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MONITORING THE IMPACT OF REDD+ IMPLEMENTATION IN THE UNESCO KAFA BIOSPHERE RESERVE, ETHIOPIA

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Abstract

In support of an active REDD+ programme in developing countries, the integration of data sources is necessary for the effective measuring, reporting, and verification (MRV) of carbon emissions reductions and increases in removals by sinks. In this research, optical earth observation data is integrated with community-based forest monitoring data to provide estimates of historical and current forest change trends. These data are further integrated with forest inventory based above-ground carbon stock estimates. This paper describes initial carbon stock estimates from forest inventories and proposes further steps to derive emissions estimates in support of a sub-national REDD+ MRV system in the UNESCO Kafa Biosphere Reserve in south-western Ethiopia.

Keywords: REDD+; MRV; optical remote sensing; forest monitoring; change detection; data integration; community-based monitoring; forest inventory

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1. Introduction

In discussions under the UN Framework Convention on Climate Change (UNFCCC), considerations for Reducing Emissions from Deforestation and Degradation in developing countries (REDD+) have been put forward as a means to mitigate the effects of global climate change. In anticipation of an active REDD+ carbon market, participating countries are expected to establish robust measuring, reporting, and verification (MRV) systems, following principles outlined by the International Panel on Climate Change (IPCC) for monitoring and reporting of national greenhouse gas (GHG) inventories. In developing countries, however, significant capacity gaps still exist, both in terms of data availability and processing capacity [1].

Key processes to be monitored and measured within a REDD+ MRV include deforestation and forest degradation, as well as carbon stock changes within key land use and land cover (LULC) categories. While deforestation, the conversion of forested lands to non-forest lands, is relatively straightforward to measure using earth observation time series data in combination with national maps and field data, measuring forest degradation presents significant challenges. Relatively large-scale degradation, such as that resulting from selective logging, can be assessed from space-borne satellite data using such techniques as spectral mixture analysis (SMA) [2]. Capturing small-scale degradation, on the other hand, continues to challenge the process of MRV for REDD+ [3]. Finally, measuring carbon stocks in key carbon pools is a key step in the estimation of emissions in a REDD+ MRV. Current technologies available to measure and monitor all of these processes and quantities carry with them uncertainties that must be properly quantified and reported in a REDD+ MRV [4], [5].

Improved data sources and methods have the potential to reduce the uncertainties within REDD+ MRV systems, which in turn would allow for an increase in estimated emission reductions while still maintaining a conservative approach where appropriate [6]. Further research into the implications of improved data sources and methods on uncertainties involved in REDD+ monitoring and MRV is currently needed. The knowledge gained from such research is vital in addressing the capacity gaps currently present in countries participating in REDD+. The development of methods to quickly and effectively measure, report, and verify emissions and removals by sinks is vital to kick-start meaningful implementation programmes in support of REDD+ in developing countries [3].

2. Study Area and Methods

The afro-montane coffee forests contained within the UNESCO Kafa Biosphere Reserve in the Southwest of Ethiopia represent some of the country’s last remaining cloud forests. These forests therefore represent an important national carbon store. Under the International Climate Initiative (ICI) of the German Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), this project aims to monitor the effect of REDD+ related project activities implemented under a programme by the Nature and Biodiversity Conservation Union (NABU) in the Kafa Biosphere Reserve on carbon emissions and removals.

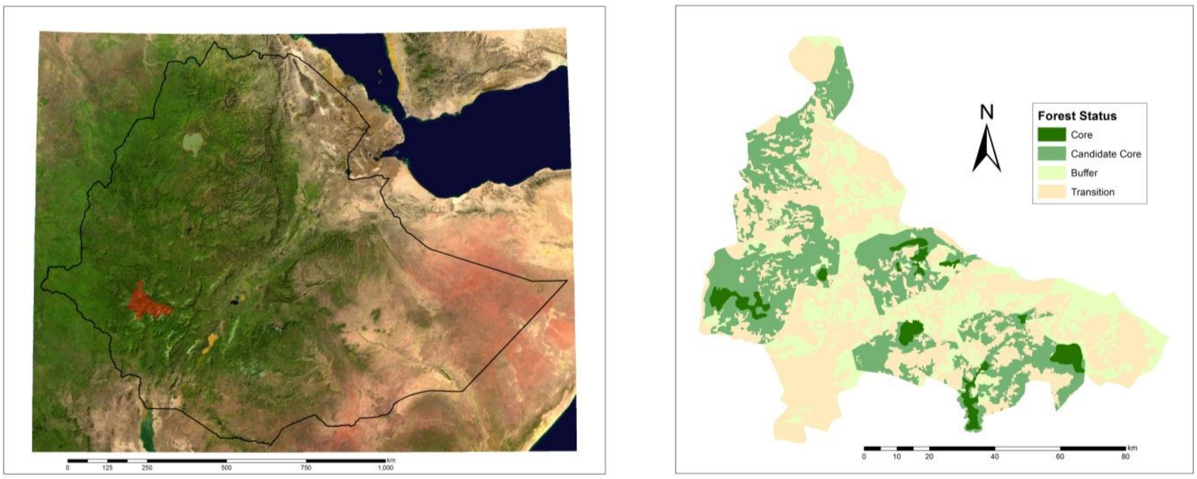

Figure 1. The study area is situated within the UNESCO Kafa Biosphere Reserve in the southwest of Ethiopia (left panel). The Biosphere Reserve is divided into Core, Candidate Core, Buffer, and Transition forest zones, pertaining to their protection status (right panel).

As defined by the International Panel on Climate Change (IPCC), Measuring, Reporting, and Verification (MRV) of REDD+ activities is centred around the calculation of CO_2 emissions over the reporting timeframe. Emissions throughout the reference and reporting periods are estimated from Activity Data (AD) and Emissions Factors (EF) according to the formula:

$$Emissions = AD\ X\ EF$$

Activity data relates to the areal change experienced by forests (generally measured in hectares) which is specifically induced by human activities (e.g. conversion of forest land to agricultural land). Emission factors refer to the quantity of carbon stocks released as a result of these activities per unit area (generally measured in tonnes carbon per hectare).

The MRV system developed in this study features the integration of several data sources (depicted in **Error! Reference source not found.**Figure 2), including remote sensing data, field-based forest inventory, and community-based monitoring data. Landsat5 TM, Landsat7 ETM+ and SPOT5 data are used to detect current and historical forest change trends at a medium to high resolution spatial scale. Remote sensing based change analysis is supported by a continually updated community-based database including geo-referenced data on forest change over time. Carbon stock changes associated with forest change are estimated through the integration of optical satellite data with field-based biomass measurements and forest carbon emission models. Carbon stock estimates are acquired through forest inventory data, where biomass in key pools (above-ground biomass being the most important in most tropical forests) is measured and scaled up to relevant forest strata. Carbon transfers between pools over time are represented by a carbon budget modelling approach, where activity and emissions data are integrated in a carbon budget model to estimate the fate of carbon in each pool as a result of land use change. By focussing on areas of active change identified using optical time series data and ground-based data integrated with ongoing monitoring of land use change trends, this study aims to demonstrate the utility of such an integrated approach to REDD+ implementation and monitoring. The main goal of establishing this integrated monitoring framework is to support REDD+ activities in Kafa with a consistent and transparent system for data collection, analysis, and interpretation.

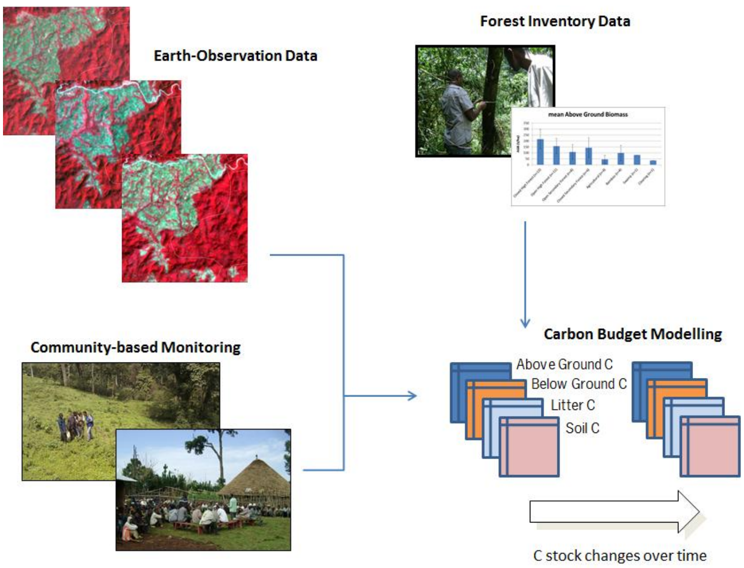

Figure 2. Integrated monitoring concept in support of measuring, reporting and verification (MRV) of REDD+ activities. Change data from earth observation data is supported by community-based monitoring data. These data are further integrated with forest inventory based carbon stock data in a carbon budget modelling environment to provide estimates of reductions in emissions and increases in removals over time.

3. Results and Discussion

To obtain initial estimates of carbon stocks in the different forest types within the Kafa Biosphere Reserve, a two-stage stratified random sampling procedure was employed to select plots in which to carry out forest inventory measurements. Forest strata were determined by first producing a map representing intact and disturbed forest was produced using an unsupervised classification of Landsat7 ETM+ data from 2010. This forest map was overlaid with the UNESCO Kafa Biosphere Reserve forest status map, indicated the current four forest categories under the Biosphere Reserve: Core, Candidate Core, Buffer, and Transition Zones, yielding eight classes representing intact and disturbed forests within each of the four Biosphere Reserve zones. Above-ground biomass (AGB) determined through this approach revealed that intact core and candidate core zones contain relatively high biomass as expected. Intact forest areas were shown to have much higher variability than disturbed forest areas. This variability likely results from image classification errors as well as natural heterogeneity within the forest classes. While future sampling for forest inventory data collection will benefit from improved forest change maps using historical optical time series data, the number of strata should also be changed to reflect natural heterogeneity within forest classes (e.g. due to altitude or soil types). Given the lower variability within disturbed forest strata, these preliminary results indicate that land use or disturbance history is an effective criterion for forest inventory sampling. An added advantage to using land use and disturbance history as a criterion for stratified sampling is that small-scale forest degradation, which typically occurs in Kafa forests as a result of household firewood harvesting [3].

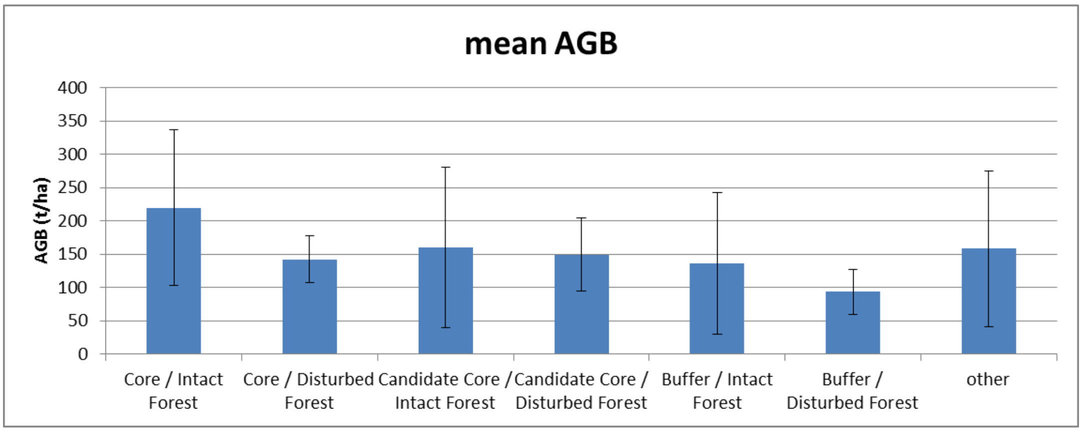

Figure 3. Mean above-ground biomass (AGB) measured in each of the UNESCO Kafa Biosphere Reserve forest zones stratified by disturbance history. Error bars represent standard deviation of the measurements.

4. Conclusions/Outlook

The next steps in this research are focussed on establishing a historical record of deforestation and degradation within the Kafa Biosphere Reserve using a combination of earth observation data and community-based disturbance and forest inventory data. This record will not only improve the forest inventory sampling methods described above, but will also allow preliminary estimates of carbon emissions and removals by sinks, since uncertainty in Activity Data has been shown to be the most problematic in estimating emissions [5]. The integration of satellite-based change data with community-based monitoring data on changes in local forest is expected to strengthen the MRV of REDD+ activities in the Kafa Biosphere Reserve. This research will help to determine how spaceborne optical data can be employed in an interim REDD+ monitoring framework in combination with field-based data streams, and how a REDD+ MRV can ultimately be used to kick-start REDD+ activities in the short-term.

References

[1] M. Herold, “An assessment of national forest monitoring capabilities in tropical non-Annex I countries: recommendations for capacity building.,” *GOFC-GOLD*, 2009.

[2] C. M. Souza, D. A. Roberts, and M. A. Cochrane, “Combining spectral and spatial information to map canopy damage from selective logging and forest fires,” *Remote Sensing of Environment*, vol. 98, no. 2-3, pp. 329-343, Oct. 2005.

[3] M. M. Skutsch, A. Balderas Torres, T. H. Mwampamba, A. Ghilardi, and M. Herold, “Dealing with locally-driven degradation: A quick start option under REDD+,” *Carbon balance and management*, vol. 6, no. 1, p. 16, Dec. 2011.

[4] J. Penman et al., “Good Practice Guidance for Land Use , Land-Use Change and Forestry,” *Intergovernmental Panel on Climate Change (IPCC)*, 2003.

[5] G. Grassi, S. Monni, S. Federici, F. Achard, and D. Mollicone, “Applying the conservativeness principle to REDD to deal with the uncertainties of the estimates,” *Environmental Research Letters*, vol. 3, no. 3, p. 035005, Jul. 2008.

[6] J. Pelletier, N. Ramankutty, and C. Potvin, “Diagnosing the uncertainty and detectability of emission reductions for REDD + under current capabilities: an example for Panama,” *Environmental Research Letters*, vol. 6, no. 2, p. 024005, Apr. 2011.