

BUSITEMA UNIVERSITY

Faculty of Natural Resource and Environmental Sciences

**ASSESSMENT OF ABOVE GROUND CARBON STOCK CHANGES IN MOUNTAIN
ELGON NATIONAL PARK FORESTS**

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**A Dissertation submitted in partial fulfillment for the award of
Bachelor of Science degree in Natural Resource Economics**

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Declaration

I, Naturinda Zerubabeeli do hereby declare that this research work has been through my own efforts and never has it been submitted to Busitema University or any other Institution of higher learning for the award of a degree or any other qualification.


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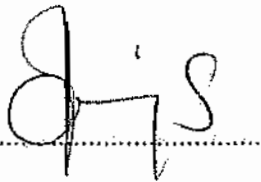
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Approval

This is to confirm that this research report titled *Assessment of above ground carbon stock changes in mountain Elgon National park forests* is original and has only been through the efforts of Naturinda Zerubabeeli after pursuing a three year Bachelor of Science in Natural Resource Economics of Busitema University. He has therefore fulfilled part of his requirements for the Award of the Degree in Natural Resource Economics of Busitema University.

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Dedication

I dedicate this work to whoever is ready to address the Natural Resource and Environmental challenges using sustainable and economic ways for caring for the present and future generations. Thank you, change begins with you.

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God being the epitome of everything I do has made all things possible. For that he promised that he will always stand with us in times of hardships and joy. Glory be to God.

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LIST OF ACRONYMS

CO ₂	Carbon dioxide
°C	Degrees centigrade
C	Carbon
CDM	Clean Development Mechanism
DBH	Diameter at Breast Height (1.3M)
DNA	Designated National Authority
Exp	Exponential
FACE	Forests Absorbing Carbon Emissions
FAO	Food and Agricultural Organization
g	gram
GHG's	Green House Gases
GIS	Geographical Information System
GPP	Gross Primary Production
GPS	Global Positioning System
GtC	Gigatons of carbon
H	Height
Ha	Hectare (10000m ²)
IFER	Institute of Forest Ecosystem Research
IPCC	International Panel for Climate Change
km	kilometer
I-CERs	long-term-Certified Emission Reductions
m	metre
MENP	Mountain Elgon National Park
Mg	Megagrams
MW	Mega Watts
NFA	National Forestry Authority
NGO	Non Governmental Organisation
NTFP	Non Timber Forest Products
PEMA	Participatory Environmental Management Programme

PES	Payment for Ecosystem Services
PHRD	Policy and Human Resources Development Fund
Ppm	Parts per million
sq mi	square mile
t/Ha	tones per Hectare
t-CERs	temporary Certified Emission Reductions
UIA	Uganda Investment Authority
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	US Dollar
UWA	Uganda Wildlife Authority
WMO	World Meteorological Organization

ABSTRACT

This study on assessment of above ground carbon stock changes in Mount Elgon National Park forest over the years 2002-2013 was carried out in the selected southern and northern parts of the forest. A selection 44 of permanent plots that were established and first measured in 2002 by UWA- FACE was done. These plots were re-measured to achieve the study's objectives. The main objective was to compare above ground carbon stock changes in MENP over the years 2002-2013. The specific objectives included; finding the overall tree biomass production, comparing carbon stocks per hectare in the compartment area and conservation area, finding out carbon levels as per planting years in the compartment area as assessed in 2002 and 2013, to compare the above ground carbon stocks per hectare of trees by their genera in both compartment and conservation areas and finally to estimate the potential economic value of carbon sequestration by Mount Elgon forests. In data processing and analysis, all data collected from sampling plots in the Field-Map database were used for statistical evaluation. The data was summarized into tables and analyzed using Excel and Minitab. The results were illustrated using graphs for easy interpretation and discussions to draw conclusions. The results indicated that there was a significant increase in above ground biomass production between 2002- 2013. The results showed that above ground biomass increased from 581 t/Ha in 2002 to 778 t/Ha in 2013. There was also increased aboveground carbon stock from 291 t/Ha to 389 t/Ha. There was much above ground carbon stock in the early years of planting compared to those in late years of planting as assessed in both 2002 and 2013. This was due to increased natural biomass growth through ageing exhibited in the tropical forests. It was also observed that the compartment area has the highest levels of aboveground carbon stocks in tones per hectare compared to conservation area both as assessed in 2002 and 2013. The results also showed that different tree genera store varying levels of carbon in tones per hectare. It was revealed that Mount Elgon forest have a potential offset value of \$ 20 per hectare per year if carbon sequestered is traded in a carbon market. It was recommended that establishment of schemes such as payment of ecosystem services (PES), carbon markets such that the beneficiaries in conservation practices and projects are rewarded should be done. There is need to research further on above ground carbon sequestration potentials including litter, twigs, other vegetations and shrubs which have not been captured in this study to enable the building of a strong information bank for policy makers.

Keywords: *above ground carbon stocks, forest, offset values*

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CHAPTER ONE:

1.0 Introduction

1.1 Background

Understanding the role of terrestrial ecosystems in the global (C) cycle has become increasingly important as policy makers consider options to address the issues associated with global climate change (Wisniewski & Sampson 1993, Brown 1997, Wayburn 2000). With the increasing concern about the rise in atmospheric carbon dioxide (CO₂) concentration and its implications for global climate, the role of tropical forest management in mitigating CO₂ emissions is receiving attention. Thus, determining the amount of changes in vegetation biomass has become important for understanding the global C budget, including the fate of CO₂ produced by burning of fossil fuels and forest clearing (Detwiler & Hall 1988, Brown et al 1993), and the management of existing C pools on land for emission mitigation (Brown 1999). The estimation of aboveground biomass (AGB) is necessary for studying productivity, carbon cycles, nutrient allocation, and fuel accumulation in terrestrial ecosystems (Bannari et al, 2006).

Biomass and carbon for tropical forests are globally undergoing greatest change. However, reliable estimates for them are few (Brown 1997). Biomass and carbon influence the C cycle. Tropical forests produce sources and sinks of CO₂ that are exchanged with the biosphere. Assessments of the magnitude of these sources and sinks require reliable estimates of biomass density of forests and change over time (Brown 1997). About 50% of the forest biomass is C (Chidumayo 1993, Brown 1997). This amount is the potential percentage of biomass C that can be added to the atmosphere as CO₂ when the forest is cleared for other land uses. Likewise it is also the percentage of biomass CO₂ that can be removed from the atmosphere by restoring forests or establishing plantations (Brown 1997).

Based on the United Nations Framework Convention on Climate Change (UNFCCC) of 1992, mitigation plans for greenhouse gas emissions have to be formulated by different countries to arrest the problem of global warming. Options for mitigation include avoiding emissions, conserving existing C pools on land (slowing down deforestation or improving forest harvesting), and expanding C storage in forest ecosystems by increasing the area and /or C

REFERENCES

- Bannari, A., Pacheco, A., Staenz, K., McNairn, H., Omari, K., (2006).** Estimating and mapping crop residues cover on agricultural lands using hyperspectral and IKONOS data. *Remote Sensing of Environment* Vol. 104, Pp 447–459. DOI: 10.1016/j.rse.2006.05.018
- Begumana 2000.** Carbon fixation on Mt. Elgon - An assessment of carbon dioxide sequestration through reforestation. NBS Report, Kampala.
- Bert D, Danjon F. 2006.** Carbon concentration variations in the roots, stem and crown of mature Pinus pinaster (Ait.). *Forest Ecology and Management*. 222(1-3):279-295.
- Blanc, L., Echard, M., Herault, B., Bonal, D., Marçón, E., Chave, J. and Baraloto, C., 2009** Dynamics of aboveground carbon stocks in a selectively logged tropical forest.
- Brand D; (1998):** Opportunities generated by the Kyoto Protocol in the forest sector. *Commonwealth Forestry Review* 77:164-169.
- Brown, S. & Lugo, A.E., 1982.** The Storage and Production of Organic Matter in Tropical Forests and Their Role in the Global Carbon Cycle. *Biotropica*, 14(3), pp.161-187.
- Brown, S., 1997.** Estimating biomass and biomass change in tropical forests. *FAO Forestry Paper*, 134, p.55. Available at: <http://www.fao.org/docrep/W4095E/W4095E00.html>.
- Brown, S., 2002.** Measuring carbon in forests: current status and future challenges. *Environmental Pollution*, 116(3): 363-372.
- Brown, S., Gillespie, A.J.R. & Lugo, A.E., 1989.** Biomass Estimation Methods for Tropical Forests with applications to Forest Inventory Data. *Forest Science*, 35, pp.881-902.
- Bunker, D.E. et al., 2005.** Species loss and aboveground carbon storage in a tropical forest. *Science* (New York, N.Y.), 310(5750), pp.1029-31.

Busienei Vivian Jepkemei, 2010. Potential economic value of carbon sequestration in kakamega forest and surrounding farms.

Chave, J. et al., 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia*, 145(1), pp.87-99.

Chave et al., 2014. Improved allometric models to estimate the aboveground biomass of tropical trees. *Global Change Biology* (2014)20, 3177–3190, doi: 10.1111/gcb.12629.

Chave, J., Riera, B. & Dubois, M.A., 2001. Estimation of biomass in a neotropical forest of French Guiana: spatial and temporal variability. *Journal of Tropical Ecology*, 17, pp.79-96.

De Gier, A., 2003. A new approach to woody biomass assessment in woodlands and shrublands. In: P. Roy. (Ed), *Geoinformatics for Tropical Ecosystems*, India, pp. 161-198. Easterling, D.R. et al., 2000. C

Elias M, Potvin C. 2003. Assessing inter- and intra-specific variation in trunk carbon concentration for 32 neotropical tree species. *Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere*. 33(6):1039-1045.

FAO, 2001. Deforestation continues at a high rate in tropical areas; FAO calls upon countries to fight forest crime and corruption (Press Release 01/61), FAO.

FAO, 2004a. Global forest resources assessment update 2005, Terms and definition, Rome. [Online] <http://www.fao.org/docrep/007/ae156e/ae156e00.HFM> (Accessed on February 6, 2007)

Gibbon, A., Baroody, J. & Hayward, J., 2009. Guidance on coffee carbon project development using the simplified agroforestry method., Rainforest Alliance.

Gibbs, H.K. et al., 2007. Monitoring and estimating tropical forest carbon stocks: making REDD a reality. *Environmental Research Letters*, 2(4), p.045023.

Glenday J; (2005): —Carbon Storage and Emissions Offset Potential in an East African Tropical Rainforest. *Forest Ecology and Management* 235.

Glenday, J., 2008. Carbon storage and emissions offset potential in an African dry forest, the Arabuko-Sokoke Forest, Kenya. *Environmental monitoring and assessment*, 142(1-3), pp.85-95.

Gole, T.W. et al., 2008. Floristic composition and environmental factors characterizing coffee forests in southwest Ethiopia. *Forest Ecology and Management*, 255, pp.2138-2150.

Hairiah, K. et al., 2011. *Measuring Carbon Stocks Across Land Use Systems: A Manual*, Bogor Indonesia: World Agroforestry Centre (ICRAF), SEA Regional Office.

Houghton, B.R.A. et al., 2003. Revised estimates of the annual net flux of carbon to the atmosphere from changes in land use and land management 1850 –2000. *Tellus*, 55B, pp.378-390.

ICRAF, 2007. *Wood Density Database*, Nairobi, Kenya.

IPCC, 2001. *Climate Change 2001: Working Group I: The Scientific Basis*. Cambridge University Press, New York.

IPCC, 2003. *Good practice guidance for land use, land-use change and forestry*. Institute for Global Environmental Strategies (IGES), Hayama.

IPCC, 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories* H. S. Eggleston et al., eds., Japan: the Institute for Global Environmental Strategies (IGES).

IPCC, 2007. *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.

IPCC, 2007. *Climate Change 2007: The Physical Science Basis. Summary for Policymakers*, Paris.

Isabirye, M., Verbist, B., Magunda, M., Poesen, J., and Deckers, J. (2008). Tree density and biomass assessment in agricultural systems around Lake Victoria, Uganda. *Afr. J. Ecol.*, Vol 46 (Suppl. 1), 59–65. DOI, 10.1111/j.1365-2028.2008.00930.x

IUCN, 2011, Red List of Threatened Species. Available at: www.iucnredlist.org [Accessed April 22, 2012].

Johan Cohn (march 2011). Variation in above ground biomass in Nyungwe Forrest, Rwanda

Ketterings, Q.M., Coe, R., van Noordwijk, M., Ambagau, Y. and Palm, C.A., 2001. Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. *Forest Ecology and Management*, 146(1-3): 199-209.

Kindermann G, Obersteiner M, Rametsteiner E, McCallum I: Predicting the deforestation-trend under different carbon-prices. *Carbon Balance and Management* 2006.

Lamlom SH, Savidge RA. 2006. Carbon content variation in boles of mature sugar maple and giant sequoia. *Tree Physiology*. 26:459-468.

Losi, C.J., Siccama, T.G., Condit, R. and Morales, J.E., 2003, Analysis of alternative methods for estimating carbon stock in young tropical plantations. *Forest Ecology and Management*, 184(1-3): 355-368.

Lu, D.S., 2006. The potential and challenge of remote sensing-based biomass estimation. *International Journal of Remote Sensing*, 27(7): 1297-1328.

Malhi, Y. et al., 2002. Forests, carbon and global climate. *Philosophical Transactions of the Royal Society*, 360(1797), pp.1567-1591

Medjibe, V. P., Putz, F. E., Starkey, M. P., Ndouna, A. and Memiaghe, H. R., 2011. Impacts of selective logging on aboveground forest biomass in the Monts de Cristal in Gabon. *Forest Ecology and Management* 262: 1799–1806

Mokany, K., Raison, R.J. & Prokushkin, A.S., 2006. Critical analysis of root: shoot ratios in terrestrial biomes. *Global Change Biology*, 12(1), pp.84-96.

Munishi, P.K.T., 2004. Carbon Storage in Afromontane Rainforests of the Eastern Arc Mountains of Tanzania: their Net Contribution to Atmospheric Carbon. *Journal of tropical forest science*, 16(1), pp.78-93.

Pearson T.R.H., Brown S., Ravindranath N.H., 2005. Integrating carbon benefits estimates into GEF

Pearson, T., Ravindranath, N.H. & Brown, S., 2005. Integrating Carbon Benefit Estimates Into GEF Projects, USA NY New York.

Pearson, T., Walker, S.M. & Brown, S., 2007. Winrock Terrestrial Sampling Calculator. In Sourcebook for Land Use, Land Use Change, and Forestry Projects. Fayetteville: BioCarbonFund Winrock International.

Petterson RC. 1984. The chemical-composition of wood. *Advances in Chemistry Series*. (207):57-126.

Peters-Stanley et al., 2013. Leveraging the carbon market to protect clean water. http://www.awra.org/meetings/HealthyForest2013/PP/slides/HFW_S12_Wilkerson_Ethel.pdf

Sasaki, N., Chheng, K. and Ty, S., 2012. Managing Production. Forests for Timber Production and Carbon Emission Reductions their Role in the Global Carbon Cycle. *Biotropica*, 14(3), pp.161-187.

UNFCCC, 2012. United Nations Framework Convention on Climate Change. Available at: <http://unfccc.int/2860.php> [Accessed February 25, 2012].

UNFCCC, Local data for wood density Reference NO. 16a, Available at: <http://cdm.unfccc.int/>, United Nations, 1992. United Nations Framework Convention on Climate Change (UNFCCC). [Online] <http://unfccc.int/resource/docs/convkp/conveng.pdf> (Accessed on July 7, 2006)

Zobel BJ, Buijtenen JPy. 1989. Wood variation: its causes and control. Berlin: SpringerVerlag.