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Carbon Business Opportunities and Benefits: Mitigating Climate Change and Harnessing Local Economy in Africa: Ethiopian Case

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ABSTRACT

Carbon sequestration projects in Africa have the potential to provide increased investments for poverty alleviation. Potential benefits include sustainable development, biodiversity conservation, and ecological restoration. The Kyoto protocol was a lost opportunity for Africa and it has only benefitted 3% from carbon trading. Massive sustainable local community based natural resource management efforts have been undertaken and there had been lots of success stories in the last 25 years in Ethiopia. Sustainable Land Management (SLM) practices constitute key adaptation and mitigation measures by resulting in reduced soil erosion, improved water retention, and improved land productivity. The overall objective of SLM Program is to improve the livelihood of land users and communities through implementation of SLM activities in the framework of community-based participatory watershed development plans. Environmental rehabilitation efforts in Ethiopia have brought about reclamation of waste lands, re-vegetation of degraded hillsides, restoration of damaged pasturelands, and adoption of improved soil and water conservation and management technologies in cultivated lands. In consequence, these efforts have apparently led to enhanced carbon sequestration and both above-and below-ground carbon stocks. SLM practices and climate change adaptation and mitigation strategies are mutually supportive and represent win-win options. Carbon stocks could be quantified through different approaches from plot to country level and an integrated approach to quantify and identify carbon pools at a country level on land use basis and different SLM practices would add values in economics and environmental sustainability to encourage Ethiopia to further contribute to the mitigation of global warming while generating income to the community.

Keywords: Carbon trading, Mitigation, Carbon pools, Synergy, Global warming, Carbon stock, Frameworks

INTRODUCTION

Background

Carbon sequestration projects in Africa have the potential to provide increased investments for poverty alleviation. Potential benefits include sustainable development, biodiversity conservation and ecological restoration. The Kyoto Protocol's Clean Development Mechanism (CDM) recognizes carbon sequestration through forestry as a way to mitigate global warming and also allows industrialized countries to offset their carbon emissions by investing in forestry projects in developing countries. In addition, many private organizations are voluntarily promoting carbon sequestration projects to reduce their carbon emissions. Carbon sequestration projects present mutual benefits for environmental conservation and economic development opportunities in poor countries. Countries also require effective strategies to combat the growing threat of widespread natural resource degradation. Accordingly, efforts to mitigate climate change through carbon sequestration projects could bring in money both to raise local incomes and regenerate natural resources. Parts of Africa and Central Asia are recognized as being particularly vulnerable to adverse climate change brought about by global warming. In particular, these areas likely will face higher inter-annual variability of rainfall, more extreme climate events such as floods and droughts and the dryland areas already severely affected by land degradation-irreversible desertification. Numerous studies have been conducted on climate change impact on various facets of human life including agriculture, weather pattern and

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wildlife. The potential consequences of the steady increase in atmospheric CO_2 emissions are partially mitigated by photosynthesis in plants that removes CO_2 from the atmosphere and sequesters it in soil [1,2].

Carbon sequestration through different land uses has gained attention in recent years as it might become a source of additional income to farmers. In this paper, we review the prospects for farmers making money by adopting practices that sequester carbon for the comparative potential of carbon sequestration as a GHG mitigation alternative. Reducing net carbon emissions to the atmosphere is increasingly being considered as a way of addressing the climate change problem. Carbon sequestration is an appealing alternative as it allows continued energy consumption, while potentially benefiting farmers and the environment. As a result, the sequestration alternative has attracted interest of researchers, energy industry, policy makers and farmers alike. Numerous methodologies for carbon sequestration projects (CSP) have been developed targeted at reducing carbon fluxes primarily through management interventions involving land use, land use changes and forestry (LULUCF) [3-5].

Objective

The objective of C-Sequestration is to reverse land degradation due to deforestation and inadequate land use/management in the tropics and sub-tropics through the promotion of improved land use systems and land management practices which provide win-win effects in terms of economic gains and environmental benefits, greater agrobiodiversity, improved conservation and environmental management and increased carbon sequestration with efficient carbon trading systems to empower local communities for their global efforts of Kyoto protocol, Copenhagen and Paris conventions and other global and frameworks [6,7].

MITIGATING CLIMATE CHANGE THROUGH CARBON SEQUESTRATION

Employing farming practices that involve minimal disturbance of the soil and encourage carbon sequestration, farmers may be able to slow or even reverse the loss of carbon from their fields. In the United States, forest and croplands currently sequester the equivalent of 12% of U.S. carbon dioxide emissions from the energy, transportation and industrial sectors. Several farming practices and technologies can reduce greenhouse gas emissions and prevent climate change by enhancing carbon storage in soils; preserving existing soil carbon; and reducing carbon dioxide, methane and nitrous oxide emissions. These include conservation tillage and cover crops, improved cropping and organic systems, irrigation and water management, grazing land management. Crop rotation, soil erosion management, nitrogen use efficiency, land restoration and land use changes, methane capture, biofuels and other renewable energy options. Biofuel substitution is the use of agricultural land for the production of biomass that can be converted to biofuel. This fuel can be used onsite to offset the energy used for agricultural production or the biofuel can be transported offsite for large-scale energy production. Every acre used for biofuel production can produce a net sequestration rate of 1.5 MMT of carbon [8-12].

The long-term carbon retention capacity of soil depends on sound land management. Soil sinks cannot be created unless practices are adopted that increase the carbon content of the soil. Those practices, which can vary depending on the type of soil and climate, include: decrease in the amount of land left fallow; the use of direct drilling, which does not disturb the soil as much and reduces the amount of CO_2 released into the atmosphere; the use of legumes and/or grasses in crop rotation; the conversion of marginal farmland to perennial grasses or trees; the use of rotation grazing and high-intensity short-term grazing; the planting of shrubs and trees as windbreaks; and the restoration of wetlands. Many management methods aimed at storing carbon in soil sinks also contribute to environmental sustainability. Increasing the organic matter content of soil helps improve the soil’s agronomic capabilities. It also produces better soil and better crops, improves water conservation, reduces erosion, and improves wildlife habitat and species protection, leading to greater biodiversity. Forests and ecosystems in general may have a limited capacity to accumulate C [13-17]. First, this is because the capacity to sequester C is limited by other factors, such as nutrient availability and other biophysical factors. Second, photosynthesis may have a CO_2 saturation point, above which it will no longer respond to an increase in atmospheric CO_2 concentration. A third reason is that climate change may lead to ecosystem degradation, in turn, limiting the capacity to sequester C. Forests in the absence of disturbances are expected to take up C for 20-50 years after establishment and, therefore, they should be considered as a time-buyer until other technologies are developed to reduce emissions [18-20].

Different scenarios for carbon sequestration

The potential capacity for different TEs to sequester carbon is highly dependent on land-use practices and forestry activities. The CS potential of ecosystems depends on the type of land, while in the case of forests management determines substantially the CS rates. The most common methods to increase the sequestration rate in terrestrial ecosystems are reforestation and afforestation. Conversion of cropland to grassland can also provide relatively large annual increase in carbon stock while shift to conservation agriculture is very important for increasing soil organic matter [21-26].

Agricultural soils can play in addressing the Global Warming crisis. Farmers can play a central role in sequestering carbon in their soils by fostering deep-rooted perennial plant species that have significant biomass in their root systems. Soil biomass is a natural carbon sink and should be used to create carbon credits which can be traded alongside those currently traded for forests [27,28].

Practicing conservation tillage, improving agricultural productivity, reducing soil erosion, and improving water management improve soil quality and increase the carbon stored in soil. It is estimated that these practices have the potential to restore between 40 to 112 pg of carbon globally [29]. Successful soil sequestration projects and activities in Africa must have a strong sustainable development component, such that the project improves the livelihood of farmers by improving agricultural productivity, reducing the risk of crop failure, providing access to better agricultural inputs, such as organic fertilizers. Changes in soil carbon can be monitored and measured, however, because carbon sequestration is a new field some technical challenges remain. A good first step to addressing these challenges will be the development of a measurement and monitoring manual. While the majority of land use projects to date have been in the forest sector, soil carbon projects in semi-arid and sub-humid Africa provide the following unique opportunities [30-37]:

The land has relatively low opportunity cost relative to humid tropical forests, where in many cases climate mitigation may not be able to compete with logging or agricultural land demands. Large areas of degraded and desertified lands are in need of technical assistance and capital for restoring farmlands, grasslands and savannas. While exact estimates of desertification are difficult to obtain, estimates range from 3.47 to 3.97 billion hectares of desertified land. Therefore, while the tons of carbon per hectare are relatively small relative to forests, the overall potential for cost- effective climate mitigation is quite large. A carbon accounting system needs to assess the changes in the amount of carbon stored in each of these pools over the life of the forest [38,39].

The amount of carbon stored in each of these pools is most commonly estimated by developing relationships between easily measured things like stem diameter or stem volume and harder to measure things like canopy and root biomass. It is also necessary to establish the pattern of changes in pools like soil carbon and under story over the time frames of forest growth [40].

SLM FOR CARBON SEQUESTRATION AND CLIMATE CHANGE MITIGATION: ETHIOPIAN EXPERIENCE

SLM, in addition to its role in adaptation, provides a significant potential as a mitigation measure. Globally, agriculture and land use changes are major contributors of GHGs). This means, in other words, appropriate agricultural practices and land use and land cover management offers a great mitigation potential. Sustainable forest management, reducing emissions from deforestation and forest degradation (REDD) is one of the recognized mitigation options. Soil carbon sequestration also has a huge mitigation potential with a wide-range of synergies such as improved productivity and soil health. Agriculture and SLM are important domains through which developing countries can contribute to global mitigation efforts as they fall within National Appropriate Mitigation Actions (NAMAs). Environmental rehabilitation efforts in Ethiopia have brought about reclamation of waste lands, re-vegetation of degraded hillsides, restoration of damaged pasture lands and adoption of improved soil and water conservation and management technologies in cultivated lands. In consequence, these efforts have apparently led to enhanced carbon sequestration and both above-and below-ground carbon stocks. SLM practices and climate change adaptation and mitigation strategies are mutually supportive and represent win-win options. Supporting local, national and regional African farmer organizations in overcoming barriers to adopt SLM technologies and accessing the carbon market is pivotal to enhance carbon trading. Initiatives need to develop cost-efficient methodologies for farmers to access carbon markets and their income benefits, and that lower barriers to adoption of sustainable land management practices which enhance land productivity and sustainability. An option for adaptation to climate change and necessary condition for sustainable agriculture in itself is sustainable land management (SLM) and rehabilitation of degraded lands [41,42]. Community Based Integrated Watershed Management (CBIWSM) approach was adopted as one of the top climate change adaptation strategies in Ethiopia. Massive sustainable local community based natural resource management efforts have been undertaken to reverse this situation and there are a lot of success stories in the last 25 years in Ethiopia which includes: Water harvesting, Irrigation (crop diversification and intensification), Zero grazing, A (re)forestation, plantation, agroforestry, closure areas, protected forests, intensive and integrated watershed management approach/ SWC and conservation agriculture. Land degradation is primed to exacerbate climate change impacts. Conversely, SLM practices constitute key adaptation measures by resulting in reduced soil erosion, improved water retention and improved land productivity. Sustainable Land Management (SLM) requires addressing of the underlying causes to land degradation. Environmental rehabilitation efforts in Ethiopia have brought about reclamation of waste lands, re-vegetation of degraded hillsides, restoration of damaged pasturelands and adoption of improved soil and water conservation and management technologies in cultivated lands. SLM practices and climate change adaptation and mitigation strategies are mutually supportive and represent win-win options [43-45].

The Kyoto protocol was a lost opportunity for Africa and it has only benefitted 3% from carbon trading. The prevailing international prices for carbon credits range from \$3.50 per ton CO_2 at Chicago Climate Exchange to \$15.80 per ton CO_2 in various European markets. Carbon credits from carbon sequestration projects in Africa are therefore worth millions of dollars. At present, the Plan Vivo Project in Uganda and the Nhambita Community Carbon Project in Mozambique are already selling carbon credits to United Kingdom-based companies and sharing their carbon revenues with local farmers. There is also recent Humbo CSP in Ethiopia [46].

CARBON SEQUESTRATION AND ACCOUNTING METHODS

Application of appropriate biomass estimation methods and transparent and consistent reporting of forest carbon inventories are needed in both scientific literature and the GHG inventory measures. Different approaches, based on field measurements, remote sensing and GIS have been applied for AGB estimation. The traditional techniques based on field measurements only are the most accurate but have also proven to be very costly and time consuming. The use of remote sensing (RS) techniques has been investigated, but as yet this approach has met with little success for multi-age, multi-species forests and only with limited success in forests with few species and age classes representing a broad range of biomass distributions. Nevertheless, even where RS data are useful for estimating forest biomass/carbon, ground data is still necessary to develop the biomass predictive model (i.e., calibration) and its validation. A sufficient number of field measurements are a prerequisite for developing AGB estimation models and for evaluating the AGB estimation results. GIS-based methods require ancillary data such as land cover, site quality and forest age to establish an indirect relationship for biomass in an area. Research needs also include the development of cost-effective biomass monitoring systems and developing and evaluating criteria for assessing sequestered, the identification and quantification of land-based sources and sinks; assessing the relationships between sustainable land management and biomass sequestration, as well as the relationship biomass-land degradation, RS, GIS-modeling, ground-based forest biomass assessment, carbon accounting, participatory tools and the use of related statistical instruments in particular [20,31-33].

Remote sensing

Remote sensing (RS) for the assessment of biomass in the framework are not restricted to forests rather, they assess the present biomass regardless of cover type. The biomass of all components of the ecosystem is considered: the live mass above and below ground of trees, shrubs, palms, saplings, etc., as well as the herbaceous layer on the forest floor and in the soil. The greatest fraction of the total above-ground biomass is represented by these components and, generally speaking, their estimation does not represent many logistic problems. Remote sensing imagery can be extremely useful in carbon stock inventories in several ways: (a) the estimation of above-ground biomass, indirectly, through quantitative relationships between band-ratio indices (NDVI, GVI, etc.) with measures of biomass or with parameters directly related to biomass (e.g. Leaf Area Index, LAI). (b) Classification of vegetation cover and generation of a vegetation types map. This partitions spatial variability of vegetation into relatively uniform classes, which can be used as sampling framework for the location of ground measurement sites and the identification of plant species. (c) As upscaling mechanism through spatial interpolation procedures for variables such as estimates of biomass, biodiversity and land degradation indices [47].

Field measurement

Above-ground biomass is estimated from quadrat measurements by volume, through allometric calculations involving standard forestry measurements and procedures, (i.e., tree height –H-, diameter at breast height-DBH-, basal area-BA-, wood density –WD- and crown dimensions). Predictive equations, based on a regression approach are also used for estimation of biomass based on allometric and volume measurements. To the tree biomass estimate in the 10 × 10 m quadrat, the estimates from shrubs, deadwood and debris measured in the nested 5 × 5 m quadrat are added. The herbaceous layer, the litter and other organic debris collected in the field from the 1 × 1 m quadrat are taken to the laboratory, dried out and weighted. The surface dry organic matter estimate per m^2 is added to the estimates of total above-ground biomass for each of the field sampling sites (10 × 10 m quadrats). Below-ground biomass is estimated from root biomass as a function of above-ground biomass by non-destructive methods. These rely on calculations of below-ground biomass for similar types of vegetation and coefficients (e.g. 0.2 as the ratio of below-ground to above-ground biomass in forests, depending on the species). For agro-ecosystems the estimation of biomass makes sense only as the fraction of crop residues added back to the soil, used as animal feed, or for any other non-destructive use, discounting the harvest fraction. Crop growth models are used to project estimates of biomass into the future, when an estimate is required [22,39]. Thus, average expected crop yields and crop residue production are used as indicators of biomass production in crops.

Total carbon stock for present land use

For carbon accounting purposes, the total carbon stock for a given area, which may be a soil or LUT polygon or a PCC, present in the current land use pattern, can be calculated from:

$$C_{\text{stock total}} = C_{ag} + C_{bg}$$

$$C_{bg} = C_{bg\text{-}biom} + C_{soil}$$

$$C_{\text{stock total}} = C_{ag} + (C_{bg\text{-}biom} + C_{soil})$$

where $C_{\text{stock total}}$ is the total stock of C in the ecosystem, including aboveground (C_{ag}) and below-ground (C_{bg}) pools. The constituents of the belowground pool are the carbon content in roots and all below-ground biomass ($C_{bg\text{-}biom}$) and the C in the soil (C_{soil}) as organic C in SOM.

The values of $C_{\text{stock total}}$ after the estimation of aboveground biomass, its conversion to C, the estimation of C in belowground biomass (roots, etc.) and the modeling of SOM turnover to establish SOC are calculated for particular sites where the biomass measurements have taken place, in this case the 10 × 10 m quadrats.

Biomass estimates for below-ground biomass (BGB), i.e., roots, can be estimated as a fraction of aboveground biomass (AGB) by applying the same coefficients as in the estimation for present land use:

- BGB = 0.25 AGB for coniferous vegetation;
- BGB = 0.30 AGB for broadleaf vegetation and crops.

In the case of crops, the coefficient 0.3 should be used. Then, for a given site or polygon:

$\text{Biomass}_{(\text{total})} = \text{AGB} + \text{BGB}$

The value of total biomass can be estimated from the equation above. Independently of the choice of model, the biomass estimates obtained, by necessity, will be referenced spatially to either a pixel or a polygon representing the land unit or Eco zone or pedo-climatic unit from which the climate, soil and site data were extracted to run the model. Therefore, biomass estimate values must be interpolated spatially.

Estimation of carbon stock implicit in potential land use

$Carbon_{(in\ biomass)} = 0.55 Biomass_{(total\ =\ AGB\ +\ BGB)}$

Carbon in biomass and carbon in soils are added for the estimation of total carbon in present land use. The conversion of biomass to carbon is achieved through standard species-dependent coefficients reported in published work; e.g. Carbon = 0.55x biomass. Carbon stock is derived from:

$Carbon\ stock_{(total)} = C\ as\ biomass\ (above\ and\ below) + SOC$

The soil Carbon (SOC) is estimated from analytical data of samples taken at the quadrat sites, or from reported data in soil survey reports of the area of concern. Conversion of SOM to SOC, when values of SOC are not reported, can be made through standard conversion factors **(e.g. SOC=0.57 × SOM)**. This may seem simplistic, but it is the best alternative, short of conducting an intensive and costly soil analytical and calibration effort.

DATA REQUIREMENT

Input data should include

- Time series satellite imagery
- Topomap
- Land use dynamics (detailed data of each land use and land use type)
- Agroecological map
- SLM practices inventory for each land use type
- Input use pattern
- Detailed biophysical and socioeconomic data
- Biophysical data (climate, soil, topography, other land characteristics)
- Land characteristics and quality
- Vegetation dynamics (forest density and species richness, type, degradation level)
- Vegetation parameters (basal area, DBH, height, canopy cover)
- Cropping systems data (area, pattern, calendar, operation sequences, type, yield and productivity data)
- Area cover by each land use and land use type
- Socioeconomic data from interview and secondary data sources
- Agricultural technologies and yield
- Demography and settlement patterns
- Miscellaneous

CONCLUSION

Quantification at landscape and spatiotemporal pattern facilitates carbon trading at country, East Africa Region and continental level. This calls for establishing frameworks, integrated approaches and synergy among actors in modeling and predicting carbon sequestration potentials and promote best SLM practices to enhance marketing channels and institutional settings for effective carbon trading. Due attention should be paid to the following issues to enhance carbon accounting to optimize economic and ecological benefits of local communities in particular and Ethiopia at large.

- Local communities should be rewarded and empowered for their tireless local efforts in recognition of their contribution to mitigating global climate changes through carbon sequestration **(*Think Globally and Act Locally to achieve the Kyoto protocol*)**. To achieve this goal, there is a need to develop tools and cost-effective methods of c-sequestration assessment and c accounting (Carbon credit) system applicable at local and regional level.
- Promotion of improved landuse systems and land management practices which provide win-win effects in terms of economic gains and environmental benefits to facilitate carbon trading systems to empower local communities for their contribution to mitigation global climate change.

- Monitoring carbon trading in space and time
- Estimate the Economics (cost) of carbon sequestration of public efforts in the form of carbon trading for income generation
- Reliable Carbon Accounting System (CAS)/guideline for local communities to benefit from global carbon trading.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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