Agroforestry Land Use Systems for Climate Change Adaptation and Mitigation in Ethiopia: A Review

Abiot Molla Agemas
Department of Natural Resource Management, Debremarkos University, Debremarkos, ETHIOPIA

Abstract
Deforestation and forest degradation are major contributors to recent increases in atmospheric greenhouse gas concentrations and changes to the world's hydrological cycle. For instance most of the European countries, the industrial process emissions are typically 1-2% of total emissions in the world. In Ethiopia, the current contribution is very low as compare to a global scale, but will more than double from 150 MtCO_2e to 400 Mt CO_2e in 2030. Realizing the threat of global warming, reducing Emissions from Deforestation and Degradation (REDD+) both the Kyoto Protocol in 1992 and Paris climate change agreement in 2012 were built. To upon these commitments Ethiopia has adopted a new, sustainable development model by initiating the Climate-Resilient Green Economy (CRGE) for achieving the following four pillars: i) Improving crop and livestock production while reducing emissions; ii) Protecting and reestablishing forests; iii) Expanding electricity generation from renewable sources v) Use of modern and energy-efficient technologies. Among many climate smart Agriculture practice in Ethiopia, Agroforestry is the one which is inclusive others agricultural practicing. The aims of this paper were to reviews the possible opportunities to raise the potential environmental role of agroforestry in supporting the climate smart agriculture in Ethiopia.Studies on indigenous agroforestry systems in southeastern Ethiopia indicated that, the average total biomass carbon stock were, Coffee accounted for 11 % and Enset 9% of total biomass C on average of which trees accounting for 39–93 % of the total biomass carbon stock. On the other hands, SOC stocks (0–60cm) were 109–253 Mg ha^{-1} in the indigenous agroforestry systems. Various agroforestry systems practice in different parts of Ethiopia has also contributed to biodiversity conservation. One of the oldest indigenous agroforestry systems that were practiced in Hararghe highlands of eastern Ethiopia is the retaining of scattered apple-ring Acacia (*Faidherbia albida* (Delile).Therefore, an Agroforestry practice provides both provisioning and regulating services and there by contributing to the mitigation of global climate changes.
Keywords, Agroforestry, climate change, climate smart
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1. Introductions

The major challenges of global environment are accumulation of heat trapping greenhouse gasses, which raise the global temperature regime, stratospheric ozone depletion, pollution of air, deforestation and degradation of ecosystems and loss of biodiversity (IPCC, 2007). Population growth, industrialization and urbanization are cited as the driving forces of environmental changes. Deforestation and forest degradation are now widely acknowledged by the scientific community as major contributors to recent increases in atmospheric greenhouse gas (GHG) concentrations and changes to the world's hydrological cycle (Hansen et al., 2013). For example, in the City of Paris internal automobile trips generate emission of 3,670 kt CO_2e, while trips with origins or destinations outside of the City contribute 2,862 kt CO_2e (Mairie de Paris, 2009). For most of the European countries, the industrial process emissions are typically 1-2% of total emissions in the world (Carney *et al*, 2009). Ethiopia's contribution to GHG emissions is very low as compare to a global scale. However, if current practices prevail, GHG emissions in Ethiopia will more than double from 150 MtCO_2e to 400 Mt CO_2e in 2030(Ethiopian CRGE, 2011). Out of the 150 Mt CO_2, more than 85% of GHG emissions came from the agricultural and forestry sectors followed by power, transport, industry and buildings, which contributed 3% each (Ethiopian CRGE, 2011). If the current rate of land use conversion continues, GHG emissions from Ethiopia will increase from 150 million Mg CO2e in 2010 to 400 million Mg CO2e in 2030 (Bishaw et al. 2013).

Realizing the threat of global warming, United Nations established the IPCC and created the Kyoto Protocol by United Nations Framework Convention on Climate Change (UNFCCC) as the first international agreement on mitigating GHGs, in 1992. The goal of this protocol is to reduce the GHGs of committed countries by at least 5% compared to the 1990 level, Reducing Emissions from Deforestation and Degradation (REDD+) by the period 2008-2012 (Van Kooten, 2000). However, the agreement has not been done in the year of 2012. The recent agreement in Paris on December 2015 was built on the foundations of the UNFCCC on Climate Change. The Agreement requires all countries developed and developing to make significant commitments to address climate change. Countries responsible for 97 percent of global emissions have already pledged their Nationally Determined Contributions (NDCs) for how they will address climate change. Countries will revisit their current pledges by 2020 and, ideally, strengthen their emissions reduction targets for 2030. To upon these commitments Ethiopia has adopted a new, sustainable development model by initiating the Climate-Resilient Green Economy (CRGE) for achieving the following four pillars (CRGE, 2011):

1) Improving crop and livestock production practices for higher food security and farmer income while reducing emissions; 2) Protecting and reestablishing forests for their economic and ecosystem services, including as carbon stocks; 3) Expanding electricity generation from renewable sources of energy for domestic and regional markets; 4) Use of modern and energy-efficient technologies in transport, industrial sectors, and buildings. Among many climate smart Agriculture practice in Ethiopia, Agroforestry is the one which is inclusive others agricultural practicing.

Agroforestry is defined as "an ecologically based natural resource management system that integrates trees with crop and/or animal on farms with aim of diversifying and sustaining income and production while maintaining ecosystem services" (ICRAF 2000). Agroforestry provides a number of ecosystem services. It includes provisioning Services such as diversification of household income, regulating services such as soil conservation, watershed protection, sinks for carbon and there by contributing to the mitigation of global climate changes (Jose and Bardhan, 2012).

This paper reviews the possible opportunities to raise the potential Environmental role of agroforestry in supporting the climate smart agriculture in Ethiopia. Moreover, to identifies the opportunities and challenge of practicing agroforestry in Ethiopia.

2 Climate smart Agroforestry practice In Ethiopia

2.1 Description of the major types of Agroforestry practice and systems in Ethiopia

Agroforestry practice in Ethiopia is not a new concept rather an age-old practice whereby farmers maintain trees on croplands. Integration of tree/shrub species into the agricultural crop is emerged together with agriculture (Hailu & Asfaw, 2011). The growing of fruit crops in isolated gardens started during the early periods of Christianity in Ethiopia (SLUF, 2006). The same report indicated that cultivation of both domesticated and wild fruits were concentrated in monasteries and churches as sources of food for nuns, monks, hermits and warriors. The total area that is covered by an agroforestry system in Ethiopia is not well-documented (Brown *et al*., 2012). According Brown et al., 2012, some estimates based on satellite imagery it was around 2.32 million ha by excluding scattered trees on crop and grazing lands. Though type of agroforestry practice not yet well documented in Ethiopia, Hoekstra et al. (1990) by considering altitude, topography, and intensity of land use systems identified eight AFPs like alley cropping, trees in homegardens, fodder tree planting, trees as living fences, farm boundary and road side planting, trees on contour bunds, and gully planting as age-old AFPs in Ethiopia. Other study identified nine types of AFPs in various parts of Ethiopia providing diverse ecological and socioeconomic services (Tesemma, 2007). These are banana-based multi-story gardens, teff and acacia integrated agroforestry, boundary eucalyptus and cereal crops in agroforestry, conservation based agroforestry, vertically and horizontally packed agroforestry, multi-strata perennial crop agroforestry, enset-coffee-tree-spice-based agroforestry, fruit trees-bamboo combined with enset vegetable farming and bamboo combined with cereal farming. Moreover, Bishaw (2001) indicated that alley cropping with hedgerows of trees or shrubs and annual crops, fodder tree planting mixed with grass and herbaceous legumes on unproductive pasturelands are other important AFPs in Ethiopia.

Homegardens agroforestry systems are the most popular in most parts of Ethiopia (Abebe, 2005; Mengistu & Hager, 2009; Agize et al., 2013). It is found manly in Southern and southwestern regions of Ethiopia ((Negash et al., 2012; Abebe , 2010 ; Moges, 2009; Muleta et al., 2007) and North-Western Ethiopia (Linger,2014). These are characterized by high species diversity and usually 3-4 vertical canopy strata (tree layers upper storey, herbaceous layer near the ground and intermediate layers in between. Trees like *Cordia Africana, Milletia fruginea, Albezzia gummifera, Ficus* spp, and *Acacia* spp, are among the species that form the upper storey of home gardens.

The practice to maintain trees in croplands is also a common traditional agroforestry practice in Ethiopia. In this agroforestry practice, trees from the original vegetation are retained and are encouraged to regenerate in the arable fields and pastures. The canopy cover reaches 5-15%, for example in central Rift Valley (Belayhun, 2011). The trees are chosen for their general usefulness providing multiple products such as fodder, fruit, fuel wood, medicinal products or vegetable. The fertility benefits of *Moringa stenopetala* (Abay *et al.,* 2013; Solbamo, 2011), *Faidherbia albida* (Degu, 2010); *Croton macrostachyus* (Ashagre et al., 1998); *Cordia africana* (Yadesa et al., 2001); *Millettia ferruginea* (Hailu et al., 2000); *Hypericum revolutum* (Kewessa et al., 2015) have been demonstrated so far. Among parkland tree species, the potential of *F. albida* is well recognized.

2.2 Potential role of agroforestry for climate change mitigation and adaptation

Climate change mitigation is the natural process of removing excess carbon dioxide (CO_2) from the atmosphere and storing it in long lived pools of carbon by fixing it or locking it up from being released back to atmosphere. The pools here include both aboveground and belowground plant biomass. The belowground biomass components of plants include root, soil microorganism and the relatively stable forms of organic and inorganic carbon in soils (Nair *et.al*, 2009).

Agroforestry systems are often taking up large amounts of CO_2 from the atmosphere and storing the C in standing vegetation (biomass), soil organic matter, and harvested biomass products (Montagnini and Nair 2004; Schoeneberger 2009).

The Intergovernmental Panel for Climate Change (IPCC 2007) report concluded that agroforestry would offer the highest potential of C sequestration in developing countries (Verchot et al. 2007). Different agroforestry practices have different potential to store carbon and depending on their species composition and different ecological and environmental variables (Kumar and Nair, 2011; Nair et.al, 2009)

A number of studies indicated that agroforestry in the tropics has higher C densities than field crops or pasture (Albrecht and Kandji, 2003; Nair et al., 2009; Nair, 2012). Currently, agroforestry is estimated to be practiced on 1000–1023 Mha globally and to sequester from 30 to 322 C Pg yr^{-1} (Zomer et al, 2009; Jose and Bardhan, 2012). An additional 12,000 Mg of C per year could be sequestered, increasing to17,000 Mg C per year by 2040, simply through improving tree management practices. Literatures on carbon stocks and sequestration potential to its role in climate change mitigation have been very limited in agroforestry systems of Ethiopia. Studies in southeastern Ethiopia the average total biomass carbon stock of indigenous agroforestry systems were 67 Mg ha^{-1} with trees, Coffee accounted for 11 % and enset 9% of total biomass C on average of which trees accounting for 39–93 % of the total biomass carbon stock (Negash and Starr, 2015). The same study on the same area indicated that SOC stocks (0–60cm) were 109–253 Mg ha^{-1} in the indigenous agroforestry systems. Other authors also investigated the aboveground biomass carbon stock of coffee based agroforestry was 18.66 t C ha^{-1} (Seta and Demissew, 2014). Other studies in Wolayitta Zone, Ethiopia, Homegarden and parkland agroforestry accounts total carbon stock of 86.4 (Mg/ha and 51 Mg/ha respectively, (Bajigo et al., 2015). The potential of agroforestry systems to sequester carbon varies depending upon the type of the system, species composition, and age of component species, geographic location, environmental factors, and management practices (Jose, 2009). The carbon sequestered within agroforestry systems may have a positive impact on the global GHG balance (Harvey et al. 2010).

2.3 Agroforestry and biodiversity conservation

Agroforestry increases biodiversity through the integration of trees, shrubs, crops and/or animals into the system. Agroforestry contributes to biodiversity conservation through outside and inside their habitat. The inside contribution of Agroforestry to biodiversity conservation is through: (i) the provision of supplementary habitats for species (Jose 2009); (ii) conservation of remnant native species and their gene pools (Das and Das 2005; Harvey and Villalobos, 2007); (iii) preventing the degradation and loss of surrounding habitat; (iv) buffering the pressure on deforestation of the surrounding natural habitat; and v) provision of corridors and stepping stones for persistence and movement of area-sensitive floral and faunal species through linking fragmented habitats in the landscape (Nyhus and Tilson, 2004, McNeely and Schroth,2006, Bhagwat et al. 2008, Jose 2009). Agroforestry systems also help to maintain a high number of species outside their native forest habitat through reducing the pressure of humans on natural forest and keeping valuable tree species on their farms act as islands or refuges (Tolera et al., 2008). For example, study showed that converting coffee and cocoa agroforestry systems to plantation reduced total species richness by 46% while the conversion of natural forest to agroforestry resulted in only an 11% reduction in species richness (De Beenhouwer et al., 2013).

Various agroforestry systems practice in different parts of Ethiopia has contributed to biodiversity conservation. One of the oldest indigenous agroforestry systems that were practiced in Hararghe highlands of eastern Ethiopia is the retaining of scattered apple-ring Acacia (*Faidherbia albida* (Delile) A. Chev.) (Poschen, 1986). Different Studies as indicate in the table 1 agroforestry practices in different parts of Ethiopia contribute the retention of woody species in the farmlands. Some of the woody species retaining in agroforestry system were mainly *Cordia africana*, *Eucalyptus camaldulensis* , *Millettia ferruginea* and *Euphorbia candelabrum* (Mengesha, 2010), and *Albizia gummifera* , *Acacia abyssinica* , *Ficus sur* and *Ficus vasta* (Muleta et al. 2008).

Table 1. Agroforestry systems at different parts of Ethiopia and their contribution to biodiversity conservation

Type of Agroforestry system	Study place	Vegetation type	No. woody species found	Sources/reference
Southeast Ethiopia				
Traditional agroforestry	Sinan district, bale zone	Woody species	55	Molla & Kewessa,2015
North				
Fruit trees farms	Adiarkay, Debark, Dejen	Edible indigenous fruit trees	17	Fentahun & Hager (2010)
Homegraden	Hintalo Wejerat of Tigra	Fruits & fodder trees, vegetables, herbs	40(66)	Haileselasie & Gebrehiwot (2012)
South				
Coffee-enset system	Four districts, Sidama zone	Woody species + cultivated crops	198 (61)	Abebe et al. (2006)
Traditional homegardens	Around Gate Uduma, Gedeo	Trees, shrubs, herbs	165(31)	Debessa (2011)
Indigenous agroforestry	Aleta wondo district, Gedeo	Trees, shrubs, vegetable crops	50(40)	Negash & Achalu (2008)
Various homegardens	Wolayta and Gurage zoneo	All floristic species	60	Asfaw & Woldu (1997)
Southwest				
Homegardens	Basketo, Kafa zone	Trees, shrubs, climbers, spice	149-192 (30-32)	Woldeyes (2011)
Central				
Trees on farms	Three districts, Arsi zone	Woody species	90	Mengesha (2010)
Homegardens	Sebeta-Hawas district	Trees, shrubs, herbs, climbers	14(30)	Kebede (2010)
Trees on farms	Welmera & Alemgana	Tree species	27	Duguma & Hager (2010)
Homegardens	Beseku, Arsi Negelle district	Woody species	64	Tolera et al. (2008)
Country level				
Agroforestry systems	West, north and south Ethiopia	Trees + shrubs + climbers + herbs	429(27)	Asfaw (2002)
Homegardens	Central, eastern, western, south Ethiopia	All floristic species	162	Asfaw & Nigatu (1995)

The value in the parenthesis shows that percentage of trees; sources Negash *et.al* 2013

Conclusion and recommendation

Though type of agroforestry practice not yet well documented in Ethiopia eight AFPs like alley cropping, trees in homegardens, fodder tree planting, trees as living fences, farm boundary and road side planting, trees on contour bunds, and gully planting as age-old AFPs in Ethiopia. Homegardens agroforestry systems are the most popular in most parts of Ethiopia. It is found manly in Southern and southwestern regions of Ethiopia and North-Western Ethiopia.

Different agroforestry practices have different potential to store carbon and depending on their species composition and different ecological and environmental variables. A number of studies indicated that agroforestry in the tropics has higher C densities than field crops or pasture. Currently, agroforestry is estimated to be practiced on 1000–1023 Mha globally and to sequester from 30 to 322 C Pg yr^{-1}. Agroforestry practices also increases biodiversity through the integration of trees, shrubs, crops and/or animals into the system. For example, study showed that converting coffee and cocoa agroforestry systems to plantation reduced total species richness by 46%.

Therefore, expanding and practicing of agroforestry practices are one of the means to retaining the species and reducing the emission of GHG into the atmosphere.

Conflict of interest
The authors declare that they have no conflict of interest.

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