



Review Article

Impact of Climate Change on Food Systems: A Narrative Review

Wycliffe Tumwesigye^{1,2,*}, Abebe Aschalew², Wambi Wilber^{2,3}, Anteneh Destra²

¹Department of Economics and Environmental Management, Bishop Stuart University, Mbarara, Uganda

²African Centre of Excellence for Climate Smart Agriculture and Biodiversity Conservation, Haramaya University, Dire Dawa, Ethiopia

³National Agricultural Research Organization, Bulindi Zonal Agricultural Research and Development Institute, Hoima, Uganda

Email address:

wtum2012@gmail.com (W. Tumwesigye)

*Corresponding author

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Abstract: In recent years it has become clear that climate change is an inevitable process in many parts of the world and has a negative impact on agriculture and food systems particularly in Sub-Saharan African countries. Climate change involves variations in temperature and precipitation across the globe. The environmental changes associated with climate change have a significant impact on the food supply chains food environments and food systems in general. These changes affect food production, storage, processing, marketing, availability, promotion, affordability and quality along the food value chain. Consequently, climate change affects global food security and peoples' income especially, in developing countries where the predominance of rain-fed agriculture in much of these countries results in food systems that are highly sensitive to rainfall and temperature variability. The narrative review aimed at evaluation of published literature to understand the impact of climate change on food systems across the globe. Literature search from 2000-2019 was carried out using key words and key phrases in Google search Engine. Elsevier agriculture journals, JSTOR journals, Google Scholar, ResearchGate, Nature and Climate Change journals. More than 120 relevant publications were retrieved of which 44 were scrutinized and used for this publication. The study found that increased rainfall and temperature affect food availability, utilization, crop yields, food markets, food prices, consumption patterns and food insurance. The review recommended that all stakeholders should adopt relevant policies about climate change mitigation and adaptation options along different food value chains. This will enable farmers to produce sufficient food required to feed the projected 9.8 billion people by 2050 thus contributing to sustainable development goal number two: -End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

Keywords: Food Systems, Food Value Chain, Climate Change, Food Environment, Food Supply, Food Quality

1. Introduction

Climate change has significantly affected biodiversity, food systems and human health across the globe for the last four decades. "Climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer" [1]. A food system gathers all the elements (environment, people, inputs, processes, infrastructures,

institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes [2] and these are complex in nature [3]. Food systems affect climate change and climate change affect food systems. The two are interlinked and affect each other either negatively or positively. Both climate change and food systems are interlinked and affect each other at the same time. The effect begins from local to national, regional and finally amplifies to the global scale. All stakeholders need

to join hands to understand the complex system in order to benefit from it while mitigating the effect of climate change. Inaction and delays in mitigating and adapting to climate change can be catastrophic for food and agriculture sectors [5]. Food systems are influenced by social, economic, political, environmental contexts, and the human beings involved in the food chains. People include producers, information providers, policy makers and regulators, workers in health, forestry, trade, finance, companies and consumers [5]. Commercial food production and processing in all Industries utilizes fossil fuels which emits GHGs that contribute to climate change. Most of the GHGs come from developed countries that own majority of the food Industries, which provides the largest employment to their population. Likewise, developing countries also contribute a small percentage of GHGs from their food processing Industries [6]. Research show that agriculture contributes about 33% of global greenhouse gases emissions and climate change results into shortage of food stuffs leading into escalation of prices up to 226% in 2002 [7]. The entire food value chain is affected by climate change and vice versa and this has unfavorable consequences on humanity across the globe and the region at greatest risk of the impact of climate change is Africa [8]. The impact of climate change on food systems and be look at based on two aspects: - (i) food supply chains and (ii) food environments. Food supply chains (Figure 1) include food production, food storage and distribution, food processing and packaging, food retail and markets; while food environments include: food availability and physical access, food affordability, food promotion and advertising, and food quality and safety. These processes and practices may affect climate and climate may affect them but the extent to which the two affect each other is not well documented [9] hence need for this review.

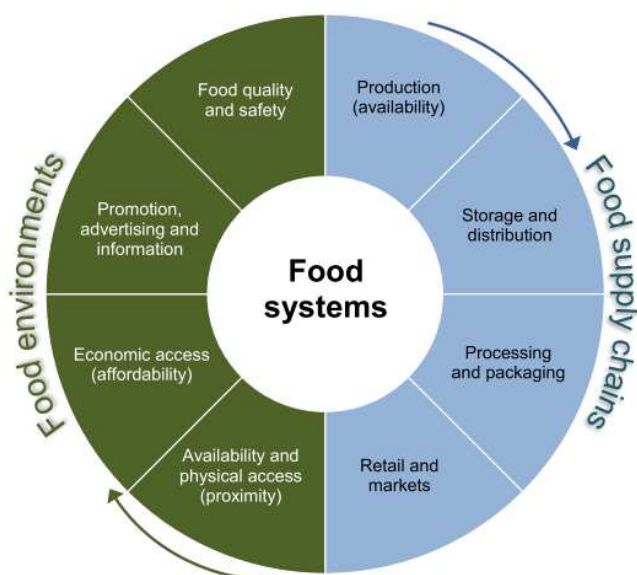


Figure 1. A simplified diagram of food system (source: HLPE, 2017).

Figure 1 shows all the stakeholders involved in the food system in any one environment across the globe. The pertinent question is how does climate change affect food supply chains

and food environments? The author will attempt to respond to this question based on scientific literature from global, Sub Saharan Africa and Ethiopia.

2. Methodology

A thorough literature search of published peer-reviewed journal papers was conducted for the years 2000-2019 using key words and key phrases in Google search Engine. Elsevier agriculture journals, JSTOR journals, Google Scholar, Research Gate, Nature and Climate Change journals. More than 120 relevant journal papers, conference proceedings, government reports, farmer groups report, FOA e-books, CGIAR reports, HLPE reports, policy briefs, published students' dissertations were retrieved of which 44 were scrutinized and used for this publication.

3. Global Impact of Climate Change on Food Systems

Climate change affects food systems at a global scale. Food systems include the growing, harvesting, processing, packaging, transporting, marketing, consumption, and disposal of food and food-related items. High average temperature and insufficient rainfall affects crop health and yield for the majority of the crops. Climate change has no boundary and therefore global warming affects both developed and developing countries though at varying intensities. Crop models projected reduction in corn yield of 127- 482.6 kg/acre by 2100 [10] and many other agricultural crops in in USA [11] thus affecting global food security. Similarly, wheat yield in Russia was predicted to decrease by 5-11% due to rainfall variations and temperature rise [12], and wheat being the major cereal in the country, its yield decrease has a significant effect on peoples' livelihood. Increased temperature from 0.02-0.07°C per year was reported to have a negative effect on barley and millet yield in mountainous region of Nepal [13]. Likewise, United States Department of Agriculture points out that increase in atmospheric CO₂, rising temperature and changing rainfall patterns affects agricultural productivity [7]. Previous studies show that increased CO₂ concentration in the atmosphere has a positive effect and increased temperature a negative effect on maize yield in India [14]. Erratic rainfall in Swaziland resulted into decreased maize production in 1990 to 2009 [15] and corn and soya bean yield reduced in the USA [11] and the global temperature increase of +2°C is predicted to have negative affect on the four major global foods (wheat, rice, maize and soya bean) production across the globe, which will negatively affect global food security [16]. Annual decrease in soya bean and corn yield was predicted to be up \$220 million in 2009 alone in China because of climate change [17]. Severe drought and decreased rainfall was reported to reduced maize yield in Swaziland [15]. Increase in maximum and minimum temperature of 1.45°C and 1.26°C respectively, and increase in precipitation of 2.5mm was reported to increase *durum*

wheat production in eastern Algeria [18]. Additionally, European researchers predicted that climate change is likely to affect corn supply and increase the demand thus increasing the prices which affects livestock sector in the region [19] and increased global warming have a negative effect on cereals production [20]. Slight increase in temperature poses stress on soya bean resulting into reduced yield in Myanmar. Similar studies made in Asia predicted that maximum temperature decreases wheat yield thus affecting people's livelihood [21].

4. Impact of Climate Change and Food Production in Sub-Saharan Africa

The impact of climate change is more pronounced in developing countries than developed countries due to limited resources for adaption and mitigation capacity. In addition to these, the predominance of rain-fed agriculture in much of developing countries particularly Sub-Saharan African countries results in food systems that are highly sensitive to rainfall and temperature variability and change. Climate change affects farmer's choice of crops by replacing high revenue crops like maize with heat-tolerant millet that earns less income to the farmers in Ghana [22] and this has a significant effect on annual household income. Maize production was predicted to decrease due to climate variations in Kenya [23] and this has a negative effect on stallholder farmers' household income thus enhancing poverty. Insufficient and too much rain was reported to influence crop production due to increased diseases for various crops in Zimbabwe [24]. Fall army worm has spread to many areas where it has not been reported before due to increased temperatures in different regions. High temperature and reduced rainfall was predicted to reduce banana yield up to 46%, which is the most staple and income generating food stuff in Uganda [25] thus enhancing food insecurity and household poverty. Crop yields for maize, wheat, rice, peas, groundnuts, banana, Irish potato, and cassava were predicted to positively follow rainfall patterns in the country for 40 years period [26] and its reduction?? decreased crop production. Other studies showed that increased temperature and CO₂ concentration was predicted to have a positive effect on soya bean yield in Mozambique [27]. Similarly, drought and extreme weather events were reported to result into crop failure and reduced maize yield in Tanzania [26, 27]. Based on previous studies done in SSA, crop yield for most crops, is negatively affected by reduced rainfall and increased temperature.

5. Impact of Climate Change on Food Production in Ethiopia

Impact of Climate change on crop yield is also reported in Ethiopia. The yield of most crops are predicted to decrease in the Sahel region countries that include Burkina Faso, Ethiopia, Kenya, Senegal, Zambia and Zimbabwe due to decreased rainfall and increased temperature with the exception of maize that depicted a positive trend with increased temperature [30]. Teff, the major staple food for Ethiopians was predicted to

change distribution and decrease yield due to increased temperature and erratic rainfall thus affecting food security for the country. Yumbya et al (2014) predicted that teff production will severely drop causing a loss of US\$ 651 by 2050 if rainfall and temperature keep changing as observed in 2014. This will exacerbate poverty and enhance food insecurity in the country, if no mitigation and adaptation strategies are not put in place for the smallholder farmers. Additionally, climate change is predicted to reduce crop production resulting 8% loss of Ethiopian GDP [32]. Some foods crops such as millet require sufficient sunlight for drying before storage. In areas where there is high and consistent rainfall during the harvest period, millet seeds will change color, scent and some germinate leading to yield losses and increased waste thus affecting food security in the region. A survey of 372 farmers in the Amhara Region revealed that climate change will result into flooding, decreased rainfall and increased temperature in the current and future decades [33].

6. Climate Change, Food Storage and Distribution

Food storage and distribution affected by climate change and interchangeably. Fresh fruits and vegetables need to be stored in large refrigerators and transported by airplanes to the buyers in different countries. This contributes to the CFCs that deplete Ozone layer hence contributing to climate change and global warming. Similarly, food transport using trucks and large vehicles requires fossil fuels that contributes to climate change during transport. This is worsened by using old vehicles that consume a lot of petrol and diesel due their bad mechanical conditions. It is recommended to use new vehicles in order to reduce fossil fuel consumption thus reducing climate change impact to the environment. Studies show that many supply chains enhance climate the impact of climate change [34]. Decreased food production resulting from climate variations increase food demand thus escalating market prices [35]. Food pre- production activities such as developing and delivering fertilizers, seeds, feeds, farm implements, irrigation systems, information and research and development; production of crops, fish, and livestock; post-production activities like storage, packaging, transportation, manufacturing and retail; consumption activities either in homes or dining establishments; and waste and disposal that occurs throughout the system all contribute to climate change and can be used as mitigation measures and to climate change [7].

7. Climate Change, Food Processing and Packing

Commercial food processing and packing is done in industries. Food packing is reported to contribute 1.27% of UK GHGs [36]. Food waste and associated packaging is reported to contribute 50% of the greenhouse gases to the environment [37]. Studies in Sweden show that Alcohol

consumption in the population of the country contributes 52 kg CO₂e to 202 kg CO₂e per person per year [38]. The contribution to global warming increases when alcohol processing and parking is included in the calculation. Due to limited capital, most African countries use non-degradable packing materials which spend decades in soils hence affecting water infiltration and crop productivity. There is limited technology to process, recycle and re-use food wastes and this together with negative attitude of the people culminated into increased soil degradation and global warming. Consequently, food production and food security are undermined in Africa.

8. Climate Change and Food Markets

Climate change influences food markets at both retail and wholesale across the globe. Climate change decreases crop yields and increases prices of agriculture products. Xie *et al* (2018) noted that decreased wheat production in China increased consumer prices hence rising the market prices and affecting farmers livelihood. Similarly, climate trends, domestic and international market dynamics, and domestic policy changes have been reported to affect Mexico's maize sector [40] and higher global temperature was predicted to result into poor food stock returns in China [41]. Greater levels of climate change are reported to have greater socioeconomic impact at the global level by reducing economic gains [42] and high temperature enhance crop prices and price volatility [43]. Increased temperature and rainfall were reported to have both positive and negative impact on crop product markets in different regions of Nepal. This ranged from increased production costs, increased prices, changes in product quality, changes in consumption patterns and shifting of plantation season [44].

9. Conclusion

Based on this review, climatic conditions mainly temperature and rainfall are changing in most part of the world. Developing countries are badly affected because of limited capacity (both financial and technical) to adapt or mitigate the impact of climate change in the food value chains. SSA countries have majority of countries with the highest number of malnourished people who need emergency help from World Food Program, some due to civil wars and others due to limited suitable land for food production. In most households, agriculture is carried out by women and men and children wait to eat the already prepared food from the sweat of women. This has increased food and nutritional insecurity in many households resulting into several associated diseases. Effect of climate change on food systems is a complex and multidisciplinary challenge that affects all food value chains. As such, complex and multidisciplinary solutions involving all stakeholders (researchers, policy makers, private sector, national government, international agencies, FAO, World Bank, donors, World Food program, men, women and

youth) should be involved, at local, national, regional and global levels to discuss the way forward for sustainable food production amidst climate change and variability in the present and future centuries. Climate affects both the food chain and food environment; it's a multidisciplinary problem and requires multidisciplinary approach to design and implement possible options, hence it requires combined efforts from all stakeholders at all levels.

10. Recommendations

Food wastage should be avoided at all levels of food value chain in all countries across the globe. Developed countries as producers of most food should help developing countries by supplying them with food and avoid wastage to enhance food security in less developed countries.

Green food production and economy should be enhanced across all sectors of food production. This will minimize emission of major greenhouse gases such as CO₂, Nitrous Oxide and Methane and reduce climate change impact across the globe.

To attain food security by 2050, it is recommended that all stakeholders adopt appropriate policies about climate change mitigation and adaptation options along the entire food chains across the globe. This will enable farmers produce sufficient food required to feed the projected 9.8 billion people by 2050 thus contributing to sustainable development goal number two: -End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

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References

- [1] UNFCCC, "United Nations Framework Convention on Climate Change Working Group II: Climate change impacts, adaptation and vulnerability," *United Nations Framework Conv. Clim. Chang.*, no. February 2011, p. 7, 2011.
- [2] HLPE, "HLPE Report # 12 - Nutrition and food systems," vol. Report 12, no. September, 2017.
- [3] L. Chase and V. Grubinger, "Introduction to Food Systems," *Food, Farms Community Explor. Food Syst.*, 2014.
- [4] J. A. L. Paul P. S. Teng, Mely Cabellero-Anthony, Goh Tian, "IMPACT OF CLIMATE CHANGE ON FOOD PRODUCTION: OPTIONS FOR IMPORTING COUNTRIES," p. 20, 2015.

- [5] M. T. Niles *et al.*, "Climate change & food systems: assessing impacts and opportunities," no. April, p. 82, 2017.
- [6] N. Höhne *et al.*, *Contributions of individual countries' emissions to climate change and their uncertainty*. 2010.
- [7] J. Hatfield *et al.*, "Climate Change and Agriculture in the United States: Effects and Adaptation," *USDA Tech. Bull. 1935*, p. 186 pages, 2013.
- [8] M. Parry, C. Rosenzweig, and M. Livermore, "Climate change, global food supply and risk of hunger," *Philos. Trans. R. Soc. B Biol. Sci.*, vol. 360, no. 1463, pp. 2125–2138, 2005.
- [9] S. S. Myers *et al.*, "Climate Change and Global Food Systems : Potential Impacts on Food Security and Undernutrition," no. February, pp. 259–278, 2017.
- [10] E. Osei and S. H. Jafri, "Climate Change Impacts on Corn and Soybean Production in Iowa State.," 2017.
- [11] P. C. Westcott, M. Jewison, W. Agricultural, and O. Board, "2012 corn production prospects started out very promising : Early corn plantings typically beneficial for yield prospects 2012 production prospects started out very promising :," no. July, pp. 1–30, 2012.
- [12] L. Saikkonen and M. Ollikainen, "Impact of Climate Change on cereal grain production in Russia Impact of Climate Change on cereal grain production in Russia," no. September, 2014.
- [13] S. Poudel and R. Shaw, "The Relationships between Climate Variability and Crop Yield in a Mountainous Environment: A Case Study in Lamjung District, Nepal," *Climate*, vol. 4, no. 1, p. 13, 2016.
- [14] A. Abebe, H. Pathak, S. D. Singh, A. Bhatia, R. C. Harit, and V. Kumar, "Agriculture, Ecosystems and Environment Growth, yield and quality of maize with elevated atmospheric carbon dioxide and temperature in north – west India," *"Agriculture, Ecosyst. Environ."*, vol. 218, pp. 66–72, 2016.
- [15] M. T. Masarirambi and T. O. Oseni, "Effect of Climate Change on Maize (Zea mays) Production and Food Security in Swaziland," *J. Agric. Environ. Sci.*, vol. 11, no. 3, pp. 385–391, 2011.
- [16] K. Lumpur, "Four crops feed the world The world is getting hotter The major crops alone cannot feed a hotter world The United Nations Sustainable Development Agenda (SDA 2030) Global Action Plan for Agricultural Diversification (GAPAD) Crops For the Future (CFF)," 2016.
- [17] S. Chen, X. Chen, and J. Xu, *Impacts of Climate Change on Corn and Soybean Yields in China*. 2013.
- [18] M. Zargar, N. Rebouh, E. Pakina, A. Gadzhikurbanov, M. Lyashko, and B. Ortskhanov, "Impact of climate change on cereal production in the highlands of eastern Algeria," *Res. Crop.*, vol. 18, no. 4, 2017.
- [19] S. Frank, H.-P. Witzke, A. Zimmermann, P. Havlik, and P. Ciaian, "Climate Change Impacts on European Agriculture : a Multi Model Perspective," pp. 1–15, 2014.
- [20] J. Höhn, "Impact of global warming on European cereal production.," *CAB Rev. Perspect. Agric. Vet. Sci. Nutr. Nat. Resour.*, vol. 9, no. 022, 2014.
- [21] S. Ali, Y. Liu, M. Ishaq, T. Shah, and A. Ilyas, "Climate Change and Its Impact on the Yield of Major Food Crops : Evidence from Pakistan," vol. 1, pp. 1–19, 2017.
- [22] P. M. Etwire, D. Fielding, and V. Kahui, "The impact of climate change on crop production in Ghana: A Structural Ricardian analysis," *Univ. Otago Econ. Discuss. Pap. No. 1706*, vol. 2293, no. 1706, p. 34P, 2017.
- [23] N. Ruth, "University of Nairobi ON MAIZE PRODUCTION USING GIS : CASE STUDY OF," no. August, 2017.
- [24] R. Kasimba, "Impacts of climate change on crop production practices among small holder farmers in Gurube district, Zimbabwe," 2012.
- [25] G. Sabiiti, J. M. Ininda, L. Ogallo, F. Opijah, and A. Nimusiima, "Empirical Relationships between Banana Yields and Climate Variability over Uganda," no. 3, pp. 3–13, 2016.
- [26] K. Mikova, E. Makupa, and J. Kayumba, "Effect of Climate Change on Crop Production in Rwanda Effect of Climate Change on Crop Production in Rwanda," no. January, 2015.
- [27] M. Talacuece, F. Justino, R. Rodrigues, M. Flores, J. Nascimento, and E. Santos, "Modeling of Soybean under Present and Future Climates in Mozambique," *Climate*, vol. 4, no. 2, p. 31, 2016.
- [28] P. Mbanguka, L. Team, and A. Inades, "Climate Change in Tanzania," 2018.
- [29] B. M. Msongaleli, "Assessment of the impact of climate variability and change on rainfed cereal crop productivity in central Tanzania," 2015.
- [30] Inoussa Boubacar, "The Effects of Drought on Crop Yields and Yield Variability in Sahel." University of Wisconsin-Stout, pp. 1–30, 2010.
- [31] J. Yumbya, M. D. B. I. J. D. E. Vaate, D. Kiambi, F. Kebebew, and K. P. C. Rao, "GEOGRAPHIC INFORMATION SYSTEMS FOR ASSESSMENT OF CLIMATE CHANGE EFFECTS ON TEFF IN ETHIOPIA.," *African Crop Sci. J.*, vol. 22, no. 4, pp. 847–858, 2014.
- [32] A. W. Yalew, G. Hirte, H. Lotze-campen, and S. Tscharaktschiew, "Climate Change, Agriculture, and Economic Development in Ethiopia," 2018.
- [33] M. Teshome, "Perceived Impact of Climate Change on Crop Yield Trend in Denbia Woreda of Amhara Region, Northwest Ethiopia," vol. 2, no. 7, 2017.
- [34] T. K. Dasaklis and C. P. Pappis, "Supply chain management in view of climate change : An overview of possible impacts and the road ahead," no. September 2013.
- [35] FAO, "CLIMATE CHANGE: IMPLICATIONS FOR FOOD SAFETY," *African Crop Sci. J.*, vol. 12, no. September, pp. 1–30, 2017.
- [36] M. Local and F. Work, *Local food and climate change*.
- [37] L. S. Dilkes-Hoffman, J. L. Lane, T. Grant, S. Pratt, P. A. Lant, and B. Laycock, "Environmental impact of biodegradable food packaging when considering food waste," *J. Clean. Prod.*, vol. 180, pp. 325–334, 2018.
- [38] E. Hallström, N. Håkansson, A. Åkesson, A. Wolk, and U. Sonesson, "Climate impact of alcohol consumption in Sweden," *J. Clean. Prod.*, vol. 201, pp. 287–294, 2018.

- [39] W. Xie, J. Huang, J. Wang, Q. Cui, R. Robertson, and K. Chen, "China Economic Review Climate change impacts on China's agriculture: The responses from market and trade," *China Econ. Rev.*, no. November, pp. 1–13, 2018.
- [40] H. Eakin *et al.*, "Anthropocene Agricultural change and resilience: Agricultural policy, climate trends and market integration in the Mexican maize system," *Biochem. Pharmacol.*, vol. 23, pp. 43–52, 2018.
- [41] H. Hong, F. Weikai, and J. Xu, "Climate risks and market efficiency," *J. Econom.*, vol. 208, no. 1, pp. 265–281, 2019.
- [42] K. Matsumoto, "Climate change impacts on socioeconomic activities through labor productivity changes considering interactions between socioeconomic and climate systems," *J. Clean. Prod.*, article in press, 2018.
- [43] W. Thompson *et al.*, "Automatic Responses of Crop Stocks and Policies Buffer Climate Change Effects on Crop Markets and Price Volatility," *Ecol. Econ.*, vol. 152, no. February, pp. 98–105, 2018.
- [44] A. K. Barreto, J. Merz, N. Clot, and T. Hammer, "Climate Changes and Their Impact on Agricultural Market Systems: Examples from Nepal," *Sustainability*, pp. 1–16, 2017.