Research Application Summary

Impact of land use/cover change on soil carbon stocks, livelihoods and opportunities for mitigation in Mt. Elgon region

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Abstract

The study was conducted to assess community perception on landuse/cover change and its impact on the their livelihood. Knowledge on community copping strategies in improving and maintaining soil carbon levels was also investigated. Analysing of the spatial and temporal pattern of land use/cover change at different altitudes in Mt. Elgon region between 1960 and 2009, a quantification of soil organic carbon (SOC) pools and fluxes with respect to the present land use were also done. The study aimed at predicting future effects of alternative land use change scenarios on soil organic carbon. It explored above-ground biomass and carbon stocks of different land cover types, i.e., tropical natural forest, cultivated lands and encroached forest to examine the total amount of carbon sequestered. Household interviews were used to obtain information on community perception on land use/cover change and its impact on the their livelihood and community copping strategies in improving and maintaining soil carbon levels. Preliminary results indicated that there were significant differences in SOC among the different land cover types, where the tropical natural forest stored more carbon compared to cultivated land and encroached forest. Soil organic carbon also significantly changed with soil depth. There was more aboveground carbon sequestered in the forest compared to encroached and cultivated land. Encroachment on tropical natural forest resulted into a loss of 84.3% of the above ground carbon sequestered. This study recommends that existing natural forests be conserved to avoid loss of carbon which contributes to carbon dioxide, a greenhouse gas involved in global warming.

Key words: Carbon sequestration, carbon stocks, land use, land cover change, Mt. Elgon, soil carbon, Uganda

Résumé

L'étude a été menée afin d'évaluer la perception des communautés sur le changement de l'utilisation des terres / du couvert végétal et son impact sur leurs moyens de subsistance. La connaissance sur les stratégies de lutte communautaires dans l'amélioration et le maintien des niveaux de carbone du sol a également été étudiée. En analysant la distribution spatiale et temporelle de changement dans l'utilisation des terres / du couvert végétal à différentes altitudes dans la région du Mt. Elgon entre 1960 et 2009, une quantification des réservoirs de carbone organique du sol et les flux à l'égard de l'utilisation actuelle des terres ont également été effectués. L'étude a visé à prévoir les effets futurs des scénarios alternatifs de changement d'utilisation des terres sur le carbone organique du sol. Elle a exploré la biomasse au dessus du sol et les stocks de carbone des différents types d'occupation du sol, c'est à dire, forêt tropicale naturelle, des terres cultivées et des forêts envahies afin d'examiner la quantité totale de carbone séquestré. Les entretiens avec les ménages ont été utilisés pour obtenir des informations sur la perception des communautés sur le changement de l'utilisation des terres / du couvert végétal et son impact sur leurs moyens de subsistance et les stratégies de lutte communautaires afin d'améliorer et de maintenir les niveaux de carbone dans le sol. Les résultats préliminaires ont indiqué qu'il y avait des différences significatives dans le carbone organique du sol entre les différents types de couverture de terre, là où la forêt tropicale naturelle a stocké plus de carbone par rapport aux terres cultivées et la forêt envahie. Le carbone organique du sol a également changé de manière significative avec la profondeur du sol. Il y avait plus de carbone au dessus du sol séquestré dans la forêt par rapport aux terres cultivées et celles de forêts envahies. L'envahissement de la forêt naturelle tropicale a entraîné une perte de 84,3% du carbone séquestré au dessus du sol. Cette étude recommande que les forêts naturelles existantes soient conservées de manière à éviter la perte de carbone qui contribue au dioxyde de carbone, un gaz à effet de serre impliqué dans le réchauffement climatique mondial.

Mots clés: Séquestration du carbone, stocks de carbone, utilisation des terres, changement du couvert végétal, Mt. Elgon, carbone du sol, Ouganda

Background

Although forests have a great potential for carbon sequestration, the role of soil as a net sink for atmospheric carbon dioxide (Co_2) has not yet been fully explained (Lal *et al*., 1995). Under article 3.4 of the 1997 Kyoto Protocol, the idea of sequestrating carbon in soils as soil organic carbon (SOC) is implied as a possible means to reduce atmospheric CO_2, and this approach is being considered by countries which are signitories to the protocol. There is inadequate knowledge on the form of SOC pools and fluxes that are affected by land use/cover change. Hence, there is a need to understand how soil organic carbon is affected by land use change and how these impacts affect rural livelihood. An understanding of the relations between above ground C stocks and land cover types is therefore required especially in the context of the global C balance. Therefore, this study explored above-ground biomass and carbon stocks of different land cover types in the mountain Elgon region of Kapchorwa district, Eastern Uganda. The study was conducted to obtain information from the community about their perception on landuse/cover change and its impact on the their livelihood and SOC. Knowledge on community copping strategies in improving and maintaining soil carbon levels will be investigated. The study also embarked on evaluating the spatial and temporal pattern of land use/cover change at different altitudes in Mt. Elgon region between 1960 and 2009, quantified the soil organic carbon pools and fluxes with respect to the present land use and also predict future effects of alternative land use change scenarios on soil organic carbon in Mt. Elgon region.

Literature Summary

Land use/cover changes are important elements of the global environmental change. Land use patterns result in land cover changes that cumulatively affect the global biosphere and climate. Intensification of land use in the fragile mountain environments due to increase in human and livestock populations has profound effects on the system leading to land degradation. About 77.3% of all land use change is due to removal of forests and conversion of grasslands for arable land use (Lal *et al.* 1995). Long-term experimental studies have shown that SOC is highly sensitive to changes in land use, with changes from native ecosystems such as forest or grassland to agricultural systems almost always resulting in a loss of SOC (Jenkinson, 1977).

Terrestrial carbon stocks consist of above and below ground carbon (Nirmal Kumar *et al.*, 2010). Since carbon sequestered is stored in the form of woody biomass, the simple way to increase carbon stock is to plant and manage trees. As trees grow, they sequester carbon in their tissues, and as the amount of tree biomass increases the increase in atmospheric CO_2 is mitigated (Losi *et al.*, 2003). In the humid tropics, maximum potential in carbon sequestration will be achieved by focusing on increasing aboveground biomass in woody vegetation rather than as soil carbon, given the smaller pool size of soil organic matter and short mean residence time.

Climate change and the threat of related extreme conditions like floods, landslides and droughts that are manifested around Mt. Elgon in Uganda/Kenya have major implications on livelihood and economic development such as destruction of property (crop fields, animals, households, roads among others) making the affected communities more vulnerable because they have limited capacity to adapt to the impacts (NAPA, 2007; Environmental Alert, 2010). Unless a society learns to adapt to sustained climate change, its wealth will decline and its social fabric will weaken. Effective adaptation strategies imply reducing present and future vulnerability to climate change and include coping strategies in practices and processes in light of the perceived climatic change (Nair *et al.*, 2009). It is the process through which people reduce the adverse effects of climate on their health and wellbeing and take advantage of the opportunities that their climatic environment provides. Small holder farmers are particularly vulnerable to changes in climate that reduce productivity and negatively affect their weather dependent livelihood systems. Evidence suggest that increasing extreme events like drought, floods and landslides may exacerbate poverty levels, leaving many rural farmers trapped in a cycle of poverty and vulnerability to diminishing resources. Therefore this study aims at assessing the socio-economic impacts, vulnerabilities and adaptations to climate change by small holder farmers with specific focus on understanding how it impacts on their livelihood systems, their perceptions / opinions, and adaptation strategies/ coping mechanisms in place. The manifestations of climate change on small holder farmers around Mt.Elgon ecosystem are clear, with serious implications on their livelihood assets, economic development and social fabrics.

Study Description

The study was conducted in Mt. Elgon protected area and the Benet settlement areas on the slopes of the mountain in Kapchorwa district, Uganda. This area was chosen because of the unique trend of events that have taken place in the area involving forest encroachment by the Benet communities and gazettement by the government dating way back in 1936, when Mt. Elgon forest was gazetted as a crown forest. Forest encroachment and gazettement activities have, over time, led to changes in land cover types in the area. Four land cover types exist as a result of land use change including Natural forest (THF-well stocked), the encroached forest (THF-

Degraded), and grassland/agriculture crop land cover types. Three land cover types were identified for the study, i.e., Natural (undisturbed) forest (THF- Normal), Encroached forest (THF-Degraded) and Grassland/Agricultural fields. The natural forest is at the highest altitude, followed by the encroached forest and grassland/ agricultural fields as one moves from top to the bottom of the mountain.

Research Application

There were significant differences in SOC among the different land cover type (P=0.000). The results also indicated that soil organic carbon for the different land use is significantly (P=0.025) influenced by the soil depth. There were no significant difference in the soil organic carbon between cultivatived land and encroached forest (Fig. 1). However, there were significant differences in amount of soil organic carbon stored by the forest compared to the cultivatived land and encroached forest. The differences in soil organic carbon were more visible under soil depth 0-15 cm compared to 15-30cm soil depth (Fig.1).

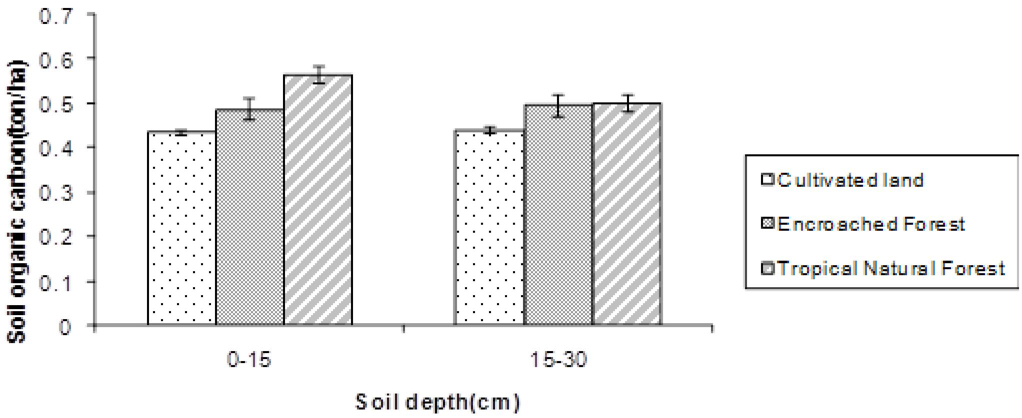

Figure 1. Variation of SOC among different land cover types.

Three equations were used to estimate tree biomass irrespective of the land cover type (when all the data sets from all land cover types were combined), the predictability of the models were assessed using the mean square error (MSE), PRESS statistics and predicted R. Brown *et al.* (1989) equation gave the least MSE and PRESS and a high Predicted R^2 (Table 1). Therefore, the best model for all the land cover types is Y= exp $\{-2.4090 + 0.9522 \ln(D^2HS)\}$ as developed by Brown *et al.* (1989) (Table 1).

Using the biomass (Table 2) from mature trees and poles and saplings (dbh 5-10cm) estimated according to the Brown *et al.* (1989) equation, the One-way ANOVA revealed a significant variation in the total above ground biomass in the different vegetation cover types (P=0.022).

Table 3 indicates that mature trees contributed more aboveground carbon stored compared to poles, saplings and undergrowth. There appear also to be more aboveground carbon sequestered in the forest compared to encroached and cultivated land. Data on community perception on Climate change is being analyzed and is therefore not presented.

From the study, soil organic carbon significantly changes with change in land cover type and varies with soil depth. Forest

Table 1. The general MSE, PRESS and Predicted R^2 irrespective of land cover type.

Allometric equation	MSE	PRESS	Predicted R^2 (%)	Source of equation
ln(PWF) = a + b*ln(D) + c*ln(HT) + d*ln(CR)	1.64	224.82	88.76	NBS (2003)
$W = 0.11\, \rho D^{2+c}$	2.92	468.81	77.72	Ketterings *et al.* (2001)
Y= exp {-2.4090 + 0.9522 ln(D^2HS)}***	1.37	206.89	80.54	Brown *et al.* (1989)

***Best Model.

Table 2. Total above ground biomass.

Category	Above ground biomass in per land cover (t/ha)		
	THF-Natural	THF-Encroached	Grassland
Mature trees	616.99	33.39	5.15
Poles & Saplings (5-10cm)	1.07	0.34	1.80
Saplings (dbh<5cm)	24.65	2.66	0.12
Undergrowth	9.84	19.16	34.63
Total	652.15	55.16	41.70

Table 3. Total above Ground Carbon (TAGC) in the different land cover types.

Categories	Land cover type			Ratio of FOR:ENC: GRSCarbon
	FOR (tC/ha)	ENC (tC/ha)	GRS (tC/ha)	
Mature trees (dbh >10cm)	277.65	15.03	2.32	119:7:1
Poles & saplings (dbh 5-10cm)	0.48	0.15	0.81	3:1:5
Saplings (dbh <5cm)	11.09	1.20	0.05	221:24:1
Undergrowth	4.43	8.62	15.58	1:2:4
TAGC	293.65	25.00	18.76	16:1:1

FOR- Natural Forest, ENC- Encroached forest and GRS- Grassland area.

land cover type has higher soil organic carbon compared to cultivated and encroached forest due to minimal disturbance in the forest compared to other land cover types. The allometric equation by Brown *et al.* (1989) had less residual mean square, indicating that it was more precise in estimating above ground biomass for all land cover types compared to NBS (2003) and Ketterings *et al.* (2001) equations. Mature trees had higher aboveground carbon compared to poles, saplings and undergrowth in all land use types. Overall, there was thus more aboveground carbon sequestered in the forest compared to encroached and cultivated land.

Results indicate that conversion of land cover from forest to encroached may result into a loss of 84.3% of the above ground carbon sequestered in the natural tropical forest. This study recommends that existing natural forests be conserved to avoid loss of carbon which contributes to one of the green house gases called carbondioxide, resulting into global warming.

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