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Estimation of aboveground volume, carbon stocks and NPP using terrestrial and satellite data of Amhara region, Ethiopia

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Abstract

The interest in forest productivity estimation has increased in the last years as it is very important for forest management and the estimation of carbon stock, wood and non-wood products, etc. However, there are no estimates of productivity and stored volume and carbon of different forest cover types throughout the Amhara region, Ethiopia. The objectives of this study are the estimating of volume, aboveground carbon and net primary productivity (NPP) of the Amhara region. This will be done by (i) terrestrial inventory), (iii) land cover classification and (iii) extrapolation of terrestrial estimates over the whole region based on the classified map. For this reason, inventory data were collected from 5 forest regions (Ambober, Gelawdiwos, Katassi, Mahiberesilasse and Taragedam) with 4 natural forests, 2 plantation forests and 1 exclosure. The sites were selected to address the different forest types (natural forest, woodland and shrub land) in different agroecological zones of Amhara region. The terrestrial inventory data were collected in 220 sample plots. Individual tree parameters such as DBH, height, core increment samples, etc were collected to calculate the volume, above ground carbon and NPP for the study regions. In order to be able to extrapolate our terrestrial estimate, we obtained a land cover map which matches our forest types. The digital land cover class of the Amhara region from the Amhara's Bureau of Agriculture and more regrouped in to (i) forest, (ii) shrub land, (iii) woodland and (iv) non-vegetation area. The final step, we extrapolated our terrestrial volume, carbon and NPP over the entire region. The methodology presented here demonstrated the possibility of estimating forest volume, carbon stock and their productivities for the forest area of the Amhara region. It can also be further improved by addressing more land cover types and integrating with fine resolution land cover maps.

Key words: Volume, Carbon, NPP, Land cover classification, Amhara

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1. Introduction

Forest ecosystems provide plenty of ecosystem goods and services (Hailemariam et al., 2015). Deforestation of tropical forests contributes for up to a fifth of global anthropogenic carbon dioxide emissions (Groom and Palmer, 2012). Global warming, due to the release of greenhouse gases, is causing unprecedented environmental and social changes. Therefore, the idea of Reducing Emissions from Deforestation and forest Degradation (REDD) was conceived by United Nations Framework Convention on Climate Change (UNFCCC) as the main carbon emission reduction mechanism by developing countries like Ethiopia (Vanderhaegen et al., 2015).

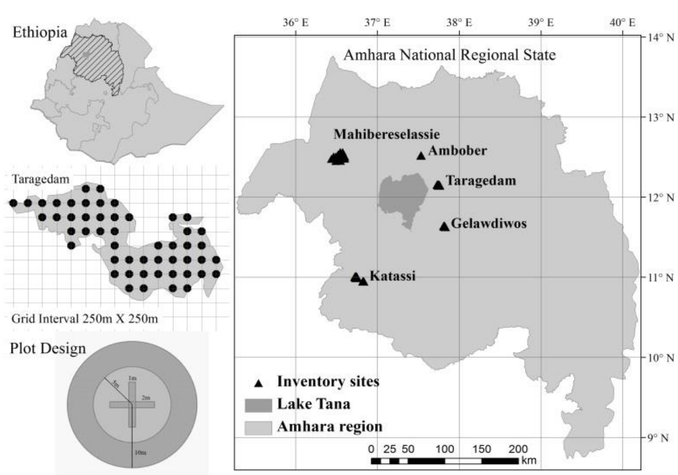
Forest management has been proposed as a way to mitigate the impacts of climate change and sustain the supply of ecosystem goods and services (Spittlehouse, 2005). Integration of terrestrial and remotely sensed satellite data are emerging approaches for forest management activities at a larger scale (Neumann et al., 2016). However, such large scale studies in the Amhara region as well as Ethiopia are lacking. Studies are mostly limited to small scales. Therefore, we aim to fill this gap with the following objectives: (i) estimation of aboveground volume, carbon and NPP of different forest types of Amhara region and (ii) Extrapolate terrestrial estimations over Amhara region.

2. Data

2.1. Inventory data

The forest inventory was conducted in Amhara region of Northwestern Ethiopia in 2014. Different forest types such as natural forest, planation and exclosure/shrubland under different agroecological zones were selected. The selected study sites are Ambober (exclosure), Gelawdiwos (natural and plantation), Katassi (natural and plantation), Mahibereselassie (natural) and Taragedam (natural) (Figure 1).

Figure 1Study area, sampling design and plot



Field inventory data came from 220 plots collected from July – September, 2014. We first delineated the forest sites and overlaid a systematic grid for each forest site. The systematic grid was used to get the full representation of each forest site and determine the number of sample plots to be measured. Different grid intervals and number of plots for the different forest types and sites were employed depending on the size of forest areas. A circular fixed area sampling plot was then established at each grid nodes for forest condition measurements. Each plot has two concentric circles and cross shaped plot at the center. All trees with greater than or equal to 10 cm diameter at breast height (dbh) found in the plot were measured. Species, dbh (cm), height (m), height to the live crown (HLC) (m) and tree ring were measured for those trees. Saplings greater than 1.3m height and less than 10cm dbh were measured with in the inner circle. We counted saplings based on dbh class (less than 4cm, 4cm – 6cm and 7cm – 9.9 cm) and measured a median height of every species in every dbh class. Seedling between 50cm and 1.3m height were counted in the central cross-shaped plot.

2.2. Land cover map

Studies on land use land cover classification of the Amhara region are generally seldom. The studies available are mostly limited to small scale areas (Garede and Minale, 2014; Tesfaye et al., 2014; Wondie et al., 2011). We obtained land cover map from the office of Amhara National Regional State (ANRS) for our extrapolation purpose. The ANRS produced a land cover map of 12 classes with 200m x 200m pixel resolution. The land cover classes are afro-alpine, bare land, cultivation, grassland, highland bamboo, natural forest, planation, shrub land, urban, wetland and water. Landsat satellite images were used for classification.

3. Methods

Given the small amount of forest resource, high species diversity and the current forest conservation policy by the state, it is nearly impossible to undertake destructive sampling for the development of allometric functions in Amhara region. However, very few allometric functions are developed for commercial tree species in Ethiopia (Berhe et al., 2013; Negash et al., 2013). Therefore, we used existing mixed species allometric functions developed for tropical forests by Brown, (1997) and Chave et al., (2005) for volume, biomass and carbon calculations(Temesgen et al., 2007). We calculated NPP as the sum of biomass increment, mortality, and turnover of foliage and fine roots (Neumann et al., 2015).

We first merged the 12 land cover classes classified by ANRS to 6 classes for fitting our terrestrial inventory land cover types. Therefore, plantation, highland bamboo and natural forest are grouped as forest. Afroalpine and shrubland are grouped into shrubland. Woodland remained as woodland. Bareland, cultivation, grassland and wetland are grouped as non-vegetation. Water and urban classes remained as water and urban, respectively. Our final land cover classes are (i) forest, (ii) shrub land, (iii) woodland and (iv) non-vegetation area as well as water and urban areas.

4. Results and Discussion

We calculated the volume, carbon and NPP of Forest, shrub and woodland forest types for the entire Amhara region as presented in Table 1. The forest carbon stock and productivity of forests are considerably low as compared with other tropical and European forests (Negash and Starr, 2015; Neumann et al., 2015).

Table 1 Volume, Carbon and NPP estimates of Amhara region

Land cover	Volume (m^3 ha^{-1})	Carbon (MgC ha^{-1})	NPP (gC m^{-2} $year^{-1}$)
	$\bar{x} * 10^6$	$\bar{x} * 10^6$	$\bar{x} * 10^6$
Forest	16.2	8.4	13.6
Shrub	52.7	21.4	55.7
Woodland	25.7	11.1	14.7

5. Conclusion

Our result is first attempt to present regional volume, carbon and NPP estimations under different forest types. The results can be incorporated in to a forest management plan of the Amhara region. The result and methods should be further improved by incorporating additional terrestrial data for different forest types and fine resolution land cover maps.

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