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Research Article

An Environment Friendly Practice, the Climate Smart Agriculture Crop Production and Soil Management Systems: A review

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Abstract:

Climate Smart Agriculture (CSA) is an environment friendly agricultural approach for all global living communities and the crop production systems should be designed with some main principle of crop production and soil management with distinct objectives like mitigating the greenhouse gas emissions, lesser the soil disturbance, adapting to altering and changing climatic and environmental conditions, lower the water and soil pollution and securing and pledging the food production sustainably. This comprehensive review delves into the realm of climate-smart agriculture, emphasizing its pivotal role in fostering environmentally friendly practices for crop production and soil management. Illustration from a means of research, this paper meticulously examines the adoption and impact of these strategies, shedding light on their effectiveness in mitigating climate change consequences. By synthesizing diverse findings, it provides a nuanced understanding of the intricate relationship between climate-smart agricultural techniques and sustainable practices. The review also explores into the implications for resilience and productivity enhancement, offering insights into how these approaches can contribute to the overarching goal of fostering a resilient and environmentally conscious agricultural landscape.

1. Introduction

Agricultural farming production systems are the most economical business and source of livelihood of many developing countries around the world. It is predicted that in the 2050 the world population will increase up to 9.1 billion which will definitely depend on Agriculture farming production for their food requirements ((See Figure 1), (George, 2018)). The pressure on Agricultural production system will increase due to rapid increase in global population. The climate change is a serious threat to food security arrangement and considered as a prime problem of 21st century (Rani and Reddy, 2023) because currently climate is changing rapidly which affecting deeply and very dangerously agricultural crop production system. Agricultural sector is very susceptible to climate change and also a main part of the climate problem. Currently approximately it generates 19-29 % of total Green House Gas (GHG) emissions through the use of pesticides, synthetic fertilizer, heavy machinery and other technological tools and techniques (World Bank, 2020). The farming communities are greatly affected by climate change. The most common changes which global are facing are unpredictable rainfall period, unreliable rains, altered rainfall pattern, massive-than-usual rainfall, high temperature, the strength and direction of wind, and sudden rise and fall in soil and air temperature, migration and outbreaks of insect-pest, the irregular occurrence of floods and drought, and extreme weather conditions (Porter et al., 2014). According to the Intergovernmental Panel on Climate Change (IPCC), each of the last four decades has been successively warmer than any decade that preceded it since 1850. Global mean sea levels have been rising due to the melting of glaciers and ice sheets and the thermal expansion of seawater. Moreover, satellite altimeter measurements indicate a rise in global mean sea level of about 3.3 millimeters per year from 1993 to 2017. Arctic sea ice has been decreasing in extent and thickness over the past few decades. The minimum extent of Arctic Sea ice in September, at the end of the summer melting season, has reached record lows in recent years. The Mauna Loa Observatory in Hawaii has been monitoring atmospheric CO2 concentrations since the late 1950s, showing a clear upward trend. There is evidence suggesting an increase in the frequency and intensity of certain extreme weather events, such as hurricanes, heatwaves, droughts, and heavy precipitation events. Attribution studies are increasingly able to link specific events to the influence of human-induced climate change. These changes are seriously affecting resource-poor farmers, their crop growth, development, yield and increase prevalence of insect pest and diseases on crop, because rise in temperature decreases the grain filling period, caused grain sterility and final reduced crop yield.

These climatic changes are occurring directly or indirectly due to human activities that disturbing and change the composition of global atmosphere which form a layer of different toxic gases over the earth. Long term creation of these gases composes and makes the ordinary climate heater than usual. These gases include Carbon dioxide (CO_2) which is release from industries, factories, fire woods and vehicles engine; Nitrous oxide (N_2O) which is released from synthetic fertilizer when exposed to sun rays; Methane (CH_4) which is produced primarily from oxygen lacking (anaerobic) conditions when animal dung is fermented or when rice paddy field is cover with water; Ozone (O_3) gas release from vaporizer sprays such as household sprays, perfumes and cosmetic sprays. The changes are also occurring due to burning of crop residues and woods expose the soil carbon and the store carbon in the trees, which easily release to atmosphere; heavy tillage operation expose the soil surface and the store carbon easily move to atmosphere; Poor managements of animal manure lead to release more biogas (methane) into atmosphere; over-accumulation and rearing of livestock caused land degradation and rapid greenhouse gases emissions; unproductive use of energy in poultry production increased carbon emissions into atmosphere; non-selective use of synthetic agro-chemical pesticides sprays disturbing natural balance of eco-system. The adverse and negative effects of the climate change on crop productivity are already being suffered by the agriculture production sector and farming communities around the globe. For example, in India, rice crop production systems were decreased by 23 % during 2001-2002 (FAOSTAT, 2012) due to long term drought spell. Similarly, in Indonesia, flooding caused approximately about 1344 million tons of sufferers in rice crop production (Redfern et al., 2012). In the Mississippi a city in the USA, the flooding before and during the harvest season of crop caused a probable loss of up to 8 billion US $ in 2008 (USGCRP, 2009). To make safe future food and crop production system, crop production system will require adapting to and mitigating climate change. In addressing the dual challenges of food security and climate change in Africa, there is a recognized need for substantial agricultural reforms [26]. A case in point is Zambia, situated in Southcentral Africa, where proactive agricultural measures have been implemented. These measures include the adoption of protective practices such as organic mulching of surface crops, crop rotation involving legumes and cereals, and the cultivation of improved crop varieties [35]. These initiatives in Zambia hold promise for bolstering soil fertility and carbon fixation capacities, leading to a significant increase in average grain yields and ensuring local food security. In developed nations, where agriculture is well-established, characterized by high economic efficiency, abundant per capita land resources, and advanced mechanized production, the focus of Climate-Smart Agriculture (CSA) development is primarily oriented towards reducing greenhouse gas (GHG) emissions and enhancing agricultural resilience to climate change. These countries leverage their developed infrastructure to integrate high-tech solutions, formulate and implement policies, enhance agricultural system flexibility, and concurrently improve production efficiency while curbing GHG emissions [39].

An example is California in the United States, renowned as one of the world's most productive and resource-rich agricultural regions. California's CSA objectives center around the sustainable management of water resources and the reduction of GHG emissions [40]. Through a comprehensive approach involving legislative measures and regulations, coupled with relevant agricultural techniques from the public research system, the California government has successfully achieved its target of GHG emission reduction. This signifies a strategic alignment of advanced technology, policy frameworks, and agricultural practices to foster sustainability and resilience in the face of climate challenges.

In order to maintain food security and uninterrupted supply of food, the Agricultural production systems requires to be changed to a high capability and steady productive system, which also work for yield enhancement of small land holding farmers. But there is a difficulty which technologies and agricultural practices are suitable and appropriate to reach the above objective to mitigate climate change, escape drought, and low diminish of soil and water resources, food requirements and food security for future population. Higher concentration is needed to alternative means of strengthening the agricultural farming production sector, particularly the adoption of sustainable land management, crop production technologies and climate smart agriculture (CSA) practices and tools. Main advantages of these technologies are enhancing food production exclusive of more diminishing soil and water reservoir and resources, no more soil degrading, restoring soil fertility, maintain natural environmental balance, reducing and controlling of pollution, increasing the flexibility Agricultural farming production systems to climatic threats and improving their abilities of carbon sequestration and alleviate climate change.

There is an urgent and vital need to follow and adapt various traditional to agricultural farming production systems techniques to the changes occurring due to climate change, such as unpredictable rainfall period, unreliable rains, massive-than-usual rainfall, and sudden rise and fall in soil and air temperature, migration of insect-pest and extreme weather conditions in order to able agricultural production more flexible and resilient climatic stresses, shocks and pressures. Long terms actions are also needed to reduced and mitigate climate change and its harmful effect on global especially on agriculture farming production systems. In other words, to really decrease the extent, rate and speed of climate change, some of which can be accomplished by adapts, modifies, adjusts and changes to agronomic practices, agriculture production farming systems practices and soil management practices, i.e., through climate smart agriculture (CSA) technologies. CSA is a combination of mutually both latest and older agricultural production practices and technologies that are considered more helpful in serving farming communities to follow climate change and to alleviate climate change. World banks define CSA as Climate smart agriculture is a unified and integrated advance technological approach to managing crop land and crop production practices, landscapes, forest, fisheries and livestock that concentrates the interlinked challenges and dispute of food security and climate change (The World Bank, 2020). CSA is advancement for the emergent agricultural policies to make safe sustainable food security in climate change. CSA gives the ways to assist stakeholders and associates from local to national and international stages recognize agricultural policies appropriate to their local conditions.

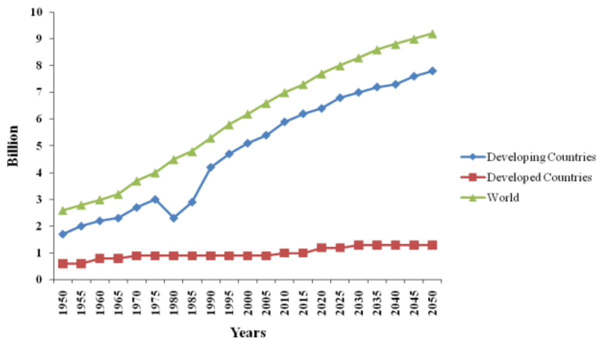

Fig. 1: Projected population growth from 1950 to 2050.

Origin of Climate Smart Agriculture:

Climate smart agriculture is relatively new concept which was initiated in 2009 and promoting for better integration of adaptation and mitigated activities in agricultural development for food security under climate changes. Climate smart agriculture explains agriculture practice towards climate change, mitigating the impact of agriculture on climate and also maintains or increases the productivity. The term climate smart agriculture described by FAO at The Hague conference on agriculture Food security and climate change, in 2010. Development of agriculture and food security is a holistic and sustainable way by integrating social, economic, and environmental aspects. Although the concept has received from several parties, it is widely promoted by UN agencies such as: the food and Agriculture organisation, international fund for agriculture development, environment programme, World Bank and world Food programme. It is also used in other organisation such as consultative group on international Agriculture Research (CGIAR) and approved in number agriculture policies (FAO, 2015). CSA promotes by researcher, farmers, private sector, civil society and policy makers to climate-resilient pathways depends on building evidence, increasing local institutional effectiveness, foresting coherence between climate and agricultural policies, linking climate and agricultural financing. In 2012, Climate smart agriculture integrated landscapes approach, in the country implementation with green economy. National food security and development depends on three main objectives: Enhance food security by increasing agriculture productivity and incomes, build resilience and adapt to climate changes and Remove greenhouse emission where it is possible (FAO, 2015).

FAO projects sustain and to work on CSA like FAO required Economic and policy innovations for a climate-smart agriculture (EPIC) programme and the Mitigation of climate change (MICCA) programme. These programme best evidence for CSA but the best technical research and the field work on MICCA programme which supply that climate smart agriculture practices can reduce greenhouse emission, better livelihoods and build local communities to adapt climate changes. This evidence may support international climate negotiation under the model of UN Framework convention on climate change. CSA is also linked in FAO's ecosystem approach to fisheries. Its main evidence to managing fisheries and implementation of significant development and although natural changes in the ecosystem to produce fish food, revenue and livelihoods is maintained for ever benefit of the current and future generations. Livestock play a vital role in climate in marshy food supply system. FAOs facilitates occupied in multi-stakeholder partnership, the global agenda for sustainable livestock and the livestock Environmental Assessment partnership (LEAP) (FAO, 2015).

1.1. Advantage of CSA:

Climate-smart agriculture increase sustainable productivity, improves farmer resilience, remove decrease agriculture's greenhouse gas emission, and increase carbon sequestrations. It supports food security and delivers environmental benefits. CSA demonstrated practical techniques such as mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agro-forestry, improved grazing, and improved water management and innovative practices such as better weather forecasting, more resilient food crops. To solving all the problems, policy leaders should take integrated approach for food security, poverty and climate changes. These approaches included in; reducing a variety of emission from agriculture such as nitrous oxygen from livestock emission, fertilizer application and methane from rice cultivation, promoting activities which may increase carbon storage merge animal and trees with food production and improve soil fertility. Integrated planning of land, agriculture, forests, fisheries and water at local, watershed and regional scales that are properly captured, diversifying income sources and genetic traits of crop that help to farmers against an uncertain climate, developing sound risk insurance and risk management to provide safety nets that reach at the poorest farmers, Exploring carbon finance which may promote the agriculture development practices and many other direct benefits for farmers and the environment. (Fusco et al., 2020; Zhao et al., 2023).

1.2. Research Status of CSA:

In many developing countries, agriculture serves as the primary economic pillar. The intricate challenges posed by climate change pose threats to agricultural production and food security, necessitating a multifaceted approach to address these issues. In light of this, the paramount focus for Climate-Smart Agriculture (CSA) development goals in these nations is on elevating agricultural production efficiency, ensuring food security, and fostering economic growth. Simultaneously, there is a recognition that gradual reduction of greenhouse gas (GHG) emissions within agricultural systems requires additional investments [3].

The CSA framework is embraced in developing countries, where tailored solutions are devised based on the specific circumstances of different regions. The overarching objective is to harmonize agricultural development with climate resilience, acknowledging the unique challenges faced by each locality. This underscores a commitment to sustainable and adaptive agricultural practices that contribute not only to food security but also to the economic well-being of developing nations. In (2010) the term climate smart agriculture was introduced by the food and agricultural organization (FAO), act as innovative cleaner production by conventional farming that aimed to increase the efficiency of all natural resources, resilience and productivity of agriculture production system as well as reducing greenhouse gas emissions. The unfavourable effect of climate change on crop production on the farm and regional level can be minimized by using CSA practice and technologies (Imran et al., 2018). It is an approach to help agricultural systems worldwide, and to deal with three challenge areas that is increasing variation to climate change, improvement of climate change, and ensuring global food security by different innovative policies, practices, and financing. CSA concept according to soil for food security and climate launched at UNFCCC 21st conference at the ratio of 4 per 1000 initiatives. CSA policy required to incorporate an integrated set of measures supported consistent metrics. So, CSA initiated for the principles of sustainability, both at the agriculture and food system levels (Torquebiau et al., 2018). CSA is necessary approach for cropping with climate change. CSA has the potential to increase productivity and resilience which may be reducing by the vulnerability of hundreds of millions of smallholder farmers. CSA technologies and approaches helps to protect natural resources for future generations but also play an important role to increase resilience and improve livelihoods of significant bring together people with multiple perspectives, roles and responsibilities (Torquebiau et al., 2018). Current gaps in knowledge, work within CSA and different agendas for interdisciplinary research and science-based actions identified at the 2013 Global Science Conference on climate-smart agriculture and explained with three themes, first is landscape and regional issues, second is farm and food systems, and third is institutional and policy aspects (Steenwerth et al., 2014). CSA is widely promoted for reorienting agricultural development, under the realities of climate change. Research for development activities is important, given the need to utilize infrequent resources which may effective. Many priorities setting will be applied from short to medium term at relatively local scales. Many aspects make it challenging to prioritise by CSA research, including with multi-dimensional nature (productivity, adaptation and mitigation), immediate climate impact, and the temporal dependency which may affect the benefit and cost of CSA adaptation (Pathak et al., 2012).

In recent years CSA approaches has been heavily contested, predominantly impact on social equity. CSA may transfer many responsibilities for climate change mitigation to marginalized producers and resources managers that may block the emergence of more equitable agricultural system (Thornton et al., 2018). Similarly, CSA has come from many countries, particularly in Africa, that include agricultural adaptation and CSA determination (Richard et al., 2016). CSA remains a work in progress, but research is now emerging on the politics and governance of adaptation and the transformations that will be needed in farming systems in the future (Chandra et al., 2017). Climate change is currently dependent on the global environmental changes and global nature causes and magnitude of climate change indicates the requirement international collective action for an effective, efficient, and equitable policies response (Harris, 2007). The United Nations Framework Convention on Climate Change (UNFCCC, 2008) identified two policies which contain mitigation of climate change by reducing greenhouse gas in the atmosphere and enhancing carbon sink, and adaptation to the impact of climate changes in the world where as climate-smart agriculture act as climate change adaptation and mitigation intervention. Research in Punjab (Pakistan) focuses on growth strategies by improving efficiency and expansion of the production base “increasing capacity” (Foley et al., 2011). Expansion of production base is also impractical as cropping area in Punjab is saturated by growing pressures of population and urbanization. Agriculture research inherently complex different evidence-based policies, plan, and farmer training strategies in socio-ecological environment. The Punjab government has recently released the Punjab Agriculture policy to improving research capacity (GoP, 2017). The policy emphasis needs to satisfy for the rights of smallholder farmers, who are the backbone of the sector. Although majority of climate change responses heavily focused on adaptation (90%), and the agriculture, livestock and forestry sector accounts for 82% (Tubiello, 2012). The majority of climate change adaptation has been directed towards improving the climate resilience of high-cost, large-scale infrastructure projects (sustainable infrastructure 63%). The resources assigned to soft/non-structural adaptation is still very limited whereas the cost of CSA adaptation keeps increasing and is estimated to exceed 3-5% of GDP by 2030 (Foley et al., 2011). The presence of world “Sustainable” in CSA should signify about the impact of agriculture on future generations, and its environmental, economic, and social implication. Early next on CSA shows complex concept depending on several conditions (access, availability, utilization, stability) which is to be taken. Climate smart of the farming system can be frequently assessed by using food security such as the Household Food insecurity Access scale indicated social resilience and CO2 emission. The human activity dependent on the climate, increasing temperature, higher frequency of weather extreme and also a greater seasonal variability illustrated new intimidation for agriculture worldwide. Agriculture is also viewed as solution of climate change, because it plays an important role in greenhouse gas mitigation. Climate smart agriculture supported to threats land-use system that make the adaptation-mitigation at all scales and helps the farmers to the solution of climate change (Redfern et al., 2012; The World Bank, 2023).

1.3. Future Prospect of CSA:

Climate-smart agriculture is a technologically innovative response where different challenges faced through the agriculture due to climate change. Climate change played an important role not only on agriculture development but also on food security. Today, almost one billion people will go to bed hungry. Following current estimation, that the global population will increase more than two billion by 2050, estimate of the increase varies between 50% and 70% depending on the efficiency and consumptions pattern changes. Many pathways that alternate on sustainable agriculture system and its sustainability depend on agro-ecological zone, farming system, cultural preference, institutions and policies (George, 2018). In the future, we will need more and more climate-smart agriculture to support sustainable and reasonable evolution for agriculture systems and livelihoods across scales, due to increasing attention on economic development, the reduction of poverty and food security. CSA guides both stakeholders and policymakers to meet the challenges presented. So, the implementation changes done, and the adjust agriculture and food security to attain sustainability goals. In the application of climate smart agriculture, the limitation of methodology options with other search criteria such as conservative agriculture, agro forestry, etc. In this case various countries involved, number of projects would increase significantly, and then climate smart agriculture production would be more realistic. It is our intention to address this climate-smart agriculture objective in the future. However, some other factors that emerges the economic barriers, such as the importance of institution in uptake of CSA technologies and the engagement of private sector in agricultural development. It will help to support the stakeholders by addition of good policy and institutional framework that can minimize the farmer challenges, reducing CSA adaptation and increasing agriculture sustainability. Considerable finance will be needed to rapidly implement proven programs and support poverty alleviation and food security goals in changing climate (Torquebiau, 2018). Going forward, the country profile methodology will be further involved to inducing better reflect system and to integrate newly evidence on impact from CSA project, pooling all scientific evidence on large dataset. Expansion of the country profiles, global footprint (both in countries and continents), the next chapter in CSA’s story will be implanted into decision-making tools through climate smart investments profiles to substantial climate risk profiles into sectoral priorities. By using CSA country profiles, CSIP’s and Substantial climate risk profiles can make better prepare their food system for impact of climate change in an integrated way that reduce the sector contribution to underlying problem, and thus addressing one of the most pressing challenges of our time (Tubiello, 2012).

Climate smart agriculture practices can create both public and private benefits and thus comprise a potentially significant means of making solution to environmental issues, poverty and food insecurity. In case of private benefits and advantages to the farming communities by enhancing and protecting natural capital such as water resources, soil organic matter percentage and numerous type of biodiversity CSA can enhance productivity, decrease cost of productivity and stability of crop production (Matteoli et al., 2021). Besides, CSA farming practices contribute to developing soil fertility level, texture and structure, put in high quantity of biomass to the soil surface, causing minimum soil interruption, conserving water and soil resources, increasing activities and mixture population of soil fauna and increasing methods of basic cycling. At the meantime CSA practices has the ability to create public ecological goods in the form of advanced watershed implementation, biodiversity maintenance and alleviation of climate change. Furthermore, the CSA technologies has the ability to increase the soil organic matter of the soil, of which carbon (C) is the major part, therefore CSA reduce GHG emissions and help to increase the carbon sequestration. Increasing the productivity would also decrease the need for extra and supplementary land exchange to agricultural which will result to low GHG emission (Lal, 2004; Corsi et al., 2012).

CSA is an approach that assists to guide procedures needed to change and reorient agriculture farming production systems to efficiently support improvement and make sure food security in a changing climate (FAO, 2020). CSA aims to undertake three major objectives, sustainably increasing agricultural farming productivity yield and incomes: adapting and building flexibility and resilience to changing climate, reducing and / or removing greenhouse gas emissions, where feasible and possible. These entire three objectives are relevant and vitally important for the adaptation of appropriate agricultural practices and mitigation of climate change. CSA included a broad collection of practices. In this paper we have discussed numerous practices which are appropriate to mitigate climate change risks.

2. Particular Climate Smart Agriculture Practices for Mitigation of Climate Change:

CSA occupies Agriculture farming practices that develop and enhance farm efficiency and productivity, assist farming community adjust to the harmful effects of climate change and lessen climate change effects, e.g., by soil carbon sequestration or decreases in greenhouse gas emissions (CIMMYT, 2019). CSA practices, such as the practiced of conservation agriculture, which aims conserving and saving soil moisture content, preserving the crop plant residues for the purpose of soil fertility, disturbing the soil as modestly as achievable and crop diversifying throughout crop rotation or intercropping pattern.

CSA is an advance approach for renovating and reorienting agricultural farming systems to hold up food security underneath the new truths of the climate change. Extensive alteration in rainfall patterns and changing temperature pattern warn agricultural production systems and enhance the susceptibility of people reliant on agriculture for their living, which comprises majority of the world's poor population. Risk of climate change disturbs the available food markets, increasing the population-wide threats to food supply. Risks can be decreased and control up to some extent by enhancing the adaptive power of farming communities as well as increasing flexibility and resource use-efficiency in the field agricultural production. CSA encourages coordination and communication among farming communities, scientist, expert, researchers, civil society and policy makers towards a sustainable climate-resilient trails throughout some actions which are building evidence, enhancing the local institutional efficiency, promotions consistency between climate change and agricultural production system policies and connecting climate change and agricultural system financing. (Lipper et al., 2014).

CSA is an agricultural innovation that sustainably enhances productivity, increases adaptive capability, decreases, eliminates and control the greenhouse gases emissions where possible on earth. At the rural or local level, it protects farming communities from the bad effects of the climate change, increases farm productivity, yields and family incomes, for strong and more elastic communities. At the nationwide level, it helps convey food security and progress goals help to improve economy, while reducing pollution and decreasing harmful gases emissions. (CGIAR, 2020), The specific CSA practices such as crop production management practices and soil management recommended by different scientist and reviewer are briefly discussed in the below sections.

2.1. Climate Smart Crop Production Practices

To manage the challenges and destruction of climate change these CSA practices are adapting at field/farm level which are mainly focused on crop production system. These CSA crop production practices are mainly followed for the purpose to mitigate the particular effects of climate change that cause heat and moisture stresses and tensions. Besides, these CSA crop production and management system practices focus on conserving on soil and water resources in order to enhance and maintain sustainability of production intensities. This is done mainly with the help of practices that keep safe the soil free from erosion and degradation, preserve soil moisture, increase soil fertility level, help to control insect, pest and diseases, make stronger seed system and decreasing harvest and post-harvest losses.

It also encircles the practices with a clear focus on adaptation to explicit climatic pressure, and practices to concurrently decrease production hazards and lesser greenhouse gases emissions. The majority of these practices prevents soil erosion and degradation that discharges most of the useful quantity of the carbon (C) and the water into the atmosphere; encourage soil, water and biodiversity conservation; and finally increase the productivity and yield.

In addition, the successes and breakdown of plant crops have forever been subject to existing ecological aspects, and the systems for adjusting the stresses produced by these features continue to be the focus of wide studies in a numerous of disciplines. Crop production is more and more exposed to threats linked with latest and sprouting climatic changes. These are changes in ecological situation that create major challenges to farming communities. The planet earth is facing additional and more severe weather trials, such as unpredicted and serious precipitation, upper coastal waters; geographic alters in storm and changer in drought patterns, and heater temperatures (IPCC, 2012).

The crop production CSA practices adapt at filed level for mitigation risk of climate change included crop variety selection, crop diversification, reducing crop development periods, crop breeding, improved planting materials (seeds and vegetative cutting, strong and pure seed system and access to high quality seed), cropping pattern, Integrated Pest Management (IPM), eco system management, post-harvest management and technology, small scale mechanization, promote Agro-forestry and crop insurance. (See Figure 2)

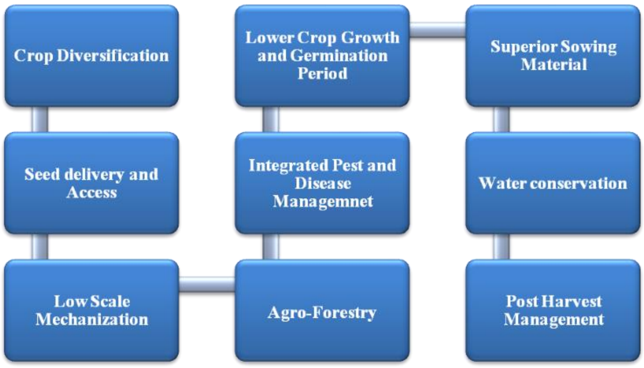

Fig. 2: Principle of climate smart agriculture crop production management system.

a. Crop Diversification

The crop diversification means the adding and growing different type of crops on farmer's farm to mitigate, diversify or reduce the risk of total crop failure or partial failure due to climate change or insect-pest diseases. These diversified cropping system techniques significantly helps to maintain the soil fertility and have the ability to reduce soil diseases. Besides, crop diversification also helps in weeds, diseases and insect-pest control. This also helps out in soil organic matter enhancement and finally increased farmers yield and income (Tittonell, 2015). The crop diversification practices adapt in the form of crop rotation, inter cropping, cover crops, mixed cropping, relay cropping and row intercropping. The crop rotation referred to the practice of growing of different type of crops on same piece of land in successive seasons. The crop rotation increases and maintains the soil fertility, keeps plant disease and insect pest under control, control weeds, enhance crop nutrient availability, distribute labor force more consistently and mitigates the risk of climate change. According to the principles of crop rotation, crops of the same family should not follow each other, crops of the same type of root system should not follow each other, the restorative crops should be grown after exhaustive crops on same piece of land, green manuring and forage crop should be also included in rotation and the leguminous crops should also be included in rotation at least every two to three years in order to enhance the soil fertility. Another crop diversification technique is intercropping which mean that the practice of growing two or more than two crops simultaneously in the same land in the form of row cropping and relay cropping system. This way the land and resources utilized efficiently. The practice of planting cover crops is mainly done for the covering of barren and free lands and decrease soil erosion and nutrient losses by leaching.

These all crop diversification practices are basically engaging to help in balancing all aspects of plant physiology, crop nutrients requirement, and fulfill economic and nutritional necessities. As result the crop diversification practices assists farmers not only diversify risk of climate change but in reality diversify the loads made on the soil foremost to develop soil superiority over time (van Zonneveld et al., 2020).

b. Decreasing Crop Growth and Germination Periods

To mitigate risk of climate change numerous pre plantation techniques and methodologies are adapted to reduce crop development and growth periods. These techniques are adapted to escape high temperature, drought, long dry spells and unpredictable rainfall patterns through managing of time essential for plant growth and germination. These agronomic techniques included the growing of fast maturing crop plants such as mung bean, chickpeas, cowpeas etc. Dry plantation is also a water and moisture conservation technique to utilize the whole annual rainfall by growing different crops before the start of the first rains (Ahmad et al., 2019)

According to (Baudron et al., 2013) CSA enhances the soil's water quantity by enhancing infiltration rate decreasing runoff and rate of evaporation. Improved infiltration rate increases the water use-efficiency and defenses crops plant against drought. Mulching cover and protects the soil from the adverse effect of high temperature and evaporation, e.g., in rained semi-arid land of Mexico, soil water substance during dry and summer times was 10-20 mm upper in maize fields under CSA compare to those with usual tillage and crop residue removal. Infiltration rate was on typical 24-38 mm ha-1 larger on CSA fields in South African region as compared to traditionally tilled field (Peter and Ries, 2013).

In addition, the seed priming is also a pre germination technique which is done for the purpose to faster germination and decrease growth cycle to escape the drought stress and un-favourable conditions. Besides, crop shocking is also a phenomenon in which plants crop are purposely killed to speed up drying of its edible seed in order to escape drought and shorten the periods of growth and development. These all CSA, pre plantation, Agronomic techniques are used for the purpose of shorten and reducing the period of crop growth and development to avoid and escape high temperature, drought and unfavorable conditions. Through these techniques farmer's crops mature early with low land utilization and water resources. Theses CSA techniques are considered significant for the soil and water conservation. The impact of extreme and stressful environment and climate can be reduced through these CSA techniques.

c. Superior and Vigorous Sowing Materials Seeds / Cuttings

The risk of climate change can be mitigated and control up to some extent by adopting CSA cropping practices. Some essential key input for climate smart crop production system is superior seeds and sowing plant materials of the well-adapted breeding varieties. It is not possible to harvest excellent crops with dire seeds (FAO, 2011). The plant breeders from different locations of the world are conducting experimental trails and crossing methods to develop quality and superior crop plant varieties that have great resistant to climatic change challenges, efficiency in resources utilization to control and decrease their bad impact on agriculture crop production and eco-system. Mostly the crop varieties are bred for the purpose of most reliable climatic qualities such as resistance to drought, flooding and salinity, resistance to frost during seedling or pollination, resistance to heavy rain that compress rain, resistance to high temperature during grain filling period, resistance high temperature that inspire germination, enhance high yield, disease resistance, and insect-pest tolerance. Moreover, breeding for superior and new crop varieties which better adapted to the thermal stresses such as heat, cold, drought, water logging and upper atmospheric and environmental CO_2 concentration is repeatedly recommended as the main long-term variation to climate change as present crop cultivars were chosen for extensive with diverse targets (Ceccarelli et al., 2010)

The drought tolerance seed have the ability germinate and mature early, so the period between germination and maturity are shortening in case of unreliable rainfall. The crop varieties with early maturation are selected. The early maturing seeds varieties are developed to have the ability to mature early and have lower periods between germination to maturation because when the conditions for growing are unfavorable i.e., high temperature and low rainfall then these varieties adjust by shorten their germination to maturation periods. Another form of reducing the growing period is the quality of reduction in flowering and pollination in crop seed varieties which help to escape dry spells when plant production is susceptible. Besides, the flood tolerant trait should be included in plant variety in order to enhance crop plant resistant to anaerobic conditions, because flooded soil conditions generate anaerobic conditions that are injurious for germination of an early stage of growth and development of crop especially rice crop. Furthermore, in flooded soil the extra accumulation of iron (Fe^{2+}) can injure the rice root. Iron tolerance rice crop varieties can decrease chance of damage to rice crop root system. The soil salinity is another major problem for crop growth and development. Soil salinity usually happen by practicing agriculture nearer to coastal area or due to soil salinization in dry land area were rainfall minimum. For this purpose, the salt tolerant varieties should be commonly practiced in coastal and dry land area in order to protect crop losses and enhance yield, because the salt tolerant crop breed varieties are more resistant to superior soil salinity. Another factor breeder should give priority is the breeding of crop that are much rich in iron, zinc, vitamin A or some other important micronutrient which are very important content of human diet and nutrition, the including of these qualities in crop varieties breeding traits are referred to bio-fortification. In addition, the produce bred variety should have strong resistant to internal or external diseases attacks which decrease yield.

d. Seed delivering and access system to the Farming communities

Seed is an important entity in crop production. A poor seed cannot give us a strong plant, that’s why the seed should be encoded with good climate smart agriculture qualities. The purpose of development, certified, official release and the official registration of well adapted crops seed varieties are imperative steps taken towards the vital goal of ensure farming communities have access to the superior seeds and vigorous planting materials. But accomplishing this eventual goal also needs a consistent mechanism for distributing the crop seeds of the most appropriate varieties to farming communities. Usually, the farmers take seeds by two different systems. One way is from formal systems and the other way is referred to informal systems (Louwaars, 2022).

The formal seed systems depend on both private and governmental organization for the purpose of plant breeding, multiplication, quality control, seed certification, seed distribution and marketing. This is a straightforward method of seed delivering. In this method the all stage of seed production is subject to regulation, inspection and certification. The formal seed are multiplied and produce under high check and balance and proper protocol. The getting and purchasing of seed from unregulated and unregistered sources is referred to informal seed system. These sources included saving seed from previous years, getting seed from neighbor or friend, purchasing seed from nearest local shop, exchange of seed with other farmer and getting seed as a gift from another friend. This is especially done in developing countries of the world where crop production systems are the mainly exposed to tremendous weather events and sever climatic conditions. For such crop production systems, which are normally characterized by low input agriculture production, smaller scale property and partial market engagement, it is mostly important to sustain community-based crop seed production system and delivery channels. In regions of the globe where climate change is predictable to have the maximum impact, the majority of the seeds supplied throughout community-based deliverance systems are chief food safety crops. These crops plants include cowpeas, beans, open pollinated maize, cassava sweet potato peanuts and yams. Small and medium scale enterprises are useful sources for ensuring that superior seeds of the mainly appropriate varieties are accessible to small scale farming communities and are surrounded by easy contact in their area.

The seed breeder should support farming communities by working jointly with different collaborator concerned in the seed value supply and production chain and to create the skills of small-scale farmers to produce superior quality banked seed materials to plant or distribute with the help of informal seed systems, as well as contributing in the formal seed system sector. This can be accomplished through the interventions such as, Advocate a strategy environment that encourages diverse and comprehensive seed systems; Promote crop seeds reproduction of superior varieties at local level with collaboration of farmers; Cooperate with private and Government shareholders involved in the different crop seed value supply and production chain; Develop farmers' capabilities on superior practices of saving, sowing, selection and preservation of planting seed materials; and the Integrated Seeds Sector Development program which provides technological direction and information to set up comprehensive and incorporated seed models.

e. Integrated Pest and Diseases Management

Climate change will affect the geographic spread and population establishment of a wide range of insect-pest, diseases and different weeds. The increase in temperature directly impacts the reproduction, survival, spread, and population dynamics of pests. It also influences the intricate relationships between pests, the environment, and their natural enemies (Parkash et al., 2014). It will also be limiting and reducing the activities and abundantly occurring of natural enemies and predator, that's why controlling of insect-pest, diseases and weeds in crops field in more efficient ways will be difficult in order to maintain a best level of field crop production. With the increasing in international trade and exchange of germplasm, these changes in climate will create some new and technical challenges for the insect pest management. IPM is an integrated ecosystem approaches focused and based on a wide range of field management practices that combine biological, chemical, cultural, mechanical, and genetic methods; prevention measures; field monitoring and pest identification rather than overreliance on chemical control. Moreover, the Determinations regarding the necessity of control measures should rely on contemporary tools, including forecasting methods and scientifically validated thresholds. Direct pest control methods are only employed as a final recourse when economic losses, deemed intolerable, cannot be averted through indirect measures (Boller et al., 2004).

Furthermore, Global climate change has profound implications for agriculture, particularly in its impact on agricultural insect pests. The influence of climate change extends both directly and indirectly to agricultural crops and their corresponding pests. Direct impacts manifest in changes to pests' reproduction, development, survival, and dispersal. Indirectly, climate change alters the intricate relationships between pests, their environment, and other insect species like natural enemies, competitors, vectors, and mutualists. Insects, being poikilothermic organisms, have body temperatures dependent on environmental temperatures. Therefore, temperature stands out as a crucial environmental factor affecting insect behaviour, distribution, development, and reproduction. The primary drivers of climate change—increased atmospheric CO2, rising temperatures, and decreased soil moisture—have the potential to significantly influence the population dynamics of insect pests, consequently affecting the percentage of crop losses (Kocmánková et al., 2010; Fand et al., 2012).

Climate change opens up new ecological niches, providing opportunities for insect pests to establish and spread in novel geographic regions and transition between regions. The intricate physiological effects resulting from elevated temperatures and increased CO2 can profoundly alter interactions between agricultural crops and insect pests. Consequently, farmers can anticipate encountering new and heightened pest challenges in the coming years due to the evolving climate. The expansion of crop pests across geographical and political boundaries poses a substantial threat to global food security. This is a shared global concern, affecting countries and regions universally, highlighting the urgency for collaborative efforts in addressing the challenges presented by the changing climate (Bale et al., 2002).

These practices of integrated pest and weed management engages the use of suitable measures to depress the expansion of pest populations and maintain pesticides and further interventions to stages that are cost-effectively justified; decrease or minimize threats to human being health and the surroundings; and interrupt as small as possible the agricultural ecology. The capability to build good decisions in the crop field is critical for efficient integrated pest and weed management. Chemical control and management of pest, weed and diseases is in reality used as final option and just when other procedures have unsuccessful. The Integrated pest and weed management significantly help to decrease problems of insect and pest resistance.

The main steps and principle for an IPM approaches includes are protection, control and suppression of dangerous living organisms (especially insect-pest) by growing healthy crops, follow crop rotation and inter-cropping techniques; use of enough crop cultivation management techniques such as pursue seed sowing dates and densities, the seedbed preparation and sanitation, under-sowing techniques, adapt conservation tillage practices, pruning and method of direct seed sowing. Besides the IPM approaches also encircles and focus on the growing of proper pest resistant and tolerant crop cultivars and certified seed and crop planting material. The IPM also embraces fair soil fertility level and best water management system, building optimum use of organic matter (OM). The IPM also help to prevent dispersion of destructive organisms with the help of crop field hygiene and sanitation procedures such as, the removal of disease affected crop plants or infected plant parts, regular sanitization of farm machinery and farm equipment. Moreover, the IPM play role in safety and improvement of significant beneficial organisms such as by the operation of environmental infrastructures within and external production locations.

Another preventative approach of IPM is to control the damaging organisms (especially insect-pest) through monitoring with satisfactory techniques and methodologies by clarification in the field and where possible concern, forecasting and early diseases or insects' diagnosis systems (e.g., traps). Based on the early obtained observation and Monitoring results it is determined whether and when to apply the tools and techniques, what type of insect pest managing inputs tools will be applying. The conservative, physical, cultural, sustainable biological and other non-chemical and organically methods must be practiced and should be given priority over chemical control methods if they give suitable insect-pest control. The Pesticides/Weedicides must just be only applied as a final option when there are no sufficient non-chemical alternatives are available and the use of pesticides/insecticides is cost-effectively acceptable. The pesticides and weedicides applied shall be selective and have the ability and focus to finish a particular problem and have lower or no side effects on human being health other non-targeted useful organisms and the surroundings, while their application should be reserved at least levels. The important thing to do at the end is to monitor and explore the success of the applied insect-pest, diseases and weed management measures.

The IPM also focuses on the use of environment friendly and organic chemicals that do not destroy eco-friendly organisms and natural enemies. To control and avoid killing and destroying of friend bees and insects, the chemical spray should be done during afternoon time when the flower nectar secretion is minimum, and minimum number of bees are foraging. The crop diversification should be done by adapting multi-cropping system in order to destroy insect shelter and reduces the buildup of insect, pest, weed and diseases. Besides the IPM also encircles the adaption of biological insect-pest and disease control practices in the form of predator, natural enemies, growing of repellant crops and use of organic and environment friendly bio-pesticides. The IPM also subject to follow and adapt culture insect-pest diseases control techniques and procedures through mulching in order to destroy and break the insect-pest and disease cycle. In addition, the exploration and mechanical control of insect pest, diseases infested crops plant, parasitic wasps and natural predators such as mites, ladybird beetles and lacewings are play very significant role in natural suppression of whiteflies. Spry of Neem tree leaves, onion or garlic extract, dusting of red chilies powder help to control whitefly.

In the honeybee keeping regions and areas, plants crop that are resistant to honeybees like Mexican marigold are toxic and should be planted away from honeybee hives.

As the climate changes with passage of time, the national regulatory authority, policy support and institutional agenda frameworks should be built up to facilitate the implementation of integrated pest and weed managing practices on farms and farming communities. In fact, the agenda frameworks must support crops grower training in integrated insect pest and weed management; sustain the inspection systems, including those practices used in society groups, that are used to identify and explain the changes in the behaviors of insect-pests and natural predators and enemies; develop suitable quarantine measures to stop the entrance and establishment of crop plant insect-pests; and formulate suitable managing policies to respond to possible outbreaks. Other significant elements of some approaches to encourage a shift to flexible crop plant production systems which include Phyto-sanitary frameworks and some other actions that can assist the establishment of markets for sustainable goods; and the visible association between policy makers, factories industries and farmers group on the regional, national and international registration procedures for the mainly suitable pesticides, weedicides and insecticides to a climate smart approach (FAO, 2016).

f. Post-Harvest Management of Farm Produce

In the hazardous situation of climatic conditions, the sustainable food security is very necessary. Food and post-harvest losses occur during harvest and post-harvest of any food produced. The FAO (Food and Agriculture Organization) estimates that 1/3rd of food products is lost every year and 50-60% of cereal yields can be lost at the storage stage due to the lack of technical possibilities for their proper harvesting and storage (FAO, 2022). Further researches reports approximately 17% of agricultural production is attributed to food waste, while post-harvest losses account for an additional 13% of the total (Sawicka, 2020). In economically disadvantaged nations, post-harvest losses range from 20% to 50%, whereas in wealthier nations, these losses generally fall between 10% to 20%. The brunt of these losses is predominantly borne by developing countries, exerting adverse effects on the economy, society, and even the environment, consequently exacerbating issues of food insecurity (Agrios, 2005). Approximately one-third of the globally produced food, amounting to 1.3 billion tons annually, goes to waste, spanning both affluent and developing nations. In middle-class and wealthy countries, edible foods are frequently rejected, contributing to this staggering figure. Within developing nations, over 41% of food losses occur at the retail and buyer levels, while early stages of the supply chain, such as postharvest and processing phases, are responsible for losses. Notably, 35–45% of grains and vegetables face rejection or loss after leaving the farm. Wealthier nations experience postharvest losses in vegetables and fresh fruits ranging from 5 to 40%, while in less affluent nations, these losses surpass 30%. The transportation phase from initial agricultural production to final consumption witnesses the loss of new products and fruits. The initial table underscores how losses in the rural manufacturing segments of three industrialized nations often surpass all levels, primarily due to high merchant demands. In these countries, food delivery businesses contribute significantly to waste, as customers return 16–35% of their orders. Conversely, in developing nations, losses in the fresh produce chain outweigh those in processing and packing, attributable to factors such as seasonality leading to unsalable surpluses and the imperative to reduce perishable foods in hot and humid climates. Additionally, agricultural manufacturing processes in these regions result in notable losses, likely due to insufficient technology, funds, and knowledge (Hassan et al., 2010; Attenda et al., 2011).

These losses should be minimized up to great extent of possibilities in such a way to maintain and balance the food security. The number of losses, the type of food vanishes and loss, the ways of losses, other factors responsible for losses and the socio-economic characteristics of the region of losses are very important and significant to understand when working for losses reduction and control. The impact of these factors on food losses is also essential. The increase in crop production and crop yield have improved the lifestyle of poor, but it is also severely necessary to ensure that food crop produced is not lost or waste totally during harvest or post-harvest. The proper care should be kept of crop produced and necessary measured should be taken for the control and minimizing of post-harvest losses of food crop produce on sustainable ways. By controlling, minimizing and proper management of the post-harvest losses will benefit the farming communities and also help to ensure food security on urgent basis. It will also reduce the high pressure and burden on agriculture sector and will bring prosperity, and hunger will be reduced and control to the possible level. Besides of the effects of climate changes, cereal crops losses and wastes during harvest and post-harvest is reported 20 % in Africa due to inefficient agronomic and harvest practices, rotting, pest infestation and wasting.

Food and Agriculture Organization of the United Nations forecast that approximately 1.3 billion tons of the foods and food materials are worldwide wasted per year during harvest, post-harvest, carrying and marketing management (Gustavasson et al., 2011). Control and decline up to some level in these losses would enhance the quantity of food availability for human use and consumption and will increase worldwide food security. (Mundial, 2008; Trostle, 2010). Control and reduction in food losses also increases food security by enhancing the actual income for all the farming communities and consumers (World Bank, 2011). Besides, crop production gives major proportion of usual incomes in numerous regions of the globes (70 percent in Sub Saharan Africa) and dropping food loss can directly enhance the actual incomes of the farmers (World Bank, 2011). That's why post-harvest management is measured a vital CSA practice for successes of agriculture productivity. The post-harvest management should be included in agricultural policies.

loss: is still some appropriate improvement required for proper management, control and reduction of post-harvest losses in order to enhance farmer's income, these improvements can be achieved by adapting some important ways and techniques such as; Accurate timing of harvest should be follow and moisture content should be according to the requirement of harvest of a crop; Suitable and recommended harvesting methods and procedures should be take on for minimum grain and pulses loss; Appropriate care should be given to transportation of farm produce, grain and pulse to minimize loss; Quick crops grain drying methodologies should be adapted for reduce of moisture level of grain and prevents bacterial and fungal infestation; crops shelling should be done in order to minimize chance of grain damage; Crops grain should be stored in a fumigated place and hermitic bags or silos that will protect the grain from the attack of borers and mites etc.

By adopting these proper techniques and technologies of post-harvest management the losses will be minimize and control up to high level which will improve the farmer's income and crop productivities in the shocking situation of climate changes.

g. Use of Lower Scale Mechanization on Farm

Farm mechanization is the application of farm machinery, farm power, tools for agricultural land preparation, farm production, farm tillage operation, crop sowing, harvesting and processing. The use of small-scale mechanization is considered vital and beneficial for farmers to increase their output value and decrease input cost. Low use of machinery has positively changed the livelihood of farming communities. The losses during harvest and post-harvest and food processing have been minimized through this approach. The little use of farm machinery also helps to maintain soil structure. It also assists the low transfer of CO_2 release from soil to atmosphere. Besides, the small-scale mechanization also reduces the GHG emission, that's why use of small-scale mechanization is included in CSA practices. This is considered an eco-friendly approach for agricultural crop production, because it helps to mitigate and adjust the threats of adverse climatic conditions and challenges to crop production.(Ehiakpor et al., 2019).

Small level mechanization relies on hand tools equipment, Animal dependent technology and mechanical and automatic power technology. These technologies are considered environment friendly and help to mitigate risks of climate changes. These CSA technologies have reduced the use of heavy farm machinery for agricultural production due to which the productivity and efficiency of agricultural farming system has increased. It has also reduced burden and workload on women and men farmers by providing agricultural labor.

These CSA technologies have reduced agricultural field preparation input costs associated with tillage operations, whether it done manually or through by machinery. In mechanized rice-wheat production systems in India, the field operational input costs were 15 percent lesser under low scale farm machinery use. In the manual maize production systems in Malawi, small-scale farm machinery operated field required 20 percent lower labor than conventionally prepared furrow and ridges crop fields. The decrease in crop field preparations with the help of CSA practices such as small-scale mechanization technology also lets timelier planting and sowing, which supports booming harvests (Ngwira et al. 2012).

h. Agro-Forestry Management

Agro-forestry is an environment and soil friendly CSA approach. It refers to the combine and mix growing of forest trees and crops on agricultural land for the purpose to increase the crop production and yield; to maintain ratio of carbon in air, soil and plants which provide high energy to the plants; to enhance the soil fertility and structure and to improve the water absorption capacity of soil and maintain soil moisture. It is clear that in this CSA approach trees and crops are grown in integration for different product and services. Trees produce include nuts, oil, fruits, beverages, resins. Gums, flavors, latex, fodder for livestock, leaves for food and nutrition, fuel wood, timber and biomass for energy making. Besides, trees also give some services such as being a host to insect-pest, carbon capture, bee and insect habitats for the purpose of pollination, help in nitrogen fixation, shelter from wind, rain and sun, control soil erosion, better regulation of water and modifying of day to day-to-day weather and climate.

Agro-forestry is the planned arrangement of agriculture crops and forest trees to produce, productive, dynamic and sustainable ground use practices (USDA, 2018). Same like several other practices of CSA, agro-forestry is both older and latest practice to help in mitigation risks of climate change. While the name ‘’agro-forestry’’ is moderately new, agro-forestry has been adapted for millennium, diverse yielding, multistoried food-forests system in both the temperate and the tropical climates. The current interest in agro-forestry of the previous few decades has been obsessed in fraction by the need to relate the profits of perennial agriculture system to address several of the problems and challenges of strip crop and the animal agricultural production systems.

Climate change and sudden climate variability has endangered the safe delivery and supplies and eco-friendly system services from forest and trees that are necessary to livelihoods, vital to food security, essential to environmental sustainability to national development. Sustainable forest and agricultural crop production management give a basic foundation for the climate change mitigation and adjustment and helps to food security through numerous ways and means. Climate smart forestry will need further widespread application of sustainable forest and crop production management (Agro-forestry) principles.

Agro-forestry systems can be applied at a sequential and spatial level for a soil owner, who can apply diverse agro-forestry practices. (See Table 1) The most common Agro-forestry practices are (i) Alley cropping, (ii) Forest farming, (iii) Wind breaks, (iv) Silvopasture, (v) Home Gardening, (vi) Wood Lots, (vii) Fodder Banks, (viii) Biomass Transfer, (ix) Indigenous Fruits Tree Production, (x) Terrace / contour Stabilization, (xi) Riparian Forest Buffers (xii) Natural Regeneration. These all practices are helping to mitigate bad effect of climate change on globe (Mosquera-Losada et al., 2009). The agro-forestry is a concentrated and intensive land and soil management methodology that optimizes the advantages from the biological exchanges produced when trees and shrubs are knowingly combined with plant crops and livestock. There are mainly five basic kinds of agro-forestry practices currently in the North America which are Silvopasture, windbreaks, riparian buffers, alley cropping and forest farming. Agro-forestry is an intentional, intensive, interactive and an integrative approach (AFTA, 2020).

Common Practices of Agro-Forestry	
Alley Cropping	Agricultural plant crops grown concurrently with long-term forest tree crops.
Wind Breaks	Linear plantings of forest trees and shrubs to increase, safeguard, and give profit to people, soil, livestock, and water.
Forest Farming	The cultivation and growing of high-value plant crops below the shelter of a managed forest canopy.
Silvopasture	The Combines growing and management of trees with forages and livestock production.
Home Garden	The growing of some Tree species in home garden, its common in high population area
Woodlots	The growing of single tree variety or a mixture recognized typically for fuel-wood, poles and timber.
Fodder banks	The fast emergent fodder varieties planted in a wedge on their personal or in a combination among fodder grasses for slice and lug.
Biomass transfer	The practice of green leaf or mulching by means of flora of cut shrubs and trees carried on cropping area.
Indigenous Fruit Tree Production	The production of domestic and enhanced species of native fruit trees.
Terrace/ contour Stabilization	Usually practiced in high land area for the purpose to stop soil erosion.
Natural Regeneration	The natural regeneration of forest trees, these tree regenerate by itself according to environment.
Riparian Forest Buffers	Natural and re-established flow side forests prepared up of grasses, shrub and tree plantings.

Table 1: Common Practices of Agro-Forestry in crop production

2.2. Soil Management:

It is projected that with increasing level of greenhouse effect and global warming rainfall levels will have to decline, arise in more extreme events. It is also predicted that evaporation and transpiration rate will increase. These climate changes and harsh events will decrease the accessibility of soil moisture for crop plant growth and development. The higher and intensive temperatures rate will also raise the speed of soil organic matter (SOM) breakdown and decomposition (mineralization), particularly close to soil surface and near plant root, which will influence the soils impending ability to sequester the carbon and hold water (Kassam et al., 2009). In cropping production, grazing and the forest systems, in general, climate change and inconsistency may influence and affect the soil health and structure for the plant growth and development through: reduced or unpredictable rainfall; supplementary regular and harsh stages of drought that lesser the capability of the soils to make the water and all the nutrients accessible to crop plants.; more extreme rainfall and the storms that raise the threat of the soil erosion through the water and wind and enlarged the soil surface temperatures intensity and larger speed of the soil mineralization of OM.

To manage and control the challenges and destructions of climate changes, proper soil management is very necessary for all type of crop production systems.

CSA practices for soil management mainly focus on conserving soil resources in order to enhance soil formation level and production. These CSA practices protect the soil from erosion and degradation, preserve its moisture level and increase its fertility and OM content.

Sustainable and climate smart agriculture practices refers to a series of soil management practices that fulfils current requirements without risking future generations' ability to fulfil their own needs from that soil.

Conventional and usual soil management practises that endanger the biological community of the soil may also endanger soil longevity and fertility by limiting the soil's ability to adapt in the long term. Over-cultivation decreased or increased water abstraction, under-fertilization or over-fertilization, reckless use of biocides, failed to uphold soil organic matter levels, and eradicating natural vegetation are all examples of management practices that might endanger soil sustainability. Physical and chemical processes including salinization, desertification and increasing soil erosion) as well as biological processes (e.g., by decreasing soil fertility) may all pose a danger to sustainability. When soil management is inadequate, a combination of these issues might jeopardize the sustainability of soil simultaneously. Soil management strategies will provide immediate and long-term benefits to soil flexibility, mostly through an increase in soil organic matter (OM) levels.

Soil fertility must be sustained and improved for viable and fruitful agriculture. “Productive” soil will help to push optimal agriculture outputs close to the limits set by soil type and climate. Agricultural experts have long recognised that soil management strategies are crucial not just for boosting the production of agricultural commodities, but also for curbing the emerging global pollution/contamination (Powlson et al., 2011). Therefore, attention must be paid to not only securing soil against erosion (which causes land scarcity), but also implement various techniques that prevent soil pollution and degradation. Sustainable soil management involving appropriate nutrient management and effective soil conservation methods are some of the primary difficulties to attaining ultimate food security (Acosta–Martínez et al., 2017).

Fig. 3: Principle of Climate Smart Agriculture Soil Management System

The CSA soil management practices will perfectly have both instant and long-term advantages to the soil flexibility, typically through the enhance in the soil organic matter OM levels. The main rubrics for soil management are integrated soil-crop and water management and Integrated Soil Fertility Management (ISFM) for improving soil fertility, and Conservation Agriculture (CA), which is aimed at building soil structure, and consequently, resilience It should be recognized that both concepts include multiple practices that often overlap with one another as well as field management concepts (e.g., cover cropping can build soil fertility, improve soil structure, and reduce pest / disease / weed infestations). The main practices comprised under CA and ISFM are presented below. (See Figure 3)

a. Integrated Soil Fertility Management (ISFM)

Integrated soil fertility management is among the CSA practices. It emerges all agronomic strategies relating to crops, mineral fertilizers, organic inputs and other alterations that have been made suited to a variety of agricultural patterns, soil fertility status and socioeconomic profiles (Vanlauwe et al., 2011). Integrated soil fertility management (inorganic and organic) to address the issue of low nutrient retention capacity, which is especially prominent in tropical and subtropical soils where soil OM and organic compounds are rapidly degraded. Integrated soil fertility management (ISFM) is an approach used in intensive cropping systems around the world to correct or avoid macro- and micronutrient shortfalls by combining organic matter (mulch, compost, crop wastes, green manure) with fertilizers.

b. Integrated Soil–Crop Water System Management (ISWSM)

The integrated soil crop water management is another CSA approach. It is very critical for climatic stability and reduced climatic perils and tensions. Soil organic matter level, the soil's nutrient preservation ability and soil biota can be strengthened by using resonance management of soil-crop water interrelations. Regions that have already achieved nitrogen (N) balance can use new integrated soil–crop water system management approaches to improve crop yield and fertilizer use efficiency, such as developing higher quality cultivars, slowly releasing nitrogen modifications, location-specific agricultural activities, precise crop rotation and efficacious irrigation systems etc. (Tilman et al., 2002). The ideal chemical, physical, and biological conditions for productive crop development (food, fuel, fibre, flower, fodder and trees) can be provided by this integrated soil crop management.

c. Precise Nutrient Monitoring and Management:

Precise nutrient monitoring and management is one of the most important and dominant practice of CSA. It helps to mitigate risk of changing climatic conditions. Fertilizer application relies on maximizing fertilizer efficiency while ensuring environmental safety; therefore, monitoring the fertilizer application is one of the most challenging tasks of CSA (Vitousek et al., 2009). Delgado and Lemunyon (2006) portrayed that nutrient management is the art and science intended to connect the irrigation, tillage, and conservation of water and soil for the optimization of crop fertilizer usage efficiency, profitability, reliability and net profit while minimizing the off-site mobility of nutrients with less environmental consequences. Nitrogen and phosphorus are chiefly highlighted in plant nutrient management as these are the principal pollutants that enter and leave the fields via fertilizer (both inorganic and organic) (Edmeades et al., 2011). The use of manure and nitrogen-fixing plants to recycle nitrogen on the farm is the most common practice used in organic and low- external input agriculture to improve soil quality and provide nutrients. Organic and green manures as well as nitrogen from legumes can be handled with extreme precision via crop rotation. Moreover, in contemporary agriculture, microbial-based biofertilizers have emerged as integral components that play a pivotal role in enhancing crop productivity and fostering sustainable agro-ecosystems. This category encompasses a diverse array of microbial-based bio-products, each with bioactivities crucial for stimulating and improving the biological processes within the intricate plant–microbe–soil continuum. Various soil microorganisms, particularly bacteria and fungi known for their Plant Growth Promoting (PGP) traits, contribute to the production of efficient biofertilizers. The classification of microbial-based bioformulations generally falls into four categories: (1) Nitrogen-fixing (NF) bacteria, (2) Phosphorus-solubilizing/mobilizing microorganisms, (3) Composting microorganisms, and (4) Biopesticides. It's noteworthy that beyond their primary functions, these microbial groups may exhibit additional PGP traits, including the production of phytohormones, siderophores, amino acids, and polysaccharides. These secondary traits could plausibly contribute to further enhancing crop improvement (Pathak, 2016).

d. Water use Efficiency and Irrigation:

Water use efficiency (WUE) is the major parameter of climate smart agriculture. Water is the single most powerful resource for agriculture's long-term viability. Improving WUE is the primary issue facing agricultural water management (Chartzoulakis and Bertaki 2015). As the climate changes, more emphasis should be made on conserving water, minimizing evaporation, and maximizing infiltration and moisture retention in the soil profile through SOM management and the adoption of drought-tolerant species. Irrigation boosts crop and grassland productivity especially in dry lands. (Wang et al., 2010)

Scientists must keep a watch on the salinity of our agricultural areas, which is linked to irrigation, because it is a major limiting factor in crop production. In terms of application and functionality, irrigation scheduling tacks are extremely diverse. To resolve soil and water salinity in agricultural landscapes, novel soil and water management methods and strategies must be used to mitigate salinity and make use of salt-affected soils and saline water (Sakadevan and Nguyen, 2010). Integrated soil and water management strategies for adjusting to current soil and water salinity and limiting potential salinity development include: permanent raised bed (Akbar et al., 2007) precise irrigation scheduling (Howell, 2003); and conversation and management strategies of soil such as incorporating the crop residue, implementation of manure and gypsum, reduced tillage, cover crops and crop rotation that promotes the soil water-retention capability, soil organic matter and infiltration.

Conservation Tillage

Conservation tillage is the key point in soil management practices of CSA. Tilling (e.g., digging or ploughing) of the soil surface causes distorts the soil structure and stimulates the oxidation of soil organic matter. Both of these factors contribute to soil degradation due to wind and/or water erosion, as well as a depletion of soil fertility due to the loss of soil organic matter. Reduced tillage and, in some situations, organic fertilizers (e.g., manure, green tree leaves, ash, etc.) establish an environment where soil biological processes can maintain soil structure and create higher soil organic matter levels (Rahman et al., 2021). Zero tillage is the term used to define as it is absolute least amount of tillage used to plant seeds. Varying kinds of technologies, such as dibble sticks, jab planters, and fitarelli planters can be used to achieve zero tillage. At best, zero tillage is performed entirely through a layer of dead surface organic matter. Minimum tillage is the method of minimizing the digging of the soil surface to that requirement to apply organic fertilizers, and in some situations, act as a catch basin for rains to optimize the quantity of moisture around the growing plants. At regular intervals, basins or Zai pits are used to perform minimum tillage. Moreover, the alarming pace of soil degradation, a significant global environmental challenge, poses a severe menace to crop productivity on a global scale. Conventional tillage practices like ploughing, ridging, and harrowing, common in intensive agricultural systems, contribute to this degradation by leaving the soil surface exposed and loosening soil particles. These actions result in heightened levels of surface runoff and erosion, exacerbating the challenge and hindering the accumulation of vital soil organic matter (UNDP, 2019). Compelling evidence points to the degradation of approximately 25 percent of the world's total land area. Each year, a staggering 24 billion tons of fertile soils are lost, with a considerable portion attributed to excessive soil tillage and other unsustainable land-use practices. This emphasizes the urgent need to address and mitigate the adverse impacts of such practices to safeguard the productivity and sustainability of global agricultural systems (Ross et al., 2019). Shifting from traditional tillage methods to minimum tillage systems can yield advantages in both the short and long term. Short-term benefits may be realized within the initial cropping seasons, while long-term benefits might become apparent only after several cropping cycles. Over the medium to long term, embracing minimum tillage is anticipated to enhance soil fertility and productivity. This improvement stems from gradual enhancements in the biological, physical, and chemical properties of the soil over time (Giller, 2009).

Therefore, comprehending the inter-temporal adoption decisions made by smallholder farmers and understanding the impacts of such adoption are pivotal. This understanding is crucial for devising targeted policies aimed at addressing the constraints these farmers face in utilizing resources effectively and promoting sustainable agricultural practices (Maggio et al., 2021).

3. Conclusion

Climate smart soil practices and climate smart crop productions measures are discussed in this review to mitigate climate change and enhance crop yield. In this comprehensive review, we delve into climate-smart soil practices and innovative crop production measures as strategic avenues for mitigating climate change and optimizing crop yields. Through this succinct yet enlightening overview, we've uncovered actionable possibilities for both climate change mitigation and adaptation, showcasing a myriad of methods tailored to diverse cropping systems across varying climatic conditions. It is noteworthy that the precision of climate-smart agriculture practices and adaptation actions is contingent upon locality-specific conditions, introducing a dynamic element to implementation strategies. In light of this, we strongly advocate for the establishment of climate-smart and adaptable cropping systems. Such systems should embrace integrated approaches that involve a synergistic implementation of related sets of management practices, rather than the isolated adoption of specific practices. This holistic approach ensures resilience and efficacy in the face of the ever-evolving challenges posed by climate change. It is recommended that establishing climate-smart and flexible cropping systems may occupy the implementation of the integrated approaches involved of related sets of the management practices rather than the implementing definite practices one a time.

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