
*Journal of Scientific Research & Reports*

***18(2): 1-9, 2018; Article no.JSRR.39661***
***ISSN: 2320-0227***

# Agriculture System and Climate Change: A Systematic Literature Review

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Author RI contributed in collecting the literature related with the writing theme and selected papers which have been identified based on the parameter and co-author conducted method of systematic review. Both authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/JSRR/2018/39661
Editor(s):
(1) Rahul Kumar Jaiswal, National Institute of Hydrology, WALMI Campus, Bhopal, India.
Reviewers:
(1) Lawal Mohammad Anka, Nigeria.
(2) Sylvester Odiana, University of Benin, Nigeria.
(3) Isaac Kojo Arah, Ho Technical University, Ghana.
Complete Peer review History: http://www.sciencedomain.org/review-history/23333

***Review Article***

***Received 26th November 2017***
***Accepted 20th February 2018***
***Published 24th February 2018***

## ABSTRACT

Agriculture system is still taking the high risk in order to feed the people around the world. Climate is changing now and will have the big problem of agriculture productivity. Feeding people in the future is not easy. We need to take some actions regarding climate change. Objectives of this paper were addressed by performing a systematic review of both academic, scientific and grey literature elaborating on food security and climate change. This paper discussed that it is necessary to generate evidence that can show how and why climate vulnerability is a problem requiring integration into development decisions. In addition, global climate impact analysis should "come down to earth" and be validated at the local level, accounting for spatial variability, possible adaptation responses, local resource availabilities and constraints, and socio-economic determinants. We conclude with a recommendation for a specific action to enable farmers in the tropics and subtropics to address climate variability and extreme events.

*Keywords: Food; farmers; productivity; adaptation.*

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## 1. INTRODUCTION

Now more than ever, the observed and anticipated impacts of climate change are recognized as a development challenge. Higher temperatures, changing precipitation patterns, more frequent and/or extreme events, and rising sea levels will change the distribution of water resources, the productivity of food systems, the spread of human and animal diseases, as well as strain critical infrastructure and networks, disrupting ecosystems, livelihoods and economies around the world. Climate change is a significant driver of change for food security [1] because it's threatens food production and its stability as well as other aspects of food system such as storage, food access and utilization [2]. For over 30 years it has been generally accepted that trends towards increasing temperatures and changing precipitation patterns in agricultural areas will have major, generally negative, implications for cropland productivity and will increase stress on global food production in the coming decades.

The food security concept was therefore defined and delimited, after which the different pathways leading to food security were identified. The FAO distinguishes four aspects of food security: food availability at local or national level, food access (consumption) at household and individual level, the stability of food access over time, and food utilisation resulting in a good nutritional status – the ultimate goal [3]. All these comprise four key dimensions of food supplies: availability, stability, access and utilization. According to [4] the first dimension relates to the availability of sufficient food, i.e., to the overall ability of the agricultural system to meet food demand. Its subdimensions include the agro-climatic fundamentals of crop and pasture production (2) and the entire range of socio-economic and cultural factors that determine where and how farmers perform in response to markets. The second dimension, stability, relates to individuals who are at high risk of temporarily or permanently losing their access to the resources needed to consume adequate food, either because these individuals cannot ensure *ex-ante* against income shocks or they lack enough ‘‘reserves’’ to smooth consumption *ex-post* or both. The third dimension, access, covers access by individuals to adequate resources (entitlements) to acquire appropriate foods for a nutritious diet. Finally, utilization encompasses all food safety and quality aspects of nutrition; its subdimensions are therefore related to health, including the sanitary conditions across the entire food chain.

Robust trends in global agricultural productivity are emerging from the growing literature on climate impact assessments, with clear indications of differential responses across regions. While climate change effects on agriculture will be felt everywhere, some regions will be more negatively affected than others, while some regions may benefit from climate warming – up to a point. Convergent results are showing negative effects on food supply in tropical zones but some positive effects in high-latitude regions. Moderate warming may benefit crops in the mid and high latitudes in the short term. However, any warming in seasonally dry and low-latitude regions would decrease yields [5].

Building awareness is a critical first step towards generating enough interest on the part of decision-makers to demand climate vulnerability information. It is necessary to generate evidence that can show how and why climate vulnerability is a problem requiring integration into development decisions. In addition, global climate impact analysis should “come down to earth” and be validated at the local level, accounting for spatial variability, possible adaptation responses, local resource availabilities and constraints, and socio-economic determinants. The robust and reliable evidence is critical to the development of policies to address climate impacts on agriculture and food. When used effectively, evidence can be used to guide decisions on policy, highlight options for policy action and also identify areas where insufficient evidence currently exists. However, the interaction between that generating evidence (climate science) and the needs of those developing policy is not straightforward.

This paper objective was addressed by performing a systematic review of both academic, scientific and grey literature elaborating on food security and climate change. This paper presents the synthesis that resulted from this review as well as the researcher's critical appraisal of the state of the research field. In this review, we consider the possible impacts of changes in climate variability on food system which effects on agriculture food production and farming system as well in terms of crop growth and crop yield under different future climate conditions. We then briefly review some of the major impacts of climate variability on agricultural systems at a range of scales. We then present some new analysis that seeks to link increases in climate variability with increasing food insecurity in the future, before considering the ways in which people deal with climate variability and vulnerability and how they may adopt in the coming decades. We conclude with a recommendation for a specific action to enable farmers in the tropics and subtropics to address climate variability and extreme events.

## 2. CLIMATE VARIABILITY AND ITS IMPACT OF THE FUTURE FARMING SYSTEM

Agriculture is a diverse economic sector that produces food, fibre, material and energy commodities. In most regions, agricultural productivity is directly dependent on weather and climate conditions – more so than any other major economic sector. The agriculture sector also serves a variety of purposes beyond primary production, including nature and resource conservation, recreation, greenhouse gas (GHG) mitigation and various other so-called ecosystem services [6].

Agriculture system is of central importance to society, and climate change is a major concern for agricultural systems and food security. Due to the rapid expansion of international markets, agriculture has become an increasingly globalized sector over the course of the 20th century. Shocks to production in individual countries resulting from policy or climate change can affect prices across the globe, as demonstrated, for example, during the food price spikes in 2008 and 2010 [7,8]. Agricultural production is directly dependent on weather conditions, which – together with soil conditions – determine the conditions for plant growth. Weather conditions can be managed to some extent by, for example, using irrigation to compensate for deficient rainfall or timing the cropping season to avoid adverse weather conditions (dry, hot, cold). Climate change is inevitably resulting in changes in climate variability and in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events [9]. Changes in climate variability and extremes can be visualized in relation to changes in probability distributions, shown in Fig. 1.

From the graphic above we can explain that the top panel shows a shift of the entire distribution towards a warmer climate (a change in the mean), a situation in which more hot (and record hot) weather would be expected, along with less cold (and record cold) weather. The middle panel shows a change in the probability distribution of temperature that preserves the mean value, but involves an increase in the variance of the distribution: on average, the temperature is the same, but in the future, there would be more hot and cold (and record hot and cold) weather. The bottom panel shows the situation in which the temperature probability distribution preserves its mean, but the variability evolves through a change in asymmetry towards the hotter part of the distribution; here, we would see near constant cold (and record cold) weather, but increases in hot (and record hot weather). According to the Intergovernmental Panel on Climate Change [10] "all aspects of food security are potentially affected by climate change, including food access, utilization, and price stability". While estimated impacts differ between regions, some projects suggest yield losses of more than 25 percent for the period 2030 to 2049 compared to the late 20th century [10].

### 2.1 Impacts on Food Production and Availability of Farming System

Changes in extremes have been observed since 1950, and there is evidence that some of these changes are a result of anthropogenic influences, although attribution of single extreme events to these influences remains challenging [10]. Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes. It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20$^{th}$ century [10]. Changes in temperature and precipitation associated with continued emissions of greenhouse gases will bring changes in land suitability and crop yields. In particular, the Intergovernmental Panel on Climate Change (IPCC) considers four families of socio-economic development and associated emission scenarios, known as Special Report on Emissions Scenarios (SRES) A2, B2, A1, and B1 [11]. Of relevance to this review, of the SRES scenarios, A1, the ''business-as-usual scenario,'' corresponds to the highest emissions, and B1 corresponds to the lowest. The other scenarios are intermediate between these two. Depending on the SRES emission scenario and climate models considered, global mean surface temperature is projected to rise in a range from 1.8°C (with a range from 1.1°C to 2.9°C for SRES B1) to 4.0°C (with a range from 2.4°C to 6.4°C for A1) by 2100 [5]. Moreover, findings from the Massachussets Institute of Technology's JPM model, published in 2009, describe a mean surface warming in 2091–2100 of 4.1°C to 5.1°C relative to 1990, compared to 2.4°C in their previous 2003 study, and a 90 percent probability of surface warming of between 3.5 to 7.4 degrees [12] Increased precipitation intensity and variability are projected to increase the risks of flooding and drought, while higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate water pollution. By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double that with decreasing water stress. While quantitative projections of changes in precipitation, river flows and water levels at the river-basin scale are uncertain, it is very likely that hydrological characteristics will change in the future [13]. [14] Use observational data to analyse how soon the world will experience the onset of permanently higher temperatures. They project that many tropical regions in Africa, Asia and South America will experience unprecedented summer heat by 2040. The most immediate increase will occur in the tropics, with up to 70 percent of seasons in 2010–2039 exceeding late 20th century maximums.

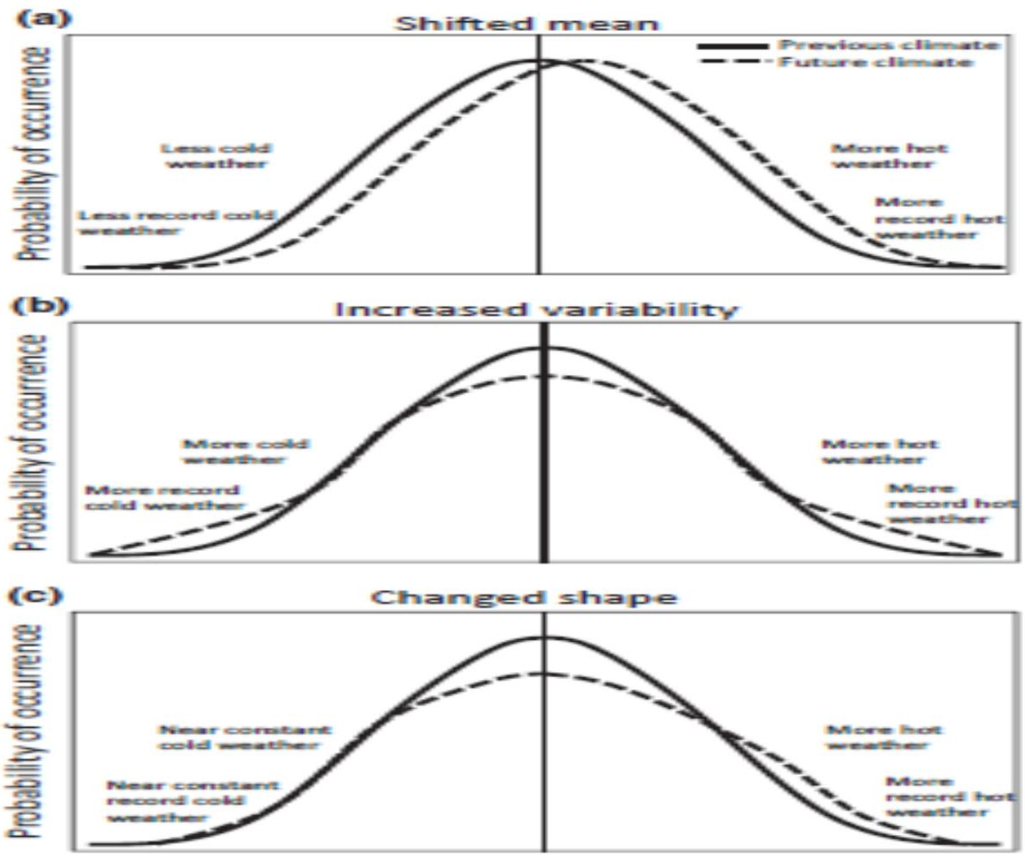


**Fig. 1. The effect of changes in temperature distribution on extremes. Different changes of temperature distributions between present and future climate and their effects on extreme values of distributions: (a) Effects of simple shift of the entire distribution towards a warmer climate; (b) effects on an increase in temperature variability with no shift of the mean; (c) effects on altered shape of the distribution, in this example a change in asymmetry towards the hotter part of distribution.**

*Source: IPCC (2014) dan adopted from Thornton et al. (2014)*

**Table 1. Global summary for maize, rice, wheat and soybean**

| | Maize | Rice | Wheat | Soybean |
|---|---|---|---|---|
| Mean yield change per year (%per year) | 1.6 | 1.0 | 0.9 | 1.3 |
| Mean yield change per year (kg/ha/year) | 84 | 40 | 27 | 31 |
| Projected average yield in 2025 (tons/ha/year) | 6.5 | 4.9 | 3.4 | 3.0 |
| Projected average yield in 2050 (tons/ha/year) | 8.6 | 5.9 | 4.1 | 3.8 |
| Projected production in 2025 (million tons/ha) at fixed crop harvested area of 2008 | 1016 | 760 | 741 | 275 |
| Projected production in 2050 (million tons/ha) at fixed crop harvested area of 2008 | 1343 | 915 | 891 | 347 |
| Projected production shortfall in 2025 as compared to the rate that double production 2050 (million tons/year) | 100 | 160 | 157 | 43 |
| Projected production shortfall in 2050 as compared to the rate that double production 2050 (million tons/year) | 247 | 394 | 388 | 107 |
| Required extra land (million hectares) to produce the shortfall at 2025 projected yields | 15 | 33 | 46 | 14 |
| Required extra land (million hectares) to produce the shortfall at 2050 projected yields | 29 | 67 | 95 | 28 |
| Yield in the year 2008 (tons/ha/year) | 5.2 | 4.4 | 3.1 | 2.4 |
| 90% confidence limit in yield change (%/year) | 0.8-2.4 | 0.5-1.4 | 0.1-0.8 | 0.3-2.0 |
| 90% confidence limit in yield change (kg/ha/year) | 41-124 | 21-68 | 4-52 | 6-60 |
| 90% confidence limit in production in 2025 (million tons/year) at fixed crop harvested area of 2008 | 640-1203 | 607-846 | 500-620 | 214-320 |
| 90% confidence limit in production in 2050 (million tons/year) at fixed crop harvested area of 2008 | 1009-1686 | 769-1072 | 618-1182 | 228-442 |

*Source: Ray et al. [19]*

Numerous studies have shown that feeding a more populated and more prosperous world will roughly require a doubling of agricultural production by 2050 [14,15,16,17,18] translating to a 2.4% rate of crop production growth per year. It is important to note that the top four global crops – maize, rice, wheat, and soybean – are currently witnessing average yield improvements only between 0.9 to 1.6 percent per year, far slower than the required rates to double their production by 2050 solely from yield gains. This is because yield improvements are below, 2.4% per year in many areas of our most important agricultural lands. At these rates maize, rice, wheat and soybean production may increase by, 67%, 42%, 38%, and, 55% respectively, by 2050 globally. There is a 90% chance that the total global production increase from yields alone would be between 34–101% for maize, 21–59% for rice, 4–76% for wheat, and 13–84% for soybean by 2050. Thus, if these yield change rates do not increase, land clearing possibly would be needed [17] if global food security is to increase or even maintained (Table 1).

According to [19], top three rice and wheat producing nations are witnessing very low yield growth rates. China, India and Indonesia are witnessing rice yield increases of only 0.7%, 1.0%, and 0.4% improvement per year. China, India, and the U. S., the top three wheat producers similarly were witnessing yield increases of only 1.7%, 1.1%, and 0.8% per year, respectively. At these rates, we found that yield driven production growth in India and China could result in nearly unchanged per capita rice harvests, but decline steeply in Indonesia. In many of the smaller crop-producing nations, maize, rice, or wheat yield improvement rates are below the 2.4% doubling rate. Elsewhere rice yields are increasing too slowly to overcome the impact of their population growth. Clearly, the world faces a looming and growing agricultural crisis. Yields are not improving fast enough to keep up with projected demands in 2050. For every aspect of future crop production and climate impact, technology and local management practices do and will play a crucial role, and the interactions of environmental, technological and management changes must be better understood and better modelled. Technological change in the agricultural sector proceeded unevenly in the twentieth century [19].

## 2.2 Impacts on the Stability of Food Supplies of Farming System

The second dimension of food security is the stability of food supply. Temporary disruption of supplies can have long-term impacts. The two options for fulfilling demand – food imports and domestic production – imply several reasons for instability of food supplies. A major reason for instability in the food supply is high fluctuation in food prices (price volatility). Volatile prices lead to poor investment strategies of producers and immediate impacts on consumers, especially in developing countries where consumers spend a large share of their income on food. Another source of instability is conflicted, which increase food supply risks. Low and fluctuating prices are a core problem for stable food production. Agricultural price volatility increases the uncertainty faced by farmers and affects their investment decisions, productivity and income.

It should also be noted that global food prices are determined by a small share of food products that are traded on the global market. The share of cereals traded compared to the volume produced is small and has increased slightly over the last four decades, from 9% to 13%. Annual fluctuations in world cereal production are in the same order of magnitude, varying from +9.8% to –3.9% of the previous year's production [20]. This implies that supplies to the world market (the sum of the surplus in the supply of each region) can be reduced by one-third or increase two-fold. Demand in the world market does not follow this trend, however, and probably even moves in the opposite direction in case of poor harvests. These yearly trends describe the risk of discrepancy between supply and demand on the world food market. For this reason, with open markets, developing countries are very vulnerable to fluctuations in global food supply and prices and temporary protection of their own agricultural markets are promoted for these countries.

Agricultural prices are forecast to decline over the next two years but to remain well above the levels of the first half of this decade. However, by 2030–2050, the current scenarios of losses and constraints due to climate change and environmental degradation– with no policy change – suggest that production increases could fall to 0.87% towards 2030 and to 0.5% by 2030–2050 [10]. Should global agricultural productivity rise by less than 1.2% per year on average, then prices, rather than declining, can be expected to rise by as much as 0.3% per year. In addition, a production short of demand, a greater geographical inequity in production and demand, combined with possibly more extreme weather and subsequent speculation in food markets, could generate much greater price volatility than before. In turn, this could potentially induce a substantially greater reduction in food security than that seen in the current crisis, if appropriate options for increasing supply and security are not considered and implemented.

## 2.3 Impacts of Climate Change on Access to Food of Farming System

Accessibility to food concerns both physical access and affordability. Access to markets concerns transportation of commodities and its costs as well as the transmission of price developments to producers. Poor transmission of price incentives to producers results in broadening the gap between consumers and producers, especially in periods of changing diets. According to the latest UN estimates, almost all of the world's population growth between 2000 and 2030 will be concentrated in urban areas in developing countries (Fig. 2).

By 2030, almost 60% of the people in developing countries will live in cities, if present trends continue, urban population will equal rural population by around 2017 [21]. Poor connections between urban and rural areas hinder price transmissions towards local markets, broadening the gap between urban demand and rural production in increasing demand for traditional products or for product diversification.

The majority of more than 1 billion individuals who are food insecure are small-scale farmers living in rural areas, women and children. There are about 500 million small-scale farmers worldwide that support more than 2 billion individuals – one-third of humanity. In many developing countries, particularly in Africa and Asia, small-scale farmers, the majority of whom are women, produce 80 percent of the food consumed [22]. Moreover, the evolving of a financial crisis and economic recession are further aggravating the stability of food system. Energy insecurity and high energy prices will continue negatively affect the avaibility and access to food, particulary given that the production, transportation and distribution of food are reliant on energy markets. The major long-term challenge to global food security will be to meet the increased demand and changing diets of the world's rapidly increasing population, the majority of whom will be children and youth. According to [22] global food production must increase by 70 percent by 2050 to keep pace with increasing demand. In addition, the unpredictable impacts of climate change on the global food system, compounded by a significant reduction and degraded environmental resource base particularly the increasing shortage of fresh water will further exacerbate food insecurity and other vulnerabilities of the poor.

Just under a billion people globally do not have adequate food to meet their basic nutritional needs [23]. Globally, sufficient calories are produced to feed the current population, but access to a safe, sufficient and nutritious diet is unequal around the world. As the global population is expected to grow from about 7 billion [24] to more than 9 billion by mid-century, there is the potential for the food security crisis to deepen. The FAO has predicted [25] that demand for food will grow by 38% by 2030 and 60% by 2050. The food security challenge, in essence, is to meet the rising demand for food in ways that are environmental, socially and economically sustainable, and in the face of evolving world-wide markets, distribution mechanisms and global climate and demographic changes, and by so doing provide an acceptable, safe and nutritious diet for all. In future, food supply (including production, processing and distribution) must – as far as possible – use the same or less land and fewer inputs, produce less waste and have a lower environmental impact [26]. This food must be safe, nutritious and affordable, and available to all, with improved equity of distribution, and reflect social and cultural needs. Therefore, pressure on production systems needs to be reduced by helping consumers to make the right food choices for health and sustainability.

Climate change impacts on crop yield are different in various areas, in some regions it will increase, in others, it will decrease which is concerned with the latitude of the area and irrigation application. The crop yield can be increased with irrigation application and precipitation increase during the crop growth; meanwhile, crop yield is more sensitive to the precipitation than temperature. If water availability is reduced in the future, soil or high water holding capacity will be better to reduce the frequency of drought and improve the crop yield [27]. With climate change, the growing period will reduce and the planting dates also need to change for higher crop production. Climate change can decrease the crop rotation period, so farmers need to consider crop varieties, sowing dates, crop densities and fertilization levels when planting crops [28].

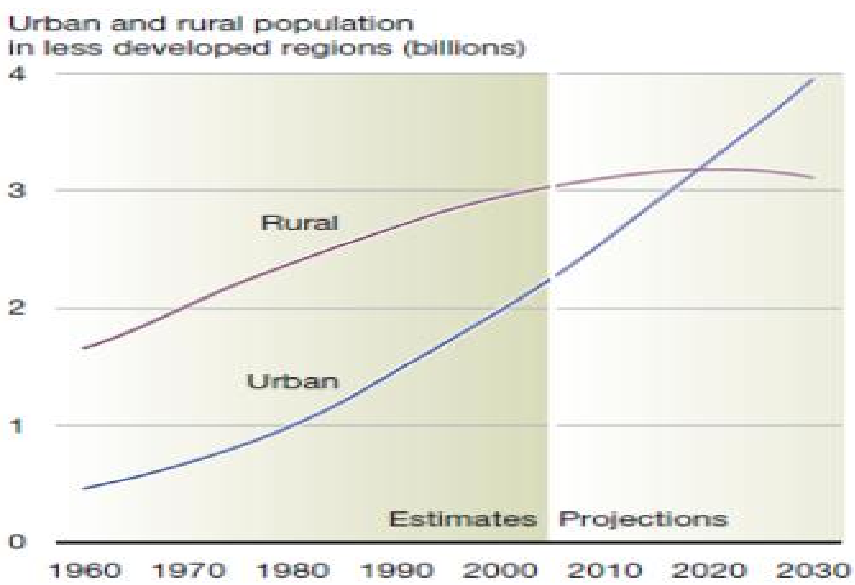


**Fig. 2. Urbanization in Developing Countries between 1960 and 2030**
*(Source: UNEP, 2007)*

## 3. CONCLUSIONS

Regarding the climate change, farming system now is facing the problems in terms of food production, food availability and food access. On the other hand, world population has increased and need to be fed. Therefore, farming system needs to be changed of mission and its vision in the future in terms of technology particularly in developing countries where small-scale farmers are dominated.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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