Modeling carbon dynamics of dry tropical Afromontane forest ecosystem in Ethiopia

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Introduction

Understanding the past and current trend and modeling carbon dynamics of forest ecosystem is crucial for effective implementation and measuring, reporting and verification (MRV) of REDD+ and other many forest management and conservation initiatives. This study was conducted in Ethiopian to estimate carbon stock and model carbon cycle in remnant pristine forest ecosystem. For this study, Biogeochemical-mechanistic models, Biome-BGC Version 4.1.1,(Thornton et al., 2002) first developed as FOREST-BGC was used which depicts forest ecosystem biochemistry (Running & Coughlan 1988). The Biome-BGC model simulates, on day or monthly resolution time, the cycling of energy, water, carbon and nitrogen within a given ecosystem (Thornton 1998) or species level (Pietsch et al. 2005).

Objectives

- Estimating carbon stock of Ethiopian forest using local terrestrial data derived from forest inventory
- Evaluating the applicability of mechanistic ecosystem model Biome -BGC for Ethiopian dry-Afromontane forest carbon stock estimation

Methods

Model spin up and simulation

We started model simulation with spin up or self-initialization using pre-industrial N_2-deposition and CO_2- concertation because there is no available initial observation data for study forest. Hence, spin up creates steady state or virgin forest in the temporal averages of all ecosystem pools. It started with a low carbon content in the leaf pool (e.g. 1 gm^{-2}) and a certain soil water saturation and is terminated when the mean soil carbon content (i.e. the last pool to reach a steady state) does not change by more than 0.5 gm^{-2} between two successive simulation periods.

After a steady state normal simulation was done in each of four study sites for 250 years using increasing N_2-deposition and CO_2-concentration between 1765 and 2014. The aboveground carbon, soil carbon and net primary productivity (NPP) were derived from field inventory data of 156 sample plots in all study sites and used for model calibration and validation. NPP was derived from tree core increment taken from representative tree trunks at DBH height.

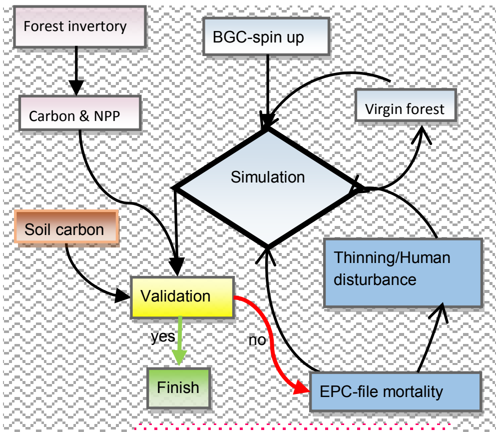

Fig.1: BGC simulation flow diagram

Simulation requirments

Biome-BGC uses three main input files:

i) **Meteorological ata**: daily minimum and maximum temperature, incident solar radiation, vapor pressure deficit and precipitation. For our modeling the metrological data covered the period between 1779 to 2010 was extracted for the nearest 1 km day met grid cell. This 31-year record was repeated as necessary to create meteorological records for model runs of longer duration;

ii) **Model initialization file**: that contains information on how to run the model and the site information, such as soil texture, effective soil depth, aspect and altitude. In addition, it includes N_2-deposition and fixation, CO_2 file with average annual atmospheric CO_2 concentrations;

iii) **Ecophysiological constants (EPC-files)**: that describes the biomes to be modelled. The Congo-basin tropical evergreen broadleaved forest (EBF-file) was adopted for our model simulation in four of the study sites.

Results

Table. 1. Inventory results of the four study sites

Inventory parameters	Gelawdiwos	Injibara	Metema	Taragedam
Volume (m^3/ha)	101.7±68.4	79.3±60.6	29.25±10.15	38.8±58.7
Volume increment (m3/ha/yr)	4.3± 2.6	3.7±2.5	1.28± 0.47	2.1± 2.7
Biomass (ton/ha)	120.8±92.9	82.5±68.6	26.08±10.97	34.1±69.3
Biomass increment (ton/ha/yr)	4.2± 2.8	3.6±34.3	1.05± 0.43	0.8± 3.0
Carbon (ton/ha)	60.4±46.5	41.2±34.3	13.04±5.49	17.0±34.7
Carbon increment (ton/ha/yr)	2.1±1.5	1.8±1.4	0.53±0.22	0.8± 1.5
NPP (g/m²/yr)	643.1±416.1	533.6±421.1	156.4±63.0	245.2±457.1
Stand density index (SDI)	374.1±227.5	221.6±137. 4	155.0±58.1	101.7±161.7

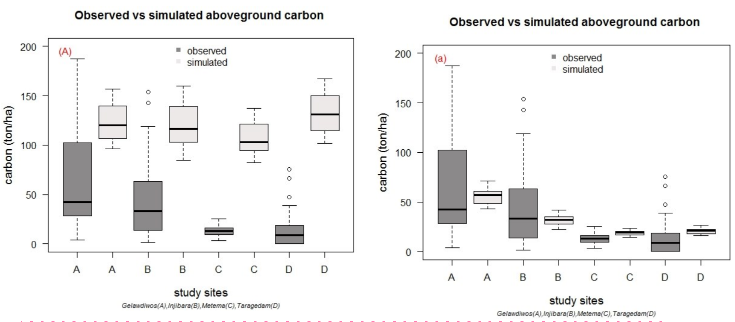

Fig.2 Observed vs BGC-simulated aboveground carbon (without thinning (A) with thinning (a)).

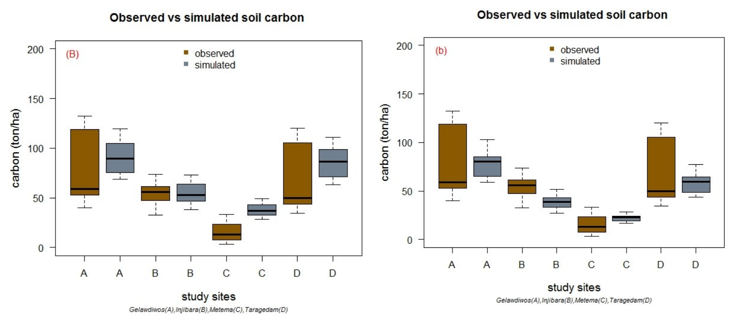

Fig.3: Observed vs BGC-simulated soil carbon without thinning (B) with thinning (b).

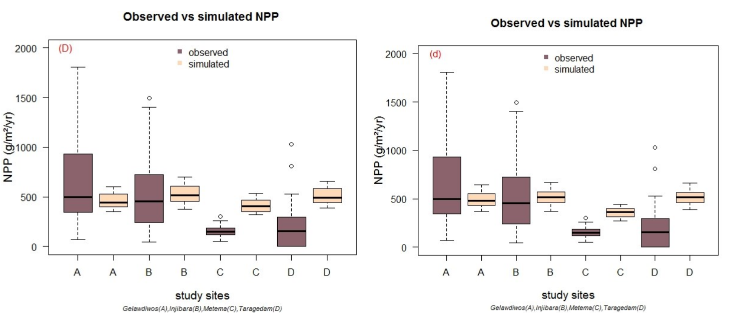

Fig.4: Observed vs BGC-simulated NPP without thinning (D) with thinning (d)

The total aboveground carbon density ranged from 120.80 ton/ha to 26.08 ton/ha across the study sites (Table 1). The average aboveground increment of the two study sites (Gelawdiwos and Injibara) is found within a range of some moist tropical forest growth rates (Djomo et al., 2011) though the two study sites (Metema and Taragedam) has showed very low mean carbon increment. This implied that there is serious human interference or biomass extraction which is in line with the low stand density index result of the two sites.

The simulated result using Congo-basine evergreen broad-leaved forest (EBF) have depicted higher predictive aboveground carbon (Fig.2 A). Because Biome–BGC simulation accounts fully-sotcked old aged virgin forest. As a result the sumulated abveground stock found to higher than live forest carbon stock of study sites which are under great humanc distrubance presssure. Hence, Biome–BGC was parametrized in a way that mimic our currernt distrubed forest carbon stock through thinning intervention (Fig 3 a). The proportion of thinned inensity was done according the stand density index (SDI) (Gelawdiwos,3%,Injibara, 6%; Metema 9% and Taragedam, 12%). However, no siginigfican difference has seen between simulated and observed soil carbon and NPP(Fig. 1 B &C respectively). In addition, thinning intervention didn´t show a clear difference on soil carbon and total NPP.

Conclusion

The whole study sites showed low forest volume and cabon stock which shows high human intereferance and biomass extraction.The default Congo – basin tropical evergreen broadleaved forest (EBF-file) is less aplicable for aboveground carbon stock estmation but with simple human distrubance intervention it depicts our disturbed forest carbon stock and NPP.

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