Sofia Perez

ENSC/GEOG 315

April 29, 2020

Dr. Gee & Dr. Labosier

Introduction and Description of Scientific Mechanisms

The impact of climate change on nutrition is a topic that is especially relevant when discussing future negative occurrences impacting living organisms. The mechanism of climate change that relates most directly to nutrition is increased concentrations of atmospheric carbon dioxide which ultimately leads to a rise in dietary deficiencies. For example, foods such as wheat, rice, and soybeans have been found to exhibit decreased concentrations of iron and zinc when exposed to higher levels of carbon dioxide (Kellie, 2015). This is especially concerning because 2-3 billion people depend on crops such as these for their iron and zinc intake (Ziska, 20160).

CO2 increase in the atmosphere is a well-known driver of climate change and increasing temperatures caused by various forms of pollution such as the burning of fossil fuels, emission of greenhouse gases, and more (NASA, 2020). When CO2 levels rise between 540 and 960 ppm due to pollution, protein concentrations in crops are likely to decline (Ziska, 2016). Micro and macroelements including iron, zinc, calcium, magnesium, copper, sulfur, phosphorus, and nitrogen will decline in staple crops (Ziska, 2016). Carbohydrate contents like starches and sugars will in turn, increase (Ziska, 2016). While CO2 does stimulate plant growth, it reduces nutritional value. The science behind these impacts is that the more CO2 a plant has, the less proteins it needs for photosynthesis, causing a reduction of those essential nutrients (Ziska, 2016). Furthermore, a rise in CO2 causes an increase in carbohydrate buildup in plant tissue which dilutes other minerals and nutrients (Ziska, 2016). This also reduces a plant's need for water resulting in fewer nutrients to be taken in through the roots in the form of water and thus a less nutritious food source (Ziska, 2016).

Supporting Scientific Data

The US Global Change Research Program published datasets which were a compilation of research from a variety of sources. Figure 1 focuses on protein concentrations in wheat flour and Figure 2 displays the concentration of essential minerals in a variety of crops at a ppm of 689 (Ziska, 2016). Ppm, or parts per million is the ratio of the quantity of CO2 to other gases in the atmosphere.

In Figure 1, as carbon dioxide levels rise, protein concentrations fall. Carbon concentrations on the graph start at the beginning of the last century at 293 ppm and increase to 385 ppm in 2008 then rise to a 715 ppm projection by 2100 as predicted by RCP, representative concentration pathway, 6.0. As the CO2 concentrations increase, it is demonstrated that the protein concentration in wheat flour grows smaller, beginning at 19% concentration and dropping steadily to a projected of 17.5% in 2100 (Ziska, 2016).

Figure 2 focuses on essential mineral concentrations in wild plants and crops as related to carbon dioxide increase. More specifically, the graph tracks concentrations of nitrogen, phosphorus, potassium, carbon, sulfur, manganese, magnesium, iron, zinc, copper, and ionome in barley, rice, wheat, soybean, and potato plants at a CO2 concentration of 689 ppm. The change in mean concentration as a percentage is in the negatives for every essential mineral with nitrogen at -16%, the most decline, and manganese at -4%, the least decline. Barley and potato plants are shown to be most impacted with a drop in protein concentrations of around -17% each (Ziska, 2016).

These datasets are the result of findings from multiple scientists that track the concentration of protein and essential nutrients in crops over time which is then compared with trends in CO2 concentration to draw conclusions. Datasets like these are then used to back up assertions such as the one that climate change makes crops less nutritious to consume because of higher CO2 concentrations. Higher temperatures are directly correlated to higher CO2 concentrations and global warming. These datasets both show increases in CO2 concentrations in ppm over time (Kellie, 2015). Thus both Figures 1 and 2 support the consensus that CO2 levels are rising and causing crops to become less nutrient and protein rich as a result.

Environmental Impacts

There are many environmental impacts catalyzed by increased concentrations of atmospheric carbon dioxide and decreased nutritional value in food. As previously discussed, an increased amount of atmospheric CO2 stimulates carbohydrate production and thus reduces the nutritional value of most staple plants (Ziska, 2016). However, this is not the only environmental impact related to the nutrition and safety of food.

Climate change can alter weeds, insects, and various fungal groups by making them more prominent which prompts farmers to use more pesticides on crops. This would make plants less nutritious and safe to consume (Ziska, 2016). Warmer temperatures and fluctuating weather patterns also increase the amount of pathogens present in food such as *salmonella* and *toxoplasma gondii* which pose serious human health risks (Ziska, 2016).

Heat waves also pose a serious threat to livestock as it increases susceptibility to disease, reduces fertility, and decreases milk production (EPA, 2017). The availability of food for livestock to graze would also be severely reduced due to droughts, especially for animals that primarily consume grains (EPA, 2017). Environmental impacts directly relate to societal impacts, and are the root of the majority of human health and nutrition issues.

Societal Impacts

There are a myriad of societal impacts brought about by climate change and the nutritional value of food. Some of the most concerning impacts however are related to international, human health, food distribution, and access. The most vulnerable groups of people are the poorest that already struggle with having access to foods with high nutritional value (EPA, 2017).

The loss of nutritional value and availability of food due to climate change along with the disruption of traditional transport pathways could cause serious ramifications globally (EPA, 2017). Not only would this damage the international economy and global market due to scarcity, depending on the region there could be varying effects based on population depending on the region(EPA, 2017). Due to climate change and an increase of carbon dioxide concentration in the atmosphere being a universal problem, there would likely not be very much humanitarian aid to countries hit the hardest by this food scarcity and global market collapse, as each country would have their own domestic issues to address.

Human health is one of the major areas where effects of poor nutrition in food will be seen (Ziska, 2016). These impacts can be observed in foodborne illnesses, nutritional deficiencies, and more. Due to the protein alteration in certain plants brought about by increased CO_2 levels, the prevalence of food allergies will continue to increase as it has been since 1997

(Ziska, 2016). For example, an increase of the protein Amb a 1 has been observed in plants which is most associated with ragweed pollen allergies (Ziska, 2016).

More serious issues are also caused by climate change such as an increase of foodborne pathogens by insect vectors. Due to rising temperature and humidity, the transmission rate of foodborne pathogens will increase causing illnesses such as norovirus, listeria, salmonella, and E. coli in humans (Ziska, 2016). While some of these foodborne pathogens cause unpleasant yet manageable side effects, others could potentially result in death or long-term consequences. Aside from illnesses caused by an increase of CO2, the significant loss in nutritional value causes an overall reduction of human health and can increase nutritional deficiencies (Ziska, 2016). Deficiencies in iron, zinc, vitamin A, and iodine are what is known as “hidden hunger” because it is a subtle deficiency yet one of the leading health risk factors in the world (Ziska, 2016). This negatively impacts metabolism, the immune system, cognitive development, and maturation.

These effects also pose a great risk when it comes to the distribution and availability of food, especially to at-risk impoverished populations. The increased risk for extreme weather events and quicker rates of food spoilage make fresh produce more difficult to distribute to areas, especially areas that are farther away from farms (Ziska, 2016). Thus access will be limited based on locality and due to the scarcity of fresh produce, wealthier populations will have more resources and thus better access (Ziska, 2016). For example, Hurricane Katrina caused increased food prices due to scarcity and natural disasters such as that will be more common due to climate change (Ziska, 2016).

The most at-risk populations are children, pregnant women, low income individuals, those with weak immune systems, and the elderly (Ziska, 2016). This raises a significant concern of decrease in population and the longevity of humans, especially if pregnant women are unable to get the nutrients they need which not only puts them at risk, but could cause their babies to have many long-term problems.

Mitigation Strategies for Global Climate Change

Mitigation strategies are less specialized to the impacts of climate change on nutrition, and focus more widely on climate change as an entity. Some of the most viable and well-known strategies for reducing emissions are reducing sources of emission by cutting back on the burning of fossil fuels and enhancing the sinks that hold emissions such as forests, oceans, and soil (NASA, 2020).

Some examples of mitigation strategies to reduce emissions are enhancements of technology for clean and renewable energy and imposing a taxation system based on emissions. Using solar, wind, hydroelectric, and geothermal sources of energy through technology such as solar panels is a common way to mitigate climate change through a reduction of emissions

(UCAR, 2009). More fuel efficient vehicles such as hybrid cars that use less fuel and emit less pollutants are also a popular mitigation strategy. Scientists also suggest cycling, walking, and using public transport as less expensive and easier ways to reduce emissions in the short-term (UCAR, 2009).

Examples of mitigation strategies to enhance carbon sinks include improving crop and grazing land in order to maximize carbon storage in soil by restoring cultivated soils, enhancing fertilizers to reduce N20 emissions, and dedicating energy crops to replace fossil fuels. Another method is improving afforestation, the establishment of new forests, and reforestation, replanting trees that have been previously cut down(UCAR, 2009).

Mitigation strategies that are market-based include cap-and-trade systems as well as carbon taxes. A cap-and-trade system is an approach in which the government sets an upper limit on emissions and emission allowances based on those distributed to companies (C2ES, 2018). This allowance is then used by companies to innovate in order to discover the most cost-effective and efficient ways to reduce emissions (C2ES, 2018). Carbon taxes are a set price that emitters have to pay for each ton of greenhouse gas released (C2ES, 2018).

Adaptation Strategies for Impacts on Nutrition

Adaptation strategies that are more specific to the loss of nutrition and yield of crops include developing stress resistant plants, such as drought resistant plants (Raza, 2019). Drought is a major reason why plant yields decrease and protein is not created to the normal extent in many staple crops. Other solutions include changing planting and harvesting times, rotating crops, implementing irrigation techniques, and changing cropping schemes (Raza, 2019).

Scientists have also been looking into ways to genetically modify plants through molecular and integrated breeding in order to force their adaptation to extreme weather. This is done through altering the genome, for example, one of the genome's specific to the ability to withstand high heat in wheat is 7D (Raza, 2019). If scientists could take these properties and enhance them in plants, they could scientifically make crops resistant to the impacts of climate change that cause them to lose nutritional value (Raza, 20190). As an example, farmers in Mali where most of their livelihood comes from agriculture implement adaptation strategies such as using organic fertilizers and rotating planting dates. It was concluded that their use of short-duration maize varieties was the most effective in producing a solid amount of food (Springer, 2020). The study on these farmers concluded that building farmer's ability to adapt increases food security in spite of climate change's negative impacts (Springer, 2020).

Conclusion

With consideration of all the adaptation and mitigation strategies presented, the best course of action is a mitigation strategy, as it is more effective to reduce the problem rather than attempt to adapt to the consequences of it. A strategy that holds a lot of promise in terms of effectiveness and longevity is market-based. Implementing carbon tax or cap and trade programs would reduce emissions at the lowest cost (C2ES, 2018). Eleven U.S. states and more than 50 other jurisdictions have successfully implemented market-based mitigation strategies successfully (C2ES, 2018). Furthermore, the United States already has 30 years of experience using these strategies in order to get rid of leaded gasoline and to reduce smog as well as acid rain (C2ES, 2018).

Putting a price on emissions based on the damages they cause gives businesses the flexibility to innovate and become more environmentally friendly in the best interest of their company. For example, in 1990 a cap-and-trade program was implemented to reduce acid rain and emissions were cut twice as fast as predicted at a low cost (C2ES, 2018). Carbon pricing policies such as the aforementioned not only reduce emissions, but create funding for the creation of new clean energy strategies (C2ES, 2018). More than $1 billion in revenue from one of these programs, RGI, have been put towards environmental initiatives (C2ES, 2018).

Overall, market-based strategies are multifaceted in the problems they address. They not only motivate companies by using incentives as well as punishments, they stimulate the economy with allowances. This causes innovation to occur more efficiently and cheaply than other adaptation strategies.

Figures 1-2

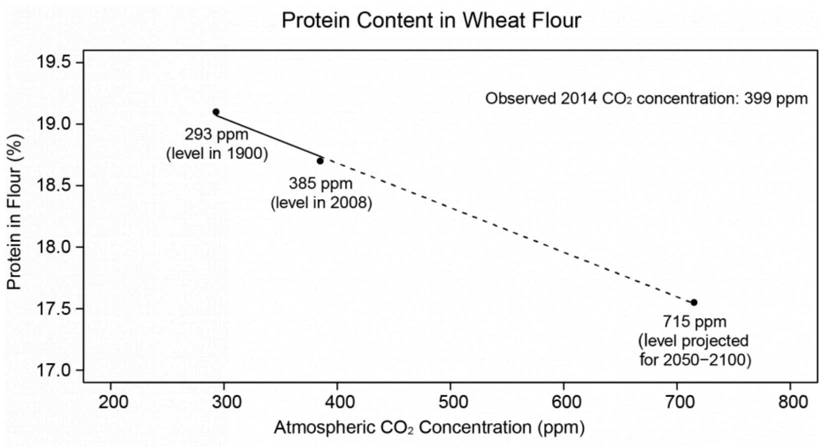

Figure 1. The measurements are in percentages for the protein concentrations in wheat flour and in parts per million for the atmospheric carbon dioxide concentration. The graph displays an inverse correlation between CO2 concentration in the atmosphere and protein concentration in plants. (Ziska, 2016)

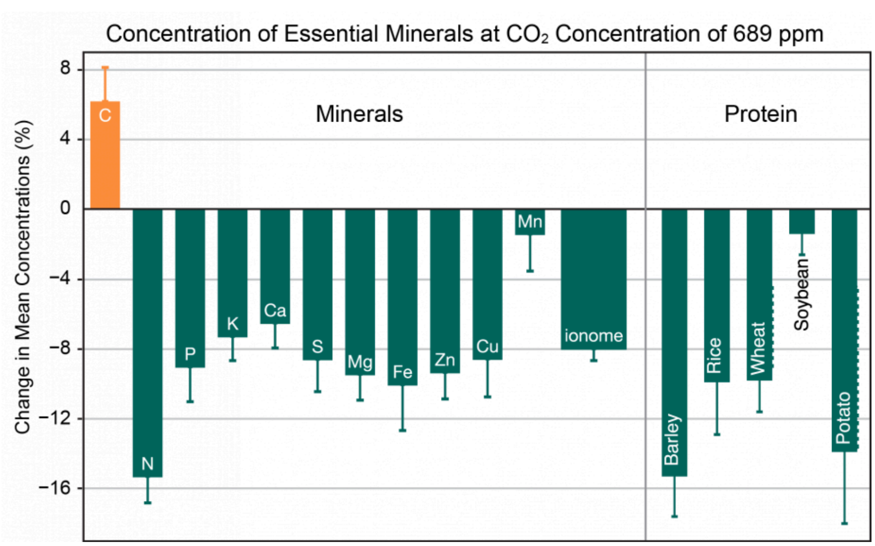

Figure 2. Concentration of essential minerals at CO2 concentration of 689 ppm. The figure displays an inverse correlation between atmospheric CO2 concentration and concentration of essential minerals. The measurements are by change in mean concentration by percent for essential minerals and parts per million for carbon dioxide concentration (Ziska, 2016).

References

Climate Change Adaptation and Mitigation. (2020, February 6). Retrieved April 20, 2020, from https://climate.nasa.gov/solutions/adaptation-mitigation/

Climate Mitigation and Adaptation. (2009). Retrieved April 20, 2020, from . https://scied.ucar.edu/longcontent/climate-mitigation-and-adaptation

EPA, (2017). *Climate impacts on agriculture and food supply.* Retrieved April 3rd, 2020 from https://archive.epa.gov/epa/climate-impacts/climate-impacts-agriculture-and-food-supply.html#main-content

Kellie. (2015). *Rising carbon dioxide levels will have an impact on food nutrition.* Retrieved March 20th, 2020 from http://environment.harvard.edu/news/faculty-news/rising-carbon-dioxide-levels-will-have-impact-food-nutrition

Market-Based Strategies. (2018, May 14). Retrieved April 29, 2020, from https://www.c2es.org/content/market-based-strategies/

NASA. (2020). *The causes of climate change.* Retrieved March 20th, 2020 from https://climate.nasa.gov/causes/

Raza, A., Razzaq, A., Mehmood, S. S., Zou, X., Zhang, X., Lv, Y., & Xu, J. (2019, January 30). Impact of Climate Change on Crops Adaptation and Strategies to Tackle Its Outcome: A Review. Retrieved April 21, 2020, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6409995/

Diallo, A., Donkor, E. & Owusu, V. *Climate change adaptation strategies, productivity and sustainable food security in southern Mali*. (2020). Retrieved April 29th, 2020 from https://doi.org/10.1007/s10584-020-02684-8

Ziska, Crimmins, A., Auclair, A., DeGrasse, S., Garofalo, J. F., Khan, A. S., … Walls, I. (2016). *Ch. 7: Food safety, nutrition.* Retrieved March 20th, 2020 from https://health2016.globalchange.gov/food-safety-nutrition-and-distribution