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Review Paper

IMPLICATION OF CLIMATE CHANGE MEDIATED BY RADIATIVE GASES ON FOOD SECURITY: A CRITICAL REVIEW

Saroj K. Prasad
Department of Agronomy, Banaras Hindu University, Varanasi

Abstract: Climate change, a continuous global phenomena but in modern era the pace of demographic, socio-economic and technological development exacerbate it. These developmental activities increase the proportion of radiative gases (CO_2, CH_4, N_2O *etc.*). Among the radiative gases, CO_2 contributes major anthropogenic GHGs, accounting for 76% followed by methane 16%, nitrous oxide 2% and fluorinated gases 2%. The increase in concentration of radiative gases in atmosphere leads to extreme weather events, global warming, sea level rise, uneven rainfall and increased infestation of weeds, pests and diseases. Higher concentration of radiative gases, particularly CO_2 affects several physiological processes of the crop and alters micromolecules (protein, carbohydrate) and micronutrient (Fe, Zn etc). This altered nutrient composition of crop affects the quality of food grain, considered to be the biggest global threat of food and health security.
Keywords: Climate change, food security, health, radiative gases.

Introduction

The climate change is refers to the long-term trend in weather, generally over decades or centuries *i.e* shift in the patterns of weather events, over the long term. According to Intergovernmental Panel on Climate Change (IPCC), climate change as "a change in the state of climate that can be identified by changes in the mean and or the variability of its properties, and that persists for an extended period, typically decades or longer" (IPCC, 2007). Climate change is attributed directly or indirectly to human activity that alters the composition of the global atmosphere. The human induced climate change as defined by United Nations Framework Convention on Climate Change (UNFCCC) has largely been related to greenhouse gas emission particularly due with burning of fossil fuel and changing land use (Dyg *et al.,* 2011). Increasing concentration of green house gases (GHGs) in atmosphere are influenced by a multitude of factors includes global economic and technological development, increased production and consumption of energy, land use pattern and excess exploitation of natural resources. The major variables of climate change are atmospheric radiative active gases commonly known as green house gases (GHGs) *i.e* dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbon (CFCs),

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hydrofluorocarbons (HFCs), hydrochlorofluorocarbon (HCFCs), sulfur hexafluoride (SF_6), halones and water vapour. These variables are involve in trapping the long wave radiation and increases the temperature, variation in precipitation and weather extreme. There are several other gases that indirectly affect terrestrial and/or solar radiation absorption leads to global warming by influencing the formation or destruction of GHGs include carbon monoxide (CO), oxides of nitrogen (NOx), and non-methane volatile organic compounds (NMVOCs) (USCAR, 2010). Carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) are the key greenhouse gases (GHG) that contribute towards the global warming at 60, 15 and 5%, respectively (Pathak *et al.* 2005). These gases also lead to increase global temperature commonly known as global warming. The global warming potential of gases is the function of a molecule's ability to capture infrared radiation, its current concentration in the atmosphere and its atmospheric lifetime (Robertson and Grace, 2004). Global warming potential of different gases are measured in CO_2-equivalents (IPCC, 2001). A gas molecule with a greater atmospheric lifetime has high global warming potential (Table 1). Concentrations of CO_2, CH_4 and NO_2 in the atmosphere are increased globally by 36, 148, and 18 per cent, respectively since pre-industrial era to 2005 (IPCC, 2007a).

Radiative gases

The increase in the concentration of GHGs is very complex, which includes demographic development, socio-economic development, and technological change (IPCC, 2000). The concentration of CO_2, CH_4 and NO_2 in the atmosphere increased globally by 36, 148 and 18%, respectively since pre-industrial era to 2005 (IPCC, 2007a). The anticipated climate changes are predominately associated with the rise in the concentrations of CO_2 and a gradual rise in the earth's temperature (IPCC, 2012).

Carbon dioxide (CO_2)

CO_2 is the major driving force of climate change (IPCC, 2014), recorded 35.3 billion tonnes (Gt) CO_2 (1Gt = 1 billion tonnes = 1 Petagram (Pg) = 10^{15} g C) in 2013 (Olivier *et al.*, 2014), which was about 40% higher than in the mid-1800s (IEA, 2014). Land use change (conversion of natural ecosystems to agriculture and pasture use) is one of the sources of CO_2 emissions. The emissions of CO_2 due to land use change were estimated to be approximately 155 Pg C during the period of 1850-2000 (Houghton, 2003), and annual emissions at approximately 1.3 Pg Cyr^{-1} during the period of 1950-2005, with an annual range that varies around ± 0.4 Pg C/yr (Houghton, 2010). CO_2 release is largely contributed from microbial decay or burning of plant litter and soil organic matter (Janzen, 2005).

Methane (CH_4)

CH_4 has 25 times more global warming potential (GWP) to that of CO_2 on a 100 – year time scale (Forster *et al*., 2007). The concentration of CH_4 in the atmosphere has been increased by 148% from the last 250 years (IPCC, 2007). Indeed, methane is produced in anaerobic environment by obligate anaerobic microorganisms, either through CO_2 reduction or transmethylation processes (Hou *et al.,* 2000). The anthropogenic methane emission includes paddy cultivation, livestock fermentation, manure management, coal mining, municipal solid waste, waste water, biomass burning, oil and natural gas exploration, flaring and transports (Garg *et al*., 2004). Out of total anthropogenic CH_4 emissions, agricultural activities account for more than 50% (IPCC, 2007a), of which one third derives from flooded rice production (28–44 Tg CH_4 yr^{-1}), and two thirds from ruminants (73-94 Tg CH_4 yr^{-1}) (HLPE, 2012).

Nitrous Oxide (N_2O)

The production of N_2O is a biological process governed by a variety of anthropogenic activities such as agricultural, energy-related, industrial, and waste management fields. The total N_2O emissions are much lower than CO_2, but due to more GWP, traps more heat in atmosphere. The global atmospheric concentration of N_2O has risen by approximately 18% since 1750 (IPCC, 2007). Agriculture accounts for more than 60% of anthropogenic N_2O emissions (IPCC, 2007a), however, the emission rates vary with cropping systems, climate, and other variables (HLPE, 2012). N_2O is emitted directly (nitrogen applied to soil) and indirectly *via* nitrogen lost from agricultural lands through runoff, leaching, NH_3 volatilization, and dissolved organic nitrogen (HLPE, 2012). N_2O is generated by the microbial transformation of nitrogen in soils and manures, and is often enhanced where available nitrogen exceeds plant requirements, especially under wet conditions (Oenema *et al.,* 2005).

Food security

Food security is a multi-faceted issue influenced by socio-economic, socio-politics, global politics, climate and weather. Climate change will affect the food system and health by contributing to impaired food quantity, quality and affordability in many countries (Friel, 2010). According to FAO the term food security means “when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary and food preferences for an active and healthy life” (FAO 1996). Accordingly, Food and nutrition security is based on four key pillars availability (sufficient quantity of food for consumption), access (ability to obtain food regularly through own production or purchase) and utilization (quality and safety of food, including nutrition aspects) and Stability (risk of losing access to resources required to consume food) which affects food availability and food access (Dyg *et al.,* 2011). Climate change exacerbates the existing threats to food security and livelihoods by multiples of factors such as extreme climate hazards, diminishing agricultural yields in vulnerable regions, rising health and sanitation risks, increasing water scarcity, and intensifying conflicts over scarce resources (IPCC, 2007). The rise in (CO_2) would have a significant impact on crop production and global food security, as it is an essential substrate for photosynthesis of crops (Satapathy *et al.,* 2014).

Pillars of food security

1. Availability (production and trade):

The availability of food refers to the existence of sufficient quantities of food in appropriate quality which is supplied either through domestic production or import. It is determined by production, stocks and trade process, distribution and exchange. Food availability is probably most frequently used as a measurement of food security. Climate change directly affects food security by influencing food availability (Thompson *et al.,* 2010) through:

a. Increased CO_2 level increases the crop production but it increases the cultivation of more valuable cash crop rather than food crop.

b. Decline in agricultural production locally and globally due to increased global mean temperature.

a. Changes in precipitation (increase in the frequency, duration, and intensity of dry spells) leads to decline in food production, increase pressure on grain reserve, decreased exports and increased imports

c. Due to increase in the frequency and intensity of extreme weather events leads to decrease in surplus production in flooded areas and increased need for emergency distribution of food rations.

d. Decreased availability of fishery and forest products

2. Access:

This refers the ability to secure the resources to access food. Access to food is depended by physical, financial, social and political factors (Ericksen *et al.,* 2011). It is influenced by incomes, markets, and prices. Climate change affects accessibility of food through:

a. Increasing CO_2 undoubtedly increase the food grain production but diversion of productive assets to other cash crops could cause to increase the price of food grain.

b. Increasing global temperature would create an uncertainty of incomes, prices, and affordability uncertain.

c. Change in precipitation scenario leads to unavailability of preferred food or available at higher price.

d. Increasing migration to urban and peri-urban areas.

e. Extreme weather change would damage to agricultural production or interruption in livelihoods activities as well as loss of income and employment opportunities

3. Stability:

Stability is determined by the temporal availability of, and access to, food. Periodic shortfalls in food availability are a sign of food insecurity, even if current consumption is adequate. Climate change influenced food stability by

a. Increased global temperature leads to higher cost for storing grain and perishable products.

b. Climate change Influenced by food price fluctuations and a higher dependency on imports and food aid.

c. Change in precipitation pattern enhances instability of food supply, food prices, and agriculturally-based incomes.

d. Population displacement , migration and increased conflict over resources

4. Utilization:

It focuses on how food is used and how people secure essential nutrients from food. This includes the nutritional value of the diet, social values of foods, quality and safety of the food supply**.** It is influenced by care and feeding practices, food preparation, dietary diversity and intrahousehold distribution. The implication of climate change on food utilization includes health complications, ability to access preferred food and also impacts on food safety resulting from water pollution, increased temperatures and/or damage to stored food.

Conclusion

A multifaceted global strategy is needed to ensure sustainable and equitable food security including nutritional quality of food grain. The GHGs are the major variable of climate change leads to a gradual rise in the earth's temperature, increased frequency and intensity of extreme events (drought, heat wave and flooding). Occurrence of extreme weather phenomena not only affect crop production but also affect the nutrient content in food. This negatively impact human health through decreasing protein rich macromolecule and several microelements, such as Fe, I, and Zn, in plants which are vital for food security.

Table 1: Radiative gases and its global warming potential (GWP), atmospheric lifetime and past concentration

Greenhouse gases	GWP (100-yr time horizon)	Atmos. lifetime (years)	Increased radiative forcing (W/m^2)	Pre-1750 tropospheric concentration
Concentrations in parts per million (ppm)				
Carbon dioxide (CO_2)	1	~ 100	1.85	280
Concentrations in parts per billion (ppb)				
Methane (CH_4)	25	12	0.51	700
Nitrous oxide (N_2O)	298	114	0.18	270
Tropospheric ozone (O_3)	n.a.	hours-days	0.35	25
Concentrations in parts per trillion (ppt)				
CFC-11 (trichlorofluoromethane) (CCl_3F)	4,750	45	0.060	zero
CFC-12(dichlorodifluoromethane) (CCl2F2)	10,900	100	0.17	zero
CFC-113 (trichlorotrifluoroethane) (CCl_2CClF_2)	6,130	85	0.024	zero
HCFC-22 (Chlorodifluoromethane) ($CHClF_2$)	1,810	12	0.041	zero
HCFC-141b (CH_3CCl_2F)	725	9.3	0.0025	zero
HCFC-142b (CH_3CClF_2)	2,310	17.9	0.0031	zero
Halon 1211 ($CBrClF_2$)	1,890	16	0.001	zero
Halon 1301 ($CBrClF_3$)	7,140	65	0.001	zero
HFC-134a (CH_2FCF_3)	1,430	14	0.0055	zero
Carbon tetrachloride (CCl_4)	1,400	26	0.012	zero
Sulfur hexafluoride (SF_6)	22,800	3200	0.0029	zero
Other Halocarbons			collectively 0.021	zero

Blasing, 2013

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