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Climate change and sustainable agriculture: An option for food security

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Abstract
Climate change and its consequences are the matter of great concern all over the world as it can make life vulnerable on earth. There are clear evidences that atmospheric temperature has been gradually increasing since the beginning of the industrial revolution in 1850's. IPCC's reports conclude that most of the observed temperature increases since the middle of the 20th century is caused by increasing concentration of GHGs in the atmosphere emitted from human activities (fossil fuel burning). Climate Change is projected to have extensive effects on a number of economic, environmental and social issues, comprising agricultural production and food security in developing countries like India. Agriculture is extremely dependent on climatic factors. Change in climate leads to variation in temperature and precipitation which affects soil nutrient, crop yields, quality and production. The relationship between climate change and food security is complex. Estimation of the potential effects of climate change on food security requires a comprehensive understanding of the three aspects of food security – availability, access and utilization – and how climate change might affect each of them. Sustainable agricultural development is the need of the hour to tackle this catastrophic phenomenon. Under this, firstly increase in agricultural production and incomes to meet demand is to be considered, secondly production system is to be made more resilient for which a set of objectives (adaptation) is to be set to counter climate change and thirdly greenhouse gas emission from agriculture (mitigation) is to be checked. Considering the above concern this paper provides an overview of climate change and sustainable agriculture for providing food security to the increasing population.

Keywords: climate change, sustainable agriculture, food security, adaptation and mitigation

1. Introduction
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 [1]. The scientific evidence between climate change, temperature rise, rainfall variation and agriculture has been well recognized. The scientific evidence, including the Fourth Assessment Report (AR4) of the Inter-governmental Panel on Climate Change [1], 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. Millions of people could suffer from hunger, water shortage and coastal flooding, as the world gets warmer. The latest COP UNFCCC meetings point to the urgency of this matter. Climate change is affecting food security in the developing world in unprecedented ways. Presently, 195 nations have endorsed to decarbonize the global economy and lower the temperature rise cap from 2ºC to 1.5ºC (COP21, 2015). This milestone agreement comes from the evidence on the dangers of climate change. These evidences has already been pointed out by insightful works of Rowhani *et al*. (2011) [2], Lobell, Bänziger *et al*. (2011) [3], Ahmed *et al*. (2011) [4], and Parry (2007) [1]. Now the question is how to reduce the emissions effectively and how to lessen the climatic effects collectively in the years to come?
Taking into account multidisciplinary adaptive measures is an important step in considering national short-run as well as long-run costs and benefits. Lack of unanimity over climate policy strategies and course of action is causing further delay in applying mitigation and adaptation measures [5]. The climate change strategy and policy of mitigation and adaptation requires consideration of complex interaction of economy, environment as well as social needs of a nation and it is important to align efforts of both developed and developing nations. Recent literature shows that, if no adaptive measures will be launched, it would intensify the damage for production. Productivity can be reduced three times faster in developing countries than developed countries by 2050 (IPCC, 2007). The human systems or activities are mainly responsible for the combustion of fossil fuels and deforestation that causes the rapid climate change. The research communities and policy makers are aware of the vulnerabilities of climate change and constantly working to that end. 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 [6]. A multidisciplinary approach integrating the dimensions of physical and social science can be adopted for adaptive modeling to construct long-term climate change scenarios.

2. An Overview of Climate Change
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 [1], 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. It is estimated that climate change will affect the basic elements of life around the world like access to water, food production and healthcare. 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.

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. It is very likely that hot extremes, heat waves and heavy precipitation events will continue to become more frequent. Variation in precipitation is also expected. Increase in precipitation is expected in high-latitudes while decrease is expected in most subtropical land regions [6].

3. Reasons to Adapt to Climate Change

- Climate change cannot be totally avoided.
- Anticipatory and precautionary adaptation is more effective and less costly than forced, last-minute, emergency adaptation or retrofitting.
- Climate change may be more rapid and more pronounced than current estimates suggest. Unexpected events are possible.
- Immediate benefits can be gained from better adaptation to climate variability and extreme atmospheric events.
- Immediate benefits also can be gained by removing maladaptive policies and practices.

Climate change brings opportunities as well as threats. Future benefits can result from climate change.

3.1 Why Food Security Challenge is Important?

There are over hundreds of definitions of food security (FAO, 2003). The term usually 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. Majority of the world's poor population lives in South Asia and Sub- Saharan Africa countries, nearly 1.7 billion people and out of this, approximately for 860 million people there food security [9]. Countries are not able to provide sufficient quantities of nutritious food to these people so that they can live healthily. It is strongly believed that there is enough food in the world to feed everyone adequately but the problem is distribution and management. Therefore development and implementation of a food security plan is necessary that must include procedures for handling threats, product tampering, and product storage and distribution plan along with a monitoring procedure. Moreover there should be a corrective action that prevents products from entering commerce.

According to the first report of IPCC, the average global temperature rose by 0.74ºC during last century but the recent reports indicate that within the 21st century the temperature will be raised up to 1.1–6.4ºC (IPCC, 2007, 2011). IPCC (2007) [10] also predicted similar trends and stated specifically that the impact of climate change on agriculture would be more severe particularly on food security related issues. The higher temperature would be responsible to change in the climatic patterns like floods, draughts and incidents of the El-Nino and La-Nina. In Asia, and in particular South Asia and South East Asia, without action up to 10% of many of their regional staples, such as rice, millet and maize can be lost. The report of the Centre for Global Development (CGD, 2007) mentioned that many developing nations had already crossed or about to cross the average mean temperature in terms of the level of crop tolerance. Agricultural production can be decreased by 10–25% in the developing countries by 2080 if there is no effort initiated to reduce carbon emission to a lower level, and no implementation of certain adaptation options for climate change. The damage to crop due to climate change at around 6–8% in the developed countries is far lower compared to that of which would be in a developing countries. This kind of scenario for declined food productivity of the developing countries creates enormous pressure to the governments as most of them are occupied by agricultural dependent states [11]. We know that bridging the gap between the climate change concerns and mainstreaming adaptation development activity is not easy. Specific information is therefore required for the resilience of climate change for developmental activities along with operational guidance on how best to adapt to its impacts, within the contest of other pressing social priorities.

4. State of Food Insecurity in the World

The FAO report estimates that 795 million people in the world - just over one in nine – were undernourished in 2014-16 (Table 1). The share of undernourished people in the population, or the prevalence of undernourishment, has decreased from 18.6 percent in 1990–92 to 10.9 percent in 2014-16, reflecting fewer undernourished people in a growing

global population. Since 1990–92, the number of undernourished people has declined by 216 million globally, a reduction of 21.4 percent, notwithstanding a 1.9 billion increase in total population over the same period.

Table: 1 Number of undernourished (*millions*) and prevalence (*%*) of undernourishment

Region	1990-92		2000-02		2005-07		2010-12		2014-16	
	No	%	No	%	No	%	No	%	No	%
World	1010.6	18.6	929.6	14.9	942.3	14.3	820.7	11.8	794.6	10.9
Developed	20.0	<5	21.2	<5	15.4	<5	15.7	<5	14.7	<5
Developing	990.7	23.3	908.4	18.2	926.9	17.3	805.0	14.1	779.9	12.9
Africa	181.7	27.6	210.2	25.4	213.0	22.7	218.5	20.7	232.5	20.0
Asia	741.9	23.6	636.5	17.6	665.5	17.3	546.9	13.5	511.7	12.1
Southern Asia	291.2	23.9	272.3	18.5	319.1	20.1	274.2	16.1	281.4	15.7
Latin America	66.1	14.7	60.4	11.4	47.1	8.4	38.3	6.4	34.3	5.5
Oceania	1.0	15.7	1.3	16.5	1.3	15.4	1.3	13.5	1.4	14.2

***Source*:** SOFI 2015 [12]

4.1 Scenario in South Asia

The highest burden of hunger in absolute terms is to be found in Southern Asia. Estimates for 2014–16 suggest that about 281 million people are undernourished in the region, marking only a slight reduction from the number in 1990–92. But there has been noticeable progress in relative terms the prevalence of undernourishment has declined from 23.9 percent in 1990–92 to 15.7 percent in 2014–16. Most countries in Southern Asia have made progress towards the international hunger targets, even if the pace has been too slow for them to reach either the WFS or the MDG targets, including, for example, Afghanistan, India, Pakistan and Sri Lanka. As these countries constitute a large share of the region's population, they account for the low overall performance – India still has the second-highest estimated number of undernourished people in the world.

4.2 State of Food Insecurity in India

4.2.1 The Status and Trends in Food Production (Availability)

Food Security is both physical and economic access to food that that meets people's dietary needs as well as their food preferences. Food security as "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (World Food Summit 1996). Food security is a complex sustainable economic development, environment and trade.

Table 2: Compound Growth Rates of Area, Production and Yield of Principal Crops during 1980-1990, 1990-2000 and 2010-2011.

Crops	1980-81 to 1989-90			1990-91 to 1999-00			2000-01 to 2010-11		
	A	P	Y	A	P	Y	A	P	Y
Rice	0.41	3.62	3.19	0.68	2.02	1.34	-0.10	1.51	1.61
Wheat	0.46	3.57	3.10	1.72	3.57	1.83	1.28	2.16	0.87
Maize	-0.20	1.89	2.09	0.94	3.28	2.32	2.81	5.65	2.77
Cereals	-0.26	3.03	2.90	0.04	-0.02	1.59	0.09	2.01	3.19
Pulses	-0.09	1.52	1.61	-0.60	0.59	0.93	1.62	3.35	1.90
Food grains	-0.23	2.85	2.74	-0.07	2.02	1.52	0.37	2.12	2.89
Oilseeds	1.51	5.20	2.43	-0.86	1.63	1.15	2.14	4.60	3.59
Fibers	-1.50	2.46	3.98	2.45	2.21	-0.27	2.15	11.76	9.55

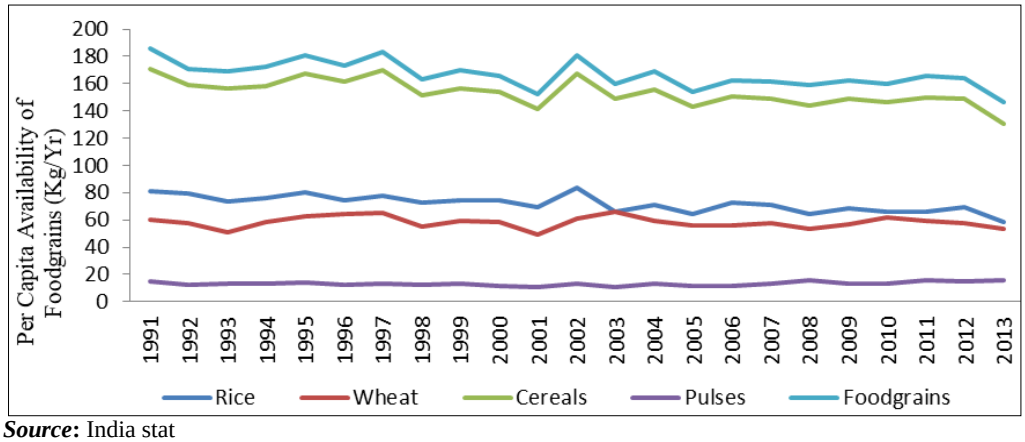
***Source*:** Directorate of Economics and Statistics, Department of Agriculture and Cooperation

Over all Food grains production in the country increased from about 50 million tonnes in 1950-51 to around 241 million tonnes in 2010-11 and production during 2009-10 is estimated at 218.11 million tonnes which is 16.36 million tonnes or 6.98% less than 234.47 million tonnes in 2008-09. Particularly, the kharif food grains production estimated at 103.95 million tonnes in 2009-10 is 14.19 million tonnes or 12% less than 118.14 million tonnes in 2008-09 and in rabi, production estimated at 114.16 million tonnes which is 2.17 million tonnes or 1.87% less than 116.33 million tonnes in 2008-09 (Annual report, 2011). Table 2 depicts the annual growth of food grains and observed the 2.12 per cent of growth in production and 0.37 per cent in area from 2000-01 to 2010-11. But in coarse cereals, pulses and total fibers have gradually declined in area and production. In fact, wheat and rice are critical for India's food security but their share of production has declined over last couple of years, while yields are stepping up. The growth rate of rice and wheat around 3.62 and 3.57 per cent per annum between 1980s and in 2010-11, it has declined to 1.51 and 2.16 per cent respectively. From the last two decades growth rates of production of total cereals has declined to 2.01 per cent from 3.03 per cent during the period 1980s as compared to the period 2010-11 (Table 2). The growth rate of production was much lower than that of population in the latter period. Similarly, growth rate of yields of food grains slightly increased from 2.74 per cent to 2.89per cent.

4.2.2 Per Capita Availability of Food grains

The per capita availability of major food grains has declined in the first decade of the 21th century (figure 1). Major crops like wheat and rice also showed a declining trend. The major

cause for this decline is likely to be the climate change. Production and availability of pulses which is the main source of protein for the majority of the population is also under threat of climate change.



***Source*:** India stat

Fig 1

5. An Overview of Climate Change and Agriculture

Global agriculture will be most influential in feeding nine billion people by the year 2050 and in addressing the needs of the 795 to 805 million people who are food insecure today. It also provides livelihoods for some 2.6 billion people worldwide and accounts for between 20 and 60 percent of the gross domestic product in most developing countries. No other sector of the economy is as effective in raising people out of poverty. And no other sector is as directly reliant on its natural resource base, the land and water resources that are the fundamental elements of crop and livestock production. Throughout much of the world, grain yields will decline by 5% with each degree Celsius increase in temperature. The vulnerability of agricultural systems to climate change is chiefly described in terms of risk. Much of this involves the increased risk associated with more frequent instances of heat stress, drought, and flooding, or what are generally referred to as production risks. The Food Policy Report 2009 suggested that agriculture and human well-being will be negatively affected by climate change [13]. Agricultural practices in their current "business as usual" form are projected to account for up to 70 percent of total human-induced emissions by 2050 if global warming is successfully limited to two degrees Celsius (WRI 2014). The impact of climate change at the global level is severe, especially in the developing world, and the social and economic implications in China, India, Brazil, and the poor countries of the tropical belt in Africa and Latin America.

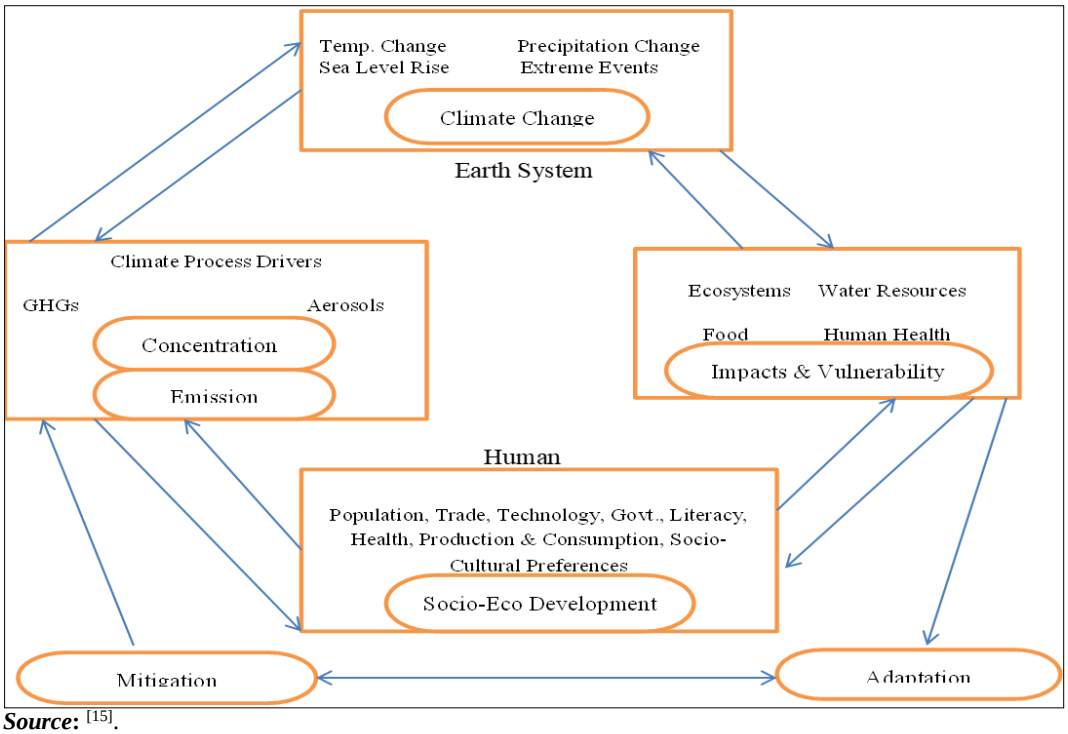
5.1 Climate Change and Indian Agriculture

Agriculture is the backbone of Indian economy and food security. India is principally an agricultural country. The agriculture sector accounts for about 13.9% (2013-14) of the GDP and employs 47% (2012) of the total workforce. Climate Change in India is accompanied by high average temperature, changed rainfall patterns, increased severity and frequency of floods, droughts and cyclones, oceanic acidification, climate changes due to GHGs, transport, industries, agricultural waste decay, high yielding techniques of agriculture, arbitrary use of natural resources, deforestation, reduction in pastures, fertility of land reduction, forests, flora and fauna disappearance. FAO has estimated that India would lose up to 125 million tons of cereals due to climate change. Agriculture and allied sectors are highly sensitive and vulnerable to climate change. Changes in climate would influence agriculture by changing the length of the growing season, crop yield, agricultural potential and shifting the geographical area. More than 60% of the cropped area in India still depends solely on monsoonal rainfall (Central Statistical Organization). The IPCC estimated that GDP in the developing and less developed countries would decline by 1.4-3.0 % due to climatic change. In India the effects of global warming are likely to be more severe. For every 2^0C rise in temperature, the reduction in GDP is 5% and for the next 6^{o}C it would be 15-16%. Likewise FAO has estimated that India would lose up to 125mt of cereals. The effects of climate change on agriculture vary regionally and by crops. Higher growing season temperatures can considerably impact agricultural productivity, farm incomes and food security.

The problems with which the Indian agricultural scenario is troubled in present times are many, but in no way the importance of the sector is undermined because it plays an important role in the holistic and inclusive growth of the country. Agriculture is fundamental for sustenance of an economy as is food for a human being. It contributes significantly to export earnings and is an important source of raw materials for many industries. Its revival is being taken on priority, through various interventions at different levels, because of its potential in reducing poverty and food insecurity. More than 60% of the cropped area in India still depends solely on monsoonal rainfall (Central Statistical Organization). Recent studies indicate a probability of 10-40% loss in crop production by 2080-2100 in India and other South Asian countries due to increases in temperature, rainfall variability and decreases in irrigation water. Rice production in many parts of India projected between 2010 and 2070 would increase by 26% in an optimistic and 9-30% in a pessimistic scenario. Every 1^{o}C temperature rise during the growing period will result in loss of 4-5 million tons in future wheat production [14].

6. Inter-Linkage between Climate Change and Socio-Economic Development

There is a close relationship between the various aspects of earth system and the human environment [figure 2]. Anthropogenic emission has been proved to be the sole cause of climate change as reported by the IPCC in its 5th Assessment Report. The immediate effect of climate change can be seen in the variations in temperature (max & min) trend and precipitation, melting of glaciers and sea level rise. Climate change also brings with it the extreme events. These events have devastating effect on the socio-economic development of the society, which includes food, health and water resources. In order to have a control over climate change it is the high time that we check our GHGs' emissions. The vulnerable regions should be focused. Agriculture and food production should be made sustainable. Appropriate adaptation and mitigation strategies should be developed.



***Source*:** [15].

Fig 2

7. Sustainable Agriculture

In simplest terms, sustainable agriculture is the production of food, fiber or other plant or animal products using farming techniques that protect the environment, public health, human communities and animals welfare. This form of agriculture enables us to produce healthy food without compromising future generation's ability to do the same.

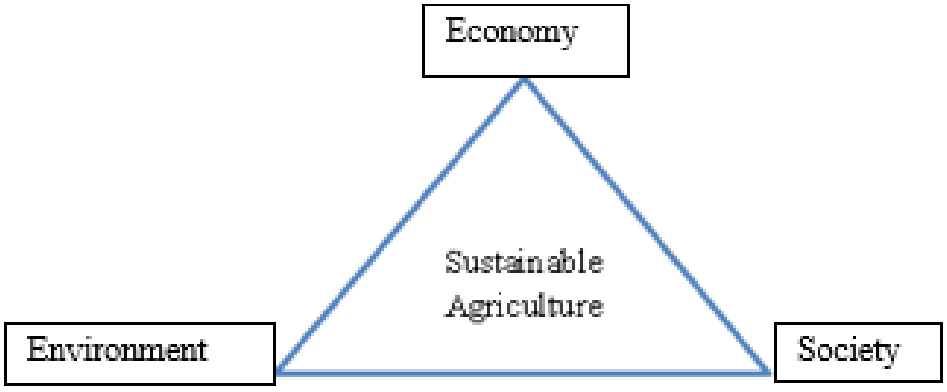


Fig 3

Sustainable agriculture gives equal weightage to environment, social and economic concerns in agriculture [16].

8. Climate Change and Sustainable Agriculture

Agricultural sustainability is to meet the needs of the present

without compromising the ability of future generations to meet their needs. Therefore, long-term care of both natural and human resources is of equal importance to short-term economic gain.

Sustainable agriculture is not a single, well-defined end goal. Scientific understanding about what constitutes sustainability in environmental, social, and economic terms is continuously evolving and is influenced by contemporary issues, perspectives, and values. For example, agriculture's ability to adapt to climate change was not considered a critical issue 20 years ago, but is now receiving increasing attention. In addition, the details of what constitutes a sustainable system may change from one set of conditions (e.g., soil types, climate, labor costs) to another, and from one cultural and ideological perspective to another, resulting in the very term "sustainable" being a challenged term.

The agricultural sector is one of the main greenhouse gases emission sector and at the same time, is perhaps the socio-economic sector that will suffer the most serious consequences of global climate change. But it is for this reason that agriculture is an excellent testing ground to launch effective processes for mitigating global warming. Several studies have stated that it is most likely that global climate change will generate different impacts on regional, physical, and biological systems. The main socio-ecosystem sectors subject to potential impacts are the water sector, ecosystems and biodiversity (an increased risk of extinction for crop and also animal species is likely**),** the coastal system (coasts will be exposed to greater risks, including erosion, due to the forecasted rise in sea level and the occurrence of exceptional events), the healthcare sector (exposure to climate change will likely impact peoples' health), and the agricultural and food sector (projections indicate changes in agricultural and forestry production, and in the availability of food products). The agricultural sector also contributes in climate change and is among the sectors most affected by global warming. However, agriculture could become an essential part of the solution to the problems of climate change**.**

8.1 Sustainable Agriculture Practices

1. **Rotating Crops**: Planting a variety of crops can have many benefits, including healthier soil and improved pest control. Crop diversity practices include intercropping (growing a mix of crops in the same area) and complex multi-year crop rotations.
2. **Planting Cover Crops:** Cover crops, like clover or hairy vetch, are planted during off-season times when soils might otherwise be left bare. These crops protect and build soil health by preventing erosion, replenishing soil nutrients, and keeping weeds in check, reducing the need for herbicides.
3. **Reducing or Eliminating Tillage:** Traditional plowing (tillage) prepares fields for planting and prevents weed problems,, but can cause a lot of soil loss. No-till or reduced till methods, which involve inserting seeds directly into undisturbed soil, can reduce erosion and improve soil health.
4. **Applying Integrated Pest Management (IPM):** A range of methods, including mechanical and biological controls, can be applied systematically to keep pest populations under control while minimizing use of chemical pesticides.
5. **Integrating Livestock and Crops:** Industrial agriculture tends to keep plant and animal production separate, with animals living far from the areas where their feed is produced, and crops growing far away from abundant manure fertilizers. A growing body of evidence shows that a smart integration of crop and animal production can be a recipe for more efficient, profitable farms.
6. **Managing Whole Systems and Landscapes:** Sustainable farms treat uncultivated or less intensively cultivated areas, such as riparian buffers or prairie strips, as integral to the farm-valued for their role in controlling erosion, reducing nutrient runoff, and supporting pollinators and other biodiversity [17].

9. Mitigation of Agricultural GHG Emissions

In 2005 agriculture contributed an estimated 10–12% of total anthropogenic emissions of greenhouse gases (GHGs). Reducing N_2O and CH_4 emissions, increasing carbon sequestration, or avoiding emissions through use of biomass for fuels or reduced land clearing are technical options to reduce emissions [18]. If deforestation through agricultural expansion were reduced by 10% for the period 2015–2020 through agricultural development pathways that involve intensification, about a further 500 Mt CO2-eq. could be stored [19]. Clearly, changes in agriculture can help reduce climate change, but whether society can also meet projected food needs under mitigation regimes remains undecided. Innovation and capacity building are required for improved farming practices.

- **Agricultural Growth:** Producing more crops from less land is the single most significant means of jointly achieving mitigation and food production in agriculture. Agricultural intensification (or the increase of yields per unit land area) is widely assumed necessary to meet projected food needs, given current economic and dietary trends. Future intensification will require more attention to the efficiency of inputs and their environmental costs. More efficient use of fertilizers, pesticides and fossil fuels, more sustainable alternatives, and breeding for efficiency will be required to reduce the carbon intensity (emissions per unit yield) of products, as well as reduce land areas and inputs that damage environmental health.
- **Technical Compatibility:** The other major option is to farm in ways that reduce GHG emissions or sequester more carbon without reducing food production. The potential trade-offs and synergies between mitigation practices and food production have been well reviewed [20]. Enhancing soil carbon also has important environmental benefits in terms of water storage, soil biodiversity, and soil aggregate stability. Soil carbon sequestration is estimated to have the highest economic mitigation potential [18], although incentives for its adoption, as well as permanence, variability and monitoring, need to be addressed.
- **Monitoring and Evaluating:** Since mitigation measures could potentially improve the cost, yields and sustainability of food, getting more precise estimations of mitigation and its effects on food systems is essential to assess actual trade-offs. At both local and national levels,

greenhouse gas budgets for specific farm practices, foods and landscapes are often unavailable, especially in low-income countries. Full accounting of GHGs across all land uses will be necessary to account for leakage and to monitor the impacts of intensification. Measurement technologies are well known, but monitoring of indicators and life-cycle analysis can be expensive and interactions among farm practices difficult to assess.

- **Economic Feasibility and Incentives:** Knowledge of the economic feasibility of agricultural mitigation and its links to investments in food security needs improvement. Smith *et al*. (2007b) estimate that less than 35% of the total biophysical potential for agricultural mitigation is likely to be achieved by 2030 due to economic constraints [18]. Farmers and others driving the expansion of cultivated areas will require incentives to undertake mitigation practices. International agreements that enable agricultural GHG reductions to count towards countries' commitments to emissions reductions could create an important policy incentive. Understanding the potential for mitigation through alternative agricultural development pathways and the incentives driving them will be important for transforming agriculture towards more sustainable practices.
- **Smallholder Farmers Implications:** Smallholders should not be expected to bear costs of mitigation without compensatory benefits to incomes and livelihoods. Investments in technological innovation and agricultural intensification strategies should be linked to increased efficiency of inputs, and to comprehensive land-use policies and payments for environmental services that discourage forest conversion and negative environmental impacts. Agricultural intensification will require appropriate institutional and policy support to create environmental benefits as well as increases in crop yields for smallholders [21]. Investments should also be made in technical and institutional innovations that reduce the costs of mitigation and increase incentives for the implementation of mitigation.

10. Conclusion

Climate change has started showing its impact on water resources and agricultural produce globally. Agricultural sector and food security are threatened and if the basic adaptive measures such as changes in crop pattern, crop breeding and types and innovative technologies, which use less water, are not used. Global food production especially in arid and semi-arid areas will further decline. These countries are not able to fulfill the required demand for water and food for people. Intensification of agricultural production must be accompanied by concerted action to reduce greenhouse gas emissions from agriculture to avoid further acceleration of climate change and avert threats to the long-term viability of global agriculture. Food systems vis-à-vis climate change need urgent action in spite of uncertainties. There is a persistent need to invest in databases and tools to inform policy and practice in the spheres of agricultural risk-management, adaptation and mitigation. Similarly, initiatives to develop capacity to tackle climate change impacts on farming and food must. Strategists need not just a holistic view of the system but rather a calculated approach that focuses on key needs and processes. The amount of food required will be even greater if current trends in diets and the existing management regimes of food systems continue. The key challenge in assuring future food security is to apply such approaches across the whole food system and across multi-purpose landscapes. Adaptation in agriculture involves various stakeholders who have different, but inter-related roles. Governments (and other public agencies), private industries and corporations, and individual producers (farmers) all have a place in the adaptation process. Governments and industries need to be aware how public initiatives (such as increased investment in income stabilization or crop insurance) and private initiatives (such as the development of new crops or crop insurance) relate to producer decisions. Agricultural adaptation options at all levels are part of a larger process, within which decisions are made continuously.

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