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Clean Development Mechanisms (CDM) and Climate Smart Agriculture (CSA): Role and Implication for Sustainable Natural Resource Management: Ethiopian Context

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Abstract
Ethiopia has been identified as one of the most vulnerable countries to climate variability and change, and is frequently faced with climate-related hazards, commonly drought and floods. The variability of rain fall and the increasing temperature were a cause for frequent drought and famine, and putting disastrous impact on the livelihood of the peoples. At the national level, World Bank suggests that climate change may reduce Ethiopia's GDP compared to a baseline scenario by 2-6% by 2015, and up to 10% by 2045. The most vulnerable sectors to climate variability and change in the country are agriculture, water and human health. To cope up the effects of climate change, adaptation and mitigation measures are being practicing in the country. At the higher level, the governments has signed and ratified all the Rio Conventions, namely the United Nations Framework Convention on Climate Change and its Protocol, the Bio-diversity Convention and the Conventions to Combat Desertification. Following these, the government has initiated the Climate-Resilient Green Economy both to adapt and mitigate climate change. There are also different adaptation measures undertaking by different peoples at different levels. Thus, the purpose of this paper is to present adaptation and mitigation measures undertaking throughout the country at different levels.
Keywords: Climate change, CDM, CSA, adaptation, mitigation, CRGE
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1. INTRODUCTION

Climate change is a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC, 2007). The global temperature and precipitation have changed rapidly over the last century due to anthropogenic increases of greenhouse gases (GHGs) in the atmosphere (for example, burning of fossil fuels, like coal, petroleum and natural gasses and widespread deforestation). The Intergovernmental Panel on Climate Change (IPCC) has predicts that the global surface temperature will increase by 1.4 - 5.8°C by 2100 years due to increasing concentration of GHGs specifically carbon dioxide. Climate change affects the biodiversity, food security, water availability, and productivity levels in Africa (Hope, 2009). The Least Developed Countries (LDCs) are dependent on agriculture, climate sensitive economic sectors, which makes more vulnerable to the impacts of climate change because of its less resilient to negative external events and low capacity to adapt than other developing countries (Bruckner, 2012). Africa continent is one of the most vulnerable continents due to its high exposure and low adaptive capacity. The vulnerability of Africa continent is only due to low level of economic development that makes less and low capacity to adapt the impacts of climate changes (Bruckner, 2012). African countries are more affected by climate change because of their reliance on agriculture as well as their lower financial, technical, and institutional capacity to adapt (Nordhaus, 2006).

Ethiopia's topography is characterized by large regional differences; it is considered an arid country, but precipitation trends exhibit high annual variability. Ethiopia has three rainy seasons: June–September (kiremt), October–January (bega), and February–May (belg). Kiremt rains account for 50–80 percent of the annual rainfall totals, and most severe droughts usually result from failure of the kiremt. The lowlands in the southeast and northeast are tropical, with average temperatures of 25°–30°C, while the central highlands are cooler, with average temperatures of 15°–20°C. Lowlands are vulnerable to rising temperatures and prolonged droughts, while highlands are prone to intense and irregular rainfall (World Bank, 2011).

Clean development mechanism (CDM) is one of the three 'flexibility mechanisms' defined under the Kyoto Protocol of the United Nations Framework Convention on Climate Change. The CDM is a project-based mechanism. An emission reduction project activity is defined as a set of interventions, or actions, to be implemented over a definite period of time. Project activities can be undertaken by private or public entities, including individuals and private businesses, called 'project participants' (UNFCCC, 2013).

In the broader Ethiopian context, climate-smart practices and technologies are being implemented within the framework of integrated watershed management, which incorporate a broad range of practices in crop and livestock production including agroforestry, crop rotation and intercropping (FAO. 2016) as well as broader soil and water conservation measures such as soil/stone bunds, terracing, infiltration ditches, and tie-ridges among others. It is important to note that although soil conservation practices, such as reduced tillage and crop rotations, have long been practiced by farmers in Ethiopia, the promotion of conservation agriculture as a package with associated benefits has experienced various challenges related to knowledge, and technology and awareness that still need to be addressed (AKLDP, 2017).

In terms of adoption, most of the CSA practices and technologies identified have low-to-medium on-farm adoption rates, despite their potential benefits to adaptation, productivity increase and mitigation efforts. Many of the key barriers to widespread adoption include limited or no access to productive inputs (improved seeds and fertilizer), lack of access to credit, lack of adequate machinery and technology (e.g. row planters), low access to formal markets to sell produce, and limited extension service quality and access particularly in relation to climate-smart agriculture. Uncontrolled and free grazing, which limits implementation of some climate-smart practices (e.g. mulching), has been part of the tradition and routine of farmers for generations (CSA ,2016).

Therefore, this review aims to give an overview on CDM, CSA and adaptation and mitigation measures undertaken in Ethiopia in response to climate change and sustainable natural resources.

Result and Discussion

Climate change Adaptation and Mitigation measures for sustainable NRM

Climate change mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2007; Chidumayo et al., 2011). The first option is to reduce the consumption of fossil fuels, thereby reducing GHG emissions; the second one is to maintain and/or increase the vegetation cover, thereby enhancing carbon sinks (carbon sequestration). Mitigation refers to any activities that reduce the overall concentration of greenhouse gases in the atmosphere. This includes efforts to switch from fossil fuels to renewable energy sources such as wind and solar, or to improve energy efficiency. It also includes efforts to plant trees and protect forests, or to farm land in ways that prevent greenhouse gases from entering the atmosphere. The concept of mitigation is relatively new concept, and it mainly focus on limiting the emission of greenhouse gases. For this aspect, Ethiopia has developing the green economy strategy (EPA, 2011; Chidumayo et al., 2011). Although mitigation and adaptation measures pursued to effectively address climate change, negotiations under the UNFCCC have tended to focus primarily on efforts to reduce greenhouse gas emissions (Parry et al., 2005). There is much concern that the increasing concentration of greenhouse gases in general, and carbon dioxide in particular contributes to global warming by trapping long-wave radiation reflected from the earth's surface. Over the past 150 years, the amount of carbon in the atmosphere has increased by 30%. Most scientists believe there is a direct relationship between increased levels of carbon dioxide in the atmosphere and rising global temperatures (Stavins and Richards, 2005).

Adaptation to climate change refers to adjustments in environmental, social and economic systems in response to the actual and expected impacts of climate change. Adaptation moderates vulnerability to climate change. An effective climate change adaptation policy must be responsive to a wide variety of environmental, social, economic, cultural and political circumstances. Adaptation to climate change has to be localized, given that adaptation to climate change is inevitably and unavoidably local (Blaikie et al., 1994; Ribot, 1995). As such, adaptation has to be a national priority and requires committed local action (Bewket, 2011). Adaptation strategies need to be diverse and specific to a particular location based on traditional roots and should benefit from modern science (Asfaw, 2010). Activities of adaptation includes things like building defenses to protect coastal areas from rising seas, switching to drought or flood resistant crop varieties, and improving systems to warn of heat-waves, disease outbreaks, droughts and floods (Shanahan et al., 2013).

Adaptation to climate change requires combining scientific knowledge with indigenous knowledge and practices. Moreover, adaptation to climate change needs to be a continuous endeavor. In Ethiopia, communities have important indigenous knowledge, skills and technologies that are essential for tackling hazardous environmental conditions including climate variability and change. In fact, they employ a number of short- and long-term climate change mitigation and adaptation strategies to cope with and overcome the impacts of climate variability and change .Thus, the use of indigenous knowledge and local coping strategies should be promoted as a starting point for planning climate change mitigation and adaptation (Chidumayo et al., 2011; Zegeye, 2013).

The role and Implication of CDM for sustainable Natural Resource Management

The CDM as an opportunity for reforestation of degraded forest lands

Under the agreement reached at the Seventh Session of the Conference of Parties to the UN Framework Convention on Climate Change in Marrakesh (COP7) industrialized countries will be able to meet a part of their emission reduction commitments under the Kyoto Protocol UNFCCC [1997] by financing Reforestation and Afforestation activities (AR) in developing countries through the clean development mechanism UNFCCC [2001].

The clean development mechanism allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tone of CO_2. CERs can be traded and sold, and used by industrialized countries to meet a part of their targets under the Protocol. It assists countries in achieving sustainable development and emission reductions, while giving industrialized countries some flexibility in how they meet their emission targets. Projects qualify through a rigorous, public process designed to ensure real, measurable and verifiable emission reductions that are additional to what would have occurred without the project.

Reforestation of these degraded forest lands and other commons is hindered by lack of availability of budgetary finance, low economic returns, and lack of entrepreneurial and managerial capacity at the level of the local communities and public service entities. Budgetary provisions for reforestation of lands, both in the national budgets and in the provincial or municipal budgets, are either absent or inadequate. Private sector investment is not likely to be available for reforestation of these lands because private rights over public lands cannot be legally acquired or because the low productivity of these lands does not assure adequate return on investment. However, these lands can be reforested by the local communities, local public service entities, or private enterprises and land-owners if adequate support in terms of capacity building and initial finance is provided to them. The CDM can potentially be a source of such financial support UNFCCC (2013).Ownership and implementation of reforestation projects by local communities and local public service entities can have several advantages (co-benefits). Direct flow of benefits of reforestation to the local entities would result in stronger engagement of the entities and would enhance the sustainability of forest resources resulting in long-term flow of carbon and non-carbon benefits. Benefits in terms of non-timber forest produce flowing at an early stage in a reforestation project would make the project more attractive UNFCCC (2013).

The clean development mechanism (CDM) can help in development and conservation of forest resources in the developing countries while contributing to the global cause of climate change mitigation. Afforestation and reforestation activities under the CDM not only contribute to local, regional, and national economies but also generate local, national, and global environmental and social benefits. The recognition of the 'carbon services' provided by forests is an important milestone in recognition of the global values created by local resources. The CDM presents a valuable opportunity to the forest owners, the forest departments, and forest dependent communities in the developing countries for creating win-win partnerships while responding to the global challenge of climate change mitigation (World Vision, 2009).

Afforestation or Reforestation CDM projects also have the potential of building synergistic effects in achieving the objectives of the multilateral environmental agreements (MEAs), particularly the Rio conventions. While afforestation and reforestation of lands under the CDM could help achieve the objectives of conservation of biological diversity and combating desertification, actions undertaken in pursuance of the Objectives under the Convention on Biological Diversity (CBD), the United Nations Convention to Combat Desertification (UNCCD), and the Convention on Wetlands of International Importance (the Ramsar Convention) would also help achieve the objectives of climate change mitigation and adaptation UNFCCC (2013).

CDM as an opportunity for Carbon sequestration

Carbon sequestration is defined as a biological, chemical or physical process of removing carbon from the atmosphere and depositing it in a reservoir. Sequestration of carbon in biological systems takes long time to achieve, these examples of successful projects demonstrate that bio sequestration can achieve the twin objectives of climate change mitigation and sustainable development (World Vision, 2006).

The Kyoto mechanisms allow the countries with Kyoto commitments to meet their target of reducing greenhouse gas emissions in a cost-effective way and motivate developing countries to join global emission reduction (UNFCCC, 2009). Thus carbon trading offers an opportunity to increase climate equity. Treaties include potential to finance mitigation and adaptation to climate change and enhance sustainable development. Carbon trading is a market mechanism to mitigate climate change. In carbon trading one party pays for another party in return for greenhouse gas emission reduction or for the right to emit (Capoor and Ambrosi, 2008).

Aforestation/Refforestation CDM projects registered under the CDM

Afforestation and reforestation projects under the CDM have already shown their feasibility. There were 96 A/R CDM project activities at various stages of the project cycle on 10 October 2013, out of which 51 were already registered. Of the registered project activities, eighteen project activities had successfully secured their first issuances amounting to 10.327 million credits. CDM afforestation and reforestation projects help mitigate climate change, increase the resilience of local communities, produce numerous sustainable development co-benefits, and capitalize on the synergies among the Rio Conventions, helping also to combat desertification and preserve biodiversity (UNFCCC,2013).

Humbo Reforestation Project registered under the CDM

Humbo community-managed forestry project overview

The project was developed by World Vision Australia and is supported by the World Bank Bio Carbon Fund. It is one of the first registered clean development mechanism (CDM) forestry projects in Africa, covering 2728 hectares

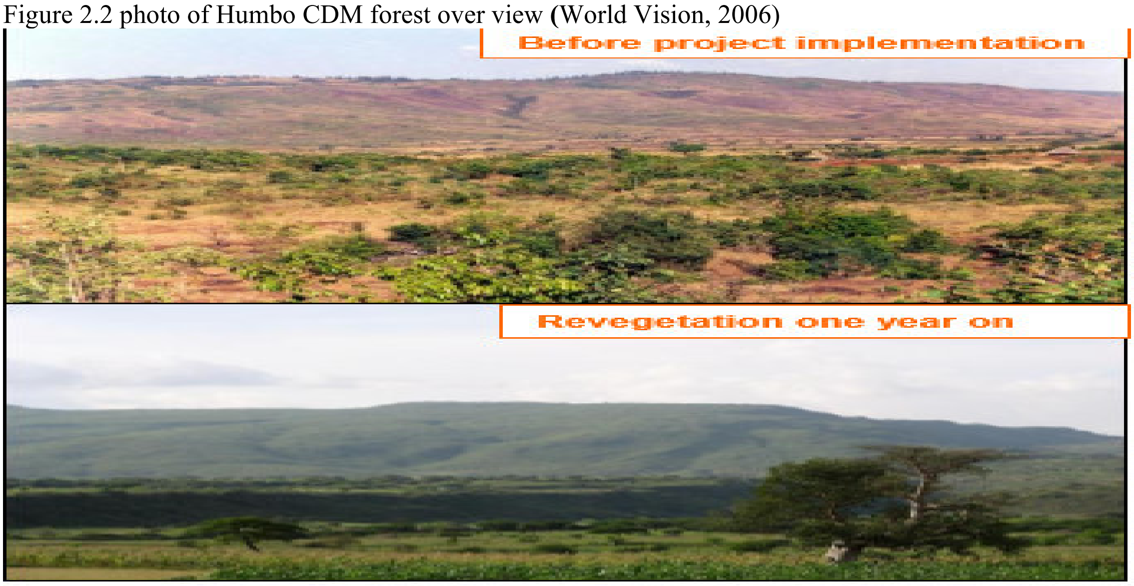
The project sought to re-establish 2,728 hectares of bio-diverse native forest, to mitigate climate change, and support income and employment generation through community-managed natural regeneration. Additional income flow through the sale of the resulting carbon emission reduction units, and other forest and non-forest benefits, would contribute to sustainable development and the alleviation of poverty in the region.

The Humbo project is Africa's first large-scale carbon trading forestry project developed under the Kyoto Protocol's Clean Development Mechanism (CDM). The CDM allows for reforestation projects to earn carbon credits (Certified Emission Reductions – CERs) for each tone of carbon dioxide equivalent "sequestered" or absorbed by the forest.

The proposed afforestation / reforestation activity, the Humbo Assisted Regeneration project, involves the restoration of indigenous tree species in a mountainous region of South Western Ethiopia. The project contributes to climate change mitigation objectives by contributing to the GHG removals by sinks through assisted natural regeneration project. Furthermore, the project compliments to the natural resource management goals of the Ethiopian Agricultural Rural Development and Forestry Coordination Office (ARDFCO), and social development goals of the Ethiopian government, and the World Vision Ethiopia, the humanitarian organization implementing the project.

Over-exploitation of forest resources and resulting deforestation in Humbo district in southern Ethiopia had brought a population of 65,000 to the brink of famine. Depletion of forest cover had resulted in scarcity of drinking water, rapid decline in agricultural productivity and high vulnerability to natural disasters. In response to this situation, the *Humbo Ethiopia Assisted Natural Regeneration Project* under the CDM (Project #2712, registered on 07 Dec 2009) was developed with the financial assistance of the Bio Carbon Fund of the World Bank. Collaborative efforts involving newly established forest cooperatives of local communities, the Ethiopian Forestry Department and the humanitarian organization World Vision Ethiopia resulted in restoration of 2,728 ha of natural forests under the banner of the project (World Vision, 2006). Successful verification and certification secured by the project resulted in issuance of 73,339 tCERs in favour of the local communities. Part of the tCERs generated under the project were agreed to be purchased by the Bio Carbon Fund. It is estimated that over its crediting period of 30 years (from 01 Dec 2006 to 30 Nov 2036) the project will bring estimated carbon revenue of US$700,000 to the local communities. Further revenue will be generated from the sale of the remaining carbon credits not purchased by the World Bank and from the sale of timber products from the project. The co-benefits of the project include socioeconomic and environmental benefits of which the value is likely to be much larger than the monetized revenue.

Figure 2.2 photo of Humbo CDM forest over view (World Vision, 2006)



Although sequestration of carbon in biological systems takes long time to achieve, these examples of successful projects demonstrate that bio sequestration can achieve the twin objectives of climate change mitigation and sustainable development World Vision (2006).

Afforestation, Reforestation and Forest Management:

CDM and REDD+ Ethiopia is now taking advantage of the emerging global carbon financing/trading opportunities such as Clean Development Mechanism (CDM) and REDD+ to catalyze afforestation, reforestation and forest management. The CDM and REDD+ projects offer the opportunity to protect the remaining natural forests and restore the forests that have been deforested or degraded due to agricultural expansion and unsustainable utilization. Afforestation and reforestation enhance forest carbon stocks and are thus crucial in climate change mitigation. The CDM afforestation/reforestation (A/R) project at 2,728 ha in the Humbo District (Wolayita) in Southern Ethiopia is expected to cut about 880,296 tons of CO_2 from the atmosphere in 30 years (Anonymous, 2006). The REDD+ project at 600,000 ha in the Bale Mountains is expected to generate about 80 million tons of CO2 emission reductions worth of USD320 million, and the CDM reforestation project at 3,000 ha about USD5.2 million, both in 20 years (Tadesse, 2009). Such projects will bring environmental, social and economic benefits to the local communities and beyond. There is a need to develop bio diverse carbon-rich plantation forests rather than fast growing single species plantations (that is, monocultures) to achieve both biodiversity conservation and climate change mitigation (Pichancourt *et al*., 2013). This requires planting diverse tree species with multiple environmental and socioeconomic benefits, especially high carbon stocks. It also requires that the species are spatially distributed across landscapes. Finding evidence and technical solutions for building larger and more stable stocks of carbon in bio diverse forests has attracted much attention in recent years from global initiatives such as REDD+. To improve the resistance/stability and resilience/recovery of forests to climate change, there is a need to increase the number of tree species and structural diversity of plantation forests and apply close-to-nature silviculture (Berendt *et al.,* 2017). Hence, tree planting in Ethiopia needs to be fine twined in line with the aforementioned approaches. The forestry sector plays a critical role to mitigate and adapt to the impacts of climate change, and thus forest resources management and development should be a priority.

Benefits of Humbo carbon project /Achievements

The Humbo project is a highly successful example of reforestation that alleviates poverty while addressing climate change through improved natural resource management. The rapidly changing face of the forest is evident in the photographs right, showing rapid re-vegetation only one year on from inception. To date, 2,728 hectares of degraded forest that were being continually exploited for wood, charcoal and fodder extraction have been protected, and are now being restored and sustainably managed. Over the 30 year crediting period, it is estimated that over 870,000 tonnes of carbon dioxide equivalent will be removed from the atmosphere, making a significant contribution to mitigating climate change. While many carbon trade deals have been stifled by the high cost of reforestation, the Humbo project has overcome this barrier through the use of the cost-effective FMNR approach (World Vision, 2006).

Forest restoration has resulted in increased production of wood and tree products, including honey, medicine, fiber, fruit and wildlife that contribute to household economies. Improved land management has stimulated grass growth, providing fodder for livestock and can be cut and sold as an additional source of income. Reforestation is also reducing land degradation and soil erosion. Water infiltration is improving, resulting in the recharging of ground water and a reduction of flash flooding. (Note: because the rainfall is seasonal, the rivers are also seasonal and don't flow for much of the year). With the likelihood that climate change may cause increased rainfall in Ethiopia's highlands, soil stability is essential for reducing vulnerability to flash flooding and stabilizing soil for agricultural production (WVA, 2008)

Crops surrounding reforested areas also benefit through modification of the microclimate, which comes about through a combination of reduced wind speed, lower temperatures, higher humidity and greater infiltration of water into the soil. The Humbo project shows that community-based restoration of forests can mitigate climate change while at the same time building environmental and social resilience to the impacts of climate change. These forests act as a carbon sink to mitigate climate change while at the same time building environmental, social and economic resilience for future climate change impacts (WVE, 2019).

The Challenges of Community Forestry for Carbon Trading

Difficulties in managing community expectations: The community struggled to understand the concept of emissions trading. The most significant outcome for the community will be greater resilience to environmental shocks as well as creation of a stable income stream from forest products. Most community members had unrealistic expectations of the level of income that would be generated through carbon sales. Ownership of the emissions reduction credits is a complicated matter since only the government is recognized as the rightful owner of the land under which the sequestration is taking place (Tadesse, 2009).

The role and Implication of Climate Smart Agriculture for sustainable Natural Resource Management (CSA)

Climate-smart agriculture (CSA) is defined by FAO (2010) as agriculture that sustainably increases productivity, enhances resilience of livelihoods and ecosystems, reduces and/or removes greenhouse gases (GHGs) and enhances achievement of national food security and development goals. The climate-smart agriculture (CSA) reflects an ambition to improve the integration of agriculture development and climate responsiveness. It aims to achieve food security and broader development goals under a changing climate and increasing food demand. CSA initiatives sustainably increase productivity, enhance resilience, and reduce/remove greenhouse gases (GHGs), and require planning to address trade-offs and synergies between these three pillars: productivity, adaptation, and mitigation (FAO, 2010).

Future climate projections indicate increases in annual rainfall for Ethiopia as a whole, with these increases being greatest in the southern and southeastern parts of the country and least in the central and northern parts of the country. The possible impacts of these changes on agricultural production in the country include, among others, the following: Changes in water availability for crop and livestock production, increased competition and conflicts over pasture and water for livestock., Geographical shifts and reductions in areas suitable for production of teff, maize, barley and sorghum (Evangelista *et al*., 2013),Shifts from livestock rearing to crop cultivation, from nomadic to sedentary livestock keeping, and/or from pastoralist to agro pastoralist (Nassef and Belayhun, 2012).

Table 1: Strategies used by pastoralists and agro pastoralists in the dry lands of Ethiopia to cope with the impacts of climate variability and change.

Strategies for coping with the impacts of climate variability and change
• Mobility (livestock and/or people)
• Modifying livestock composition (rearing different livestock species) and herd size (herd splitting; decreasing the number of livestock through selling and slaughtering/feeding during periods of droughts in which there is scarcity of water and forage, and increasing through purchasing during inter-drought periods)
• Construction and maintenance of water storage infrastructure
• Use of crop residues as animal feed
• Hay making, collection and preservation
• Reserving dry season grazing areas
• Modification of rangeland management practices (controlled grazing/regulating the frequency and intensity of grazing, controlled burning for acquisition of new growth for livestock grazing)
• Effective, efficient and participatory management of available natural resources
• Tree planting (for livestock feed and shade)
• Modification of farming practices
• Diversifying livelihood activities
• Increasing education for children
• Establishing community groups to overcome the impacts of droughts and provide alternative means of support
• Raising community awareness on climate change issues and needs for adaptation
• Strengthening existing conflict resolution mechanisms and rethinking regional boundaries

Sources: Riché et al. (2010), Chidumayo et al. (2011), Tadesse et al. (2013) and Tilahun et al. (2017).

Climate-Smart Agriculture Practices

Ethiopia's annual greenhouse gas (GHG) emissions were estimated at 150 Mt CO2e in 2010, with 50 percent and 37 percent of these emissions resulting from the agricultural and forestry sectors respectively. In agriculture, livestock production accounted for more than 40 percent of the emissions, while in forestry the main culprit was deforestation for expansion of agricultural land, which accounted for over 50 percent of forestry related emissions, followed by fuel wood consumption at 46 percent of forestry-related emissions. Figure 2.3.1 indicates the major sources of GHG emissions within the agriculture sector1 of Ethiopia. The largest proportion of emissions results from enteric fermentation, followed by manure left on pasture, both of which are related to livestock production (FAO, 2015).

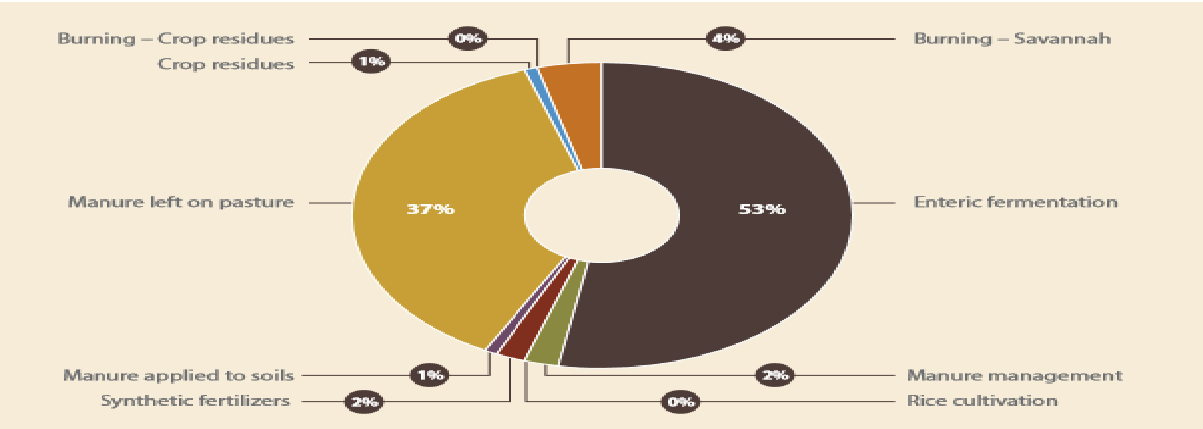


Figure 2.3.1: GHG emissions in Ethiopian agriculture in 2012 (FAOSTAT, 2015).

Ecological agriculture

Ecological agriculture, also known as conservation agriculture and climate-smart agriculture, has a high potential for both climate change mitigation and adaptation in Africa (Ching *et al*., 2011). As such, ecological agriculture is a viable option for Ethiopia. Ecological agricultural practices include terracing, crop rotation, intercropping, retention of crop residues and use of animal dung, composting, mulching, crop diversification (including farmers' varieties), water harvesting and storage, home gardening and traditional agroforestry, management of grazing areas, etc. Ecological agriculture such as avoiding the use of inorganic fertilizers results in reduced GHG emissions, particularly nitrous oxide. The agricultural system of the Konso people in southern Ethiopia is famous for its perfect adaptation to a harsh environment of steep, stony hills and little rainfalls. Traditional technologies are used for soil and water conservation, water harvesting and many more. The Konso agriculture is one of the first examples given to show that adaptation to climate change will be no problem for Ethiopia as suitable and sustainable mechanisms already exist (Kebede *et al*., 2010). In the face of environmental degradation, climate change and poverty, enhancing ecological agriculture is of paramount importance. The Tigray Project on ecological agriculture has showed positive results, both in terms of rehabilitation of degraded lands and improvement of livelihoods of local communities, and is being scaled up to many areas within the region and other regions of the country (Ching *et al*., 2011).

Home gardens and traditional agroforestry systems

Home gardening and traditional agroforestry are age-old practices in Ethiopia. Home gardening is the growing of a variety of plants (trees, shrubs, vines, herbs) around homes to produce diverse goods and services. Agroforestry is the integration of trees and shrubs with crop and livestock production systems, that is, a combination of agriculture and forestry. Home gardens and traditional agroforestry systems are time-honoured, interrelated production and agro biodiversity management systems widely practiced in the Ethiopian agricultural landscapes. A wide range of home gardens and agroforestry systems exist in different parts of the country. The traditional agroforestry systems in Konso, Sidama, Gedeo and the Rift Valley are worth-mentioning (Zegeye, 2013).

The major types of agroforestry systems in Ethiopia are homestead tree planting (home garden agroforestry), farmland tree planting, farm boundary tree planting, farm woodlots and roadside tree planting. Windbreaks/ shelterbelts are also emerging agroforestry systems. Home gardens and agroforestry systems have a range of environmental, social, economic and cultural benefits. They help to sustain the environment and improve livelihoods of people, and as such hold considerable potential for human and livestock adaptation to climate change (FAO, 2000; Asfaw, 2010). They control soil erosion, improve soil fertility, sequester carbon, moderate microclimate, provide various products (fuel wood, charcoal, construction material, timber, poles, posts, farm implements, food, medicines, fodder, spices, bee forage, etc.), increase income, and provide shade and amenity. They supplement food supplies and also serve as a buffer during periods of droughts and crop failures. Moreover, they are well placed for adding new plants to the existing flora (domestication of wild plants). Thus, home gardens and agroforestry systems can play a key role in climate change mitigation and adaptation in Ethiopia. In the face of climate change, combining the two in farming systems would be advantageous since their synergy optimizes mitigation and adaptation (Asfaw, 2010).

The agroforestry practices being promoted and tested are intended to address issues of soil fertility, soil erosion and diversification of farm produce as well as agricultural yield, resilience to climate variability (for example through provision of shade during hot spells) and creation of favorable microclimates for certain crops. Integrating perennial trees or shrubs in agricultural lands used both for crop production and grazing in Ethiopia has been documented to improve soil cover and ensure green cover during the off-season (Kitalyi et al., 2011). Other tree species that have been used in agroforestry in Ethiopia include Calliandra and Cajanus.

Figure 2.3.3 Agroforestry promotedbySustainableLand Management Program in Gagusashikudadworeda of Amhara Region (Simane,2016)

Integrated watershed management

Ethiopia is one of the countries seriously affected by land degradation, and addressing this problem is a major priority for the country. In Ethiopia integrated watershed management is conducted through various projects and programs, which include the Sustainable Land Management Programs (SLMP1 and SLMP2), Managing Environmental Resources to Enable Transitions to more Sustainable Livelihoods (MERET) project, Productive Safety Nets Program – Public Works (PSNP-PW) and numerous NGOs.

CSA in SLMP refers to proven practical techniques — such as mulching, intercropping, conservation agriculture, no-till, crop rotation, cover cropping, integrated crop livestock management, agroforestry, improved grazing and improved water management — and innovative practices such as use of drought-resistant food cropsIt is reported that soil organic matter content sequestration can be achieved by implementing sustainable land management practices that add high amounts of biomass to the soil, cause minimal soil disturbance, conserve soil and water, improve soil structure and enhance activity and species diversity of soil fauna (Woodfine, 2009).

Conservation agriculture

In Ethiopia, soil conservation practices such as reduced tillage have long been undertaken by farmers; however, the promotion of conservation agriculture technology began in earnest in 1998 through the joint promotion and demonstration of the technology on the plots of 77 farmers by Sasakawa Global (SG2000), Makobu and regional agricultural development bureaus. In terms of adoption of conservation agriculture, information from various sources indicates that in areas where conservation agriculture has been adequately demonstrated, for example in some parts of Amhara, Oromia and Tigray, adoption has been reported to be significant (Wondwossen et al., (2008).

Traditional CSA practices

Various types of traditional CSA practices have been implemented and adopted in Ethiopia. Such practices include the Derashe Traditional Conservation Agriculture, Konso Cultural Landscape, Hararghe Highland Traditional Soil and Water Conservation, Hararghe Cattle Fattening, Hararghe Small-Scale Traditional Irrigation, Ankober Manure Management and Traditional Agroforestry in Gedeo Zone, East Shewa Zone, East Wollega Zone and West GojamZone.Traditional conservation agriculture is practiced in a number of places in Ethiopia, one of which is Derashe (Sagandoye valley) special woreda in SNNP Regional State. Under this traditional practice, sorghum and maize are grown without tilling the land. Seed placement is conducted in rows using pointed sticks. Weeding is done frequently, even during the dry season when there are no crops on the farm. After harvesting, crop residues are laid on the ground following the contour in a rectangular manner to conserve moisture from rain. Animals are not allowed to enter the farm and there is no crop residue removal at all (Wondwossenet al., 2008).

The Konso Cultural Landscape

Konso area is characterized by hilly terrain and soil erosion is the major form of environmental degradation. Farmers in Konso practice a highly sophisticated yet traditional brand of terracing, agroforestry and manure management that consistently provides good harvests and maintains the integrity of the land. This traditional soil conservation activity has contributed to significant reductions in soil erosion and has also supported climate change adaptation. These and a number of other traditional CSA practices take place across Ethiopia. This traditional knowledge needs to be documented and tapped in order to develop sustainable and appropriate CSA technologies for the country (MoA, 2014).

Crop residue management

The success of conservation agriculture in Ethiopia is highly dependent on crop residue management. Crop residues provide protective cover for the soil and increase soil infiltration. Research has shown that when 35 percent of the soil surface is covered with uniformly distributed residues, splash erosion will be reduced by up to 85 percent. Approximately two tons of maize residues per hectare are necessary to obtain 35 percent soil cover, which has been established as the minimum amount required for achieving a substantial reduction in relative soil erosion (Tolesa, 2001).

CSA practice	Components	Why it is climate smart
Conservation agriculture	- Reduced tillage - Crop residue management – mulching, intercropping - Crop rotation/intercropping with cereals and legumes	- Carbon sequestration - Reduce existing emissions - Resilience to dry and hot spells
Integrated soil fertility management	- Compost and manure management, including green manuring - Efficient fertilizer application techniques (time, method, amount)	- Reduced emission of nitrous oxide and CH_4 - Improved soil productivity
Small-scale irrigation	- Year-round cropping - Efficient water utilization	- Creating carbon sink - Improved yields - Improved food security
Agroforestry	- Tree-based conservation agriculture - Practised both traditionally and as improved practice - Farmer-managed natural regeneration	- Trees store large quantities of CO_2 - Can support resilience and improved productivity of agriculture
Crop diversification	- Popularization of new crops and crop varieties - Pest resistance, high yielding, tolerant to drought, short season	- Ensuring food security - Resilience to weather variability - Alternative livelihoods and improved incomes
Improved livestock feed and feeding practices	- Reduced open grazing/zero grazing - Forage development and rangeland management - Feed improvement - Livestock breed improvement and diversification	- Improved livestock productivity - GHG reduction - CH_4 reduction
Other	- *In situ* water conservation/harvesting - Early-warning systems and improved weather information - Support to alternative energy – fuel-efficient stoves, biofuels - Crop and livestock insurance - Livelihoods diversification (apiculture, aquaculture) - Post-harvest technologies (agro-processing, storage)	- Resilience of agriculture - Improved incomes - Reduced emissions - Reduced deforestation - Reduced climate risk

Figure 2 .3 .2 Summary of some common CSA practices in Ethiopia (FAO, 2010).

Crop rotation and intercropping

Crop rotation and intercropping: In Ethiopia the promotion of crop rotation is conducted in many parts of the country as a regular extension program. The importance of crop rotation in improving soil structure, reducing soil degradation and improving yields is well documented. Increased levels of soil organic matter enhance water and nutrient retention and decrease synthetic fertilizer requirements. Crop rotation effectively delivers on both climate change adaptation and mitigation. Better nutrient management through crop rotation can decrease the use of nitrogen fertilizer and related greenhouse gas (GHG) emissions associated with the production, transportation and use of chemical fertilizers (PANW, 2012).

The area under small-scale irrigation

Ethiopia has embarked on the promotion and implementation of small-scale irrigation across the country. Consequently, the area under small scale irrigation infrastructure increased from 853, 000 hectares in 2009 to 2 ,084 ,760 hectares in 2013, while the area under irrigated crop production stood at 1, 231, 660 hectares in 2013 (MoA, 2014).

CSA and biophysical Conditions

In Ethiopia various projects and program are implemented in the different agro-ecological zones of the country. PSNP-PW is implemented in moisture-deficit food-insecure districts. Such districts are characterized by drought and low moisture, contributing to low crop production and productivity. The SLM program is implemented mainly in districts with adequate rainfall that are affected by severe land degradation, mostly as a result of erosion and inappropriate land-management practices. The Drought Resilient and Sustainable Livelihoods Program (DRSLP), which is funded by the African Development Bank (ADB), are implemented in pastoral and agro pastoral areas of the country (MOFED, 2003)

Reducing Emissions from Deforestation and Forest Degradation (REDD+):

REDD+ aims to reduce emissions from deforestation and forest degradation, and enhance the role played by conservation and sustainable management of forests in climate change mitigation. By creating financial value for carbon stocks, it aims to show the value of forests. One of the REDD+ projects is the Bale Mountains Eco Region REDD+ Project, which builds on the Bale Eco RegionSustainable Management Program (BERSMP) that has been running since 2007 and is implemented by the Oromia Forest and Wildlife Enterprise (OFWE) and the NGOs Farm Africa and SOS Sahel Ethiopia with funding from the Norwegian Government. It is the first large-scale REDD+ pilot project in Ethiopia. The aim of the project is to enhance the biodiversity and ecological processes of the Bale Mountains and improve the wellbeing of the community. The project is expected to result in an estimated 18 million tons of CO_2e emission reductions over the 20-year project lifetime.

MERET Project

Managing Environmental Resources to Enable Transition to More Sustainable Livelihoods (MERET) is a WFP-supported project initiated in the 1980s. This marked the beginning of large-scale soil and water conservation in Ethiopia. The main objective is to increase the ability of food-insecure households to meet necessary food needs and improve livelihoods through land rehabilitation, proper natural resources management, productivity enhancement, asset creation and diversification of livelihoods WFP (2016).

Figure 2.3.4 Impact of MERET Project (WFP, 2016).

Sustainable Land Management (SLM) Program

The first phase of the SLMP (SLM I) was launched in 2008. It has successfully introduced a number of sustainable land management practices and rehabilitated thousands of hectares of degraded land using physical and biological measures in 45 selected woredas and watersheds. The second phase (SLMP II) for the period 2013-2019 builds on the results of SLMP I (SLM II project document, 2013). SLM II introduced measures to address climate change or variability related risks and to maximize greenhouse gas (GHG) emission reductions so as to meet targets in the Growth and Transformation Plan (GTP) and the Climate Resilient Green Economy (CRGE) goals, while reducing land degradation and improving land productivity of smallholder farmers. The project has four components, integrated watershed and landscape management ,promotion and adoption of conservation agriculture technologies ,integrated soil fertility management, small-scale irrigation schemes, integrated tree-food crop-livestock systems at the homestead, poultry and animal fattening, beekeeping and management of public and communal lands through promotion of activities like soil and water conservation measures, water harvesting structures, forest and woodland management practices and the like (SLM II project document, 2013).

Policy	Year	Intention or goal
Environmental Policy of Ethiopia	1997	Overall guidance in the conservation and sustainable utilization of the country's environmental resources
Environmental Impact Assessment	Proclamation 2002	Ensure that the environmental implications are taken into account before decisions are made
National Adaptation Program of Action (NAPA):	2007	The NAPA represented the first step in coordinating adaptation activities across government sectors
CAADP Compact	2009	One of the pillars of CAADP is extending the area under sustainable land management and reliable water control systems
Growth and Transformation Plan (GTP)	2010	The GTP recognizes that the environment is a vital pillar of sustainable development
Agriculture Sector Programme of Plan on Adaptation to Climate Change/APACC	2011	The Agriculture Sector Climate Change Adaptation Plan
Ethiopian Programme of Adaptation to Climate Change (EPACC)	2011	More programmatic approach to adaptation planning
Climate Resilient Green Economy Strategy	2011	Carbon-neutral middle-income status before 2025

Figure 2.3.5 Ethiopia Nationally Appropriate Mitigation Actions (SLM II project document, 2013).

Climate change education for sustainable natural resources

In Ethiopia, there is generally low awareness on climate change. Thus, it is crucial to raise awareness about climate change and its impacts in the policymakers and the general public. This can be done using a variety of methods: print media (newspapers, leaflets, books, journal articles); meetings (conferences, workshops, seminars, symposiums, panel discussions); electronic media (radio, TV, internet); and bulk short text messages [bulk short message service (SMS) using mobile]. Furthermore, key environmental issues are not properly integrated into the curricula, though some elements are incorporated. Thus, there is a need to inculcate the whole range of environmental issues, especially environmental protection, biodiversity conservation and climate change, in the curricula of schools and higher learning institutions so as to raise the environmental awareness of the young generation. Deeb et al. (2011) pointed out that climate change education is greater than climate science and requires teaching across all people of all ages and engages with formal (that is, schooling), non-formal (for example, training for the workforce) and informal (for example, media) education. Moreover, Ethiopia currently developed climate change education strategy for the period 2017–2030, which mainly focuses on strengthening the integration of climate change education (CCE) into the formal education system of the country (MoEFCC and MoE, 2017).

Opportunities

Untapped opportunities to support the up scaling of CSA and conservation agriculture and implement forest based CDM (carbon project) in Ethiopia include the following:

- The government has developed policies and strategies that are pertinent to ensure food security as well as address climate change.
- The government has moreover ratified international climate change-related conventions.
- The country has developed a comprehensive green growth strategy that encompasses agriculture in the form of the Climate Resilient Green Economy (CRGE) Strategy.
- Implementation of integrated watershed management provides a good opportunity for large-scale implementation and promotion of climate-smart practices such as agroforestry and conservation agriculture.
- Resources are available in the form of projects and programs like AGP, SLM, PSNP and others such as private sector organizations and numerous NGOs in the country.
- At grassroots level there are also adequate numbers of extension and development agents to create awareness of sustainable natural resource management, climate-related awareness, and promote climate-smart agricultural activities.

Table 2: The most notable traditional climate change mitigation and adaptation strategies in Ethiopia

Table 1. The most notable traditional climate change mitigation and adaptation strategies in Ethiopia.

Traditional climate change mitigation and adaptation strategies
• Soil and water conservation (terracing, crop rotation, intercropping, mulching, crop residue retention, use of animal dung, composting, use of synthetic fertilizers, etc.)
• Tree planting (homegardening, traditional agroforestry)
• Crop diversification (growing different crops and varieties)
• Livestock diversification and use of cross-breeds
• Small-scale irrigation (by households and community groups)
• Changing crop sowing dates
• Grain storage and reduction of postharvest loss
• Collection of wild foods (edible fruits and vegetables, fish)
• Traditional water harvesting and storage (use of water wells, rainwater harvesting)
• Rangeland management
• Management of wildfires
• Indigenous forecasting and early warning systems
• Growing fruit plants (e.g. apple in the highlands)
• Sale of grains and livestock and their by-products
• Livelihood diversification and adjustment (off-farm income, seasonal migration, change in consumption pattern, taking credit, borrowing grain and/or money from relatives, land renting and remittance, seeking food aids during periods of droughts and crop failures)
• Mobility, that is, livestock and/or people (pastoral and agropastoral communities)
• Involvement of traditional institutions (Edir, Equb, religious institutions) and social networks
• Looking for assistance from the government and international agencies (e.g. food aid)

Sources: Bryan et al. (2009), Deressa et al. (2009, 2011), Riché et al. (2010), Asfaw (2010), World Bank (2011), Zegeye (2013), Kassa (2013), Tadesse et al. (2013), Addisu et al. (2016), Alemayehu and Bewket (2016), Simane et al. (2016), Zerga and Gebeyehu (2016), Belay et al. (2017), Mekonnen et al. (2017) and Tilahun et al. (2017)..

Key challenges to implementing CSA in Ethiopia

• Weak capacity on climate change adaptation and mitigation at all levels including the public sector, civil society organizations and the private sector remains a key challenge. There is a lack of skilled human resources at all levels.

•Organizations donot tend to work together in an integrated manner in CSA implementation and promotion. This is in part because of weak coordination mechanisms at federal and regional levels. In addition, there is a lack of mechanisms to bring together and coordinate stakeholders involved in different forms of CSA technology promotion.

•In Ethiopia conventional agricultural practices like frequent ploughing and removal and burning of crop residues have contributed to the deterioration of the physical quality of the soil and hence crop productivity decline is common.

In manyparts of Ethiopia live stock husbandry is characterized by open grazing, land degradation and the loss of forests, which could lead to releasing large quantities of greenhouse gases. It is also reported that livestock is the largest major source of global methane emissions.

Conclusion

An effective climate change adaptation policy must be responsive to a wide variety of environmental, social, economic, cultural and political circumstances. The clean development mechanism (CDM) can help in development and conservation of forest resources in the developing countries while contributing to the global cause of climate change mitigation. Afforestation and reforestation activities under the CDM not only contribute to local, regional, and national economies but also generate local, national, and global environmental and social benefits. The recognition of the 'carbon services' provided by forests is an important milestone in recognition of the global values created by local resources. The CDM presents a valuable opportunity to the forest owners, the forest departments, and forest dependent communities in the developing countries for creating partnerships while responding to the global challenge of climate change mitigation .To conclude that the role of CDM and climate smart agriculture is crucial to sustainable natural resource management.

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