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Climate smart agriculture: A necessity for food security

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Abstract
Food production needs to increase by 70 percent in order to feed the global population which is expected to reach 9.1 billion in 2050 and over 10 billion by end of the century. This will require major changes in agricultural production systems. Agriculture in developing countries must undergo a significant transformation in order to meet the challenges of achieving food security and at the same time responding to climate change. Enhancing cropland management is key to increase crop yield without further degrading soil and water resources. Widespread changes in rainfall and temperature patterns threaten agricultural production and increase the vulnerability of people dependent on agriculture for their livelihoods. Climate change disrupts food production, posing risks to food supply. This risk can be reduced by increasing the adaptive capacity as well as increasing resilience in agricultural production systems. Climate-smart agriculture (CSA) is an approach for transforming agricultural systems to support food security under the certainties of climate change. CSA encourages coordinated actions by farmers, researchers, private sector, civil society and policymakers towards climate-resilient pathways. It focuses on contributing to economic development, poverty reduction and food security; maintaining and enhancing the productivity and resilience of natural and agricultural ecosystem, thus building natural capital; and reducing trade-offs involved in meeting these goals. CSA aims to tackle three main objectives- sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing GHG emission. CSA helps in developing agricultural strategies to secure sustainable food security under climate change. In this view, the paper focuses on the climate change effects, prevalence of food insecurity and how CSA could be an option to tackle this menace.

Keywords: climate change, GHG emission, food security, climate-smart agriculture

1. Introduction

Climate change has emerged as a major threat on agriculture, food security and livelihood of millions of people in many places of the world [1]. Several studies indicate that agricultural production could be significantly impacted due to rise in temperature, changes in rainfall patterns and variations in frequency and intensity of extreme climatic events such as floods and drought. The estimated impacts of climate change on cereal crop yields in different regions indicate that the yield loss can be up to 35% for rice, 20% for wheat, 50% for sorghum and 60% for maize depending on the location, future climate scenarios and projected year [2]. Climate change impacts agriculture by causing changes in crop cultivation suitability and associated agriculture biodiversity, decrease in input use efficiency, and prevalence of pests and diseases.

Estimates show that world population will grow from the current 6.7 billion to 9 billion by 2050 especially in South Asia and sub-Saharan Africa. Taking into account the changes in the composition and level of consumption associated with growing household incomes, FAO estimates that feeding the world population will require a 70 percent increase in total agricultural production. At the same time, climate change threatens production's stability and productivity. Preserving and enhancing food security requires agricultural production systems to change in the direction of higher productivity. In order to stabilize output and income, production systems must become more resilient, i.e. more capable of performing well in the face of disruptive events [3].

In agro-based countries, where agriculture is crucial for economic development, transforming smallholder systems is not only important for food security but also for poverty reduction, as well as for aggregate growth and structural change. In these countries, increasing productivity to achieve food security is clearly a priority, which is projected to cause a significant increase in emissions from the agricultural sector [4]. Achieving the needed levels of growth, but on a lower emissions trajectory will require an intensive effort.

Despite the various benefits of CSA technologies, the current rate of adoption by farmers is fairly low. There are many factors that influence extent of adoption of CSA technologies such as socio-economic conditions of farmers, bio-physical environment of a particular location, and the aspects of new technologies [5]. The identification, prioritization and promotion of available CSA technologies considering local climatic risks are major challenges for implementing CSA in diverse agro-ecological zones. When designing CSA strategies at the farm level, one must consider adaptation options that are well evaluated and prioritized by local farmers in relation to prominent climatic risks in that location (FAO, 2012). Despite the importance of prioritization of CSA technologies at farm level, existing climate change adaptation programs lack such information for better adaptation planning. The purpose of this paper is to highlight that food security and climate change are closely linked in the agriculture sector and that key opportunities exist to transform the sector towards climate-smart systems.

2. Climate Change

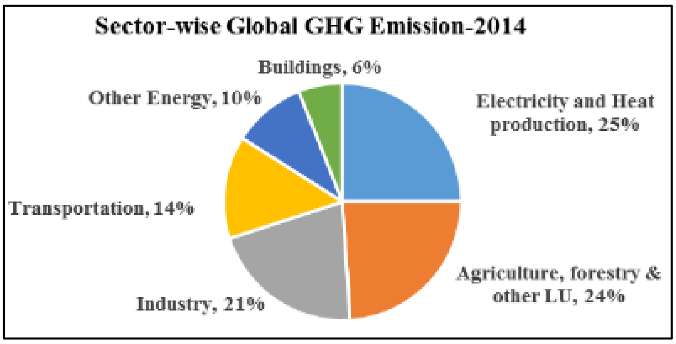
As per the IPCC, climate change refers to any change in climate over time, either due to natural variability or as a result of human activity [6]. Climate change signifies a statistically major variation in either the mean state of the climate persisting for an extended period, usually decades. Climate change occurs due to natural internal processes, external forces, and persistent anthropogenic changes in the composition of the atmosphere or in land use [7]. Since the beginning of the industrial revolution human activities have led to unprecedented changes in the chemical composition of the earth's atmosphere. The global atmospheric concentration of GHGs has increased considerably. As per the IPCC 4th assessment report [6], most of the observed increase in global average temperatures since the mid-20th century is most possibly due to the unprecedented increase in anthropogenic GHG emission. Since the pre-industrial era anthropogenic GHG emissions have added large quantities of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in the atmosphere [8].

It is estimated that for temperature rise to remain below 2°C of pre-industrial levels, the world emission should be only about 2,900 Giga tones (Gt) of CO_2 from all sources between the industrial revolution and 2100. However, till 2011, the world has already emitted 1,900 Gt of CO_2. This shows that out of the budget of 2,900 Gt, only 1,000 Gt remains to be emitted between now and 2100, which is not possible [8]. Another study by the World Resources Institute, estimates that if emissions continue with this trend, the remaining budget will be over taken in 30 years.

Climate change has become an important area of research not only in the natural sciences but also in the social sciences. It harms not only the environment but also the economic and social aspects. The scientific evidence, including the Fourth Assessment Report (AR4) of the Inter-governmental Panel on Climate Change [6], has asserted that it poses unprecedented challenges to human society and eco-systems in the coming decades, particularly in the developing nations whose main occupation is agriculture. It is estimated that climate change will affect the basic elements of life around the world like access to water, food production and healthcare. Millions of people could suffer from hunger, water shortage and coastal flooding, as the world gets warmer. At the same rate of global warming the overall costs and risks of climate change are expected to be equivalent to losing at least 5% of GDP each year. There are certain regions, sectors, ecosystems and social groups which are more vulnerable to climate change. Overcoming the menace of climate change, therefore poses a big challenge to governments and societies [9].

2.1 Sector-wise Global GHG Emissions

Global greenhouse gas emissions can be broken down by the economic activities that lead to their production. All sectors of the economy namely industry, agriculture, transportation, building, etc. emits GHGs in different amounts. The statistic shows the distribution of greenhouse gas emissions worldwide by sector as of 2014. Emissions from electricity and heat production accounted for 25 percent of greenhouse gases. While agriculture, forestry and land-use jointly emitted 24 percent GHG. Another sector which participated greatly in emitting GHG is transportation (14%). Forests can act as a critical carbon sink but its capacity to take in carbon has been mitigated by deforestation and forest degradation. Emission from agriculture is considered to be most crucial as it is also impacted by emission and at the same time it emits.



Source: [10]

Fig 1

2.2 GHG Emission from Agriculture

Agriculture is also a principal contributor to climate change by emitting GHGs. Farms emitted 6 billion tons of GHGs in 2011, or about 12 percent of total global emissions. This makes agricultural sector world's second-largest emitter, after the energy sector (which includes emissions from power generation and transport). Most farm-related emissions come in the form of methane (CH_4) and nitrous oxide (N_2O). Cattle belching (CH_4) and the addition of natural or synthetic fertilizers and wastes to soils (N_2O) represent the largest sources, making up 65 percent of agricultural emissions globally. From 1990 to 2010, global agricultural emissions increased by 8 percent. They are projected to increase 15 percent above 2010 levels by 2030, when they will amount to nearly 7 billion tons per year. These increases are mainly driven by population growth and changes in dietary preferences in developing economies [11].

The relationship between agriculture and climate change is a two-way path: agriculture is not only affected by climate change but has a significant effect on it in return. Globally, agriculture, land-use change and forestry are responsible for 24% of greenhouse gas (GHG) emissions. Within the least developed countries, this figure rises to 74% [12]. If agricultural emissions are not reduced, agriculture will account for 70% of the total GHG emissions that can be released if temperature increases are to be limited to 2°C. The mitigation options available within the agricultural sector are just as cost-competitive as those established within the energy, transportation and forestry sectors. And they are just as capable of achieving long-term climate objectives.

Table 1: CO_2 Emission from Agriculture

	World (giga gram)	South Asia (giga gram)	India (giga gram)
1961	2751636.77	452797.22	340050.32
1971	3325738.92	505785.17	370605.11
1981	3859882.41	592317.59	430869.79
1991	4556533.894	708458.8082	509415.667
2001	4673641.979	808656.145	556347.442
2016	5294155.851	947534.2854	636070.535

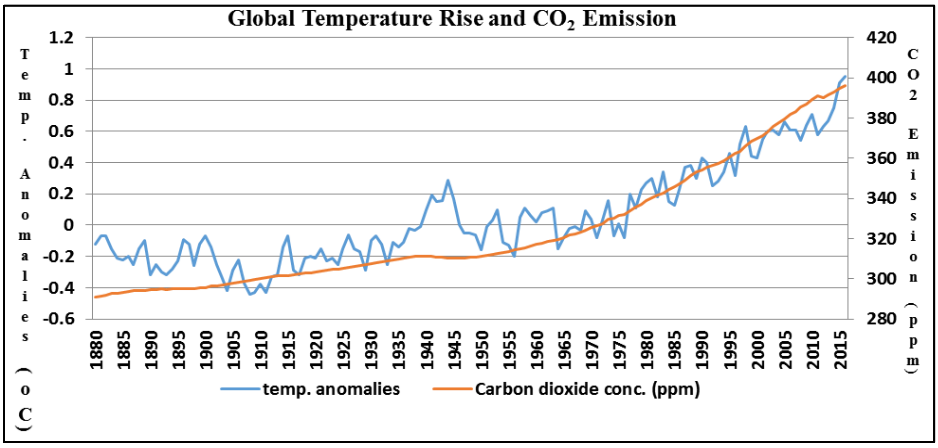
Source: FAOSTAT

Agriculture is a major source of greenhouse gas emissions. It releases large quantities of carbon dioxide through the burning of biomass, mainly in areas of deforestation and grassland. World CO_2 agriculture emission raised from 2751636.77 giga gram in 1961 to 5294155.851 giga gram in 2016, which is a missive increase. Similarly, in India also it raised from 340050.32 giga gram to 636070.53 giga gram (Table. 1). Agriculture sector is the second largest contributor of CO_2 in the total co2 after energy sector. This makes agriculture the most vulnerable and complex sector, as we cannot compromise with the food production, which is necessary to feed the increasing population.

2.3 Global Temperature vis-a'-vis CO_2 Emission

The global annual temperature has increased at an average rate of 0.07°C per decade since 1880 and at an average rate of 0.17°C per decade since 1970. The average global temperature across land and ocean surface areas for 2016 was 0.94°C above the 20th century average of 13.9°C, surpassing the previous record warmth of 2015 by 0.04°C. To date, all 16 years of the 21stcentury rank among the seventeen warmest on record [13]. During the past five decades, the earth has been warming at a higher rate of 0.08-0.14ºC between 1951 and 2012 [14]. This warming trend affects the atmosphere both over the land and over the ocean. As per IPCC reports, this temperature increase is due the greenhouse gas effect and affirms that this is primarily caused by the increase in the atmospheric concentration of CO_2 during the last 200 years. [15].

The projected temperature increase by the end of this century is likely to be in the range of 2º C-4.5°C (IPCC). For the next two decades, a 0.2°C increase in temperature per decade is projected. Even if all emissions were stopped now, a further warming of about 0.1°C per decade is expected. Variation in precipitation is also expected. Increase in precipitation is expected in high-latitudes while decrease is expected in most subtropical land regions [9]. The unprecedented rise of global temperature has effected every sphere of ecosystem not only presently but also would effect in the years to come if not checked.

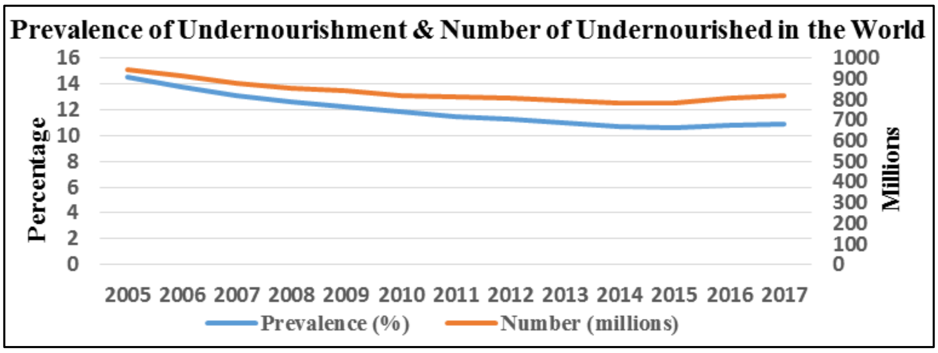


Source: National Oceanic and Atmospheric Administration

Fig 2

3. State of Food Insecurity

FAO projected that the decade-long decline in the prevalence of undernourishment in the world had reached an end, and was possibly in reverse. This was largely attributed to persistent instability in conflict ridden regions, adverse climate events that have hit many regions of the world and economic slowdowns that had affected more peaceful settings and worsened the food security situation. Now, new evidence confirms that lower levels of per capita food consumption in some countries, and increased inequality in the ability to access food in the populations of other countries, have contributed to what is projected to be a further increase in the percentage of people in the world having insufficient dietary energy consumption in 2017. The latest FAO estimates show that the share of undernourished people in the world population – the prevalence of undernourishment – appears to have been growing for two years in a row, and may have reached 10.9 percent in 2017 [16].



Source: State of Food Insecurity 2018, FAO

Fig 3

The term implies that people (at whatever scales considered, from households to nations to regions) have equal and sustained physical and economic access to a sufficient amount of safe and nutritious food to meet daily caloric requirements and to maintain an active and healthy lifestyle (FAO, 1996). It is the complexity of this definition which makes quantification challenging. Managing food security and its sustainable development is one of the biggest challenges worldwide. Climate change affects all four dimensions of food security- *availability, accessibility, utilization and stability.* To manage the food demand of the increasing population, it is very important that proper strategies like CSA are adopted that could increase the production and at the same time does not affect the environment.

4. Climate Smart Agriculture

> *"Climate-smart agriculture (CSA) is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. CSA aims to tackle three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible" [FAO].*

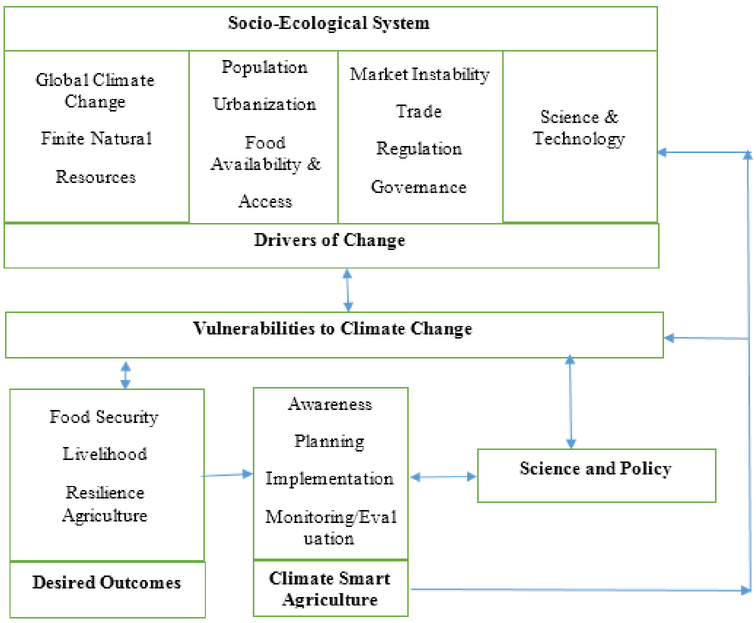
Overview: CSA concept was first presented in the FAO-2009 report entitled *"Food Security and Agricultural Mitigation in Developing Countries: Options for Capturing Synergies*, which was launched at the Barcelona Climate Change workshop held in November-09. In 2010, the FAO paper entitled "*Climate-Smart" Agriculture, Policies, Practices and Financing for Food Security, Adaptation and Mitigation"* was released as a background paper for the Hague Conference on Agriculture, Food Security and Climate Change held in October-10 (FAO 2010).
CSA focuses on fulfilling the needs of people for food, fuel, timber and fiber through scientific actions; contributing to economic development, poverty reduction and food security; maintaining and enhancing the productivity and resilience of both natural and agricultural ecosystem, thus reducing the trade-offs involved in meeting these goals. It invokes a continuous process for stakeholders, researchers and policymakers to meet the challenges presented by climate change and collectively transform agricultural and food systems towards sustainability goals [17]. CSA concept meets three objectives:

- Sustainably increasing food security through increases in productivity and incomes
- Building resilience and adapting to climate change
- Reducing greenhouse gas emissions compared to a business as usual or baseline scenario.

Along with the adaptive actions, CSA seeks to contribute to the mitigation and reduction of GHG, mainly nitrous oxide (N2O) and methane (CH4) emissions, and to balance trade-offs with food security and livelihoods. For example, combining agroforestry, afforestation and conservation efforts with agriculture to meet global food demand will help to mitigate GHG emissions, support biodiversity and concurrently preserve ecosystem services.

4.1 Necessity for Climate Smart Agriculture (CSA)

As per FAO estimate, by the year 2050 world population will increase by one third and food required for food security by 60%. Already cumulative impact of climate change since last decade has effect on productivity. Agriculture has become a high risk profession farmers increasingly prefer to migrate. This has direct impact on socio-economic process. But with available knowledge and experience, it is possible to make agriculture a sustainable livelihood means but this will require intensive efforts at ground level local level where agriculture exists and it has to be made climate smart. CSA identifies synergies and trade-offs among food security, adaptation and mitigation as a basis for informing and reorienting policy in response to climate change. In the absence of such efforts, IPCC projections indicate that agriculture and food systems will be less resilient and food security will be at higher risk. CSA calls for a set of actions by decision-makers from farm to global level, to enhance the resilience of agricultural systems and livelihoods and reduce the risk of food insecurity in the present as well as the future [18].



Source: [17]

Fig 4: Climate-Smart Agriculture- An agent for developing resilience, mitigation and adaptation within the socio ecological system [17].

4.2 Components of CSA

- **Soil and nutrient conservation**: The availability of nitrogen and other nutrients is essential to increase yields. This can be done through composting manure and crop residues, more precise matching of nutrients with plant needs, controlled release and deep placement technologies or using legumes for natural nitrogen fixation. Using methods and practices that increases organic nutrient inputs, retention and use are therefore fundamental and reduces the need of synthetic fertilizers which, due to cost and access, are often unavailable to smallholders and, through their production and transport, contribute to GHG emissions.
- **Water harvesting and consumption**: Improved water harvesting and retention (such as pools, dams, pits, retaining ridges, etc.) and water-use efficiency (irrigation systems) are fundamental for increasing production and addressing increasing irregularity of rainfall patterns. Today, irrigation is practiced on 20 percent of the agricultural land in developing countries but can generate 130 percent more yields than rain-fed systems.
- **Pest and disease control**: There is evidence that climate change is altering the distribution, incidence and intensity of animal and plant pests and diseases as well as invasive and alien species. The recent emergence in several regions of multi-virulent, aggressive strains of wheat yellow rust adapted to high temperatures is a good indication of the risks associated with pathogen adaptation to climate change.
- **Resilient ecosystems**: Improving ecosystem management and biodiversity can provide a number of ecosystem services, which can lead to more resilient, productive and sustainable systems that may also contribute to reducing or removing greenhouse gases. Services include, control of pests and disease, regulation of microclimate, decomposition of wastes, regulating nutrient cycles and crop pollination.
- **Agroforestry**: Agroforestry is the use of trees and shrubs in agricultural crop and/or animal production and land management systems. It is estimated that trees occur on 46 percent of all agricultural lands and support 30 percent of all rural populations. The use of trees and shrubs in agricultural systems help to tackle the triple challenge of securing food security, mitigation and reducing the vulnerability and increasing the adaptability of agricultural systems to climate change [3].

5. Conclusion

Climate change alters crop production and food systems. It induces greater uncertainty and risk among farmers and policymakers. Climate change as a whole effects the economy of the nation. An unified, evidence based and transformative approach to addressing food and climate security at all levels require coordinated actions from the global to local levels, research to policies and investments, and private to public and civil society sectors to achieve the scale and rate of change. With the right practices, policies and investments, the agriculture sector can move onto CSA pathways, resulting in decreased food insecurity and poverty in the short term while contributing to reducing climate change as a threat to food security over the longer term. Interdisciplinary and trans-disciplinary scientific approaches could play a fundamental and profound role in developing understanding of the processes underlying CSA and serve as partners in enumerating priorities for CSA. They form a crucial element in the knowledge base needed to implement CSA actions and manifest future transformative changes in agriculture in a changing climate. The rapid uptake of the concept after its launch indicates the tremendous demand for a framework to guide policy and technical interventions in agriculture that integrates the effects of change. Ultimately the utility of the concept and its implementation will be judged by its effectiveness in integrating climate change responses into sustainable agricultural development actions on the ground. The momentum that has already built among the research community for CSA forms the base for critical engagement by more researchers in this area. Launching a more formal governance mechanism to embed science in the information base for the CSA, would be a vital step in developing priorities, scientific engagement and funding to support the knowledge needed for policymaking decisions.

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