Chapter

# Capacity Development for Scaling Up Climate-Smart Agriculture Innovations

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## Abstract

Climate change and climate variability are creating negative impacts to agriculture. It affects both food security and crop and livestock production. In the process, it affects the livelihood of communities. Climate-smart agriculture is seen as an alternative to mitigate the challenges of climate change. Literature studies were obtained from journal articles on capacity development. The problem investigated is that climate-smart agriculture (CSA) is a recent concept which needs to be understood with climate change, and the extension advisors do not have requisite skills. Ethical tea partnership singles out tea farmers and advisors in the tea sector. The findings included the definition of climate-smart agriculture (CSA) and the linkage with climate change. It further identified key issues involved in CSA, adaptation and mitigation, and identified the technologies that need to be scaled up in order to mitigate against climate change. The study recommended the area of competency required to serve farmers by advisory services by showing the needed factors that will serve as strategies in order to scale up the needed technologies useful in managing climate-smart agriculture. The chapter recommends capacity development for extension advisors and concludes with a series of mitigation steps.

**Keywords:** climate change, mitigation, impact, climate-smart agriculture

## 1. Introduction

It is acknowledged that climate change and climate variability are creating negative impacts to agriculture. In the process it affects the livelihood of communities. Experts have attempted to explain the challenges that the continents will face due to climate change and also predicted that unless something is done, it has potential to destroy the environment which promotes food production [1, 2]. It creates a lot of effects to both food security and animal and crop production. Both developed and developing countries are going to be affected. Studies have shown that researchers can contribute by describing the potential role innovative agricultural practices and technologies can play in climate change [3, 4].

Effort have been directed to the understanding of climate change, its definition, causes and mitigation. However, not much has been done in technologies that can be used in the circumstances of climate change. According to [5] innovative agricultural practices and technologies can play an important role in climate change.

If it can be mitigated and adaptation be encouraged, they can make a difference. This chapter focuses on climate-smart technologies with these specific objectives:

- To define climate smart and how it is linked to climate change.
- To discuss the impact of climate change in agriculture.
- To indicate the impact of climate change to crops and livestock as well as the mitigation strategies that can be used.
- To identify climate-smart technologies and strategies to scale up by extension advisors.
- To indicate steps that extension advisors can adopt in scaling it.

## 2. Background and motivation

Evidence suggests that climate change has become a big matter in the world with organizations pulling their efforts in an attempt to find solution, for example, according to [6]. Climate change will exert increasing pressure on our ability to meet other major challenges, with feeding the world's growing population paramount 9.6 billion by 2050; see [7]. Over the next 40 years, the need to increase global cereal production by a minimum of 60–70% [8], the question to be asked is what is our understanding of climate change, what are the causes, and can these be mitigated? Researchers and scientists have been grappling with these questions, and some have given their understanding. Climate change plays a negative role to agriculture and causes excessive gases in the atmosphere, and the existence of "high levels of $CO_2$ would have a catastrophic effect on the planet's ecosystems" [7].

Rising air temperatures trigger several important secondary effects. Increased global day- and nighttime temperatures are causing changes to seasonality. Warmer air temperatures are melting the polar ice caps, northern latitude ice shields, and high-altitude glaciers worldwide, leading to changes in the timing and volume of freshwater discharge and rising sea levels [7].

In order to slow down this process, human beings should be helped to understand some of the steps that need to be taken. One would interrogate as to what is the link between climate change and CSA. It can be argued that while climate change increases, the vulnerability to agriculture which results in variability of temperature and reduced rainfall or in some instances brings out flood. On the other hand, Juvadi [9] identified three critical contributions that come as a result of CSA, namely: (a) CSA reduces agriculture contribution to climate change; (b) strengthens resilience to climate change and variability; and (c) sustainably increases productivity and income [9].

International organizations, such as International Crops Research Institute for Semi-Arid Tropics (ICRISAT), saw the importance of CSA to an extent that it has established projects in Africa reaching out to countries such as Ethiopia, the Horn of Africa, and Sudan with one aim to capacitate the extension functionaries in order to best serve farmers with climate-smart agriculture. The project will develop CSA technologies and CSA farms in vulnerable regions of Ethiopia and Sudan. These technologies include improved crop varieties and land management, improved soil fertility management, integrated pest and weed management, agroforestry, and improved livestock systems. These CSA farms will also serve as research and training

sites for students from the universities and be used as demonstration sites. Gender equality and the promotion of female farmers is a core activity of the project.

## 3. Rationale for capacity development in CSA

It is the opinion of the author that the need for climate change knowledge on both adaptation and mitigation is a must in order to assist in the solving the challenges posed by the negative effects of climate change in farmers especially the smallholder one because in most cases, they are not well positioned in terms of knowledge as well as financial muscle to handle the threat posed by climate change.

For example, areas that receive flood change the ecosystems leading to new host of pathogenic organisms, or in some cases the environment is altered, and new diseases emerge which threatens the survival of these smallholder farmers. Authors have developed manuals to assist agricultural advisors to cope with such situations, see [6, 9–12].

## 4. The effect of climate change in agriculture

Productivity in agriculture and the quality and quantity of produce will be low. The sector of agriculture will not be able to meet the demand of the increase in high population due to climate change. Maize production will be severely affected because there will be limited rainfall for irrigation.

There will be no products of maize that are exported to other countries, and the GDP of the country will be low [13]. It will result in poor economic growth that will lead to low level of employment.

Agriculture practices will be affected; certain cultivation method will not be considered effective because of climate change [14]. Deep cultivation method cannot be adopted because of low rainfall received [15]. Minimal cultivation will be introduced to try to meet the requirement of the crops [16]. Farmers will sell their produce at higher price trying to meet daily operational cost of the farm. There will low level of employment rate in agriculture, and other permanent workers will lose their jobs [17].

There will be an introduction of other methods of cultivation that are neglected currently [18]. The mulching method will be used because of the following advantages; it promotes the water retention in the soil; the level of water that is being lost will be minimized. It also reduces the growth of weeds. There will be newly full adaptation of irrigation systems; the drip irrigation will be fully used [19].

It is because of the following advantages the total amount of water is applied directly to the root zone of maize plants, which will help in the full development of the plant [20]. There will be less evaporation rate due to the direct application of the water in the root zone. Other methods of irrigation that waste the usage of water will not be used. The disadvantage of the furrow irrigation is the high infiltration rate and evaporation of water that will result in a great loss [21].

Agriculture inputs will be ineffective; climate change will cause other species of insects to mutate. It will affect those insecticides that are registered now; they will not be able to control the pest population. It will pose a negative impact to the yield of farmers [22] leading to farmers not being able to meet daily operational cost of the farm.

Environmental effect of climate change in the soil will be negative [21]. There will be high leaching of nutrients due to unpredictable receivable rainfall. Soil that has good base status of the soil will result in having low base status. Other soil nutrients will not be available to the root zone of the crops. It will cause the plant to suffer from nutrient deficiency. Farmers will need to supplement those leached-out nutrients [23].

There will be a high soil erosion and a washing away of the top soil by rainfall [24]. There are different types of soil erosion that will occur. The gullies and the dongas which will affect the top soil of farmers. The topsoil is rich in plant nutrients that are essential to different kinds of crops; see [25]. There will be a loss in different types of crop due to the effect of climate change. Other diversification method cannot be used due to the lack of rainfall received [25].

The potential land in agriculture will be lost because 20% of the land will be turned into desertification [26]. In the field of agriculture, there will be new species that will become more resistant to a number of chemicals, and those insects will affect the quality of production in agriculture. Shortage of scientific knowledge in climate change causes farmers not to understand fully what is actually occurring around the globe [27]. Agronomists have concluded that there will be shortage of food by 2030. Climate change affects the entire farming systems and food security. Climate change will affect stable food of other countries. There will be shortages of substitutes in the markets of stable products [28].

## 5. Identification of key issues

There are different approaches that could be used to gather data; however, for this exercise a literature review was adopted. Different search engines were used to search climate change and climate smart as well as capacity building in climate-smart agriculture (CSA). A number of documents were consulted, and related papers in journals and books were found and were consulted. All these documents were found useful in terms of expanding the frontier of knowledge on climate smart in agriculture. The findings are presented next.

## 6. Discussion on key issues of climate change

### 6.1 Definition of climate smart

Literature is full of definition of the concept of climate smart. Climate-smart agriculture (CSA) is defined as agriculture that sustainably increases productivity and resilience and reduces or removes greenhouse gases while enhancing the achievement of national food security and development goals; see [8]. This concept is supported by international multilateral agencies such as the World Bank, International Fund for Agricultural Development (IFAD), and Consultative Group for International Agricultural Research (CGIAR), and practices have been documented; see [22].

It should be realized that prior to the implementation of CSA, one has to first understand what is climate change prior to talking of climate-smart agriculture. The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods," see [7]. It is viewed as the greatest environmental challenge the world is facing in this century; see [29].

### 6.2 Capacity development training for the officers and training for farmers

It has been realized that it is imperative that technical advisors should be capacitated in the area of climate change. Literature shows that developing countries are

| Adaptation needed | Mitigation needed to be done |
|---|---|
| • Improve resilience of social and physical infrastructure<br>• Change of clones and agricultural practices<br>• Improve water and soil management<br>• Prepare for future pests and diseases<br>• Manage existing environmental threats | • Low carbon energy source<br>• Energy efficiency<br>• Change of agricultural practices, e.g., judicious fertilizer use<br>• Change in consumer behavior |

*Source: Cracknell [10].*

**Table 1.**
*Climate change adaptation and mitigation.*

putting efforts in this regard [6], while there are also pockets of areas where similar efforts are being done in the African continent. It is noted that extension functionaries have to be capacitated in this area with competencies that include communication, farming, science, social, technical, and methodological. In the past extension, advisors were not trained in the relevant areas that could be used to tackle climate change-related aspects.

Although some of these aspects may seem to be obvious, the effects of climate change may confuse the farmer and threaten his survival. It is this reason that a need for continuous training is found to be important. One example is that of tea farming in Kenya which the small-scale farmers have found themselves facing challenges such as having erratic rainfall, poor quality tea due to high temperatures, and other related challenges [10]. A training manual has been developed in order to equip extension technicians in skills that would be needed to mitigate the impact of climate change. Some of the examples that an extension advisor is expected to deliver in the case of challenges of tea farmers are shown in **Table 1**.

**Table 1** shows examples of the knowledge needed by the agricultural advisor to assist small-scale tea farmers. He will be expected to understand the steps needed to help farmers to adapt as well as to mitigate on the other hand. It should be noted that the knowledge will play a huge role in helping farmers to make profit in their farming enterprise. A training like this was provided in the Horn of Africa by different partners as included in this work; see [9].

According to [12], such training was provided to technical advisors in order to enable them to have adequate technical knowledge and tools to better advice and train farmers and thus enhance their capacity to adapt to the effects of variability and climate change. The project will develop CSA technologies and CSA farms in vulnerable regions of Ethiopia and Sudan. The CSA farms will focus on integrating promising CSA technologies and creating synergies between the different technologies [30]. Training manuals have been developed [10, 31].

There are many organizations that contribute towards training technical advisors, and they have formed partnerships, for example, ICRISAT working in the Horn of Africa has formed partnerships with organizations like International Relief Development (IRD), Malian Agency for the Environment and Sustainable Development (AEDD), and Building Resilience and Adaptation to Climate Extreme and Disasters Program (BRACED) [30, 32].

These technologies include improved crop varieties and land management, improved soil fertility management, integrated pest and weed management, agroforestry, and improved livestock systems. These CSA farms will also serve as research and training sites for students from the universities and be used as demonstration sites.

## 6.3 Types of innovations

Different types of technologies exist such as those that are related to water which may be called water-smart technologies. There are five types of technologies of which two are discussed, while the other three are presented in **Table 1**; see [33]. According to [33] these are the kind of interventions that reduce water requirements to produce the same or a higher level of yield.

Rainwater may need to be managed such as harvesting it either from rain or from the runoff by using different tools. Water management is another issue that needs more attention. The impact of 2015/2016 drought in Western Cape Province of South Africa has led to the major dams to become dry. The dam levels were estimated to be 30–40% [34]. In situ rainwater storage in rice paddies with 20–25 cm bunds can also be regarded as technology. It is believed that this technique is for rice only [33].

Another technology is called laser land leveling. In this technology the land is leveled with a laser this is done by a laser leveler. This kind of technology has been found suitable in rice fields which is a system of rice intensification; in this technology 7- to 10-day-old seedlings are transplanted at 20 cm spacing with 1–2 seedlings per hill. The other technologies are presented in **Table 2**.

These technologies include improved crop varieties and land management, improved soil fertility management, integrated pest and weed management, agroforestry, and improved livestock systems [12]. It should be taken seriously that these technologies are not exhaustive, but they can form a base to create awareness in the manner how farmers can benefit from them, if the advisor can use them to guide the farmers. The challenge is that advisors may not see their usefulness until a farmer is threatened by the effects of negative climate change. In this case an advisor needs to be trained to quickly identify the scenarios which he can make his positive contribution to solve farmer's problems; see [10].

## 6.4 Strategies of scaling up of approaches

In order to increase our understanding and actions about the technologies, one has to link a number of facts. Few of the challenges are discussed next.

### *6.4.1 Policy match*

Earlier studies have shown that the capital cost of the technology has a great bearing on technology adoption [35]. Thus, if the cost of adoption is totally private, the technology will be implemented if the private returns from investment are more than the private costs. If this is not the case, the adoption of technologies may be deferred until the benefits exceed the cost.

### *6.4.2 Financial support*

Most of the small and marginal farmers may not have access to the formal credit system. Studies have established that increased access to credit helps farmers overcome short-term liquidity constraints and increase technology adoption.

### *6.4.3 Strengthening capacity of institution*

Access to information is a key element in the adoption of new technologies; a farmer will adopt a technology that will maximize his food security. It is therefore

| Type of technology | Definition |
|---|---|
| 1. Energy-smart technologies | Technologies that help reduce energy consumption during land preparation without affecting yield levels. These also help reduce water requirements for crops |
| • Direct-seeded rice | Dry seeds are sown either by broadcasting or drilling in line |
| • Zero tillage/minimum tillage | The crop is seeded through a seeder in an untilled field, and the crop residue is incorporated into the soil. At present, this technique is limited to wheat only |
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| 3. Nutrient-smart technologies | Technologies that save/supplement/avoid chemical fertilizer use for crops and enrich carbon in the soil |
| • Green manure | Cultivation of legumes in a cropping system. This practice improves nitrogen economy and soil health/quality |
| • Integrated nutrient management | Integrated use of organic and chemical fertilizers to partially (25–50%) reduce NPK (nitrogen, phosphorus, and potassium) requirements without affecting productivity and improve soil health |
| • Leaf color chart | Standardized color charts are used to identify nutrient deficiency to estimate fertilizer doses in different field locations |
| 4. Weather-smart instruments | Interventions that provide services related to financial security and weather advisories to farmers |
| • Crop insurance | Crop-specific insurance to compensate income loss due vagaries of weather |
| • Weather advisories | Information and communication technology-based forecasting about the weather |
| 5. Introduction of stress-tolerant crops and diversification | Tolerant crops withstand biotic and abiotic stresses, and crop diversification reduces water demands and helps in harnessing nutrients from different soil layers |
| • Drought-tolerant variety | Seed variety that is tolerant to drought or relatively dry weather conditions |
| • Crop diversification (maize-wheat cropping) | Rice is replaced by maize on part of the land to economize on water use |

*Source: Taneja et al. [33].*

**Table 2.**
*Selected technology options for choice experiment.*

recommended to create institutions to build capacity among technology developers, disseminators, and farmers [10]. Farmers and other role players should be made aware that technologies should be adopted [32].

## 6.5 Mitigation

According to [36] mitigation refers to the efforts undertaken to "reduce anthropogenic [greenhouse gas] emissions or to enhance natural sinks of greenhouse gases" [36]. In agriculture, mitigation generally refers to the sequestration of atmospheric carbon dioxide ($CO_2$) in plant tissue through photosynthesis and its storage in soil organic matter and the reduction in direct emissions from fossil fuel usage and energy intensive inputs.

Efforts to reduce the impact of climate change, on the other hand, put it simple, mitigation is defined as activities aimed at "avoiding or minimizing sources of pollution that can have a deleterious effect on levels of greenhouse.

Gases (GHGs), global warming and climate change. Contributions towards reducing the levels of anthropogenic greenhouse gas production need to be actively encouraged. This includes fossil fuel-related activities, methane and nitrous oxide emissions [37].

A number of steps were identified as facts to be considered when mitigating against climate change; see [10]. In terms of livestock, the herd sex, age, and breed should be optimized in order to allow the national herd to be reduced while maintaining the same level of production. Supplementing the feed with high protein forage would reduce the methane production from enteric fermentation and increase productivity.

Extending feedlot manure management to include anaerobic digestion and the collection and use of the methane gas produced would improve the emission of negative gases in the atmosphere. The following would make a positive impact, for example, promoting the use of game in place of beef production, avoiding the burning of agricultural residues, including those from sugar cane plantations, even where such methods are accepted management practice, reduction of the frequency of fires by enhanced fire management practices, promoting savannah thickening over substantial areas, effectively managing soil organic matter, adopting minimum tillage methods, and exploring synergies between adaptation and mitigation measures in the areas of agricultural product diversification and the application of more socially beneficial agro-technologies such as permaculture to provide sustainable livelihoods [37].

The use of insurance can be piloted. Risk mitigation may involve a variety of private and government policy and institutions. The government-supported crop insurance in developed countries has often been highly subsidized [5], whereas in developing countries the situation is different. Insurance remains an individual responsibility. It has been indicated that in India, farmers were prepared to buy weather index insurance products even when these products are not subsidized [5].

### 6.6 Impacts of climate change to farmers

Different categories of farmers suffer the impacts of climate change. For example, the negative effects of climate change affect food security of the targeted households and smallholder farmers. Furthermore, the most vulnerable to the expected impacts of climate change are developing countries and their citizens who have a lower resilience to climate change impacts due to limited financial and technical resources to support adaptation. Commercial farmers in different fields like crops grapes and livestock also suffer the impacts [38].

Climate change and climate variability have been found to be presenting a negative influence to crops [39], for example, where irrigation is insufficient, crops wither and die thus reducing the yield. In a study conducted in Kenya checking the suitability of places to be used in the future, a number of problems were found. The problems include the reduced yield could further mean reduced profit and increased poverty. However certain steps need to be taken in order to mitigate against this situation. It is believed that if the advisors are conscientised about the impact, they will realize the need to be capacitated in climate smart in agriculture. Advisors have to be in the forefront of knowledge in climate-smart agriculture if they have to be meaningful to farmers.

## 7. Conclusions and recommendations

### 7.1 Conclusions

Climate smart in agriculture has its basis in the climate change and its variability. Key issues playing a role were identified as well as the rationale for training in climate change agriculture. It is important to have in mind the meaning of both concepts, namely, climate change and climate smart in agriculture (CSA). While the causes of climate change are known, i.e., both nature- and man-induced activities, it can be concluded that efforts of mitigation should become a norm. The study has identified the impacts of climate change in agriculture, and furthermore, the chapter has identified some of the technologies that are needed in CSA.

These technologies were discussed as well as how they can be scaled out based on three strategies, namely, policy matching, capacitating the extension functionaries in CSA, and financial support. CSA should be seen as an engine of green growth and a provider of environmental services.

### 7.2 Recommendations

Based on the findings, it can be stated that the following should serve as recommendations:

In order for the technology to be effectively promoted, there is a need of the following: policy financial support and the willingness of farmers to adopt such technologies on conditions the benefits outweigh the costs of implementing it.

On the other hand, there is a need for a policy within the various institutions that accommodate agricultural advisors, to craft policies that among other will encourage in service training among the advisors in keeping abreast of climate change issues, biased to women disabled and youth in farming.

There is a need to train the advisors in climate-smart principles to enable them to be ahead of their farmers with knowledge in climate change and climate smart in agriculture. A climate change module should be part of the training in tertiary institutions, as well as in high schools in order to create awareness within the changing environment of farmers.

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## Conflict of interest

I declare that there is no conflict of interest in this work.

## Acronyms

| | |
|---|---|
| UNFCCC | United Nations Framework Convention on Climate Change |
| $CO_2$ | carbon dioxide |
| GHGE | greenhouse gas emission |

| | |
|---|---|
| CSA | climate-smart agriculture |
| BRACED | Building Resilience and Adaptation to Climate Extreme and Disasters Program |
| AEDD | Malian Agency for the Environment and Sustainable Development |
| IRD | International Relief Development |
| IFAD | International Fund for Agricultural Development |
| CGIAR | Consultative Group for International Agricultural Research |
| ICRISAT | International Crops Research Institute for the Semi-Arid Tropics |





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