting for both effects

Background

- Despite substantial reductions in the rate of global undernutrition over the past few decades, there remains a large global burden of disease associated with deficits of protein, iron, zinc, and other nutrients
  - About 2 billion people deficient in at least one key micronutrient (IFPRI, 2015)
    - 1 billion with insufficient iron intake (Smith, Golden, and Myers, 2017)
    - 17% of global population at risk of zinc deficiency (Wessells and Brown, 2012)
    - 12% at risk of protein deficiency (Medek, Schwartz, and Myers, 2017)
- In the absence of climate change, widely-used global economic models of the agricultural sector generally project rising production and improved food availability per capita through 2050
- However, projected progress towards improved global food security may be slowed or potentially even reversed due to elevated CO_2 concentrations and associated climate change

Applied Dynamic Analysis of the Global Economy Model

- The version of ADAGE used for this study is a recursive dynamic, multi-region, multi-sector CGE model



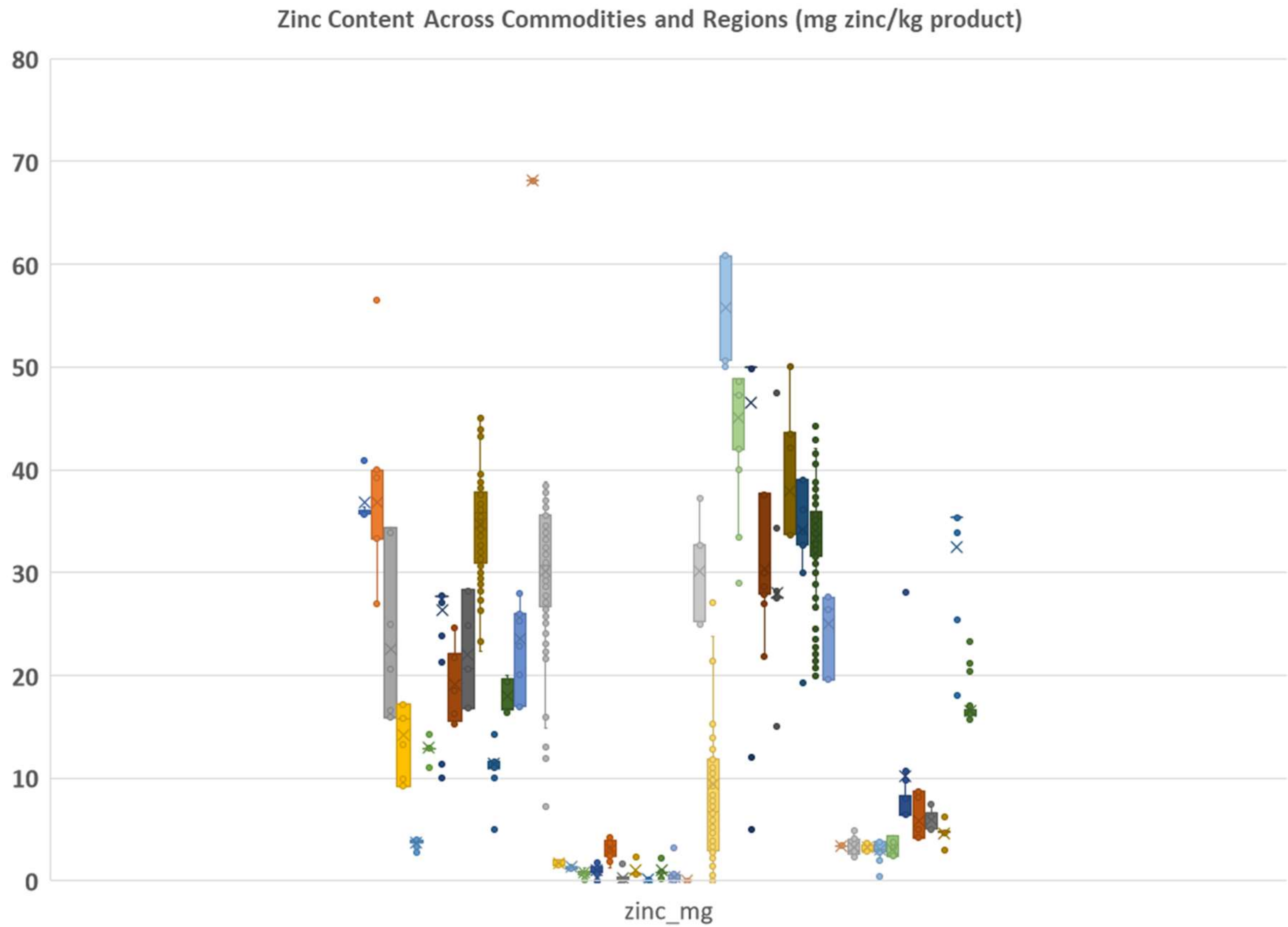
Sectoral representation in ADAGE

Sectors	Definition	Sectors	Definition
Energy		***Industry***	
Col	Coal	Eim	Energy-intensive manufacturing
Cru	Crude Oil Extraction	Man	Other Manufacturing
Ele	Electric generation	Srv	Services
Gas	Natural Gas	Trn	Transportation
Oil	Refined Petroleum	Vmt	Household transportation
Agriculture		House	Housing
Wht	Wheat	***Biofuels***	
Corn	Corn	Ceth	Corn Ethanol
Gron	Rest of Cereal Grains	Weth	Wheat Ethanol
Soyb	Soybean	Scet	Sugarcane Ethanol
Osdn	Rest of Oilseeds	Sbet	Sugarbeet Ethanol
Srcn	Sugarcane	Sybd	Soy Biodiesel
Srbt	Sugarbeet	Rpbd	Rape-Mustard Biodiesel
Ocr	Crops nec	Plbd	Palm-Kernel Biodiesel
Liv	Livestock	Swge	Advanced cellulosic ethanol from switchgrass
Frs	Forestry	Celd	Advanced cellulosic biodiesel
Food		Msce	Advanced cellulosic ethanol from miscanthus
Mea	Meat	***Byproducts***	
Vol	Vegetable Oils	Ddgs	Distillers grains with solubles (DDGs)
Ofd	Other foods products	Omel	Vegetable Oil Meal

Study design

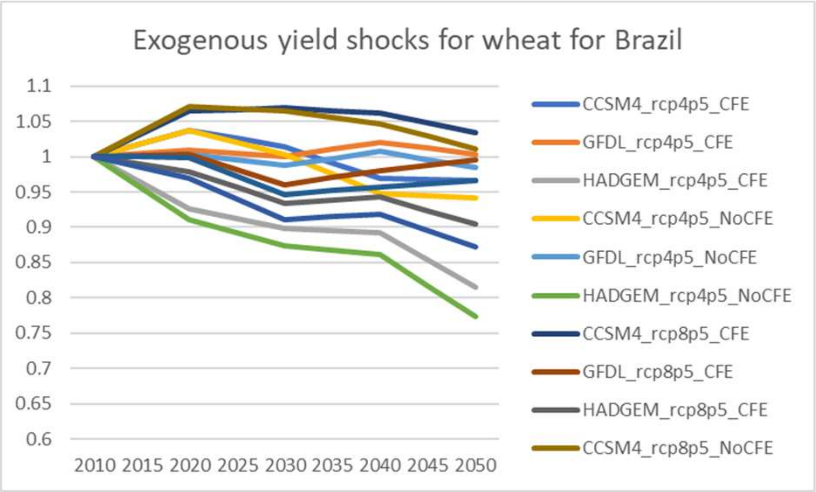
- Timeframe covered is 2010 to 2050
- Scenarios
  - REF scenario, holding climate and CO_2 concentrations constant at 2010 levels
  - RCP4.5 scenario, reflecting climate and CO_2 concentrations consistent with the Representative Concentration Pathway (RCP) 4.5 (moderate mitigation) with and without beneficial impacts of CO_2 fertilization
  - RCP8.5 scenario, reflecting climate change and CO_2 concentrations consistent with the RCP 8.5 (business as usual) with and without beneficial impacts of CO_2 fertilization
- Three major steps
  - Applied the ADAGE model to quantify future pathways of agricultural markets under each scenario
    - Changes in global and regional production, trade, prices, and consumption
  - Used data from the Global Expanded Nutrient Supply (GENuS) model to calculate nutrient content per unit of food commodity in each region, which are then multiplied by estimated consumption levels to estimate availability
  - Adjusted these nutrient levels by “CO_2 penalty” based on changes in CO_2 concentrations

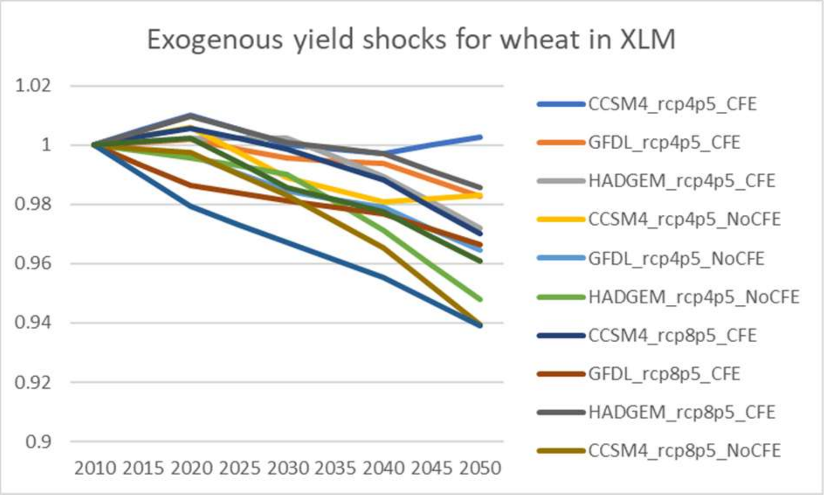
Variation in zinc content of foods



Incorporation of exogenous yield shocks

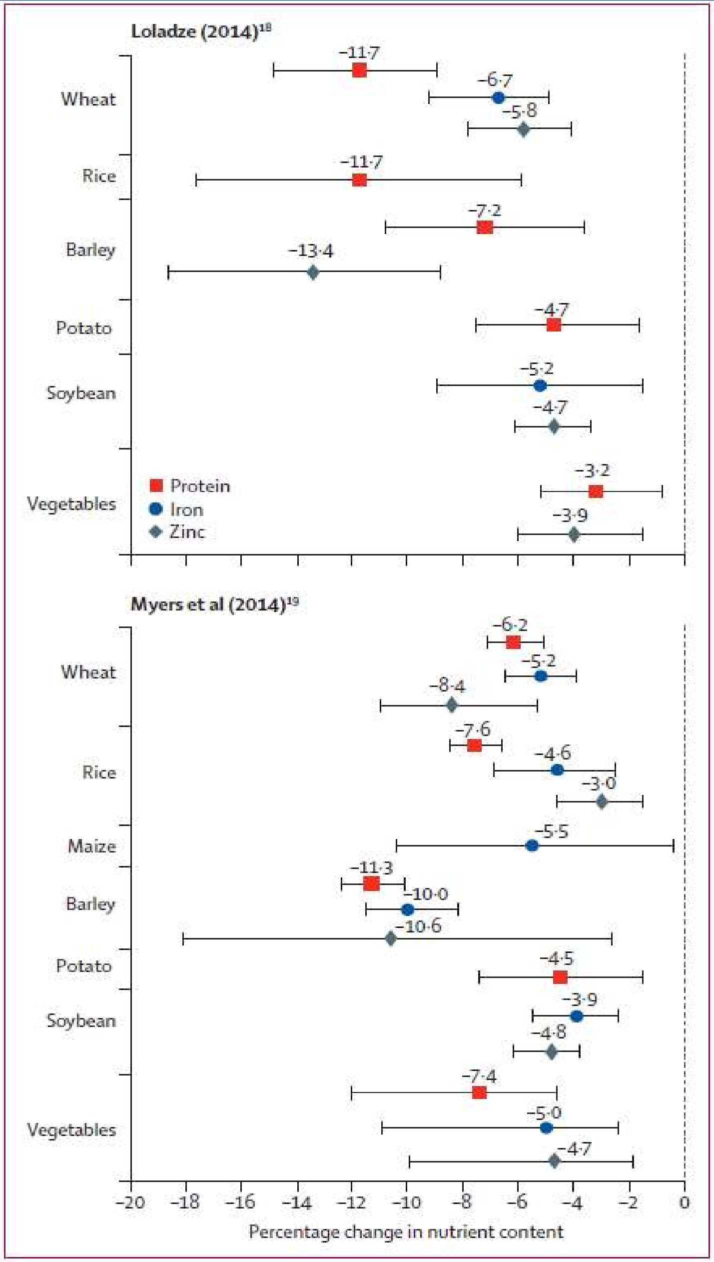
- Yield shocks estimated econometrically (Waldhoff et al., under review) and mapped to ADAGE crops and regions
- Considerable variation across regions and crops
- Based on these data, wheat is one of the more affected crops
- Many crops and pasture have relatively small changes in productivity through 2050





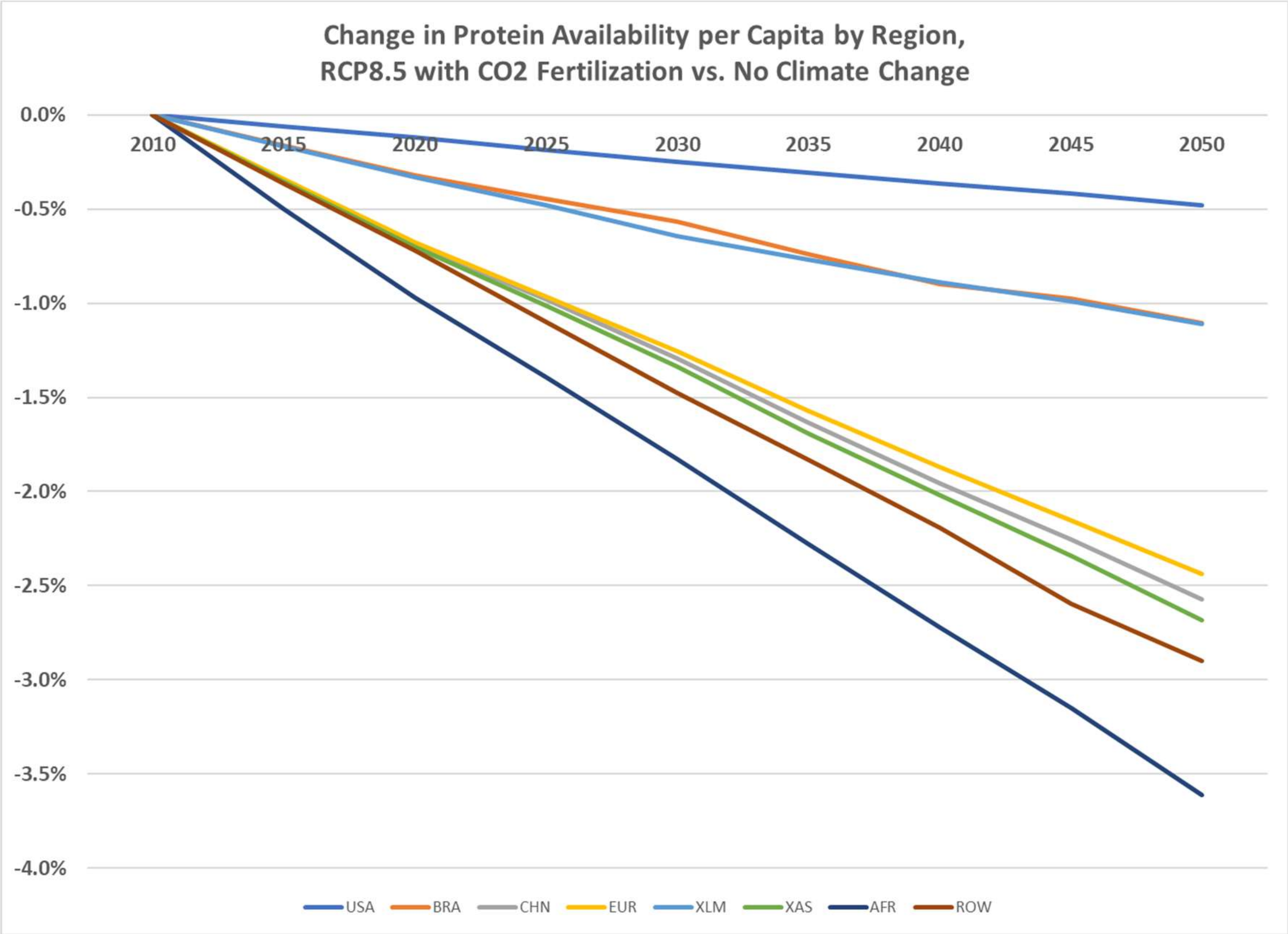
Nutrient content effects data

- There have been a number of experiments exploring the impacts of elevated CO2 levels on crop yields
- We relied upon data synthesized by Loladze (2014) and Myers et al. (2014)
- Used only data from free-air CO2 enrichment (FACE) or open-top chambers (OTCs) experiments, with the exception of vegetables (very important source of nutrients globally, but almost no FACE or OTC data for them)

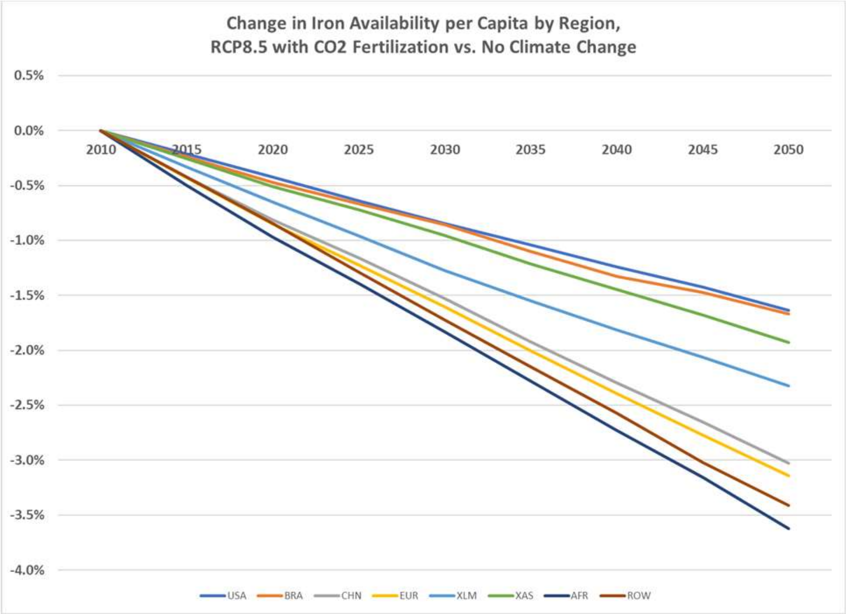


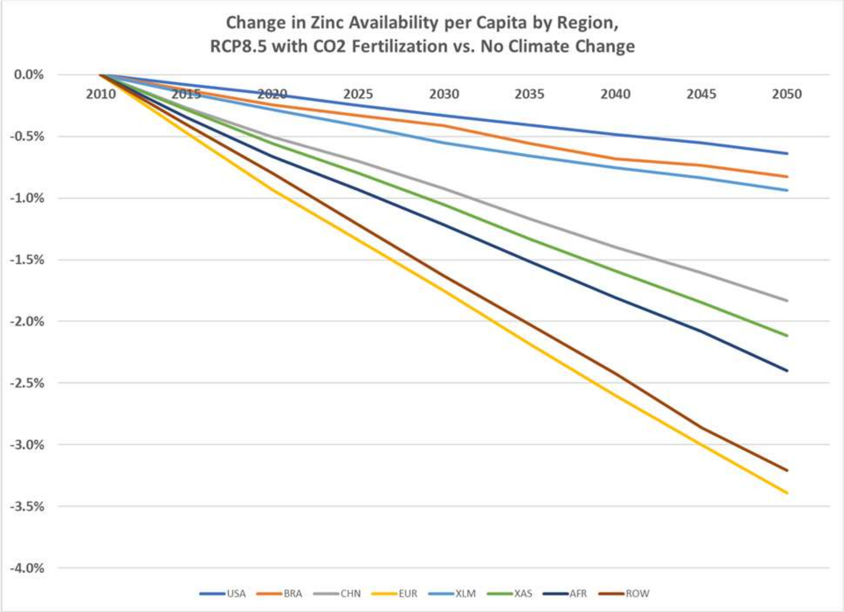
Source: Beach et al. (2019)

Change in protein availability under RCP8.5



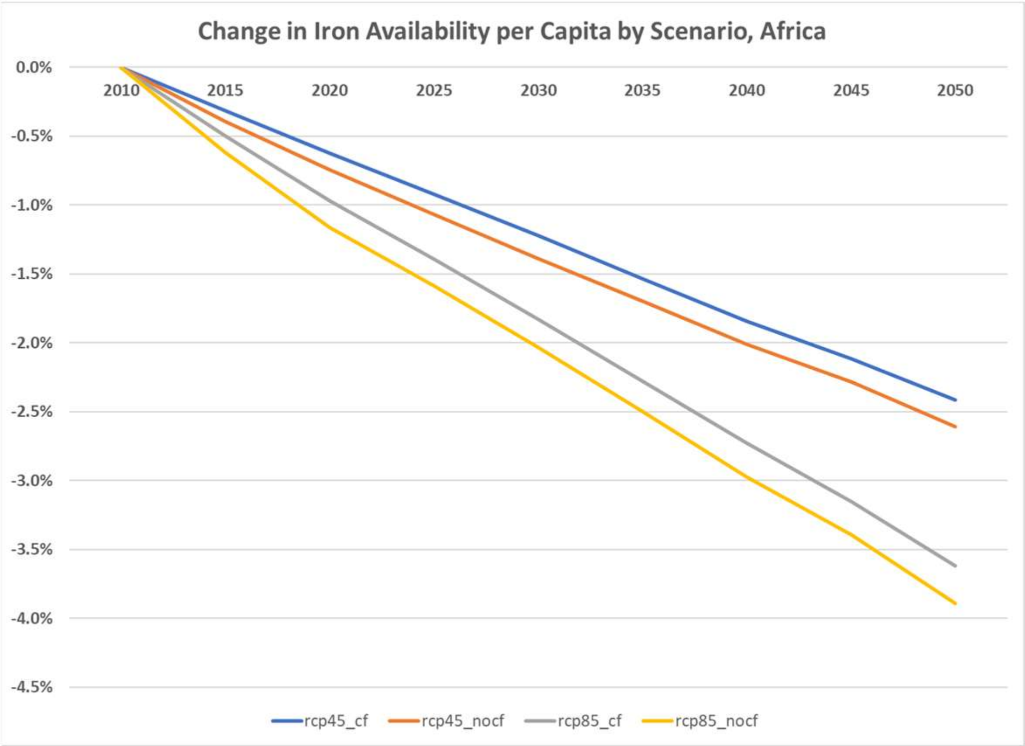
Effects on zinc and iron availability





- Generally similar magnitude of percentage reductions across nutrients
- Variation in ordering across regions between nutrients
- Reductions expected to have larger effects on nutrition in regions where many people are not receiving sufficient nutrients in the baseline

Comparing effects across climate scenarios



- Impacts vary across scenarios consistent with expectations
  - Nutrient availability is projected to decline more when CO2 fertilization is not reflected
  - RCP8.5 has larger impacts on nutrient availability than RCP4.5

Key factors influencing overall results

- Positive
  - Technological change and market adjustments under the REF scenario
  - Effects of CO_2 fertilization

- Negative
  - Changes in crop productivity from climate change
  - Changes in nutrient concentrations based on Loladze (2014) and Myers et al. (2014) parameters

- In general, countries and regions more dependent on plant-based sources of protein, iron, and zinc are more heavily impacted in this analysis
  - Larger impacts in South Asia, Middle East, and Sub-Saharan Africa than Latin America

Conclusions

- Multiple environmental and cultural factors influencing future access to protein, iron, and zinc
- This study is one of few to capture projections of future markets, climate change impacts on crop productivity, and changes in nutrient content under elevated CO_2 levels simultaneously
  - The exogenous yield shocks estimated are relatively small
- Presents a more complete picture of global food security in the context of future climate change
- Rising GHG concentrations expected to slow progress of improvements in global nutrition with disproportionately negative effects on areas currently suffering from deficiencies of protein, iron, and/or zinc such as the Middle East and North Africa, Sub-Saharan Africa, and South Asia
- While effects on nutrient content are not typically included in studies of climate change impacts on food and agriculture, we find they account for the majority of negative impacts in these scenarios

Future research

- Explore alternative climate change scenarios
  - Latest earth systems model results (CMIP6), which suggest a greater climate sensitivity to emissions
- Include effects on poultry, livestock, and fisheries
- Examine impacts of short-term disruptions due to extreme events
- Explore distributional impacts within populations
  - Impacts by age, sex, and socioeconomic status
- Extend analyses to quantify the potential health impacts associated with changes in nutrient availability
- Analyze impacts of environmental policies on nutrient availability