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Impact of Climate Change on Agriculture & Vice Versa: A Review

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Abstract:

The article tackles the intricate relationship between agriculture and climate change, shedding light on the sector's vulnerability to the issue and its significant contribution to it. It not only underlines the simultaneity of the problem of climate change adaptation in agriculture but also highlight the need of greenhouse gas reductions. Climate change disrupts agricultural practices through extreme weather events like droughts, flood and unpredictable rainfall patterns. Climate changes threaten agricultural output and food security, economic hardship and social unrest. Climate change isolates crops production hence resulting in low yields, economic losses, and changing food prices. Cattle, rice growth, fertilizer use and residue burning are principal greenhouse gas contributors of agriculture. When carving virgin forests for agricultural purposes, the ancient carbon is released and climatic patterns are disrupted, greatly exacerbating the problem. These agricultural practices include deforestation, utilization of fossil fuel, and intensive use of water. Mitigation in climate change require sustainable agricultural practices that reduced emission and improve soil health. We need to adapt agricultural practices to be more resilient in the face of climate change while also reducing agricultures contribution to the problem. The complex interplay between climate change and agriculture requires a holistic approach that integrates mitigation and adaptation strategies at local, national and global scale. Efforts to enhance resilience, promote sustainable practices and support equitable adaptation measures are essential to safeguarding the future of agriculture in a changing climate.

Keywords: climate change, agriculture, food security, greenhouse gas emission land use change, resource utilization, climate smart agriculture

Introduction

Connection between agriculture and climate change

The relationship between agriculture and climate change is of crucial importance, considering an adverse impact of the climate change on agricultural systems and a significant contribution of agriculture in the global greenhouse gas emissions (Arbuckle *et al*., 2013). As an important agricultural contributor to emissions, it is highly exposed to adverse effects of climate change (Arbuckle *et al*., 2013). Accordingly, it is necessary to carry out adaptation and mitigation practices in agriculture to respond to the challenges owing to climate change (Harvey *et al*., 2014). A climate-smart agriculture emerged as a holistic solution to address these challenges, increase food security, advocated adaptation to climate change and marginally yielded mitigation effect (Katel *et al*., 2022). Such an approach takes into account the underlying need for the agricultural systems to set their climate smart goals, which must include: increased food security, improved livelihoods in rural areas, adaptation to climate change, and mitigation of this change. This type of shift usually requires a strategic management of farmlands (Scherr *et al*., 2012).

The effect of climate change on agriculture is clear as meteorological patterns changes and high climatic variability leads to greater crop farm losses (Mirzabaev, 2018). The research has shown that climate change is one of the challenges that leads to a decrease in agricultural productivity, so some farmers may extend their crop production into adjacent natural areas to compensate the loss of production (Hannah *et al*., 2013).

Table no.1: Impact of climate change on different crops and their production

Crop	Decrease in production
Maize	24% decrease
Wheat	17% increase
Rice	Fluctuating yields, vulnerability index of 0.77, low adaptive capacity
Millet	Increasing yields, vulnerability index of 0.5, higher resilience

Moreover, the vulnerability of agriculture to intensified weather fluctuations and climate disturbances shows that there is a need for adaptive measures to strengthen the systems of agricultural productivity in the context of relevance to climate change (Mirzabaev, 2018). Agriculture contribution to reducing the climate changing effects is also

admirable one. The comparative approach has been used in studying relevance of organic agriculture in fighting climate change. The research has pointed out the fact that organic agriculture presents a greater potential for successful climate change mitigation more than the conventional techniques (Goh, 2011). Moreover, climate smart agriculture (CSA), particularly the agroforestry methods, has played a significant role in achieving these objectives. It underscores the necessity of adopting the adaptable techniques, implementing mitigation measures, and the applicability of the landscape concepts on the agricultural systems
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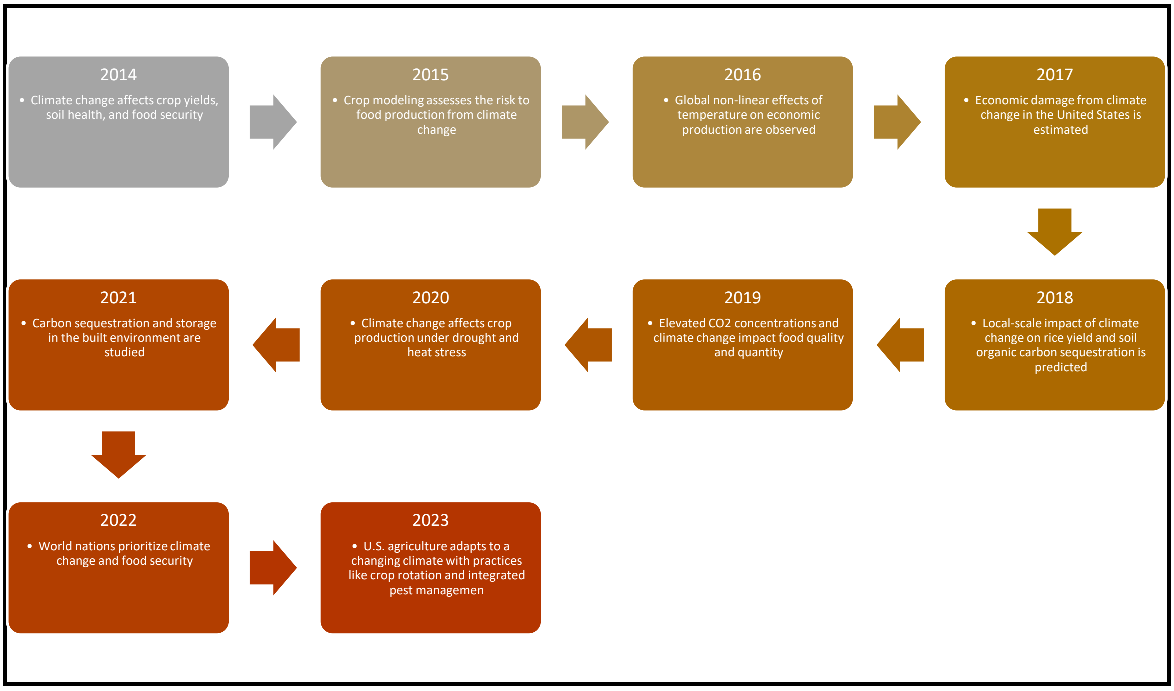

Figure 1: Impact, adaptation and mitigation for Climate change

Importance of addressing the dual challenge: reducing the impact of agriculture on climate and adapting agriculture to climate change

The issue of mitigation of agriculture's influence on climate change is a topic of vital importance because it is necessary to deal with not only the consequences of climate change (adaptation) but also the reason of it (GHG emissions) (Prokopy *et al*., 2015). An important aspect to consider in assessing agriculture's influence on climate change is to examine effects of all GHGs collectively rather than individually (Smith *et al*., 2007). The complexity involved in the agriculture and food security sectors when it comes to addressing the issues related to climate change is one of the biggest challenges, underscoring the importance of overcoming it, given than agriculture and food security are fundamental to human life (Porter *et al*., 2017).

Controlling emissions from agricultural activities is one of the most critical tasks, as the solutions within this realm can play a significant role in the global warming and greenhouse gas (GHG) emissions reduction which will lead to the reaching of 1.5°C temperature limit. These objectives are persued through the development of new policies, practices and finance that simultaneously support climate change adaptation, mitigation its effects and global food security (Torquebiau *et al*., 2018). The whole-landscape approach that is inclusive of enhanced agriculture techniques is provided as the key intervention strategy of achieving the dual objectives of the production of food and climate mitigation in tropical environments (DeFries & Rosenzweig, 2010).

The challenge facing agriculture within the context of climate change is twofold: not only must it mitigate emissions, but it also needs to prepare for an already changing and extremely unstable climate (Smith & Olesen, 2010). Taking both issues as a challenge is significant, especially while also restraining the use of ecosystem services that are beneficial to human health and living standards (Smith *et al*., 2013). Moreover, even in developing countries farmers may face dual burden of adapting consequences of climate change and coping with disruptions caused by other events such as the COVID-19 pandemic (Rasul, 2021) (Figure 1).

To achieve food security, adopt climate adaptation and mitigation measures, as well as ensure steady performance of agricultural sector amidst climatic variability and change, a comprehensive approach is needed. The increasing impact of potentially occurring climate events along the clear trends indicating climate change, underscores the need for integrated strategy to mitigate agricultural adaptation (Howden *et al*., 2007). Farmer response to climate change is deeply influenced by their assessments of how much benefit can be derived in future. Accordingly, adaptation measures can drive the change in the agricultural practices through the trial and error (Mabe *et al* 2014). Adaptation planning which would allow farmers to carry out agriculture in a manner which would lower their exposure and increase their systems' resilience to climate variability are critical to achieving agricultural productivity and lowering risks of climate change (Aryal *et al*., 2020). Poor farm households are most exposed to negative effects of climate change therefore the adaptation methods are key to enable farmers to adapt to these effects and explore how they can manage

The agriculture being forefront of climate change impact is, perhaps the most urgent sector required modernization to confront upcoming challenges at quicker pace (Kendall & Spang, 2020). Besides, climate change awareness and perspective and procedure improving in farmers through extension of services is another important role of agricultural extension services to strengthen agricultural resilience (Tilahun, 2020).

Agroforestry has been categorized as an example of climate smart agriculture technology that is both mitigation as well as adaptation tool for agriculture. By emphasizing dual benefits agro forestry illustrates the potential of 'Climate-smart' agriculture to implement adaptation and mitigation plans and addressing food security in a complementary way. Additionally, the study of adaptation strategies in agricultural sector concerning the way climate influences the productivity of production also underlines how to adapt proactively but preserve productivity of agricultural sector (Tanaka, *et al*., 2011). Addressing the dual tasks of reducing and adapting agricultural systems to the impact of climate change is of utmost importance to ensure the stability and resilience of these systems in the conditions of growing climate variability and frequency of the extreme climate phenomena.

Understanding the Current Scenario

Causes and consequences of climate change in agriculture Causes: Climate change affects the number of the things like crops yield, soil processes, water availability and the number of insects, etc. Climate change, that undeniably has significant adverse implications for food yield, crop development, and living organism's reproduction, has been well documented (Skendžić *et al*., 2021). Climate change, which includes global warming, water scarcity, lower agricultural productivity, food security, rising sea levels, melting glaciers, and biodiversity loss, is causing agricultural production and water quality to deteriorate. It has been noted that the amount of area impacted by drought has grown from around 5-10% to roughly 15-25% for major crops such as barley, wheat, rice, sorghum, soybean, and maize since the 1960s (Malhi *et al*., 2021). Furthermore, climate change is known to speed up the evolution of soil salinity, posing a significant threat to both environmental sustainability and global food security. This has the potential to spread the disease to previously untouched locations in the near future. However, soil salinity concerns have not been solved by remedial treatments such as amendment application, growth of resistant genotypes, correct irrigation, drainage, and bioremediation approaches (Eswar *et al*., 2021).

To mitigate climate risks, measures such as introducing heat and water stress-tolerant plant varieties, cultivating new stress-tolerant crops, implementing enhanced agricultural management practices, boosting water use efficiency, adopting improved conservation farming techniques, enhancing pest control methods, deploying weather adaptation strategies such as forecasting, and other climate services are being introduced to reduce climate risks (Devi *et al*., 2022). By adopting sustainable land-use practices and optimizing input usage, agriculture can significantly reduce its greenhouse gas emissions.

The crucial role carbon dioxide plays in driving climate change is extensively recognized in the literature. Human activities, especially the burning of fossil fuels, are causing a rapid rise in atmospheric CO_2 concentrations. This elevated CO_2 traps heat in atmosphere which leads to global warming (Cloy *et al*., 2012). The long-term impacts of elevated CO_2 on plant production, including effects on photosynthesis and nutrient level is significant consideration.

The share of methane emissions from agriculture, especially the digestion of ruminants, is impactful. Methane is a very strong greenhouse gas compared to CO2 that could have a quicker level of warming than the CO_2. Methane mitigation strategies such as feeding modifications in the cattle are being explored. By use of industrial fertilizers and certain land management methods, intensive agriculture is the main source of nitrous oxide emissions. Appreciating the nitrogen cycle in agriculture is crucial (Reisinger *et al*., 2021). Nitrous oxide is a potent gas that contributes to the warming of the atmosphere and the depletion of the ozone layer. Sustainable agricultural approaches and nitrogen control are essential for mitigating these emissions (Kanter *et al*., 2020).

Rainfall patterns can be severely affected by deforestation and other land uses. If forest is replaced by agricultural land it leads to carbon emissions rise and climate alteration. Many researchers have been engaged in the study of the relationship between a shift in land use and climate change, with an emphasis on deforestation which is the major contributor to climate change the crop production is highly affected by rainfall fluctuations as agricultural subjected to variable rainfall. The rainfall disruptions can cause water deficiency either aided by rain-fed or irrigated farming methods (Baker, 2021). The significance of adaptive irrigation systems in adapting agriculture in the long-term to diminishing rainfalls is highlighted by the study. Temperatures across the world are rising, which means climate change is happening, agricultural ecosystems are now subjected to direct impact. It was found that an increase in temperature can lead to reduced agricultural production and lower quality. Rising incidence of heat stress during the critical periods of vegetation jeopardizes harvest of important crops (Zhang *et al*., 2020).

Consequences

Change in growing seasons like planting and harvesting times have profound impact on crop yield and quality to the greatest extent. Research indicates that the seasonal length difference can affect the adaptability of crops and decrease the production (X. Chen *et al*., 2020). Climate change alters insect and disease distribution and their behavior which creates new problems for agriculture (Amadou *et al*., 2021). Water scarcity and droughts are closely linked to evolving rainfall patterns and increasing temperatures. Irrigation crops are more vulnerable to water shortage. Efficient irrigation systems and rainwater harvesting, among other water management practices, are highlighted as key to water shortage mitigation in agriculture (Cloy *et al*., 2012). Soil loss and deterioration are the result of climate change that makes soil productivity and total output be affected. Research is ongoing on conservation farming and agroforestry as mitigating options to reduce land degradation and make agriculture resilient in the long term (P.-Y. Chen *et al*., 2017).

Economic effects of climate change on global agricultural production

Agriculture is not only about feeding people and it matters also to the state and the world economy. The issue of food security directly impacted by climate change is major global concern. Understanding the economic impact of climate change on agriculture is imperative for shaping and guiding policies at different levels. Recent studies of the recent age have concentrated on the side effects of climate change on the agricultural yield of the world (Kitetu & Ko, 2020).

The IPCC (Intergovernmental Panel on Climate Change) report puts forward the solution to the climate issue in agriculture through a recommendation. The economic consequences of climatic change on global agricultural output are all-encompassing, and this challenge is catching more and more attention (Molina and Abadal, 2021). In order to understand the economic consequences of climate change in context, we should also investigate some economic variables including temperature fluctuations, weather extremes and rainfall patterns (Karki *et al*., 2020). These differentials also mediate agriculture practices to influence crop yields, quality as well as market trends (X. Zhao *et al*., 2021).

Research indicates that the adverse effects of climate change on the agricultural production cannot be overstated. For instance, crop yield reductions result in great economic damages, which may potentially lead to food security issues on a global scale and to market instability. Climate-related variations in terms of temperature and air conditions affect quality and nutritional content of crops. The economic influence is felt in the food industry and public health, as they remind us about the connection between climate change and agricultural productivity. Adapting agricultural techniques to changing climate often incurs cost related to technology introduction as well as adjustment in planting and harvesting time (Lima *et al*., 2021).

The study investigates the intricate relationship between climate change and agricultural outputs. This research focuses on the nutritional and physiological impact of climate change on staple foods as well as the economic impacts. The economists conduct economic analysis to estimate the price of agricultural changes because of the climate changes. This research investigates the economic viability of adaptive measures including changes in planting and harvesting dates as well as farmers plight (Iizumi *et al*., 2020).

Scientists are investigating the complicated connection between climate change and global prices of food. This research concerns the market analysis of climate-triggered supply disruptions for eliciting key factors that influence food prices increases. The research stresses that the differences carry great meaning to consumers, producers, and policymakers. Continuing the research, the following part focuses on the total impact of shrimp farming on livelihoods and the rural economy (Malesios *et al*., 2020). This analysis examines how adjustments made by farmers in terms of their production affect socioeconomic stability and income distribution in rural communities. Global agricultural trade is being disrupted by climate change. The risk of reshaping trade flows for the future world food security. Knowing the economic connections between climate change and international trade is a basic prerequisite in the attempt to find solutions for global food security. Agricultural productivity changes affect the lives in a very direct way (Georgilas *et al*., 2021).

Costs and Strategies for Adaptation: Researchers are now considering the whole economics of climate-resilient agriculture. It's essential to understand economic feasibility for policymakers as well as of professionals. This research examines the impact of new technology on agricultural production as a mean of mitigation of agricultural economics (Mase *et al*., 2017).

Climate change's indirect economic effects on agriculture go beyond the agriculture. Research investigates the secondary effects on businesses such as food processing, transportation, and insurance. Understanding these indirect economic effects is crucial for risk assessment and the creation of resilient economies(Miller *et al*., 2021).

Agriculture's contribution to climate change

Agriculture remains a cornerstone of global food security and economic stability, supporting the livelihoods of billions and forming the core of the economy (V, 2022). Its multifaceted contribution extends beyond providing essential nutrients, playing an important role in enhancing overall human well-being, economic growth, and community development (Yemoh and Yemoh, 2022). Agriculture plays an important role in contributing to climate change. This sector contributes roughly 14% of total global greenhouse gas emissions (Lynch *et al*., 2021). By analyzing its impact, the main causes can be divided into three interrelated areas: GHG, land-use change, and resources.

Greenhouse Gas Emissions (GHG):

Ruminant Livestock (cattle, goats, and sheep) play a significant role both in agriculture production globally. It accounts for 40% percent of mean daily methane emissions in agriculture (Scholtz *et al*., 2020). En route to nutrition through the digestive system of these animals, microbes are fermented and methane is generated as one of the by-products. Methane is a greenhouse gas that is more powerful than carbon dioxide and expands heat by 28 times in 100 years (Gomaa and Gado, 2021). Methane emissions in cattle waste management system is also a major problem. Anaerobic manure decomposition, especially when in large storage facilities, sees releasing methane (Orangun *et al*., 2021). Rice farming is widespread and vital to the economy in many regions thus, contributing a good proportion to the GHG issues. Based on the fact that flooding is a routine in rice cultivation that creates a situation of poor ventilation, which is optimal for the development of methane producing microbes. Whenever heating with oil or natural gas occurs, the resulting methane is released into the atmosphere. For the sake of the planet, greenhouse gas emissions from rice production account for quite a substantial part of the overall contribution of agriculture to climate change according to Thomas *et al*. (2020).

Fertilizers which are made synthetically cause 70% of agricultural nitrogen oxides emissions (Wang *et al*., 2022). For every 1 kg of nitrogen fertilizer, it contributes about 0.01 kg of nitrous oxide into air. It is a potent greenhouse gas which is emitted in huge quantity from agricultural activities. The main source is the fertilizer application since the application of nitrogen fertilizer to the soil stimulates nitrifying microorganisms that transform nitrogen compounds into nitrogen oxides. These emissions potentially increase the environmental impact caused by agriculture (Kudeyarov, 2020). The implement of nitrogen fertilizer begins nitrification and denitrification processes in soil. Such products release Nitrous oxide, thus a greenhouse gas which is much more potent in producing warming than carbon dioxide (Kudeyarov, 2020). The processes of disposal of agricultural residues, crop residues and straw together form the major part of the global warming problem. Openly burning this waste gives out excessive amount of greenhouse gases including carbon dioxide and methane in to the air, these greenhouse gases overheat the Earth which results into climate change (Singh *et al*., 2021). Aside from that, residue burning releases black carbon that passes into air as particulate matter not only do they affect air quality but also enable evaporation by making snow and ice look neutral residue burning burns soil carbon resulting in less fertile soil; extra carbon dioxide goes into the atmosphere into the atmosphere (Reddy and Chhabra, 2022).

Land Use Change:

Land-use transformations run past the complicated chain of agents that cause climate change, both through the emission and sequestration of carbon in different ecosystems. The ability of climate change to dispose rainforests is also an agricultural effect of climate change. With the increase of the world's food demand, the forests are being senselessly felled just to secure space for agriculture. By pumping and storing carbon, the forests play the carbon sinks role. Under such process as through logging and burning of these forests' deforestation takes place and the stored carbon gets released into the air and oxidized to carbon dioxide. this mechanism plays an essential role in rising the proportion of greenhouse gas contents in the atmosphere (Sweden, 2020). Peatlands play a vital role as a source of released CO_2 by storing carbon and by releasing methane, as it is a potent greenhouse gas. These aquatic ecosystems that have large amounts of water are able to store large amount of carbon in carbon-rich ecosystems, hence carbon storage in long-term. Indisputably, farming, timber harvesting and peat drainage are human activities affecting the water quality, leading the degradation of the forest residues that release CO_2 to the atmosphere. The basic agrarian transformation mostly affects peatland runoff levels, shifts from carbon sinks to sources, and also contributes to global warming (Hopple *et al*., 2020).

Resource Utilization:

Deforestation, which particularly affects the agricultural sector, leads to the climate change since it has a huge impact on the carbon cycle at a global scale. Forests, as the huge carbon sinks, are very efficient at absorbing CO_2, storing it through photosynthesis on trees and plants. The forests are cleared for agriculture, and thus, the carbon storages there are now released into the atmosphere in form of CO_2, and, consequently, they had caused the extreme rising of greenhouse gases (Bull, *et al*., 2020). Whether agriculture is conversing forest land to burn trees to obtain energy which leads to the emission of CO_2. Consistent with direct carbon emissions, deforestation also further worsens climate issues in different other respects. To illustrate one the key services provided by forests is protecting the planet with its ability to sequester carbon dioxide from the atmosphere (Domke *et al*., 2020). Alongside that, deforestation is prevalent in the tropics, i.e. areas endowed with rich biodiversity and rainfall. Reforestation has a twofold influence on the local and regional climate, one the other hand causes changes in average temperature and precipitation, and being the main reason that alters the climate variability. Globally, agriculture is a main driver of biodiversity and ecosystem services loss, which further aggravates the situation from the adaptation standpoint. Damage to habitats increases adaptation ability of all ecosystems and major event likelihood (Crompton *et al*., 2021).

Modern agriculture has a large share of total energy consumption among which wastes of energy are mostly generated from intensive agricultural practices. These unchanged approaches mainly use nonrenewable power sources like fossil fuels for working the machinery, transportation, and irrigation. The burning of fossil fuels then emits these three major greenhouse gases i.e. carbon dioxide, methane and nitrous oxide into the atmosphere. Greenhouse gases are enhanced by CO_2, being a sub product of warming, as a result, the concentrations of these gases in the atmosphere increases, thus triggering climate change (Raza *et al*., 2023). With agriculture being one of the most water-intensive activities and the demand for irrigation associated with the population growth and changing climate patterns increasing, water scarcity becomes the most souring global challenges. Mega-scale irrigations might create a phenomenon of alteration in the weather, affect rainfall pattern, and lead to the water shortages (Boru *et al*., 2020). Plants under water stress are associated with releasing more carbon dioxide through the process of "respiratory distress" and therefore water consumption is one of the key facets behind the levels of greenhouse gases emitted. Some of these agricultural practices however, play the role of decreasing consumption of resources. In agriculture, however, intensive practices wreck soil structure and accelerate the disintegration of organic matter that turns out in the release of carbon (Rahman *et al*., 2020). Fertlizers are very important to increase soil fertility and crop yield but they may cause environmental issues alongside their excessive use. This leads to the excessive release of nutrients into water, affecting water quality as well as the health of ecosystems (Chaudhary *et al*., 2020). On one hand, this wasteful procedure creates environmental problems and on the other hand, its impact on the overall sustainability of these practices is minimized.

Strategies for reducing agriculture's contribution to climate change:

Today, climate change is recognized as the most prominent irritant of the global food security and nutrition (Malhi *et al*., 2021). The heating effect that the increment in emission of greenhouse gases is causing clearly has a big influence on agricultural activities globally. This economy, which is one of the largest in the world, is very fragile to variations in the climate. These, in turn, have a tremendous impact on financial status (Mendelsohn, 2009).

Sustainable agriculture practice:

Soil quality is a key indicator, which takes into account a variety of characteristics and ecosystem activities. Effective soil management is becoming more and more important, as seen by the growing interest in sustainable agriculture. This goal is accomplished using a variety of strategies, including mulching, tillage, and soil amendments (El Chami *et al*., 2020) keeping crop leftovers and organic materials in the soil, minimizing soil disturbance, and fostering carbon sequestration. Research has demonstrated that as compared to traditional tillage, no-till significantly reduces N_2O emissions (Rochette, 2008). Planting a variety of species in between cash crops enhances nitrogen cycling, safeguards the soil, and inhibits weed growth. In addition to lowering N_2O emissions, cover crops can improve soil organic matter (Poeplau& Don, 2015). Composted organic matter and biochar (charcoal produced from biomass) enhance soil fertility and carbon storage, contributing to long-term N_2O emission reduction (Smith *et al*., 2014).

Precision Farming Technological Interventions:

According to a report by Pathak *et al*. (2022), 14.5% of global greenhouse gas (GHG) emissions were release worldwide in 2018 from the agricultural sector, which means that agriculture is a significant player in the GHG emissions. These emissions are mostly generated by rice farming (methane from fermentation of flooded fields), livestock production (enteric fermentation and manure management) and fertilizer application (nitrous oxide emissions) (Tubiello *et al*., 2014). Smart farming, another name for precision farming, has shown effectiveness in reducing green gas emission form the field of agriculture and leadin g to an optimized and productivity increase use of resources. By the standards of precision farming different types of technology and tools are employed in order to target the inputs like fertilizers, irrigation water, and herbicides in a suitable and efficacious way (Roy & George K, 2020).

Technologies to Reduce Greenhouse Gas Emissions

Various precision agricultural technologies have the potential to reduce greenhouse gas emissions:

Remote sensing: Farmers are able to focus their resources perfect with the aid of real-time data revealing conditions such as the crop health, soil moisture, and plant nutrients from drones, satellites, and other remote sensing devices (Schirrmann *et al*., 2016). To prevent water loss and methane emissions from rice grow, it is necessary to save irrigation waters. For this purpose, drip irrigation and center pivots with variable speed control applied with respect to real time situations and allowing for different application rates are used (Parthasarathi *et al*., 2019). **Livestock management:** Through the precision technologies that can lower emissions of nitrous oxide from manure and enteric methane via the use of wearable sensors and feed management systems (Hristov *et al*., 2013) is provided by the optimization of animal nutrition and manure management.

Nitrification inhibitors: Application of those substances into fertilizers allow these emissions in the form of nitrous oxide be cut by half if the conversion of ammonium to nitrate is delayed (Liu *et al*., 2013).

Agro-ecological approaches to minimize environmental impact

Agro-ecological agriculture practices such as nutrient cycling and diversification can bring being highly efficient in environment management per day (Gliessman 2020). A wide range of beneficial effects by cover crops has been recognized including inhibition of weed growth, prevention of soil erosion, and improvement of soil health which altogether led to a better-balanced system (Blanco-Canqui *et al*., 2015). In addition to farmers, tree- and shrub-growers should also be incentivized. People who establish new forests would improve soil health, store carbon, replace firewood (reducing fossil fuel consumption), and increase tree biomass (dodds, 2023). Low-carbon energy consumption is another important factor contributing to reduced greenhouse gas emissions when farms move from fossil fuels to solar and wind power (Pretty *et al*., 2003). Local food systems also minimize the journeys of food and therefore they reduce transport emissions, which are a major part of the carbon footprint in agriculture (Rehman& Farooq, 2023).

Impact of climate and insect pests on agriculture

Climate change impacts the productivity of agricultural through modification of pests and diseases in number as well as performance. other environmental variables like temperature, humidity, precipitation, plays a significant role in the procurement of breeding grounds, multiplication, and development of organisms like insects, fungi, bacteria, virus, etc. It further could be the case that pest populations change as the environment undergoes shift (Shrestha, 2019). A 2°C rise in global surface temperature is tantamount to 46, 19, and 31% MMT total increase in maize, rice and wheat local losses due to pest pressure and the total amount is 59, 92, and 62 MMT. 2018; Deutsch *et al*. frequently encounter the limitation that the ad-hoc datasets are missing, which makes difficult their use as pest and disease control operational tools (Donatelli *et al*., 2017). The excessive use of nitrogen fertilizer is a problem, since it slows down the plant's growth process thus postponing spray coverage. Using capitalizing nitrogen fertilizer more than what is supposed to be causes luxurious, green plants that promote pests. The plant’s dry mass, leaf area expansion, chlorophyll content, and grain yield increase when it receives nitrogen fertilizer. There is a possibility that an increase in nitrogen favors the deposition of carbohydrates, proteins and free amino acids building up which may have attracted bugs (Bala *et al*., 2018). Rising temperatures will not only be relevant for plant and insect phenology and physiology seen separately, but also for the connection between two trophic levels. Since all species may not react to global changes similarly, climate change has the ability to draw apart trophic bonds and induce evolutionary interventions in interacting species (Tougeron *et al*., 2020). While they are sessile, plants possess an intricate immune system, which for the majority of pest and disease attacks is an adequate tool of resistance. Pattern recognition receptors (PRRs) are cell surface receptors that take notice of the first indictors of a pathogen attacking. Pathogen-associated molecular patterns (PAMP), which are components of microbes with the same structure, to PRR. Only a few PAMPs have been clearly well-characterized like bacterial flagellin and fungal chitin (Bisht *et al*., 2019). Cotton, which is a major crop in Pakistan, has suffered greatly from climate change due to heavy use of fertilizers and pesticides and also because of their very high-water requirement. Over 60 percent of the studies undertaken showed that traditional cotton production methods and climate change, emerged as the main contributors to the decline in cotton yield in the country. Issues on the durability of the system are raised with the cotton crop’s increasing tendency to be attacked by insect and pest as well as decreased crop yields, water over consumption, degradation of natural resources and affected human health, which has resulted in an increase of chemical-based conventional agriculture (Imran *et al*., 2018).

Adapting Agriculture to Climate Change

A million factors contribute to the yield of agriculture, including fluctuations of weather patterns, crop care and land management, occurrence of diseases and pests, and the probability of raging meteorological anomalies (Rao *et al*., 2018). We get an average figure of 4-6% drop in wheat production by each degree of global temperature rise. For example, temperature increases are anticipated eventually affect corn productivity also. By 2100, it is especially expected that the regions of this world responsible for 56% of the global corn production will reduce the yields (Myers *et al*., 2015). In addition, the climate change has already undergone the shifting of the distribution locations of plant diseases and pests to different latitudes by the regional climate conditions and is likely to create additional changes to the virulence and infection rates of the plant pathogens resulting in increased yield losses. During the climatic fluctuations including higher number of excessively hot and cold days, locating the best places to grow different crops might change as well. As a result, crop management practices and cultivars production will have to design to account for these environments. Such type of changes could include, for example, changing the crops, especially those like sorghum that can grown under a drought, as well as creating new varieties that are better fit for the new environmental conditions (Anderson *et al*., 2020; Spinoni *et al*., 2019).

One of the most crucial things for devising and implementing the adaptation programs knows how farmers perceive these changes in climate. Further perspective of farmers on their climate change perceptions serves as an ideal basis for policy makers to formulate relevant adaptation policies (Abid *et al*., 2019). The search for methodical technique of how to finally battle the rising climate issues caused by human activities is one of the most urgent issues faced by mankind in the 21st century (Dupraz *et al*., 2011). Switching from coal or other fossil fuel-powered plants to solar powered ones is the major step in diminishing the level of emissions in economies (Gorjian *et al*., 2022). As far as adaptation requirements go, agriculture is one of the most vulnerable sectors to climate change mainly due to the rise of temperatures and increasing frequency of extreme weather incidents (Trommsdorff *et al*., 2023).

Through the technical achievements, farmers can be equipped with the correct information for detailed analysis of environmental aspects which can be utilized for Farm Management. We may employ software, nutrient tools, devices for measuring temperature, and tools for soil health analysis, and much more. A holistic approach involving all the stakeholders including farmers, local communities, academia, researchers, policymakers, civil society organizations, etc. holds the more prospects of success in management of the agricultural and water resources in the face of the climate change impact.

The agricultural sector's productivity is largely dependent on three key resources: energy, water, and the use of the land. With the growing energy sufficiency and energy price rising, a greater demand for energy efficiency has been put forth, and the search for alternative energy sources has been pushed to accelerated stages (Gorjian *et al*., 2019, Xue, 2017). The application of renewable sources of energy has the ability to ameliorate the sustainability of the crop breeding through the reduction of the energy on non-renewable resources. These technologies that include are solar power which is the most abundant as well as reliable energy source; with its capability to address the power demands of a huge of agricultural operations. The Photovoltaic (PV) technology which is a major converter of solar energy energy worldwide has experts predicting growth in upcoming years. It is evident that the history of the last decades is full of great technical achievements that concern the use of solar power. The production of energy by photovoltaic displays is the technology that holds the largest share in the market now and the capacity of its production reached 107 GW in 2020 (Duman&Güler, 2020).

Building Resilience in Agricultural Systems:

Climate-resilient approaches imply raising adaptability of agroculture which will help countries to increase their food production and raise income of farmers who provide the food security which holds an important position in general development of the economies in the world which pursues decreasing emission of greenhouse gases from crop fields and livestock farming. This would be effective replacement of farming activity with agroforestry activity that leads to income improvement, nutritional status of livestock, family nutrition & forest cover protection. In addition, the utilization of water resource management systems in national and regional levels can easily be adopted to undertake the impacts of climate change (Makuvaro *et al*., 2018; Shamsuzzoha *et al.*, 2018; Wada *et al*., 2014). A model and system of cultivating wheat by climate resilience in Australia has emerged. As a result of the tests on the seedlings, agronomists found that cultivation of the planting stock with to harvest an earlier way and sowing in early time of year, i.e. with the depth of 25 mm of the average soil water, may give to the farmer a better harvest. It is, therefore, the case, that the report highlights the fact that under the dry soil conditions, the output was proved to be rather positive. The wheat cultivation was moved a fortnight forward (from the last May week to the second May week), which yielded better results even exposed to challenging weather. Despite any limitations that during the study no soil water conservation practices were put into practice (e.g., no-tillage), the results were understandable (Makate, 2019). Different sectors can be involved in the process based on the governing strategies focusing on reducing the adverse effects of global warming. Therefore, in agriculture the incorporation of resistant crop varieties, crop rotation, smart water management, insurance coverage, and agroforestry promotion are the alternative solutions to the challenges that can be put in place. To address the problem, there are measures including conservation of coastal ecosystems, creation of advanced drainage systems, reducing land-use changes and the briefing of the public on the effects of climate change on coastal areas among others.

In the light of adaptation planning to cope with the negative impacts of climate change, there are some technocratic plans which involve the creation of superior agricultural techniques, affordable markets, merging modern science with indigenous knowledge and enhancement of irrigation facilities. The positive contribution of indigenous or local knowledge on climate change mitigation reflects in the impact on agriculture and the ecosystem as a whole. The scheduling of sowing, harvesting, minimal tillage activities, variation of fertilization, weather forecasting, crop insurance, and schooling of farmers on adaptation techniques are also essential proactiveness against global warming.

In addition, some animal species which have smaller size exhibits a higher level of competence in adapting to warmer or severe weather conditions. Research has evidenced that agroforestry, new methods of farming, new genotypes of plants, better conservation activities in farming areas as well as enhanced farm management practices reduced especially crop vulnerability to climate change. These adaptation measures might be difficult to adopt because regionally cropping might be a challenge, but it is the essence of maintaining food security and creating a vibrant economy. The reuse of treated effluent, development of flood-resistant structures, and installation of ultra-filtration units in tandem with disinfection techniques might help cope with excessive turbidity, as well as microbial pollution.

Through the development of desalination facilities for irrigation purposes will be promoted and the exploitation of wastewater in gardening, inspiring, and aquaculture will be enhanced to enhance water productivity. In addition, development of the idea CSA and also the predominant participation of stakeholders like technical specialists, farmers, and social leaders are much imperative.

The basic foundation of the CSA program contains, firstly, producing stable and sustainable level of yields (ensuring food security and self-sufficiency), secondly, counteracting agricultural resilience against climate change and, finally, reducing greenhouse gas emissions from agricultural activities. The CSA philosophy can create various improved procedures to be given to the farmers, for instance, resistant crops/animals types, agroforestry methods, modern irrigation technologies, crop rotation, insurance and soil fertility protection.

The sustainability application of the CSA concept is probably one of the most distinguished one among the list of the world's practices which include the agriculture's contribution to mitigate the climate change effects. CSA is a society-scaled push-the-button-and-forget-it-for-three-days method for handling the climate variations in the agricultural fields with holistic thinking and ensuring stable food production. For instance, in Hungary already those climate adaptive measures were practiced, including managing water supply, especially during the scarcity phenomena, and water quality (Brandt *et al*., 2017; Srivastav *et al*., 2021). Hence, due to the fact that the well-developed countries been successful by using of the CSA concept, the policymakers of the developing countries should also form such kind of strategies for example the tactics in the local governing bodies like the village, officials of the government, etc.) (Harvey *et al*., 2018; Makuvaro *et al*., 2018; Shamsuzzoha et)

Crop Diversification and Selection for Climate-Resilient Varieties: Agroecology provides interesting insights that say diversity among and within the species acts as a buffer against environmental change. This is on account of the fact that different species and varieties inhabit diverse niches hence react differently to change. If one species shuts down, the others can still perform, with the stabilization of community responses or ecosystem properties. When there are more species than functions, there will be a redundancy emergence in agroecosystem, which will enhance ecosystem functioning and the provision of ecosystem services. Therefore, species diversity offers is a buffer against crop failure, while agrobiodiversity reinforces ecosystem resilience (Brillouin *et al*., 2019).

Promoting the distribution of diverse life forms, both on surface and under the ground, can support a higher efficiency of resources used and a longer-term stability of ecosystem productivity (Abu-Zaitoun *et al*., 2018). The diversification includes the incorporation of the functional component of biodiversity in the cropping systems at different spatial and/or temporal scales (Ahikari *et al*., 2018). It aims to reconstitute biotic interactions that represent foundations for crop-supporting ecosystem services. This objective can be attained by emphasising crop species diversity (e.g., intercropping and crop rotation), increasing non-crop species diversity within and around the fields (e.g., flower strips, hedgerows, and semi-natural habitats), or using beneficial microorganisms such as arbuscular mycorrhizae, nitrogen-fixing bacteria, and growth-promoting bacteria to inoculate The diversity inside the ground can also be kept and fostered using different inputs, like compost (e.g., manure and crop residues) or limiting tillage actions (e.g., no-till), which favors soil stratification and, therefore, more niches (Rosa-Schleich *et al*., 2019).

From these theoretical conclusions, the hypothesis claims that the diversification of crops - planting different crop species and/or varieties both in space (land use, intercropping) or in time (seasonal rotation) can provide food system stability, diversity of diets and income generation, and help to mitigate risks from climate variability, diseases, pests and market shifts. The variety of their crops at the farm level can be increased by the farmers. Some experts argue that farmers would improve their expertise on the subject of traditional farming and the ways that it is transferred from the community to the community (Kumar *et al*., 2022). Such community-driven method as community-based biodiversity management involving farmer groups like farmer Field Schools, cooperatives, seed savers, women self-help groups, local seed banks and communities owned seed businesses can be more effective. This approach underlines and highlights the proven traditional roles of farmers across the globe who embarked on agricultural diversity practices since time immemorial. Integration of these approaches into production systems at a broader level could certainly be one of the ways to tackle the rising problem of unstable weather conditions on the global scale. These different kinds of strategies, however, allow the households to adapt to risks and decrease their vulnerability (Kremen *et al*., 2012).

more diverse the crops on the farm, the more chances there are to bear the risks and obtain more benefits, particularly, in regions where the market is inefficient. On their part, these advantages would be maximizing yields in the face of unfavourable conditions, providing a more diverse product range to address different needs, creating marketing opportunities, promoting consumption of home-grown crops that are nutritionally rich, of better quality and of cultural value, and fighting poverty (Renard&Tilman, 2019). Additionally, diversifying crops can aid in resource management, like using less irrigation water by choosing crops that collectively need reduced water. Furthermore, scholars note an indirect advantage: maintaining agricultural biodiversity can act as a crucial foundation for innovation and experimentation to combat climate change impacts, such as trials in crop improvement. Leveraging this essential resource for experimentation becomes pivotal in enhancing adaptive capabilities (Villanueva *et al*., 2015).

Minimizing Impacts of Climate Change on Agriculture

Climate-smart agricultural policies and initiatives: "Climate-smart agriculture" (CSA) is a technique that outlines the activities that will help in the switch from agricultural and food systems to more eco-friendly and climate ready models. It is one of the instruments that helps people who are on the executive side of the farming system to adapt to climate variability and change. Sustainable production and profits growth achieved, changes in climate reaction, and greenhouse gas emission reduction – CSA's top priority goals as claimed by J. Zhao *et al*. (2023). These climate-smart policies and practices should focus on the ability to maintain a balance in our short-term food and livelihood requirements without compromising on ecosystem and landscape health (Gulzar *et al*., 2020). It includes farms management, agricultural management, animal management, aquaculture, and capture fisheries. Damage management and adaptation. Climate-smart agriculture has gained more importance in response to the consequences of climate change on agriculture that have been experienced and are expected, including for example crop sensitivity to climate change (Agrimonti *et al*., 2020). The today's world urges a sane farming strategy to be implemented with a view to curb climate change and provide food security. The small-scale farmers, therefore, are currently providing big figures of the food consumed in much of South Asia and sub-Saharan Africa as indicated by Sarkar *et al*. (2020) (Figure 2).

general, climate-smart agriculture includes set of procedures and politics that engage in sustainably solving the problem of output increasing and resilience as well as deceleration of the emission greenhouse gases. Actually, this idea rose with the acknowledgement of the influence of climate change on agriculture by the people (Pinto *et al*., 2020). Climate change impacts in agriculture, consequently referred to as crop Scientists, are a global phenomenon.

They are in support of a holistic approach that would bridge together sustainable practices, adaptation processes, and mitigation activities. Enhanced knowledge of the impacts of climate change on agriculture and the evolution of climate-smart agriculture (Karki *et al*., 2020) goes hand in hand. The CSA was launched in 2009, and gradually many stakeholders and treaties took off on the CSA expansion (J. Zhao *et al*., 2023). The United Nation's (UN) Food and Agriculture Organization (FAO) introduced the

Community Supported Agriculture (CSA) to mitigate the agricultural effect of climate change. A backgrounder titled "Climate-smart Agriculture, Policies, Practices, and Funding for Food Security, Adaptation, and Mitigation" is published by FAO. The agenda 17 on Food Security and Climate Change that passed in 2010 was the backdrop of The Hague Conference which was held under the same context. This country commitments of greenhouses gas emission reductions are a further proof of the necessity of agriculture for climate change mitigation and CSA's own contribution to NDCs. Training of women at all levels is highlighted (Qureshi *et al.* 2022). Climate change is only but intensifying the challenge posed by political uncertainty in agriculture, therefore, imposing the need for comprehensive approaches of climate change in agriculture like CSA (A. Shilomboleni 2020).

A wide array of increased climate awareness and the impacts it bears on agriculture as well as the call for sustainable agricultural systems would serve as the basis for the development of climate smart agricultural systems. Climate change has already demonstrated and forecasted significant alterations to agriculture and therefore increases the pressures and provides opportunities to the food production and food security. This is illustrated in different areas and will affect the ability of various crops to produce differently.

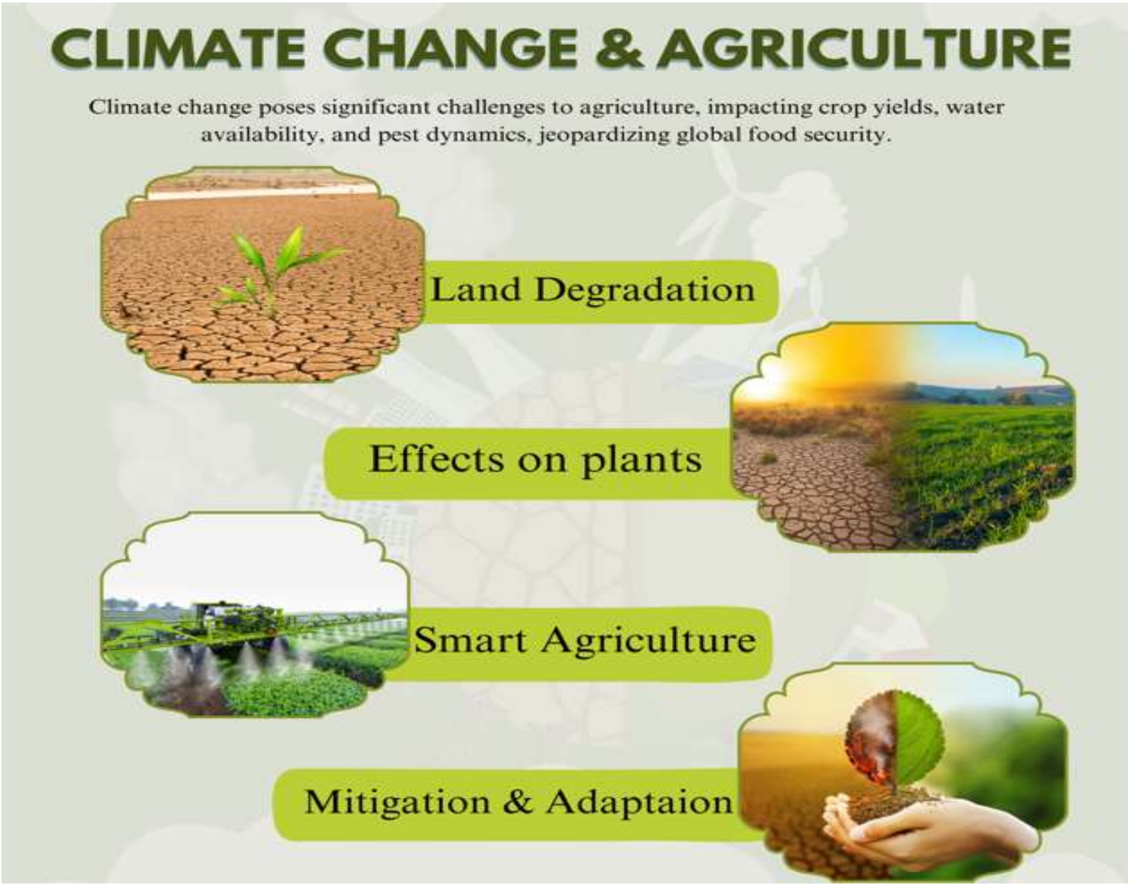

Figure 2: Effect of Climate Change on Plants and its adaptation & Mitigation Strategies

The Section that follows discusses the effects of climate change on agricultural sectors and the specificities of various crops and regions, based on Anderson *et al.* (2020). Climate change shows symptoms of affecting food supply and may reduce the possibilities of getting food. Affects food safety, Global warming, increased atmospheric CO_2, and higher frequency and intensity of extreme weather events can change produce quality a lot (Malhi *et al*., 2021). Because of the fact that the extremities of climate are increasing and the patterns of pest pressures are shifting as well as the seasonal and diurnal temperatures are changing, agriculture as a productive factor and international markets are being affected (Skendžić *et al*., 2021). With the deterioration of climate change, for the relegating farmers, agricultural production becoming intensely dependent on fertilizers and insecticides could be more expensive than ever (Ramborun et.al., 2020).

The USA's main agricultural exports, such as wheat, corn, and rice, are the main food sources in the world and are highly sensitive to thawing, drought, and climatic extremes (Schillerberg & Tian, 2020). Temperature, precipitation, and days of frost are already affecting the growing season directly and crop suitability in all states in the United States department (Eck *et al*., 2020). Climate change is causing agricultural output to be vulnerable in various Asian countries in the most food insecure regions (Ozdemir, 2021). Addressing climate change impact needs to be done both through adapting to the climate conditions change and through green practices implementation. The governments have the role of promoting CSA by means of different policies and initiatives. (Aryal *et al*., 2020). Given below are the examples of policies and programs that address climate change at the national and capital levels for agriculture.

National Policy

Zambia's National Agricultural Investment Plan integrates climate change concerns into situation analysis and countermeasures. Provides a comprehensive framework for addressing climate change in agriculture (Mulungu *et al*., 2021).Various countries in Africa are developing policies and strategies for climate-smart agriculture, including coordination of climate-smart agriculture planning and budgeting between different authorities, and climate-smart agriculture policies and strategies (Sam *et al*., 2020).

International Guidelines

The Paris Agreement and NDCs (Nationally Determined Contributions) of the Paris Agreement stress the contribution of agriculture to a sustainable future and draw attention to the role of CSA in realizing NDCs. The Global Agriculture, Fisheries and Food Security Policy (GAF5) of the Food and Agriculture Organization of the United Nations (FAO) is also directed at states to contribute to the global goal of food security in the sense of combating climate change and sustainable agricultural practices (Estrada & Botzen, 2021).

Successful climate-smart agriculture initiatives in different parts of the world:

Ethiopia

The country has undertaken different CSA projects with the Productive Safety Net (PSN) program being one of the key areas in which there is focus on food security. Efforts to mitigate climate change in agriculture emphasize the adaptation of sustainable practices (Hailu and Amare, 2022).

India: The nation has devised the Paramparagana program for providing loans and technical advice to smallholder farmers so that they can adopt climate-resilient farming methods (Angom *et al*., 2021).

International: The Consultative Group on International Agricultural Research (CGIAR) created the CGIAR Research Program with the objective of enhancing CSA policies and practices, thus facilitating adaptation and mitigation measures for climate change (Kruseman *et al*., 2020). These cases understand the initiatives of the governments and the international organizations which are of climate-smart agriculture and help to address the issues of climate change in agriculture. CSA aims to reduce the greenhouse gas emissions in line with achieving sustainable productivity increase and the adaptation to climate change. Nevertheless, adopting the CSA approaches comes with some complexities and difficulties to be overcome. Some of the major challenges are deficiency in knowledge and awareness, huge initial costs, societal and cultural obstacles, and inaccessibility to funding (Fusco *et al*., 2020). It is not only because farmers face the social-economic barriers of gender and luck of income inequalities that hinder them from using these practices. Although there are certain incentives that some of his CSA practices are pushed forward there are still plenty of factors that act as the barriers on the way to adoption. Such challenges are targeted by different studies in their research works. One way to face these obstacles is the establishment of policies and programs published by governments and international organizations that support the CSA (Sardar *et al*., 2020).

Innovative approaches to water management and irrigation: The development of innovative water management and irrigation system particularly is crucial in order for the existence of agricultural sector in a sustainable way to be ensured and the concerns with water scarcity to be addressed. Innovative methods for water management in agriculture have been studied in many cases; integration of mass water management research discipline and technology into water policy, application of water balance models in farm and watershed management, and control and adjustment of irrigation systems for sake of practicality are few of them (Nikolaou *et al*., 2020). Water management techniques innovations help a lot to achieve the goals of water efficiency. Moreover, this enables farmers and benefit producers to save money while environmental problems are being eliminated. Invisibility of implementing these innovative approaches is a great challenge of them that includes less knowledge and awareness the early costs of them and social culture hindrance and also not access to financing (Saad, *et al*. 2020). The goal of these policies and schemes is mainly to enhance the effective utilization of water in order to solve the problems of the water crisis. Worth the while examples of innovative urban water management practices from everywhere in the world today are using precision agriculture system, decentralized water infrastructure, advanced filtration and smart materials. These initiatives show the actual efficiency of intellectual methods of tackling scarcity issues and developing sustainable and robust agribusiness systems (Rana and Piracha, 2020).

However, innovative water management technologies for agriculture comprise of lots of groundbreaking solutions that ensure efficient use of this precious resource and sustain agriculture. For example, accuracy agriculture is an instance of it. This technology involves sensors, GPS, along with the data management tools and gives exact measurements for soil, crop, and environmental water necessity, helping them attain optimal water use. Also, the gain of water recovery and reuse systems are of great importance to the environmentally friendly water management where the collected and stored rainwater or runoff can be used for the agricultural purposes and this may make better the agricultural sustainability (Sharma *et al*., 2021). Data remotely collected by means of radio governance such as soil moisture sensors and weather stations allow real-time tracking of irrigation units and crops, and so assessment of when and where water is required. Furthermore, effective filtration and desalination technologies create new and sustainable water options for agriculture communities, apart from saving water resources and keeping the environment healthy. These technologies will be an enabling factor for reduced water usage, zero loss, and enhanced green agriculture (Khoa, *et al*, 2021).

Collaborative efforts between scientists, policymakers, and farmers:

Collaboration between scientists, policymakers, and farmers is essential to address the huge climate change adaptation challenges facing the agricultural sector. The success of collaboration for sustainable agriculture is highlighted in a meta-analysis of case studies, showing that stronger and better collaboration between farmers and other stakeholders is a key strategy for sustainable agriculture It turned out that. This meta-analysis of this case focused on the effective collaboration of the conditions allowing or hindering the success of the collaborative initiatives that ultimately lead to sustainable agriculture. The Concert of scientists, civil servants, and farmers in agriculture is multi-faceted. Being beneficiary, it contributes to the sustainability, the efficiency, and the profitability of the farmers. Among the range of policymakers, the community increasingly is viewed as a vital element of the knowledge collaboration with science and society to create innovations and to solve complex problems.

Effective stakeholder communication is granted in case of smooth interactions in agriculture development. The pilots' farms are spots of excellence where science and the growing of crops can meet and communicate without any communication breakdowns. Apart from farmers' associations and cooperatives, they can also contribute greatly when it comes to ease of communication between farmers and other stakeholders such as politicians and investors. (Huo *et al*., 2022) Collaboration with farmers and other stakeholders can help to make better decisions in the sector as decision makers are in a position to benefit from a wealth of data and information coming from across the industry. In this way farmers and other key actors in the industry together can make a more economically sustainable and efficient Agri-food industry that is favorable for everyone (Manyise & Dentoni, 2021). To solve the resource. The water management in the agricultural sector of the world has been widely addressed by several innovative yet collaborative approaches, including soilless agriculture, water harvesting and reuse systems, wireless technologies, and advanced filtration and desalination technologies (Suwaileh *et al*., 2020).

Conclusion

Finally, the complex connections between agriculture, food security and global warming make it quite imminent that a new approach to dealing with the present problem is necessary. At the top of the list is the agricultural sector that feels the most difficult because the climate is changing the most. It is because out of all greenhouse gases emissions about 30% of them originate from agriculture on a global scale. There is no need to point out the fact that soil quality is one of the major causes of these problems. Besides, cover crops, no-till farming, and agroecological means are promising alternatives. Modern technologies including livestock management systems and remote sensing can now be used to ensure efficiency in the use of these resources and minimize the emissions that damage the environment. Instead of a measure that is not narrowly aimed at cutting the nitrous oxide emission from fertilizer additions, use the nitrification inhibitors. Agroecological approaches, cycling of nutrients and diversification ensure good bacteria is spread and there is a minimal impact on the environment. Besides that, vegetation planting in agricultural settings has been proved an all way strategy that results to soil health rehabilitation, carbon sequestration, and lessens of the energy sources that release carbon dioxide. Participating in the transition to a local system of food production becomes the next step for reducing transportation related emissions.

By means of cooperating and collaborating joint efforts of scientists, legislators, and farmers to address these problems will serve in the design and implementation of sustainable approaches. An extensive strategy including a variety of issues such as ecological, economic and society aspects should to be created to address the effects the climate change on agriculture. At the end, the cooperation of scientists, policymakers, and farmers is of great importance as well to cope with the water problems on which the agricultural sector worldwide faces. It is quite essential to include farmers in the network because they have a vast range of expertise that will give the necessary insights and practical knowledge necessary for this cause. Efficient coordination bases on active communication between the agriculture sector stakeholders and creative approaches to collaboration give irrigation in agriculture a shot-term and sustainable perspective. Through collective efforts, farmers and other concerned constituents can construct an Agri-food sector that is sustainable, efficient and yielding good profit to all parties involved.

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