Applied of Climate Smart Agriculture Approach for Agricultural Development to African Food Security and Sustainability of Agriculture as well as Adaptation Future Climate Changes

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Abstract

Climate Smart Agriculture is a production system which or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent feasible, Climate Smart Agriculture systems rely on crop rotations, crop residues, animal manures, and good agriculture practices.

Climate Smart Agriculture is a highly knowledge-based technique for manipulating complex agro-ecosystems, for breeding locally adjusted seeds and livestock, and for producing on-farm fertilizers and inexpensive nature-derived pesticides. Such knowledge is a crucial 'reservoir of adaptations. In particular: "Within agriculture, Climate Smart Agriculture holds an especially favorable position, since it realizes mitigation and sequestration of carbon dioxide in an efficient way. Climate Smart Agriculture production has great mitigation and adaptation potential, particularly with regard to soil organic matter fixation, soil fertility and water-holding capacity, increasing yields in areas with medium to low-input agriculture and in agro-forestry, and by enhancing farmers' adaptive capacity. Paying farmers for carbon sequestration may be considered a win-win-win situation as (a) carbon dioxide is removed from the atmosphere (mitigation); (b) higher organic matter levels in soil enhance their resilience (adaptation), and (c) improved soil organic matter levels lead to better crop yield (production). Agriculture is both affected by climate change but also contributes to it. As a sector, agriculture must therefore both adapt to changes and offer options for mitigation, i.e., reducing greenhouse gas emissions and storing carbon.
Climate-smart agriculture is an approach for transforming and reorienting agricultural systems to support food security under the new realities of climate change. Widespread changes in rainfall and temperature patterns threaten agricultural production and increase the vulnerability of people dependent on agriculture for their livelihoods, which includes most of the world's poor. Climate change disrupts food markets, posing population-wide risks to food supply. Threats can be reduced by increasing the adaptive capacity of farmers as well as increasing resilience and resource use efficiency in agricultural production systems. CSA promotes coordinated actions by farmers, researchers, private sector, civil society and policymakers towards climate-resilient pathways through four main action areas: (A) building evidence; (B) increasing local institutional effectiveness; (C) fostering coherence between climate and agricultural policies; and (D) linking climate and agricultural financing. Climate Smart Agriculture differs from 'business-as-usual' approaches by emphasizing the capacity to implement flexible, context-specific solutions, supported by innovative policy and financing actions.

To conclude, Climate Smart Agriculture is a productive agro-ecosystem which might be very resilient and adaptive to climate change scenarios.

Keywords: Climate Smart Agriculture – Sustainable of Agriculture – African Countries - Climate changes.

Introduction

Climate change and agriculture are inextricably linked. Agriculture still depends fundamentally on the weather. Climate change has already caused a negative impact on agriculture in many parts of the world because of increasingly severe weather patterns. Climate change is expected to continue to cause floods, worsen desertification and disrupt growing seasons. The Food and Agriculture Organization (FAO) warns that an increase in average global temperatures of just two to four degrees Celsius above pre-industrial levels could reduce crop yields by 15-35 percent in Africa and western Asia, and by 25-35 percent in the Middle East. An increase of two degrees alone could potentially cause the extinction of millions of species.

Agricultural practices also exacerbate climate change. The Intergovernmental Panel on Climate Change (IPCC) says that agriculture contributes 13.5 percent of global greenhouse gas emissions (2004). According to Greenpeace, if calculating both direct and indirect emissions from the food system, agriculture's contribution could be as high as 32 percent. (Greenpeace includes all related activities; in addition to agricultural production, they add land use, transportation, packaging and processing.) The future of agricultural production relies on both designing new ways to adapt to the likely consequences of climate change, as well as changing agricultural practices to mitigate the climate damage that current practices cause, all without undermining food security, rural development and livelihoods. This is a huge undertaking.

Climate change and food security are related because climate change can directly affect a country's ability to feed its people. However, research shows climate change will not equally affect all countries, and will likely have the biggest impact in equatorial regions such as sub-Saharan Africa. This means that countries already struggling with food security are likely to find they struggle still harder in the future. The IPCC projects that yield from rain-fed farming in some African countries could be reduced by up to 50 percent by 2020. Meanwhile, countries such as the United States are experiencing changing agricultural land use patterns due to climate change.

How to produce more climate-friendly food

There is considerable support for organic farming as the best way to mitigate greenhouse gas emissions. Organic agriculture's emissions are generally lower than those of industrial agricultural methods. Although some modes of organic agriculture do not produce yields as high as industrial or chemical agriculture, it is a more sustainable means of cultivating the land. It builds soil quality and uses more diverse cropping systems, which in turn reduces the number of greenhouse gases emitted. And it is better at sequestering (absorbing) carbon and nitrogen than industrial agriculture.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007) dispelled many uncertainties about climate change. Warming of the climate system is now unequivocal. It is now clear that global warming is mostly due to man-made emissions of greenhouse gases (mostly CO_2). Over the last century, atmospheric concentrations of carbon dioxide increased from a pre-industrial value of 278 parts per million to 379 parts per million in 2005, and the average global temperature rose by 0.74° C. According to scientists, this is the largest and fastest warming trend that they have been able to discern in the history of the Earth. An increasing rate of warming has particularly taken place over the last 25 years, and 11 of the 12 warmest years on record have occurred in the past 12 years. The IPCC Report gives detailed projections for the 21st century and these show that global warming will continue and accelerate. The best estimates indicate that the Earth could warm by 3° C by 2100. Even if countries reduce their greenhouse gas emissions, the Earth will continue to warm. Predictions by 2100 range from a minimum of 1.8° C to as much as 4° C rise in global average temperatures.

Climate Changes and Agriculture in Egypt "Case Study"

The natural greenhouse effect raises the temperature of the planet to 33°C, thus making it habitable. On average, 343 W m −2 of sunlight fall on the earth, roughly 1/3 of which is re flecked back into space. The other 2/3 reaches the ground, which re-radiates it as longer wavelength, infrared radiation. Some of this is blocked by greenhouse gases, thereby warming the atmosphere. Naturally occurring greenhouse gases include water vapor, CO_2 , methane (CH_4) and nitrous oxide (N_2O). Reducing emissions of CO_2 could be achieved by switching to renewable energy (IPCC 1996) .

Nature provides freshwater through the hydrologic cycle. The process is as follows: production of vapors above the surface of the liquids, the transport of vapors by winds, the cooling of air–vapor mixture, condensation and precipitation (Salem 2012) .

In fact, climate is a primary determinant of agricultural productivity. In turn, food and fiber production is essential for sustaining and enhancing human welfare. Hence, agriculture has been a major concern in the discussions on climate change. Food supply vulnerability to climate change is an issue in two different ways. First, future food supply may be directly threatened by climate change. Second, food supply capacity may be altered by efforts to reduce greenhouse gases emissions as society tries to mitigate future implications of climate change. Agronomic and economic impacts from climate change depend primarily on two factors: (1) the rate and magnitude of change in climate attributes and the agricultural effects of these changes, and (2) the ability of agricultural production to adapt to changing environmental conditions (McCarthy *et al.* 2001) .

Climate is the single most important determinant of agricultural productivity, primarily through its effects on temperature and water regimes. For example, the physiographic boundaries of principal biomes are determined by mean annual temperature and soil water regimes. Climate change is therefore expected to alter the biophysical environment of growing crops and to influence biomass productivity and agronomic yields (Rosenzweig and Hillel 1998) . Positive effects may be associated with the fertilization effects of CO_2 enrichment, increases in the duration of growing seasons in higher latitudes and mountain ecosystems, and possible increase in soil water availability in regions with an increase in annual precipitation. Each 1°C increase in temperature may lead to a 10-day increase in the growing season in northern Europe and Canada. The CO_2 fertilization effect is real. However, the net positive effect may be moderated by other factors, such as the effective rooting depth and nutrient availability. Further, the productivity per unit of available water is expected to rise by 20–40% (van de Geijn and Goudriaan 1996) .

Negative effects of projected climate change on agriculture may be due to increases in respiration rate as temperature rises with attendant decreases in net primary productivity (NPP); increases in the incidence of pests and diseases; shortening of the growing period in some areas; decrease in water availability as rainfall patterns change; poor verbalization; and increased risks of soil degradation caused by erosion and possible decline in SOC concentration. The yield of rice has been estimated to decrease by 9% for each 1°C increase in temperature. Phillips *et al.* (1996) , using the explicit planetary isentropic coordinate (EPIC) model to examine the sensitivity of corn and soybean yields to climate change, projected a 3% decrease in both corn and soybean yields in response to a 2°C increase in temperature from a baseline precipitation level. However, a 10% precipitation increase balanced the negative effect of a 2°C temperature increase. The effects of climate change on crop yields may be more negative at lower latitudes and generally positive at middle and high-middle latitudes. Further, crop growth is more affected by extremes of weather than by averages. The annual average changes in temperature or precipitation used in most predictive models do not reflect the short-term effects of so-called extreme events — droughts, floods, freezes, or heat waves (Lal 2005) .

Climate Changes and Its Impact on Agriculture

Driven mainly by population and economic growth, total world food consumption is expected to increase over 50% by 2030 and may double by 2050 (Barker *et al.* 2007) . Most of the increase in food production in the next decades is expected to occur through further intensification of current cropping systems rather than through opening of new land into agricultural production. Intensification of cropping systems has been a highly successful strategy for increasing food production. The best example is the well-known success of the Green Revolution , where the adoption of modern varieties, irrigation, fertilizers and agrochemicals resulted in dramatic increases in food production. However, this strategy also resulted in unexpected environmental consequences, one of them being the emissions of greenhouse gases into the atmosphere. Therefore, future strategies that promotes further intensification of agriculture should aim at the development of sustainable cropping systems that not only consider increasing food production but that also look at minimizing environmental impact (Ortiz-Monasterio *et al.* 2010) .

At present, 40% of the Earth's land surface is managed for cropland and pasture (Foley *et al.* 2005) . The most important cropping systems globally, in terms of meeting future food demand, are those based on the staple crops, rice, wheat and maize . Rice and maize are each grown on more than 155 million ha (FAOSTAT 2009) . In addition, rice is the staple food of the largest number of people on Earth. The geographic distribution of rice production gives particular significance to Asia where 90% of the world's rice is produced and consumed. Maize is produced mainly in the Americas, followed by Asia and then Africa. Maize is important as a staple crop (mainly in developing countries) but it is also important as animal feed and, increasingly, as biofuel. Wheat is the most widely grown crop, covering more than 215 million ha around the world, with Asia covering close to 50% of the world wheat (FAOSTAT 2009).

Promoting agricultural practices that mitigate climate change by reducing GHG emissions is important, but those same practices also have to improve farmer production and income and buffer the production system against the effects of changes in climate. The overall impact predicted by climate change models vary but we are now locked into global warming and inevitable changes to climatic pattern that are likely to exacerbate existing rainfall variability and further increase the frequency of climatic extremes. Where excess rain occurs, extreme rainfall events will increase leading to flooding and soil erosion. In low rainfall, drought-prone areas there is general acceptance in the science community of more frequent moisture stress because of failed rainfall patterns and increased evaporation caused by higher temperatures (Cooper *et al.* 2008) . In Africa specifically, the projected combined impacts of climate change and population growth suggest an alarming increase in water scarcity for many countries, with 22 of the 28 countries considered likely to face water scarcity or water stress by 2025. This in turn will curtail the ability of irrigated agriculture to respond to the expanding food requirements of tomorrow's Africa (Rosegrant *et al.* 2002) .

Climate change in Asian countries:

Asia is recognized as one of the most vulnerable regions to climate change on the planet. With approximately 60 per cent of world's population residing in Asia, this phenomenon presents serious concerns for policymakers in the region. The present study analyses the impacts of climate change on economic growth for selected Asian countries during the period 1972-2009. A growth model has been developed by incorporating temperature and precipitation as proxies for climate change in the production function and a fixed effect model (FEM) and seemingly unrelated regression (SUR) have been used to estimate the model. The results reveal that economic growth is negatively affected by changes in temperature, precipitation and population growth whereas urbanization and human development stimulates economic growth. The results also indicate that agriculture is the most vulnerable sector to climate change and manufacturing is the least affected sector.

Asian countries collectively encompass the world's greatest economic, cultural and ecological diversity. About 60 per cent of the world's population lives in these countries, making Asia the most populated continent. The total economic activities of Asia make up about 25 per cent of the world's GDP (World Bank, 2010). Consequently, the region is facing many environmental and socioeconomic challenges. In 2010, Maplecroft released a climate change vulnerability index.1 Out of 170 countries, 16 countries were indented to be in a condition of extreme risk. Among them, 10 are in Asia. Below is the list of the most vulnerable countries.

It is worth mentioning here that the variation in climate and geographic features among Asian countries is very large. For example, in China and some parts of India and Pakistan (particularly areas around the Himalayas), winter temperatures are at or below freezing. On the other hand, South-East Asia and the Paci_c islands generally experience temperatures above 25°C throughout the year. Consistent with global temperature trends, Asian countries have also been experiencing a warming trend in recent decades. Climate modeling indicates an increase in temperature in Asia by 0.5-2°C by 2030 and 1-7°C by 2070 and predicts that arid areas of northern Pakistan and India and western China are likely to warm more quickly. In addition, models indicate increasing rainfall during the summer monsoon season and a reduction in winter rainfall and predict that Asia will also be affected by a rise in the global sea level of approximately 3-16 cm by 2030 and 7-50 cm by 2070 (Parry *et al,* 2007).

Climate change is resulting in the degradation of land, ecosystems, water and air quality in Asian countries. It is threatening to undermine food security as well as causing health problems. Crop yields are estimated to fall by up to 30 per cent and one billion people may be affected by a water shortage, leading to drought and land degradation by the 2050s (Christensen *et al* , 2007; 2007).Climate change has also resulted in the melting of the Himalayan glaciers, which in theshort run has raised the risk of mudslides, erosion and _ooding. The health impacts primarily consist of epidemics of malaria, dengue, and other vector-borne diseases (Martens, 1999).

Notably, Asia is dealing with increasing cases of natural hazards, such as landslides in the Philippines (2006), extreme weather events in China (2006) including storms, in the east and south, heat and drought in the central and north-eastern regions, and catastrophic in Pakistan (2010 and 2011). The impacts of the sdisasters include hunger, disease, loss of income and livelihoods, collateral damage to infrastructures, all of which affect the survival and well-being of the population.

Globally, climate change (CC) is the most serious environmental threat that adversely affects agricultural productivity Enete and Amusa (2010) . According to inter-governmental panel on climate change (IPCC 2007) report, climate change refers to any change in climate over time, due to natural variability or as a result of human activity. This climate change mainly caused by greenhouse gases (GHGs) accumulation in the atmosphere, which results in increased greenhouse effect. Climate change and agriculture are interrelated processes, both of which take place on a global scale and their relationship is of particular importance as the imbalance between world population and world food production increases. Based on some projections, changes in temperature, rainfall and severe weather events are expected to reduce crop yield in many regions of the developing world, particularly sub-Saharan Africa and parts of Asia Gornall *et al.,* (2010) The impact and consequences of climate change for agriculture tend to be more severe for countries with higher initial temperatures, areas with marginal or already degraded lands and lower levels of development with little adaptation capacity Keane *et al.,* (2009)

Climate change regional impacts are likely to be substantial and variable, with some regions benefiting from an altered climate and other regions adversely affected. Generally, food production is likely to decline in most critical regions (e.g. subtropical and tropical areas), whereas agriculture in developed countries may actually benefit where technology is more available and if appropriate adaptive adjustments are employed Ignaciuk *et al.,* (2014) In relation, crop productivity is projected to increase slightly at mid to high latitudes for local mean temperature increases of up to 1-3°C depending on the crop, and then decrease beyond that in some regions. At lower latitudes, especially seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2°C), which would increase risk of hunger OECD (2015) Warmer weather was expected to bring longer growing seasons in northern areas, and plants everywhere were expected to benefit from carbon fertilization Vuren *et al.,* (2009) (Figure 1).

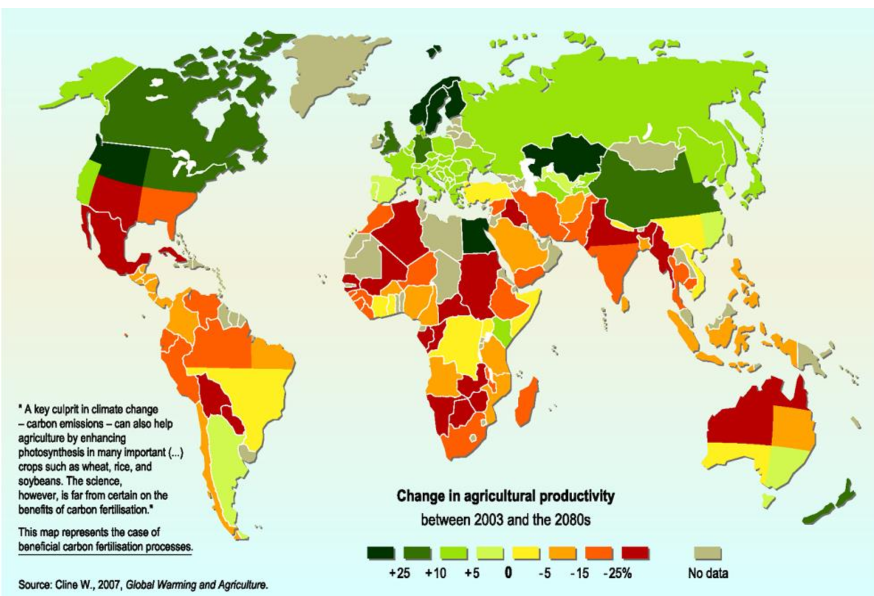


Figure 1: Projected impact of climate change on agricultural yield in different latitude.

Agriculture as a solution for climate change

The agricultural sector holds significant climate change mitigation potential through reductions of GHG emissions and enhancement of agricultural sequestration. In addition, it also has significant role to adapt climate change. Adaptation alone is not enough to offset the effects of climate change, and thus still need to be supplemented by concerted mitigation efforts Vuren *et al.,* (2009) Mostly, when we implement adaptation measure, we enhance mitigation capacity of particular area such as practicing different land use managements (soil and water conservation measure, manure and fertilizer management) in the agricultural field will help us to sequester substantial amount of carbon in the field and reduce emission of methane and nitrous oxide which are the main GHG emission means. Therefore, the management activities are interrelated and help us to adapt and mitigate climate change. Agricultural activities are relatively affordable form of mitigation option, for which many technical options are already readily available FAO (2010a). Global adoption of organic agriculture (OA) has the potential to sequester up to the equivalent of 32% of all current man-made GHG emissions FAO (2009) OA is a production system that sustains the health of soils, ecosystems and people. In OA, soil fertility is maintained mainly through farm internal inputs (organic manures, legume production, wide crop rotations etc); energy-demanding synthetic fertilizers and plant protection agents are rejected; and there is less or no use of fossil fuel OECD (2015). In relation, improved cropland management (lower use of synthetic fertilizers, reduced tillage etc), Reducing industrial livestock production and improving feeding and grazing land management, Restoration of organic soils and degraded lands to increase soil carbon sinks, Improved water and rice management, Land-use change and agro-forestry, Increasing efficiency in fertilizer production and behavioral changes of food consumers (reducing the meat content) could also be main climate change mitigation measures in agriculture sector Robert *et al.,* (2009). As earlier mentioned, the agricultural sector has also a potential to adapt to climate change in many areas. Climate change adaptation is a continuous process requiring location-specific response. Adaptation should enable agricultural systems to be more resilient to the consequences of climate change Paul et al., (2009). Farming systems and farmers will differ enormously in their capacities to respond to climate change. Differentiated adaptation strategies and enhanced climate risk management support to agriculture and farming households are critical to counter the impacts of climate change IPCC (2007) .These adaptation measures could include in particular the choice and change of species and varieties, the adaptation of the field works to the calendar (more flexibility), the adaptation of plant production practices (i.e. fertilization, plant protection, irrigation, etc.) or the adoption of plant production practices that increase the soil organic matter content or the soil coverage by plants, manure management and agroforestry practices. Some of them discussed below how these practices serve as adaptation means:

Change crop variety

It involves switching from one crop variety to another in response to climatic stresses and changes. Study done by Komba and Muchapondwa. FAO (2011) Strengthening Capacity for Climate Change Adaptation in the Agriculture Sector in Ethiopia. Proceedings from National Workshop held in Nazreth, Ethiopia., in Tanzania explained that Tanzania's farmers try to adapt climate change by using drought resistance crops. Introducing Avena species (Ingedo) species in Ethiopia as fodder crop and through time it replace the dominant stable crop i.e., barley in the highland and serve as one means to adapt CC Denman *et al.,* (2007).

Change in cropping pattern

Application of changes in how crops are cycled within a season. Farmers in the drought-prone semi-arid areas of Brazil have realized that several varieties of a single crop species can occupy a common land area, incorporating several bean varieties, maize and sorghum, among others, to increase harvest potential arid climate stresses Komba and Muchapondwa (2015) .Likewise, In Ethiopia farmers try to adapt CC by planting diversifies crops (homestead maize and other crops).

Change in cropping calendar

It is another common adaptation to climate change at the farm level, which largely involves altering the timing of farm activities to suit climatic variations or changes. In Philippines, farmers adapt to the early onset of rainy season through early cultivation of upland farms, which results in high agricultural production for the season and higher household income from farm activities Action Aid (2008) Tanzania's farmers also used planting date changing practice to adapt CC Lasco and Pulhin (2009). In addition, according to Rhodes *et al.* (2014) most West Africa counties such as Burkina Faso, Niger and Senegal already develop and implement a mathematical model for different crops to plant under changed climate by shifting planting date to adapt CC. Changing planting dates of crops helps greatly for the farmers live in East Gojam (Choke Mountain in Ethiopia) and East Hararghe for CC adaptation respectively.

Farm management practices

Change in current farm management practices such as OA practice focus on maintaining diverse farming systems (i.e. planting different crop species) also helps diversify potential sources of income for farmers, making the farming household more resilient to adverse impacts of climate on agricultural production . According to Rhodes *et al.,(*2009) also crop residue management practice is considered one of the best climate smart actions. In addition, Smallholder farmers in sub-humid Southwestern Cameroon have been adapting to variations in rainfall through different soil and water conservation practices. Ditch and check dam constructions are the major soil and water conservation (SWC) practice that helps to adapt CC in Ethiopia. Similarly, study in Ethiopia revealed that terracing and different water harvesting practices widely used to adapt the changed climate.

Climate-smart agriculture

Climate-smart agriculture (CSA) addresses the challenge of meeting the growing demand for food, fibre and fuel, despite the changing climate and fewer opportunities for agricultural expansion on additional lands. CSA focuses on contributing to economic development, poverty reduction and food security; maintaining and enhancing the productivity and resilience of natural and agricultural ecosystem functions, thus building natural capital; and reducing trade-offs involved in meeting these goals. Current gaps in knowledge, work within CSA, and agendas for interdisciplinary research and science-based actions identified at the 2013 Global Science Conference on Climate-Smart Agriculture (Davis, CA, USA) are described here within three themes: (1) farm and food systems, (2) landscape and regional issues and (3) institutional and policy aspects. The first two themes comprise crop physiology and genetics, mitigation and adaptation for livestock and agriculture, barriers to adoption of CSA practices, climate risk management and energy and biofuels and modelling adaptation and uncertainty, achieving multifunctionality, food and fishery systems, forest biodiversity and ecosystem services, rural migration from climate change and metrics , comprises designing research that bridges disciplines, integrating stakeholder input to directly link science, action and governance.

Outcomes: In addition to interdisciplinary research among these themes, imperatives include developing (1) models that include adaptation and transformation at either the farm or landscape level; (2) capacity approaches to examine multifunctional solutions for agronomic, ecological and socioeconomic challenges; (3) scenarios that are validated by direct evidence and metrics to support behaviours that foster resilience and natural capital; (4) reductions in the risk that can present formidable barriers for farmers during adoption of new technology and practices; and (5) an understanding of how climate affects the rural labour force, land tenure and cultural integrity, and thus the stability of food production. Effective work in CSA will involve stakeholders, address governance issues, examine uncertainties, incorporate social benefits with technological change, and establish climate finance within a green development framework. Here, the socioecological approach is intended to reduce development controversies associated with CSA and to identify technologies, policies and approaches leading to sustainable food production and consumption patterns in a changing climate.

The Future of Farming: Exploring Climate Smart Agriculture

Discover Climate Smart Agriculture and how it could be applied to farming
Climate Smart Agriculture (CSA) offers one possible approach based on three principles:

1. Mitigation of greenhouse gas emissions
2. Adaption to climate change
3. Stable or increased food productivity

Throughout this course we will encourage you to explore these principles and take a critical look at how they could be translated into practice, using the examples of dairy farming and wine production in the EU.

We'll examine the environmental impacts of dairy farming, the challenges farmers are facing as a result of climate change and review some climate smart approaches that might help them become more sustainable. We'll then explore wine production looking at the influence of climate change on growing grapes in Europe, what research is being done and again how we can adapt wine production to climate change.

Understand the relationship between farming and climate change

To help demonstrate the relationship between farming and climate change (and learn how CSA could be applied) we'll touch on global warming and greenhouse gases but also economic and political aspects related to the environment such as: food labelling, funding, policies and regulation.

Evaluate the future of Climate Smart Agriculture

We'll discuss how to measure the impact of CSA. We'll look at the barriers for the industry to adopting CSA and how to overcome them. We'll also explore the critical views on the concept and compare the principles of CSA to other agricultural practices.

There are no special requirements for this course. It will be of particular interest to anyone concerned with modern food production, farming and environmental challenges: this could include farmers or food producers, industry partners, school teachers, or people considering studying agriculture at University.

Climate-smart agriculture (CSA) is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. CSA aims to tackle three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible.

CSA is an approach for developing agricultural strategies to secure sustainable food security under climate change. CSA provides the means to help stakeholders from local to national and international levels identify agricultural strategies suitable to their local conditions. CSA is one of the 11 Corporate Areas for Resource Mobilization under the FAO's Strategic Objectives. It is in line with FAO's vision for Sustainable Food and Agriculture and supports FAO's goal to make agriculture, forestry and fisheries more productive and more sustainable".

What is different about climate-smart agriculture?

What is new about CSA is an explicit consideration of climatic risks that are happening more rapidly and with greater intensity than in the past. New climate risks, require changes in agricultural technologies and approaches to improve the lives of those still locked in food insecurity and poverty and to prevent the loss of gains already achieved. CSA approaches entail greater investment in

1. managing climate risks,
2. understanding and planning for adaptive transitions that may be needed, for example into new farming systems or livelihoods,
3. exploiting opportunities for reducing or removing greenhouse gas emissions where feasible.

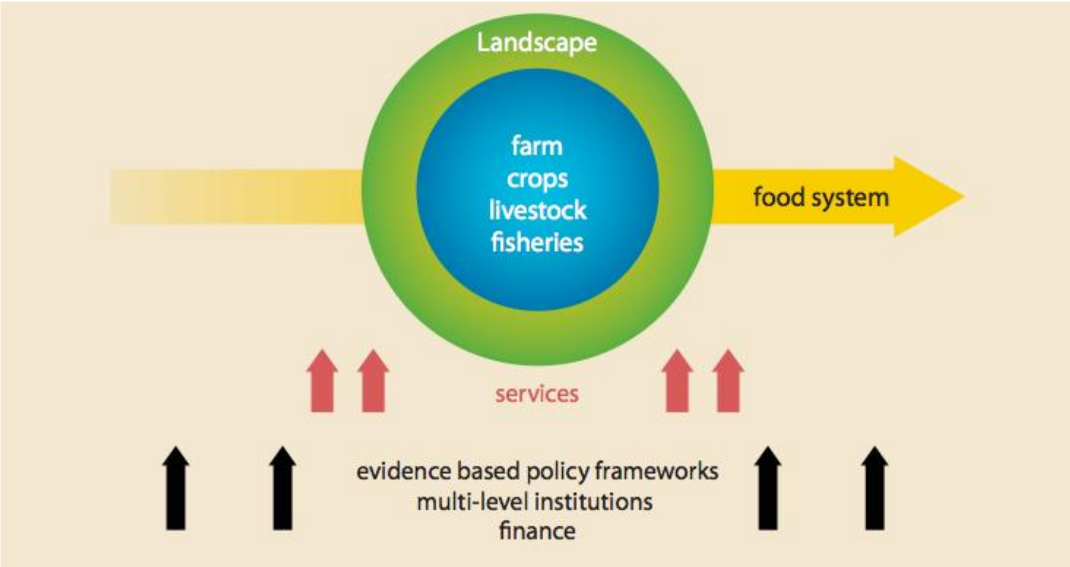
What is the history of climate-smart agriculture?

FAO coined the term CSA in the background document prepared for the 2010 Hague Conference on Food Security, Agriculture and Climate Change. The CSA concept was developed with a strong focus on food security, for now and the future, including adaptation to climate change. The CSA concept now has wide ownership among, governments, regional and international agencies, civil society and private sector. Emerging global and regional (Africa) Alliances on Climate-Smart Agriculture (ACSA) provide a platform for shared learning and collaboration among all interested parties

What are the main elements of climate-smart agriculture?

CSA is not a set of practices that can be universally applied, but rather an approach that involves different elements embedded in local contexts. CSA relates to actions both on-farm and beyond the farm, and incorporates technologies, policies, institutions and investment. Different elements which can be integrated in climate-smart agricultural approaches include:

1. Management of farms, crops, livestock, aquaculture and capture fisheries to manage resources better, produce more with less while increasing resilience
2. Ecosystem and landscape management to conserve ecosystem services that are key to increase at the same time resource efficiency and resilience
3. Services for farmers and land managers to enable them to implement the necessary changes



What actions are needed to implement climate-smart agriculture?

Governments and partners seeking to facilitate the implementation of CSA can undertake a range of actions to provide the foundation for effective CSA across agricultural systems, landscapes and food systems. CSA approaches include four major types of actions:

Expanding the evidence base and assessment tools to identify agricultural growth strategies for food security that integrate necessary adaptation and potential mitigation

1. Building policy frameworks and consensus to support implementation at scale
2. Strengthening national and local institutions to enable farmer management of climate risks and adoption of context-suitable agricultural practices, technologies and systems
3. Enhancing financing options to support implementation, linking climate and agricultural finance

'**Climate-smart agriculture' (CSA)**—agriculture and food systems that sustainably increase food production, improve resilience (or adaptive capacity) of farming systems, and mitigate climate change when possible—has quickly been integrated into the global development agenda. However, the empirical evidence base for CSA has not been assembled, complicating the transition from CSA concept to concrete actions, and contributing to ideological disagreement among development practitioners. Thus, there is an urgent need to evaluate current knowledge on the effectiveness of CSA to achieve its intended benefits and inform discourse on food, agriculture, and climate change. This systematic review intends to establish the scientific evidence base of CSA practices to inform the next steps in development of agricultural programming and policy. We will evaluate the impact of 73 promising farm-level management practices across five categories (agronomy, agroforestry, livestock, postharvest management, and energy systems) to assess their contributions to the three CSA pillars: (1) agronomic and economic productivity, (2) resilience and adaptive capacity, and (3) climate change mitigation in the developing world. The resulting data will be compiled into a searchable Web-based database and analytical engine that can be used to assess the relative effectiveness and strength of evidence for CSA, as well as identify best-fit practices for specific farming and development contexts. This represents the largest meta-analysis of agricultural practices to date.

Principles of Climate Smart Agriculture

As earlier mentioned CSA has three focal areas *i.e*. sustainably increasing agricultural productivity and incomes, adapting and building resilience to climate change, reducing and/or removing greenhouse gases emissions, where possible. Adapting and building resilience to climate change is especially important since it ensures food sufficiency despite unsuitable conditions. Resilience is defined as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change (IPCC, 2007). The Rockefeller Foundation (2009) went on to specifically define climate resilience as the capacity of an individual, community, or institution to dynamically and effectively respond to shifting climate impact circumstances while continuing to function at an acceptable level. This is achieved through several soil management practices that sequester carbon in the soil, reduce greenhouse gas (GHG) emissions and aid intensify production (FAO, 2013). Above all the practices must enhance the natural resource base. Therefore, the most important premise of CSA is the building of healthy soils (Magdoff, 2007; Stabinsky and Ching, 2012) [13] [14] through increasing the soil organic matter (SOM) status of the soil (Blanco-Canqui and Lal, 2004) . Soil management practices for CSA include; direct seeding under no/reduced-tillage (Zheng *et al*., 2014) , improved protective soil cover through cover crops, crop residues or mulch (Muzangwa *et al*., 2013) , and crop diversification through rotations (Lin, 2011; Davis *et al*., 2012)

Moreover, integrated soil fertility management, which includes both inorganic and organic sources and considers combining inputs of organic matter *i.e*. mulch, compost, crop residues and green manure with fertilizers to address or prevent macro- and micro-nutrient deficiencies should be carefully considered (FAO, 2013).

Possible Challenges and Prospects of Climate Smart Agriculture

There is a lot of skepticism about the ability of CSA to mitigate the effects of climate by fostering soil resilience and l*et al*one feed communities. This is in spite of the potential benefits of the system especially to the smallholder farmers who bear the brunt of the effects of climate. Most of the farmers are resource poor and their usually own land in marginal areas. According to Ortmann and Mache the (2003) , there are more than three million smallholder famers owning less than 1.3 hectares in marginal with low yields. CSA would be the most appropriate system for such farmers since it uses locally available resources and does not rely on the use of external inputs (Magdoff, 2007), Nonetheless, in a review on adapting crops and cropping systems to future climates, Matthews *et al*. (2013) , highlighted that most recommended adaptations will involve several trade-offs. For example, (Pretty, 2009) , points out that, farmers cannot simply cut their existing use of such inputs as fertilizer or pesticides and hope to maintain outputs and neither can they introduce a new productive element into their farming systems, and hope it succeeds. Instead the transition costs arise for several reasons, which include the following;

1) Farmers must first invest in learning about a greater diversity of practices and measures.
2) Farmers need to acquire information and management skills.
3) During the transition and learning period, farmers must experiment more, and incur the costs of making mistakes as well as of acquiring new knowledge and information.
4) New technologies often require more labor.

Moreover, specific policies and interventions for implementing CSA depend on the social and biophysical contexts in which farmers operate, which calls for different solutions for large farms with good market access and high input use, small farms with good market access and high input use, and small farms with low market access and low input use (Dobermann and Nelson, 2013) . However, Dobermann and Nelson (2013) offered a possible solution to this by suggesting the implementation of the following processes;

1) Diagnosis: which entails understanding the context in which an effort or intervention will be implemented and its links to global agro-ecological knowledge.
2) Contextualized principles: by identifying the right economic, social and ecological principles of relevance to farmers' needs.
3) Getting it right locally: through empowering local communities to improve the performance of the farming system based on agro-ecological principles and local preferences.
4) Scaling and support: by expanding the scope of the effort or intervention (in terms of numbers of people involved and the size of the territory) and create the necessary value chains, services, support systems and self-sustained business models.
5) Evidence: through monitoring and documenting the performance and learning to enrich the local and global knowledge base to influence policies that will support further implementation.

Adaptation to Climate Change in Developing Countries

Globally, agricultural and forestry systems are expected to change significantly in response to future climate change, manifesting as major transitions in livelihoods and landscapes Morton JF 2007, Reidsma *et al*., 2010., Vermeulen *et al*., (2012) and and IPCC (2007) . During the few past decades, crop yields have been reduced because of warming Lobel *et al.*, (2011) ,and the results of modelling studies suggest that climate change will reduce food crop yield potential, particularly in many tropical and multitude countries Cline (2007) , Jarvis *et al.*, (2012) Knox *et al.*, (2012) and Rosenzweig *et al.*, (2014) . Rising atmospheric CO2 concentrations will decrease food and forage quality Myers *et al.*, (2014). Price and yield volatility likely will continue to rise as extreme weather continues, further harming livelihoods and putting food security at risk

Wheeler and von Braun (2013). Global demand for agricultural products, be they food, fibre or fuel, continues to increase because of population growth, changes in diet related to increases in per capita income and the need for alternative energy sources while there is less and less additional land available for agricultural expansion. Agriculture thus needs to produce more on the same amount of land while adapting to a changing climate and must become more resilient to risk derived from extreme weather events such as droughts and floods.

The term climate-smart agriculture (CSA) has developed to represent a set of strategies that can help to meet these challenges by increasing resilience to weather extremes, adapting to climate change and decreasing agriculture's greenhouse gas (GHG) emissions that contribute to global warming. CSA also aims to support sustainable and equitable transitions for agricultural systems and livelihoods across scales, ranging from smallholders to transnational coalitions. Forming a core part of the broader green development agenda for agriculture World Bank (2011) , World Bank (2014) and Food and Agriculture Organization of the United Nations (FAO(2013) , CSA focuses on meeting the needs of people for food, fuel, timber and fibre through science-based actions; contributing to economic development, poverty reduction and food security; maintaining and enhancing the productivity and resilience of both natural and agricultural ecosystem functions, thus building natural capital; and reducing the trade-offs involved in meeting these goals. It invokes a continuous, iterative process for stakeholders, researchers and policymakers to meet the challenges presented by climate change and collectively transform agricultural and food systems towards sustainability goals Climate Smart Agriculture (2014) . Increased awareness and adaptive management are essential components of the CSA strategy. Yet, CSA is controversial. Such a broad agenda can be appropriated to support conflicting agendas or promote specific ecosystem services. GHG emission mitigation by resource-poor farmers raises equity as an issue in developing countries because it may bring farmers little benefit unless it directly provides them with adaptive capacity. Setting CSA in the context of a safe operating space for humanity with socioecological systems that support adaptive management and governance will require scientific metrics and science–policymaking dialogues Neufeldt *et al.*, (2013), that depend on strong engagement of the scientific community.

The relationship between vulnerability, resilience and adaptation was an overarching theme echoed across the conference and is crucial to CSA. Vulnerability describes exposure, sensitivity and capacity to respond to negative impacts of climate change, and adaptation is the means by which to reduce the vulnerability. Here resilience is regarded as the capacity to tolerate disturbance, undergo change and retain the same essential functions, structure, identity and feedback and is not indicative solely of returning to the same state that existed prior to a perturbation or disturbance Carpenter *et al.*, (2001), Holling (2001) and Walke *et al* (2004) . Resilience focuses on factors that enable functioning despite adverse conditions Obrist (2010) and Cumming (2011), provides a means of framing the dynamic relationships between humans and the environment (socioecological systems) and considers society's capacity to manage change Cabell and Oelofse (2012) . Thus, the principle of resilience can guide transformative change needed to meet the demands of food security, natural resource protection, and development, as well as to diminish vulnerability and promote adaptation (or adaptive capacity).

The recent increase in extreme weather events (climate shocks) threatens disruptive impacts on agriculture Easterling (2000) and Battisti and Naylor (2009).

Projected adaptive actions include improving plant performance (for example, nutrition, yields, food quality) in response to elevated CO2 and rising temperatures Bloom *et al.,* (2010), Yin (2013), and Vermeulen *et al.,* (2012); avoiding pest damage and food waste Vermeulen et al (2012) and Gutierrez *et al.,* (2007) , developing forecasting, management and insurance options to decrease the risk due to unexpected rainfall patterns, higher temperatures and shifting length in growth seasons Food and Agriculture Organization of the United Nations (FAO2013), Vermeulen *et al.,* (2012) and Gutierrez *et al.,* (2007) , and managing natural resources at the landscape and regional levels to assure the environmental quality and ecosystem services upon which agriculture depends Jackson *et al.,* (2012) , Stringer *et al.,* (2012) and . Minang *et al.,* (2014) . Solutions involve trade-offs. For instance, planning now for higher temperatures and declining precipitation in arid zones may reduce water deficits for agriculture, but it will require institutional investment to support both the intensified demand for ground and surface waters Elliott *et al.,* (2013) and Meza et al., (2012) and the necessary improvements in irrigation efficiencies Nelson *et al.,* (2014). Along with these adaptive actions, CSA seeks to contribute to the mitigation and reduction of GHG, mainly nitrous oxide (N_2O) and methane (CH_4) emissions, and to balance trade-offs with food security and livelihoods Jarvis et al., (2011) Thornton and Gerber (2010) and Valin *et al.,* (2013) . For example, combining agroforestry, afforestation and conservation efforts with agriculture to meet global food demand will help to mitigate GHG emissions, support biodiversity and concomitantly preserve ecosystem services Kraxner et al and Mbow *et al.,* (2014).

Other trade-offs that occur when abrupt environmental changes stress agricultural systems include changes in rural and urban human migration patterns, as well as loss of cultural resources, which reduces the ability to manage land use effectively Adger (2000) , Adger *et al.,* (2002) and Gray and Mueller (2012) . Without doubt, the development status of a country or region will influence the approach to mitigating and adapting to climate uncertainty and will affect the implementation and focus of the CSA strategy. For example, industrialized nations focus more strongly on mitigation of climate change through reduction of agriculture's environmental impacts, whereas developing countries' approaches to climate uncertainty emphasize stabilizing and boosting food production, improving incomes and building adaptive capacity Jarvis *et al.,* (2011), Climate Smart Agriculture (2014) and Ifejika Speranza (2010). Gender can also influence decisions and capacity for mitigation and adaptation.

Women in some regions in Africa have experienced greater exposure and vulnerability, especially to extreme events, than men, but they also have demonstrated greater collective action in farming decisions linked to social networking Chindarkar (2012) and Villamor *et al.,* (2014) .

Farm and food system issues: sustainable intensification, agro ecosystem management and food systems Considerable research on climate change and agriculture exists at the farm and food system levels, including topics such as farming practices for mitigation of agricultural GHG emissions, choice and adaptation of crops and livestock to new climate regimes, decision-making by farmers and life-cycle assessments Graaf et al., (2006) , Thornton et al., (2010), Stavi and Lal (2012) and Weber CL, Matthews HS (2008). Sustainable intensification, focused initially on increased agricultural production and food security, has now moved to a broader set of goals with multiple social, ethical and environmental dimensions Garnett *et al.,* (2013) and Godfray *et al.,* (2014). The integrative challenge for CSA is to better understand the trade-offs and choices farmers must make for greater multifunctionality and resilience to climate change. Because planning for climate change can be highly farm-, commodity- and context-specific, especially in response to extreme events, CSA is committed to new ways of engaging in participatory research and partnerships with producers Food and Agriculture Organization of the United Nations (FAO2013).

Conclusion

From this extensive review, it is concluded that globally, climate change has relationship with agriculture in one or another way. This relationship becomes strong in developing countries because their livelihood depends on agricultural activities and this activities mostly depend on climatic condition, For instance in Ethiopia, almost all farm activity is rain fed. In relation, the impact of climate change is very serious in developing counties due to their limited adaptive capacity and lack of technology and also they are the main emitter of noncarbon GHGs from their cattle and farm management mainly from use of synesthetic fertilizers. Those are the main direct emitters. There are also indirect emitters such as land use change; from runoff and leaching of fertilizers; use of fossil fuels for mechanization; transport and agro-chemical and fertilizer production.

On the other hand, by the help of the right farming practice agriculture could be the main solution for climate change by mitigation and adaptation response. Within the current and projected situation of climate change globally, only climate change mitigation is not enough so long term solution is important by combining climate change adaptation in agriculture sector. Such practices could be organic agriculture, manure management, agroforestry practice etc. Know a days, the significant relation of climate change and agriculture sector become well known. In recent years, even if the attention is not enough, the significant relation of climate change and agriculture sector becomes acknowledged. To happen this, International conventions and agreements has significant role in addition to research role.

Africa and Asia faces a lot of challenges in meeting food requirements in the face of an ever changing climate. With water becoming scarce and flooding becoming more frequent, it has led to a reduction in quality for the soil as a resource base, so interventions are required to guarantee the restoration of the resource base and become more imperative. Therefore, the need for adaptation and mitigation measures is now stronger than ever before. It therefore becomes imperative to look for alternatives. In this regard, CSA offers a viable and sustainable solution since it is based on the creation of healthy soil through integrated soil-crop system management. The overall goal is the attainment of optimal crop yield of a high quality with low negative environmental effects. By implementing CSA, the resilience of smallholder farmer soils may be preserved since soil quality management is central in ecological management. If properly implemented with provision of the necessary support, CSA will also improve productivity and food security in the smallholder farming sector as shown by the examples cited in this review. It is, however, important not to use a one size to fit all approach in implementing CSA principles in the smallholder farming sector. It is thus essential to firstly identify the precise economic, social and ecological principles of relevance to farmers' needs probably through participatory research. Since farmers are likely to adopt a measure that ensures multiple benefits such as high efficiency, diversity, self-sufficiency, self-regulation, and resiliency adoption, CSA is likely to be high within the smallholder sector.

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