Forest Ecology and Management 329 (2014) 177–185

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Assessment and prediction of above-ground biomass in selectively logged forest concessions using field measurements and remote sensing data: Case study in South East Cameroon

Shu Gideon Neba [a,*], Markku Kanninen [a], Richard Eba'a Atyi [b], Denis Jean Sonwa [b]

[a] Viikki Tropical Resources Institute (VITRI), Department of Forest Sciences, P.O. Box 27, Latokartanonkaari 7, FI-00014, University of Helsinki, Finland
[b] CIFOR, C/o IITA Humid Forest Ecoregional Center, B.P. 2008, Yaounde, Cameroon

ARTICLE INFO

Article history:
Received 24 March 2014
Received in revised form 9 June 2014
Accepted 16 June 2014

Keywords:
Selective logging
Above-ground biomass
Allometric equations
MODIS 250 m products
South East Cameroon

ABSTRACT

Within the framework of the current REDD + initiative,[1] there is an urgent need for information to guide the development and implementation of strategies for the reduction of GHG[2] emissions from developing countries. Selective logging is one of the main sources of GHG emissions; but few studies in Cameroon have analyzed the impact of selective logging activities on above-ground biomass (AGB). This has resulted in a gap in essential information needed for the design of suitable forest management policies that can guarantee reductions in GHG emissions. In this study, we assessed the impact of selective logging on AGB in a forest concession in South-East Cameroon by quantifying AGB logged and AGB damaged by logging. We equally investigated through linear regression modeling whether the density of logging roads and NDVI[3] values (from MODIS 250 m) can be used to predict the quantity of AGB logged. Allometric equations were used to estimate AGB of trees, while the surface area of logging infrastructures and the unit area value (ha^{-1}) of AGB for the forest zone of Cameroon permitted the calculation of AGB damaged by logging. The study reveals that 0.78 trees ha^{-1}; an equivalence of 6.97 Mg ha^{-1} of AGB was logged. Logging affected a surface area of 85.04 ha; approximately 2% of the study area. This is equivalent to 0.02 ha ha^{-1} and 5.65 Mg ha^{-1} of AGB damaged. The density of the logging roads explained 66% of the variation in AGB logged, while the density of the logging roads and NDVI values together explained 73% of the variation. This study concludes as follows: (i) selective logging reduces AGB stock of the forest and the magnitude of the impact varies with the different activities of selective logging, (ii) ground-based measurements facilitated by GIS permitted to quantify the impact of selective logging on AGB, (iii) logging roads and NDVI (which can either be field measured or captured remotely) can be used to indirectly determine AGB logged, hence can contribute in the measurement and monitoring of forest degradation caused by selective logging, and (iv) the findings from this study can usefully support the design of sustainable forest management policies, which are beneficiary to the REDD + process in Cameroon.

1. Introduction

The REDD + mechanism is a global initiative, which is currently being discussed under the United Nations Framework Convention on Climate Change (UNFCCC) for the reduction of GHG emissions resulting from deforestation and forest degradation in developing countries (Angelsen, 2008; Dkamela, 2010). For the implementation of the REDD + mechanism to become effective, participating countries need to develop national strategies which ensure an efficient and precise monitoring, reporting and verification of emissions reductions from REDD + eligible activities. Such a system must be robust and transparent (Parveen et al., 2005; Kanninen et al., 2007; Ramankutty et al., 2007; Olander et al., 2008; Baldauf et al., 2009; Siwe et al., 2011; UNFCCC, 2011).

Furthermore, a successful monitoring of emissions reduction in developing countries amongst other things require that all factors, which cause deforestation and forest degradation be accurately

* Corresponding author. Address: CIFOR, C/o IITA Humid Forest Ecoregional Center, B.P. 2008, Yaounde, Cameroon. Tel.: +237 50659665; fax: +237 22227450.
E-mail addresses: gideon.shu@helsinki.fi (S. Gideon Neba), markku.kanninen@helsinki.fi (M. Kanninen), r.atyi@cgiar.org (R. Eba'a Atyi), d.sonwa@cgiar.org (D.J. Sonwa).

[1] Reduced Emissions due to Deforestation and Forest Degradation and the role of sustainable management, conservation, and the enhancement of carbon stocks.
[2] Greenhouse gas.
[3] Normalized difference vegetation index.

http://dx.doi.org/10.1016/j.foreco.2014.06.018
0378-1127/

and efficiently assessed (Carlos Souza et al., 2002; Souza and Roberts, 2005).

Selective logging is a major economic activity in much of the moist tropics and is also one of the main direct causes of forest degradation, which results in considerable ecological and environmental consequences. The opening of gaps in the forest canopy, the reduction of the overall canopy cover, the disturbance of soil surface, the modification of tree species composition, tree densities, size class frequency distribution, and the loss of forest carbon stocks as well as non-timber forest products are some of the consequences of selective logging activities to the forest structure and functions (Asner et al., 2006; Laporte et al., 2007; Angelsen, 2008; Dkamela, 2010; Rist et al., 2012; Vincent Medjibe et al., 2011). From an economic perspective, Guiseppe et al. (2009) and de Wasseige et al. (2012) report that in Cameroon for example, the forestry sector contributed 6% of the GDP in 2004, created 13,000 direct jobs and about 150,000 informal jobs in 2006 and generated 26% of all non-petroleum export revenues in 2004. Because of the important role that selective logging plays in the economies of most tropical countries, increasing areas of the tropical rainforest are being allocated to forest logging concessions. For instance Blaser et al. (2011) estimates that 403 million hectares of the tropical rainforest in ITTO producer countries has been officially designated for timber production concessions, while Laporte et al. (2007) reports that more than 30% of the Congo Basin rainforest has been allocated to timber production concessions. In Cameroon alone, the area of production forest (selectively logged forest concessions) is estimated at about 6 million hectares (de Wasseige et al., 2012).

One of the characteristics of selective logging is that unlike in a clear-cutting logging system where all trees in a forest stand are completely removed, only a few number of targeted commercial tree species are logged per unit area; usually measured in hectares. Some studies (Durrieu de Madron et al., 1998; Ruiz Perez et al., 2005, Brown et al., 2005; Vincent Medjibe et al., 2011) have demonstrated that the intensity of logging through this harvesting system in Central African countries is generally low. Nonetheless, it is considered that the cumulative impact of selective logging on AGB is considerable due to the large surface area under selective logging as described above. Also, selective logging involves the harvesting of large trees. This means that corresponding large gaps are opened in the forest canopy and it is expected that a large quantity of the forest above-ground biomass is loss in the trees harvested since large trees accumulate higher quantities of AGB than small ones (Vincent Medjibe et al., 2011; Sist et al., 2014). Infrastructural development notably: the construction of log yards (which are either clear-up sites inside the forest or enlarged spots at primary and secondary road sides for the preparation of the harvested trees into logs and for the temporal storage of the logs), logging roads and skid trails (to facilitate the circulation of heavy machinery and for the evacuation of the harvested logs) is an integral part of selective logging operations and also results in considerable impact on the forest carbon stocks (Durrieu de Madron et al., 2011; Vincent Medjibe et al., 2011), thus contributing to the quantities of GHG emissions that enter into the atmosphere.

Very few studies in Cameroon have analyzed the impact of selective logging on above-ground forest biomass stock. The only well-known study in this light is the REDD + pilot study by Siwe et al. (2011). Thus, there is still a crucial need for vital information to support the development of the in-country REDD + process; including the setting up of a national system for monitoring, reporting and verification (MRV) of carbon emissions reductions.

In this study, we analyze and provide quantitative information on the impact of selective logging activities on above-ground biomass. In addition, we investigate whether the density of the roads opened during logging and NDVI values from MODIS 250 m can serve as proxies for estimating above-ground biomass that is harvested in a selectively logged forest concession. By focusing on these two aspects, our aim is to support the development of the REDD + process in Cameroon; firstly by providing quantitative information, which can support the design of forest management policies, which are beneficial to the REDD + process and secondly, by proposing proxies, which can permit the indirect assessment of above-ground biomass harvested in a selectively logged forest.

2. Material and methods

2.1. Study area

The study was conducted within a sustainably managed forest management unit (FMU) located in the South East of the Republic of Cameroon (see Fig. 1); between latitudes 2°40′ and 3°09′N and longitudes 15°20′ and 15°46′E. The study area covers a surface area of 4400 ha out of the 122,294 ha total surface area of the FMU. The vegetation type in this region is described as semi-deciduous Guinea-congolaise dense tropical rainforest, characterized by a mixture of evergreen forest and semi-deciduous forest; with a high diversity of plant species (Heckelsweiller et al., 2001). According to Harris; cited by Heckelsweiller et al., (2001), about 1500 plant species grow in this area, of which about 2–5 species are endemics. The climate is described as wet equatorial climate with an average temperature of 24 °C. The influence of the monsoon and Harmattan winds results in four distinct seasons: a long dry season (December–May), a light wet season (May–June), a short dry season (July–October), and a heavy wet season (October–November). The average precipitation is between 1500 and 2000 mm per year and the elevation ranges between 200 and 1000 m asl. The common soil type is ferralsols (ferrallitic red soils); overlaid by a deep top humus layer that result from the decomposition of vegetal material (Heckelsweiller et al., 2001; SEBC, 2002; SEFAC, 2005).

2.2. Logging operations in the study area

The logging operations in the entire FMU are carried out in accordance with the prescriptions of its management plan, which indicates the yearly logging sequence, the tree species authorized for harvesting as well as the defined minimum exploitable diameter (DME) for the different commercial tree species. Tree felling is through the use of chainsaws and is carried out by skilled chainsaw operators. Skidders or bulldozers are used for moving the harvested trees to logs yards where they are prepared into logs and stored awaiting evacuation. The logs are then transported by heavy trucks either to a sawmill or to an export terminal.

Usually, roads of different categories are constructed for the evacuation of the harvested trees and for the passage of the heavy machinery used in the logging process. Although the design of the layout of the logging roads and log yards is guided by the location of the commercial trees as well as other sustainable management considerations, the planning of the layout of these infrastructures is however not an optimized process as in the case of reduce impact logging (RIL) practices.

2.3. Data and processing

Field measured data used in the study includes forest exploitation inventory comprising data of all commercial trees present in the study area and commercial trees that were effectively harvested in the site during the 2011 logging season. The inventory data contains the diameter at breast height (DBH) of the trees, the species names, and the quality of tree bole. The relative