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Combretum-Terminalia vegetation accumulates more carbon stocks in the soil than the biomass along the elevation ranges of dryland ecosystem in Southern Ethiopia

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ABSTRACT

Dry land ecosystems including Combretum-Terminalia vegetation cover a wider area in the tropics. These resources are believed to greatly contribute for climate change mitigation in dry land ecosystems. Therefore, the objective of this study was to investigate biomass and soil carbon stocks of Combretum-Terminalia vegetation along the elevation ranges. A total of 60 nested sample plots of 20 m × 20 m were laid systematically along lower, middle and higher elevation ranges, representing 20 plots for each elevation. Within each nested sample plot inventory of woody species, litter and soil samples (0–15, 15–30 cm layers) were collected. The total carbon stocks (biomass plus soil) significantly ($p < 0.05$) differed among the three studied elevation ranges. The biomass carbon stocks were not significantly different between middle and higher elevations but both of them significantly ($p < 0.05$) differed from lower elevation, and also showed a decreasing trend from lower to higher elevations. However, inconsistence trends were observed for soil organic carbon and litter along the elevation ranges. It was concluded that woodland ecosystem has a potential to accumulate higher carbon stocks in the soil than the biomass and significantly vary along elevations.

1. Introduction

The increasing concentration of carbon dioxide (CO_2) and other greenhouse gases (GHG's) in the atmosphere is now widely recognized as the main cause of global warming. Carbon dioxide is accumulating in the atmosphere at a rate of 2.06 ppm (ppm = 10^6 molecules of air) per annum during the last ten year, the largest proportion of which resulting from burning of fossil fuels, cement production, deforestation and other land use changes (WMO, 2014). One of the strategies to reduce carbon dioxide from atmosphere through carbon sequestration in forest resources (Sheikh et al., 2009) and is well recognized under Kyoto Protocol (UNFCCC, 1997). These sinks can be in the living biomass (above-and-belowground), in soil including fine roots and in the deeper sub-surface environments (Nair et al., 2009) and locking carbon (C) in the products (IPCC, 2014).

Globally, dry land ecosystems store approximately 36% (743 Gt) of the total carbon stocks in the biomass with carbon sequestration rate of 0.4–0.6 billon tons of carbon per year. While forest ecosystems of Africa are estimated to store 356 Gt of carbon in the biomass. Of which dry land forest accounts for 59% carbon stocks (Campbell et al., 2008). Thus, managing the dry forest and woodland ecosystems is a carbon sequestering strategy to contribute to global carbon cycle (Smith et al., 1993; Dixon et al., 1994; Lal, 2005).

In Ethiopia, dry lands cover approximately 71.5% of the landmass (Lemenih and Teketay, 2004). Of which the woodland ecosystem covers 25.8%, which is equivalent to sequestering 1263.1 million tons of carbon (WBISPP, 2005; Yitebitu et al., 2010). However, loss of dry forests of Ethiopia is occurring through the destruction of habitat owing to extensive deforestation and conversion of forests to agricultural lands (Mekuria et al., 1999). The recognition of these resources in mitigating climate change on the other hand and also the effect of elevation range on biomass and soil carbon stocks have hardly studied (Houghton, 2007; Aide et al., 2012; Gillespie et al., 2012). While understanding the forest carbon storage and allocation along elevation ranges will help us better predict the response of dryland forests to regional and global carbon balance to future climate (Girma et al., 2014).

Besides, dry forest dependent communities would be beneficiaries from future payment for ecosystem services particularly carbon financing scheme through maintaining woodland resources (Alemu, 2012). Therefore, this study aimed at investigating the potentials of Combretum-Terminalia woodland in southern Ethiopia for biomass and soil carbon stocks and its variations along elevation ranges.

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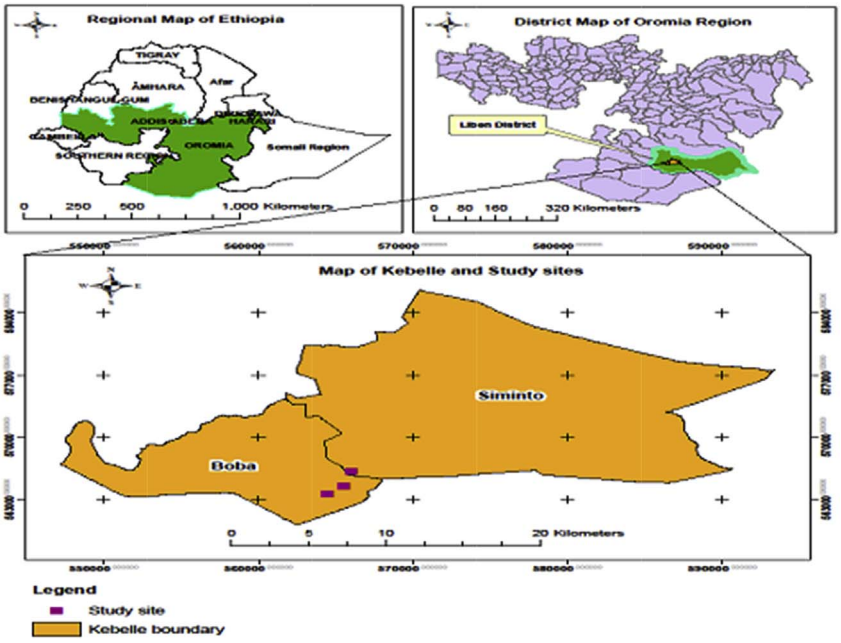

Fig. 1. Map of the study site.

2. Material and methods

2.1. Study area

The study was conducted in Liben Woreda of Guji zone, Oromia Regional State of Ethiopia. It is located at about 630 km south of Addis Ababa (Fig. 1). Geographically, it is situated between 5° 5′ 10" N to 5° 7′ 50" N latitude and 39° 32′ 30" E to 39° 36′ 30" E longitude. Except for the central mountain range and scattered volcanic cones and craters, the landscape is dominantly gentle elevation between 1000 and 1600 m.a.s.l (Coppock, 1994).

According to Ethiopian National Meteorology agency weather data from 2000 to 2014, the mean minimum and maximum temperature of the study area was 16 °C and 28 °C, respectively. The mean annual rainfall was 609 mm. Vegetation of study areas falls under *Combretum-Terminalia* dominated woodland (Haugen, 1992). Besides, species such as *Combretum molle (D. Don), Terminalia brownii (Fresen.), Acacia bussei (Harms ex Sjostedt), Pistacia lentiscus (Mart.), Commiphora africana (A. Rich.)Engl., Lannea rivae (Chiov.) Sacleux, and Olea europaea subsp. Cuspidate (Wall. G. Don)* are commonest trees species in the studied area. The upland soils are shallower, well-drained, red sandy soils and the vertisols in the lower elevation (Coppock, 1994).

2.2. Sampling techniques

Three elevation ranges, namely higher (1520–1620 m), middle (1420–1520 m) and lower (1320–1420 m), were purposively set along elevation ranges in the study area. A systematic random sampling technique was employed. A total of sixty plots (2 sites x 3 elevation ranges x 10 sample plots) sized 20 m × 20 m were systematically established. Transects were laid using GPS and compass. The sample plots were used to collect biomass, litter and soil C stocks data. In order to eliminate any influence of the edge effects on the forest biomass, all sample plots were laid at least 150 m away from nearest roads.

2.3. Woody species inventory and identification

All trees in the sample plot with diameter at breast height ≥ 5 cm, and total tree height ≥1.5 m were measured and recorded. Besides, trees on the border of the plot were measured if ≥ 50% of their basal area fall wthin the plot otherwsie were excluded. Trees with their trunks inside the sampling plot and branches outside were also considered (MacDicken, 1997). In the occasion of multi-stemmed woody species, each stem was measured and the equivalent diameter of the plant calculated as the square root of the sum of diameters of all stems per plant (Snowdon et al., 2002).

$$d_e = \sqrt{\sum_{i}^{n} di^2}$$

where d_e is diameter equivalent (at breast or stump height), d_i is diameter of the ith stem at breast or stump height (cm).

Plant specimens were collected, dried, and identified at the National Herbarium of the Addis Ababa University and using published volumes of Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1995; Edwards et al., 1997, 2000).

2.4. Litter and soil sampling

Litter samples were collected in a 1 × 1 m^2 square sub-plot within the sixty larger plots. A total of five sub-plots (four at corners and one in the center) were used for litter collection. The litter samples in this study comprised dead leaves, branches, twigs, flowers, and dead wood. The fresh litter within each 1 m^2 sub plot was collected and weighed on the site. A composite sample of 100 g was taken for laboratory analysis to oven drying at temperature of 65 °C for 24 h until it attained constant weight. This helped to determine the dry to fresh weight ratio. The total dry weight was determined in the laboratory using dry ashing method as per Allen et al. (1986). Finally, carbon in leaf litter for each site was determined.

Soil samples for determination of soil organic carbon (SOC) were collected from the five sub-plots that were used for litter collection. A total of 120 soil samples (2-sites replication x 3-elevations x 10-plots x 2- depths) were collected from soil depths of 0–15 and 15–30 cm. The soil samples for carbon analysis were collected using augur of 8 cm diameter while soil samples for bulk density were collected with soil core samplers of (5 cm diameter × 5 cm tall, 98.2 cm^3). All samples were placed in paper bags with appropriate label. The soil samples for carbon analysis were air dried and sieved with 2 mm sieve for SOC determination to mineral soil fraction of < 2 mm. The C content of the