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Component-I (B) - Description of Module

Items	Description of Module
Subject Name	**Geography**
Paper Name	Climatology
Module Name/Title	CLIMATE CHANGE AND FOOD SECURITY
Module Id	CL-36
Pre-requisites	
Objectives	• define climate change and food security, • explain the impacts of climate change on agriculture, • discuss various dimensions of food security, • explain the impacts of climate change on food security, and • Explain the importance of climate smart agriculture.
Keywords	

Contents

Introduction

We know that food systems, a product of human ingenuity, is a complex ecosystem whose outcome and sustainability is driven by its inherent potential and biophysical and social environment. Food security is the outcome of functioning food system and innate properties of the food systems. Food system and food security are influenced by a web of factors like climate change, technological interventions and structural changes in the food system, demographic changes, energy security, population pressure and income driven consumption pattern. The detailed study of climate change and food security help in better conceptualization of the effect of climate change on agriculture and consequently on food security. It is pertinent to know that, the food security is dependent on food production, socioeconomic condition, land-use, trade policy, demographics, and food - and water- borne disease.

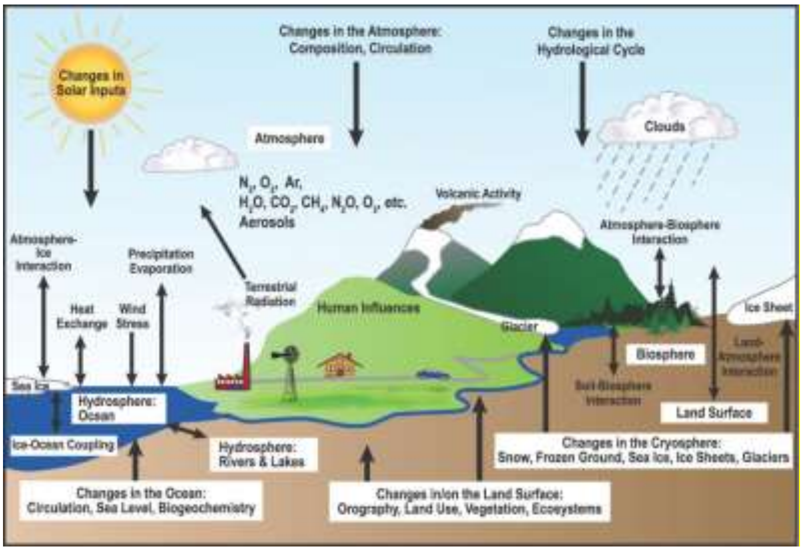
It is hard fact to state that about 800 million people across the globe are food insecure and about 2 billion thrive with food diet with insufficient nutrients. This grim scenario has led the global community to place utmost importance on food security, climate change and kindred issues through Sustainable Development Goals. As regards the relationship persisting among climate change, agriculture and food security, there is an urgent need to develop climate smart agricultural practices as today's humanity is facing greatest environmental challenge in the form of climate change and global warming. You would be well aware about the negative repercussions of climate change and variabilityon agro-biodiversity, soil resources, water resources which eventually increases the vulnerability of agriculture.In this module, it is attempted to discuss the climate change and its impacts on food security in the present day society.

Climate System

Weather and climate: Although words weather and climate sounds similar, the differences exist between the terms from the perspective of space and time. You have studied that weather reflects the state of atmosphere at a particular time and place. Weather is the daily or short term variations of different conditions of lower air in terms of temperature, pressure, wind, rainfall, etc.On the other hand, climate is a statistical measure of state of atmosphere in terms of meteorological variables like temperature, rainfall, humidity, etc. for a particular region for a period of more than 35 years. The climate can fluctuate on short time scales, producing for instance the hydrological drought and over much longer time-scale giving rise to glacial epochs.

Components of climate system: The United Nation Framework convention on climate change defined the climate system as the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions (McGuffie and Henderson-Sellers, 2005). The schematic view of the components of the climate system, their processes and interactions are presented in Figure 1. You can see from the schematic presentation, that the climate system is powered by solar radiation. Since the Earth's surface temperature has been relatively constant over many centuries, the incoming solar shortwave radiation (SWR) must be nearly in balance with outgoing longwave radiation (LWR). About half of SWR is absorbed by the Earth's surface. About 30% of SWR is reflected back to space and 20% of SWR is absorbed in the atmosphere. The LWR emitted from the Earth's surface is largely absorbed by radiatively active gases like water vapour, carbon dioxide, methane, nitrous oxide and other greenhouse gases. The downward directed component of this LWR heats the lower atmosphere and this process is popularly called greenhouse effect (IPCC, 2013).

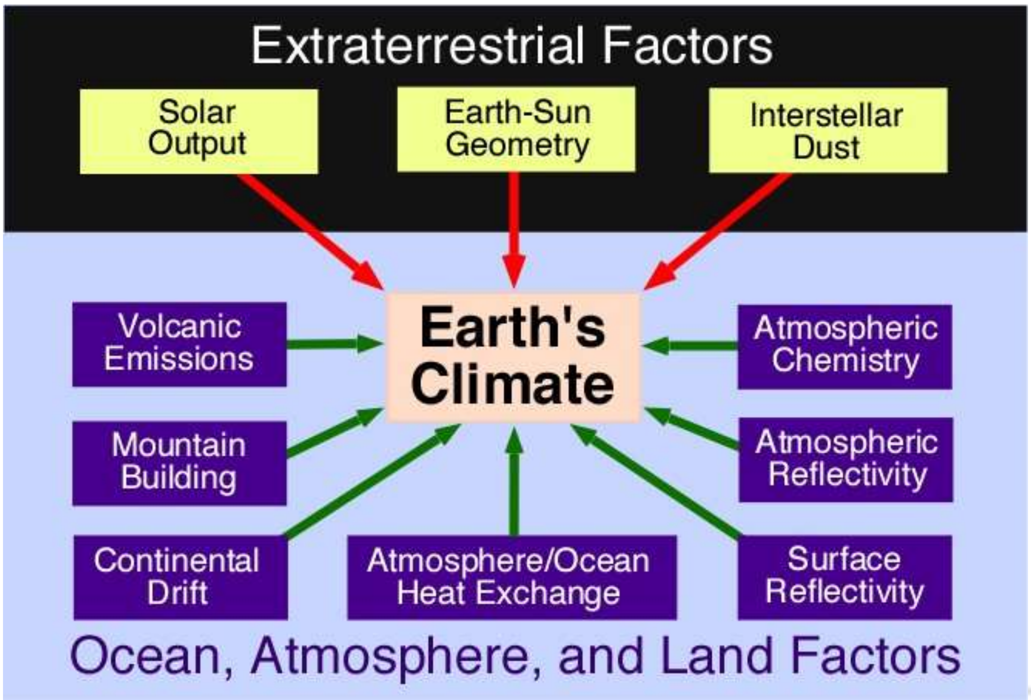
Figure 1: Components of Climate System, their Processes and Interactions



Source: IPCC, 2007

Climate Forcing: The climate system is a dynamic system in temporary balance. Changes in the climate system either due to the natural and anthropogenic reasons can perturb the Earth's radiation budget, resulting in a radiative forcing (RF) that affects climate. The forcings can be construed broadly as external and internal forcings (McGuffie and Henderson-Sellers, 2005; IPCC, 2013). The factors influencing the climate of our Earth is diagrammatically presented in Figure 2. External forcing refers to a forcing agent outside the climate system causing a change in the climate system. The galactic variations, orbital forcing and solar forcing are external forcings (IPCC, 2013). On the other hand, the processes intrinsic to Earth and its atmosphere alter climate. These internal forcing factors include mountain building (orogeny), distribution of landmasses, volcanic activity, atmospheric composition, chemistry and surface reflectivity as presented in the Figure 2.

Figure 2: Factors Affecting the Climate of the Earth

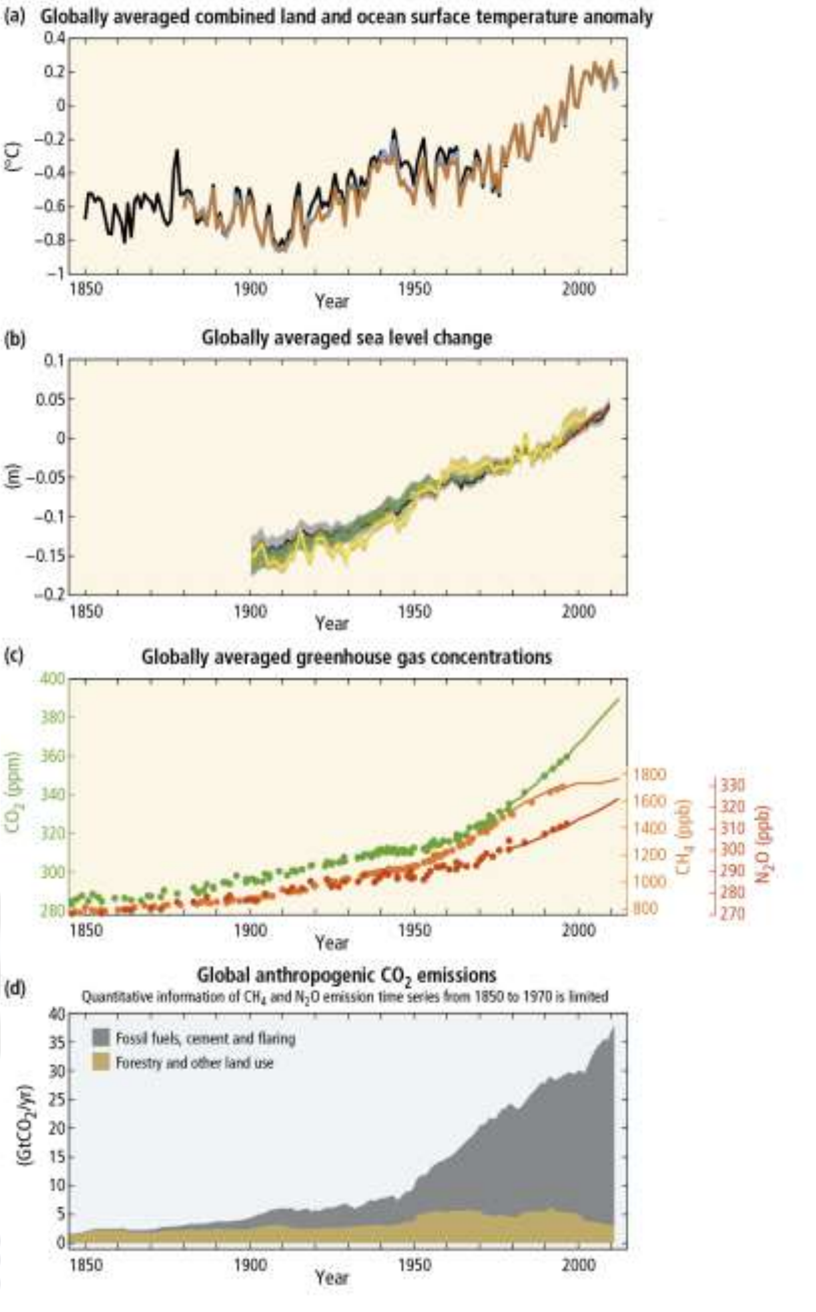


Source:http://www.physicalgeography.net/fundamentals/images/climatefactors.jpg

Climate Change

Climatic conditions are varying in nature all through the earth's history. The weather records for most part of the world exist only for few hundred years in developed countries but in less developed countries, the weather data exists for few decades only. However, the proxy indicators of past data from pollen analysis, tree rings, ice cores, beetles, sea sediments have provided ample evidence for non-static nature of climate. The IPCC in its fifth assessment report stated that warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean are getting warmer with every passing year. The amounts of snow and ice are on decline, sea level is on rise and the concentration of greenhouse gases is increasing. Climate change influences all the components of biosphere. The Figure 3a depicts the trend of globally averaged combined land and ocean surface temperature anomaly, globally averaged sea level change (3b), and globally averaged greenhouse gas concentrations (3c). The climate change that we witness is reported to be induced by anthropogenic activities and the Figure 3d exemplifies the contributions and increasing trend of anthropogenic CO_2 and the atmospheric build-up of GHG are one of the prime drivers of climate change. There is very high correlation among the variables shown in the Figure 3 as all are increasing with the record time since 1850

Figure 3: Increasing Trends of Temperature, Sea Level, GHG and CO_2

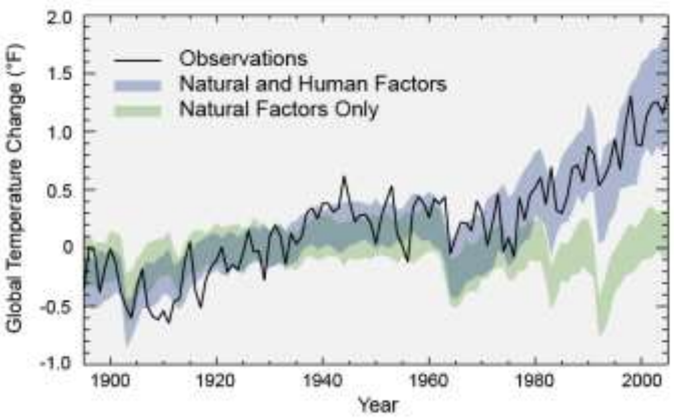


Source: IPCC, 2014

Defining Climate Change and Variability: Climate change is the variation in either mean state of the climate or in its variables persisting for an extended period, typically decades or longer. It includes temperature increase (global warming), changes in precipitation pattern, sea level rise and increased frequencies of extreme weather events. Further, climate change follows a specific pattern of change in climate or its variables over the time. On the other hand, Climatic variability refers to sudden and discontinuous seasonal or monthly or periodic changes in climate or its components without showing any specific trend of temporal change (IPCC, 2013).

Global Temperature Rise: Global temperature is considered as a popular metric indicating the state of global climate. Global warming is defined as the increase in the average temperature of earth's near surface air and oceans due to the transmission of incoming short wave solar radiation and the absorption of outgoing long wave terrestrial radiation. The globally averaged combined land and ocean surface temperature data as calculated by a linear trend, show a warming of 0.85°C, over the period 1880 - 2012 (Figure 3a). Between 1906 and 2005, the global climate system was observed by 0.74°C. The graph showing the influence of natural and human factors on global temperature change is represented in Figure 4. Changes in many extreme weather and climate events have been observed since about 1950. Particularly, the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale (IPCC, 2013).

Figure 4. Influence of Natural and Human Factors on Global Temperature Change



Source:https://19january2017snapshot.epa.gov/sites/production/files/2016-07/models-observed-human-natural.png

Climate Change and Agriculture

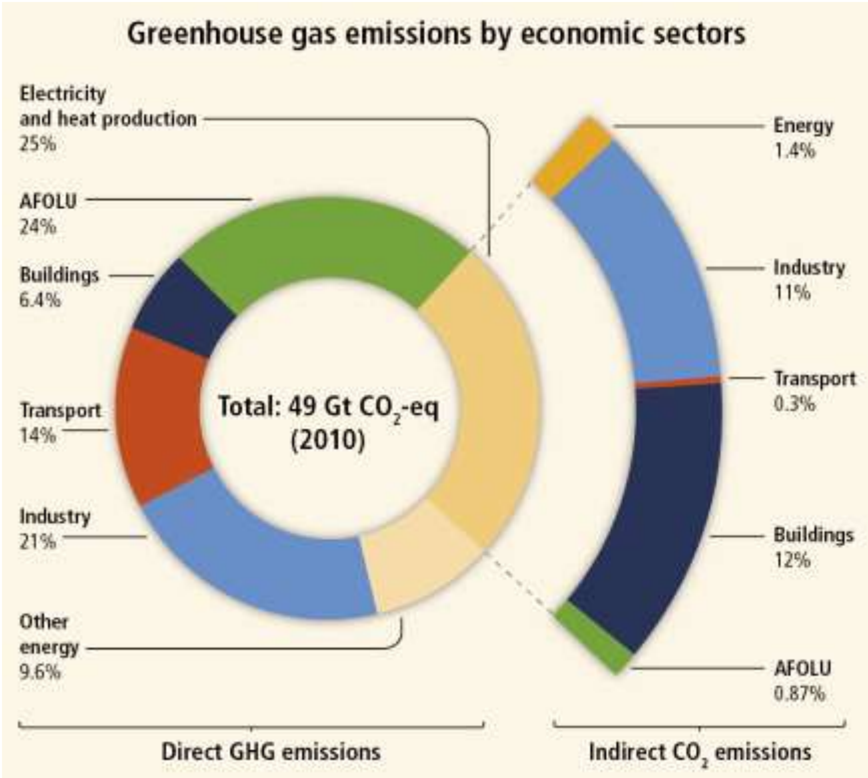
Modern agriculture with the aid of advanced technologies and practices like chemical fertilization, pest and disease control using diverse group of pesticides, irrigation, crop varieties and hybrids, etc. had increased global crop production substantially. However, converging trends in population growth, natural resource use, food prices, climate variability and climate change jeopardize agricultural production system, food and nutritional security and agricultural sustainability. Systematic understanding of the linkages between agriculture and climate change reveals the net negative impacts of climate change on crop distribution and crop production, emission of greenhouse gases from agriculture and the potential of agricultural sector to augment the global efforts to address both adaptation and mitigation to climate change.

World Agriculture: Globally, croplands cover 1.53 billion hectares (about 12% of Earth's ice-free land), while pastures cover another 3.38 billion hectares. Altogether, agriculture occupies about 38% of Earth's terrestrial surface and it is essentially the largest use of land on the planet (Ramankutty*et al*., 2008). Climate change will influence crop distribution and production and increase risks associated with agricultural farming (Scherr*et al*., 2012). IPCC through its various reports categorically states that climate change affects crop production in several regions of the world, and developing countries and island countries are highly vulnerable to negative impacts (IPCC, 2014a). Climate change induced extreme events such as drought, floods, marine transgression, abnormally high maximum temperatures have become common occurrence in the last decade.

Greenhouse Gases Emission from Agriculture

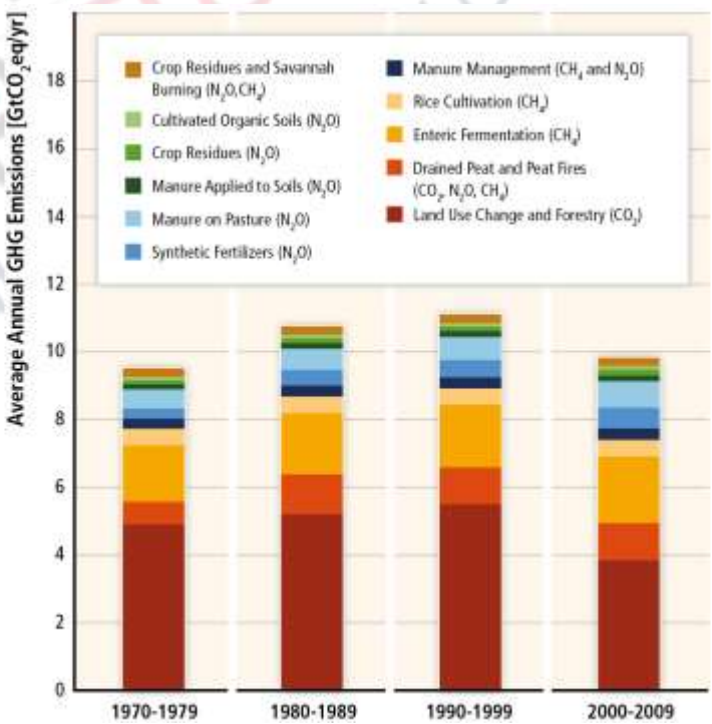
The changing concentrations of greenhouse gases are key indicator of global climate change. Total anthropogenic GHG emissions from different economic sectors in 2010 as depicted in the Figure 5 amounts to 49 gigatonne of CO_2-equivalent per year ($GtCO_2$-eq/yr). Greenhouse gases emissions are converted into CO_2-equivalents based on 100-year Global Warming Potential (GWP100). Equivalent carbon dioxide emission is defined as “the amount of carbon dioxide emission that would cause the same integrated radiative forcing, over a given time horizon, as an emitted amount of a greenhouse gas or a mixture of greenhouse gases” (IPCC, 2013). The emission data on agriculture, forestry and other land use (AFOLU) includes land-based CO_2 emissions from forest fires, peat fires and peat decay that approximate to net CO_2 flux from the sub-sectors of forestry and other land use (FOLU). The AFOLU sector accounts for about 10–12 gigatonne of CO_2-equivalent per year. The greenhouse gases emissions in agriculture as shown in the Figure 6 are mainly due to land use change and forestry, enteric fermentation, drained peat and peat fires, lowland rice cultivation and use of synthetic fertilizers, and biomass burning (Lipper et al., 2014). As regards the GHG emissions from agriculture, the most cost-effective mitigation options are cropland management, grazing land management, and restoration of organic soils. It is observed that policies governing agricultural practices are more effective when involving both mitigation and adaptation (IPCC, 2014b).

Figure 5: Greenhouse Gases Emissions from Different Economic Sectors



Source:IPCC, (2014). Climate Change 2014: Synthesis Report.

Figure 6: Average Annual Greenhouse Gases Emissions from Agriculture



Source:IPCC, (2014). Climate Change 2014: Synthesis Report.

Impact of Climate Change on Agriculture: Some of the direct impacts of climate change over the coming decades will be on agricultural food system. Climate change can affect agriculture through their direct and indirect effects on the crops, livestock, soils and pests. The potential impacts of climate change on different sectors of agriculture are presented in the Table 1. Climate change through its negative impact on crop yields increases the production and market risk and results in food insecurity among the vulnerable sections of the farming community. Climate change is reported to reduce the crop yields (Lobell *et al*., 2011). Globally, climate change is expected to reduce cereal production by 1% to 7% by 2060. Climate change could potentially interrupt progress toward a world without hunger. Climate variability and change will exacerbate food insecurity in areas currently vulnerable to hunger and under-nutrition. Food access and utilization will be affected indirectly via collateral effects on household and individual incomes, and food utilization could be impaired by loss of access to drinking water and damage to health (Wheeler, T. and Braun, J., 2013).

Table 1. Potential Impacts of Climate Change on Different Sectors of Agriculture

Sector	Impact
Crop	• Carbon dioxide fertilization effect: Increase in ambient CO_2 concentration is beneficial since it leads to increased photosynthesis in several crops, especially those with C3 photosynthetic pathway such as wheat and rice, and decreased evaporative losses. • Yields of major cereals crops, especially wheat are likely to be reduced due to decrease in grain filling duration, increased respiration, and / or reduction in rainfall/irrigation supplies. • Yield Reduction in rainfed crops is ascribed to erratic monsoonal rainfall and increased crop water demand. • Increase in extreme weather events such as floods, droughts, cyclones and heat waves will adversely affect agricultural productivity. • Increase in Pest and disease outbreak on account of rapid pathogen transmission and increased host susceptibility. • Threat to Agricultural biodiversity due to the global changes in the climate-related parameters like temperature, rainfall and sea level.
Water	• Irrigation water demand would increase with rise in temperature and evapo-transpiration rate. • The water balance in different parts of India will be affected and the quality of groundwater in the coastal region will be affected more due to intrusion of sea waters.
Soil	• Organic matter content, which is already quite low in Indian soils, would become still lower. • Rise in soil temperature will increase N mineralization, but its availability may decrease due to increased gaseous losses through processes such as volatilization and denitrification. • Change in rainfall volume and frequency, and wind may alter the severity, frequency and extent of soil erosion. • Sea level rise may lead to sea water ingression in the coastal areas, turning them less suitable for conventional agriculture.

Livestock	• Climate change and associated phenomena will affect fodder production and nutritional security of livestock. • Changes in rainfall pattern may also influence vector population during wetter years, leading to large outbreaks of diseases. • Climate change is likely to aggravate the heat stress in dairy animals, adversely affecting their reproductive performance.
Fishery	• Increasing temperature of sea and river water is likely to affect breeding, migration and harvests of fishes. • Impacts of increased temperature and tropical cyclonic activity would affect the capture, production and marketing costs of the marine fish.

Source: Aggarwal et al. (2009) and Pathak et al., 2012

Particularly in the agriculture sector, climate change adaptation can go hand-in-hand with mitigation. Climate change adaptation and mitigation measures need to be integrated into the overall development approaches and agenda.

Mitigation Strategies to Climate Change: Mitigation of climate change is considered as a human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs).Mitigation strategies essentially differ with crop, and soil environment. For instance, the methane emission from lowland rice cultivation can be mitigated to a large extent through water and nutrient management including mid-season aeration by short term drainage, use of fermented manures, improved organic matter management. The nitrous oxide emission in crop land is reduced by adopting site-specific, efficient nutrient management and also using nitrification inhibitors like neem oil, neem cake, nitrapyrin, dicyandiamide, etc. As regards the methane emissions from ruminants like cow, sheep, etc., the emissions can be reduced by altering suitably the feed composition. The carbon dioxide emission from agriculture can be reduced by the adoption of conservation tillage practices, increasing carbon sequestration, improving soil environment, manure management and soil biodiversity conservation.

Adaptation Strategies to Climate Change: Adaptation is said to be the process of adjustment to actual or expected climate and its effects. The adaptation strategies encompasses developing crop cultivars tolerant to abiotic stresses like heat stress and salinity stress, crop diversification, modifying and improving the crop management practices, harnessing the traditional/indigenous knowledge of farming community, adoption of conservation agriculture practices, resource conserving technologies weather forecasting and agricultural insurance.

Sustainable Development Goals, Climate Change and Food Security

Sustainable development of humanity and our planet is challenged by a number of environmental challenges. The challenges are Food Security, Water Security, Energy Security, Climate Change Abatement, Biodiversity Protection and Ecosystem Service Delivery. At the granular level, these challenges have commonality in terms of striking characteristics, occurrence, inter-relationships, and these challenges demand concerted effort from United Nations and other organizations. The foremost challenge is food security as it is related with other key challenges. The need to feed 10 billion people by 2050 with quality food and to provide clean environment demands productive soil, rich agro-biodiversity, augmentation of ecosystem services, continued energy supply and productive water use.

Sustainable Development Goals

The United Nations Rio+20 Summit in Brazil in 2012 committed governments to create a set of sustainable development goals (SDGs) that would be integrated into the follow-up to the Millennium Development Goals (MDGs) after their 2015 deadline (Griggs et al., 2013). There are 17 SDG's comprising 169 targets and this global development agenda spans from 2015-2030 (Lu et al., 2015). The Sustainable Development Goals (SDGs) build on the successes of the Millennium Development Goals are a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity. The goals are interconnected – often the key to success on one will involve tackling issues more commonly associated with another. Unlike the MDGs, which are targeted at poor and emerging nations, the SDGs will have a global reach. They will apply to developed and developing countries alike, and will concern the earth system as well as people (Glaser, 2012). The SDG framework addresses key systemic barriers to sustainable development such as inequality, unsustainable consumption patterns, weak institutional capacity, and environmental degradation that the MDGs neglected (ICSU, ISSC, 2015).

SDG 2 and SDG 13

The SDG 2 is to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture. The SDG 13 is to take urgent action to combat climate change and its impacts. SDG 2 and its targets are intrinsically connected to almost all other goals. The interconnectedness of food security with soil security (SDG 15), water security (SDG 6), energy security (SDG 7), climate security (SDG 13), economic security (SDG 8 and SDG 9) consumption patterns (SDG 12), gender equality (SDG 5) and political stability (SDG 16) are illustrated in the Figure 7.

Figure 7: Linkages of Food Security

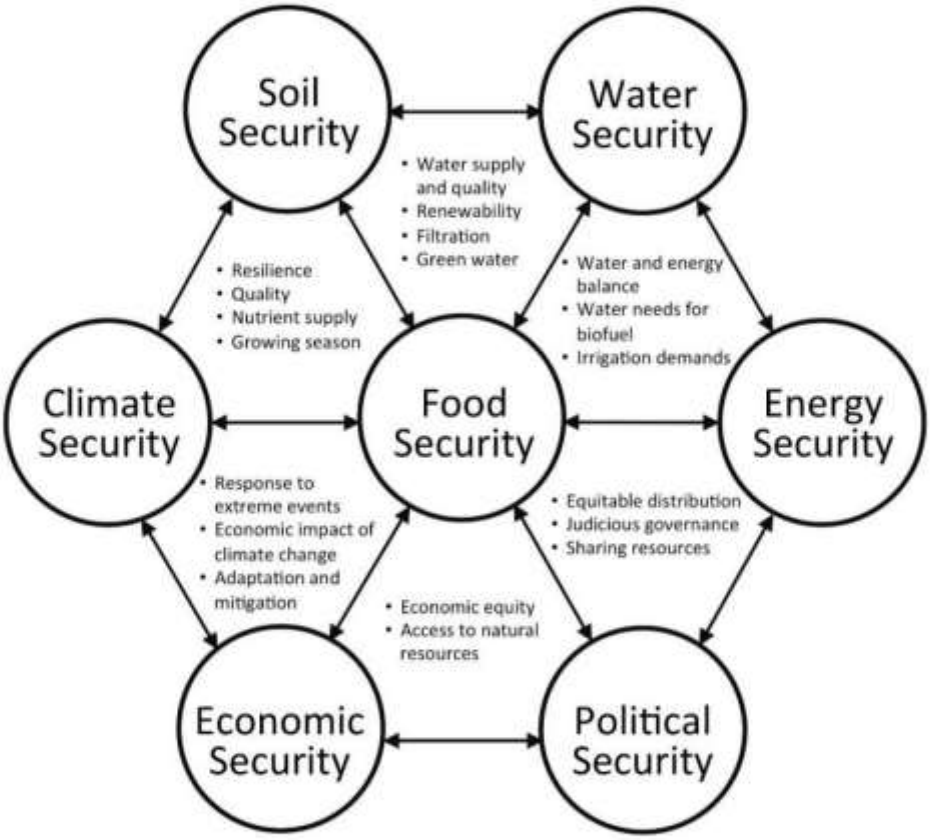


Figure 7:Food Security Linkages

Source: https://flores.unu.edu/en/news/news/taking-hunger-out-of-the-poverty-equation-food-security-and-the-sdgs.html

Food Security

The term "food security" initially was used to describe whether a country had access to enough food to meet dietary energy requirements (Pinstrup-Andersen, 2009). The concept of food security evolved and the definition agreed upon at the World Food Summit in 1996 is that food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life (Barrett, 2010).

Dimensions of Food Security

Primarily, there are four key dimensions of food security. The dimensions of food security are clearly illustrated in Figure 8. The dimensions are

- Availability,
- Stability,
- Access, and
- Utilization.

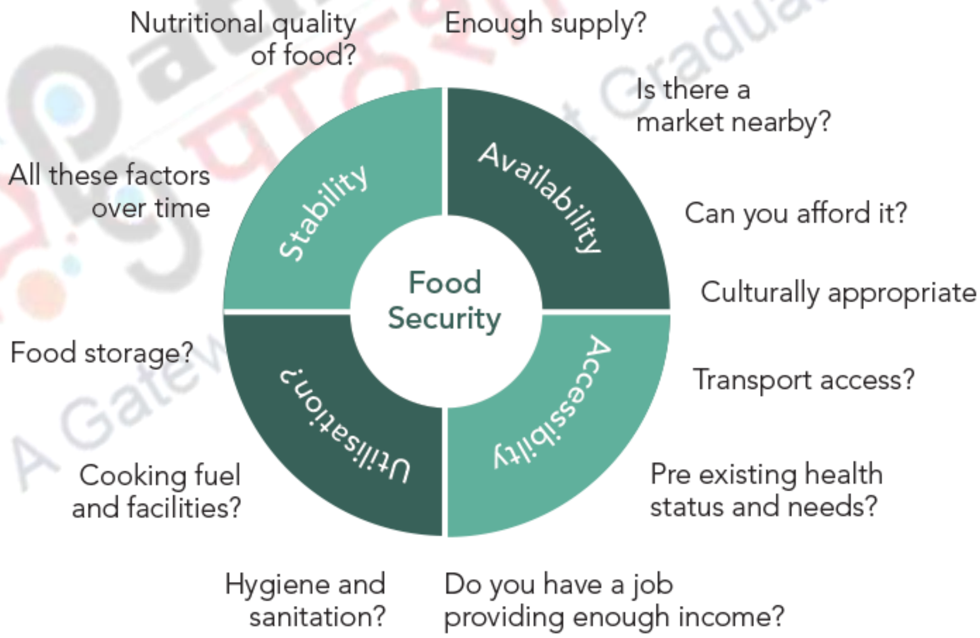
Availability: The first and foremost dimension relates to the availability of sufficient food, i.e., to the overall ability of the agricultural system to meet food demand. It is concerned with the production of the food items for the population.

Stability: The second dimension, stability, relates to individuals who could afford to have the food. The work availability, getting wage/ salary/ or self-production of food from the owned land. It means the food has to be available to the people for the whole of the year.

Access: The third dimension, access cover access by individuals to adequate resources to acquire appropriate foods for a nutritious diet. A key element in this dimension is the purchasing power of consumers and the changes in the real income and food prices. It also refer to the movement of the people or the goods for proper distribution among the masses. Hence, transport is equally important to the food from deficient zone to the zone of deficiency, apart from purchasing power.

Utilization: The fourth dimension utilization includes all food safety and quality aspects of nutrition. The available food has to be in a consumable state and therefore, the hygiene and cooking facilities are also of great concern (FAO, 2008).

Figure 8: Key Dimensions of Food Security



Source:http://www.foodsource.org.uk/sites/default/files/fig-722.png

An important component of food security is nutritional security. In order to provide safe and nutritious food, the pulse crops, which are source of protein, should be included in the cropping system. The pulse crops in addition to enriching soil fertility enhance the livelihood security of marginal and small farmers. Nutri-cereals such as *bajra*, *ragi*, sorghum, maize, etc. are usually cultivated in rainfed areas and are more climate-resilient. Additionally, the demand for coarse cereals from nutritional point of view will act as an incentive for resource poor rain fed farmers to grow the climate resilient coarse cereals. Hence, in an era of climate change, climate resilient agriculture will play an important role in human nutrition security and livelihood security. Due to changes in consumption patterns, demand for fruits, vegetables, dairy, meat, poultry, and fisheries has been increasing. There is need to increase crop diversification and improve allied activities.

Effect of Climate Change on Food Security

We know that the agricultural crop production is a product of interaction between genetic potential and the crop environment. By adopting traditional and modern breeding methods, the plant breeders are in constant urge to increase the potential crop yield. Nevertheless, the farmers are not in a position to achieve the potential yield of crop plants. There exists a yield gap between actual yield and potential yield. The yield gap is a function of biotic and abiotic stress in agro-ecosystem. The agricultural crop production will increase, if the yield gap is narrowed down. Unfortunately, the yield gap is widening due to change in climate and consequent impact on the components of agro-ecosystems.

Climate change will affect all four dimensions of food security; food availability, food accessibility, food utilization and food systems stability. It will have an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows. Its impacts will be both short term, resulting from more frequent and more intense extreme weather events, and long term, caused by changing temperatures and precipitation patterns. People who are already vulnerable and food insecure are likely to be the first affected very greatly.

Agriculture-based livelihood systems that are already vulnerable to food insecurity face risk of increased crop failure, new patterns of pests and diseases, lack of appropriate seeds and planting material, and loss of livestock. The need of the hour is climate resilient agriculture. At the same time, it is necessary to strengthen the resilience of rural people and to help them cope with this additional threat to food security. In this context, agricultural research should be tailored to meet the requirements of climate resilient farming systems.

Climate Smart Agriculture

The way forward is extremely challenging for global agriculture demanding a paradigm shift in agricultural crop production, agricultural development planning, investments in agriculture and integrated farming approach empowering small and marginal farmers. It is important to transform and reorient agricultural production system by including resilient pathways to achieve increased agricultural productivity and at the same time capitalize the synergy existing between the mitigation and adaptation to climate change. It was timely that an approach christened as Climate Smart Agriculture took shape in this century with the proactive role of Food and Agriculture Organization (FAO) and World Bank. Climate Smart Agriculture (CSA) aims at maximizing the global agricultural productivity, reducing the vulnerability of agriculture to climate change, increasing the resilience of agricultural system in the era of climate change, and reducing the greenhouse gases emissions from agriculture.

CSA is a comprehensive policy, technology and financing approach to enable countries to achieve sustainable agricultural development in the face of climate change. CSA includes sustainable agriculture and the need for adaptation and the potential for mitigation with associated technical, policy and financing implications (FAO, 2013). Climate Smart Agriculture includes farm-based sustainable agricultural land management practices like conservation agriculture, crop residue management, agroforestry, manure management, etc. CSA is site specific and adopts ecosystem approach, integrated landscape management and ensure inter-sectoral co-ordination and co-operation. CSA approach strives to provide safe operating space for global food systems.To live sustainably within planetary constraints, we must grow more on the same amount of land using less water, energy, and chemicals and adopt sustainable agricultural practices (Fedoroff, 2015).

Climate Smart Agriculture can be defined as an agricultural approach that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation) and enhances achievement of national food security and development goals.

Goals of Climate Smart Agriculture

The goals of climate smart agriculture are:

- Sustainably increase agricultural productivity and incomes in order to meet national food security and development goals
- Build resilience and the capacity of agriculture and food system to adapt to climate change
- Seek opportunities to mitigate emission of greenhouse gases and increase carbon sequestration

Climate smart agricultural practices are adopted at all scales including food supply chains, and landscape. CSA addresses the challenge of meeting the growing demand for food, fibre and fuel, despite the changing climate and fewer opportunities for agricultural expansion on additional lands. Further, CSA emphasis on poverty reduction and food security; maintaining and enhancing the productivity and resilience of natural and agricultural ecosystem functions (Steenwerth*et al*., 2014).

Summary and Conclusions

Agriculture has contributed immensely for the existence of humanity. Modern agriculture had exhibited its potential to feed seven billion people. The issues and challenges related to agriculture gains urgency on account of growing human population, competing uses for natural resources, increased dependency on few food crops, lack of biological diversity in agro-ecosystem, inadequate knowledge of ecological processes and negative impacts of climate variability and climate change. Agriculture too contributes to climate change through the emissions of greenhouse Gases to the tune of 10-12% of global total greenhouse gases emissions.

Scientific understanding of the linkages between agriculture and climate change reveals the disruptive impacts of climate change on crop distribution and crop production and the potential of agricultural sector to augment the global efforts to address both adaptation and mitigation to climate change. In order to maximize the global agricultural productivity, to reduce the vulnerability of agriculture to climate change, to increase the resilience of agricultural system in the era of climate change, to reduce the greenhouse gases emissions from agriculture, to achieve food and livelihood security, to reduce poverty and improve nutritional wellbeing of people.

International Organizations like Food and Agriculture Organization (FAO), World Bank and Consultative Group on Integrated Agricultural Research (CGIAR) conceptualized the reformative and transformative approach in agriculture called Climate Smart Agriculture (CSA). CSA includes sustainable agriculture and the need for adaptation and the potential for mitigation with associated technical, policy and financing implications. All said, sustainable agricultural practices, policies and finance can effortlessly move agriculture sector onto the resilient pathways paving way for food security, poverty eradication and mitigation of climate change.