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Approach to data collection for soil carbon modelling in Benin

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Abstract			
Carbon stocks and changes in carbon stocks in forest ecosystems can be estimated either by direct measurements or using modelling approach. Given that direct measurements are expensive and time-consuming, modelling is preferred in countries with limited resources like Benin. But, in practice modelling is complemented by direct measurements in order to increase the validity of the model estimates. The objective of this technical paper is to provide guidance to collect data through direct measurements in order to improve the applicability of model-based approach to estimate soil carbon stocks and its changes in forest ecosystems. Further objective is to encourage the estimation of soil carbon pool in developing tropical countries.			
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1 Introduction

Forest soils are large carbon pool subject to fast dynamics in the tropics due to favorable climate (temperature, precipitation) conditions for organic matter decomposition (Mäkipää et al. 2012). However, this pool is less studied in tropical Africa owing to lack of resources and technical capacities (Guendehou et al. 2014). As a result, when estimating carbon balance in forest ecosystems in Benin or elsewhere in tropical countries, the assumption that there are no changes in carbon stock in soil is usually used. This certainly leads to an underestimation of the carbon balance. Forest soil carbon stocks and stock changes can be estimated using two approaches: direct measurements and modelling.

The direct measuring of soil carbon changes are expensive and time-consuming. Given the limited resources available for research in many tropical countries including Benin, a reasonable approach would be to apply the soil carbon modelling for estimation of soil carbon stock changes. This approach needs, however, empirical data on the rate of litter decomposition, as litter input and litter decomposition are the main drivers of the soil carbon stock changes.

This technical paper provides guidance on how to generate data, needed for soil carbon modelling, using the litter bag experiment. It also describes how direct soil carbon measurements can be conducted to support the modelling.

2 What is litterbag experiment?

The litter bag experiment studies the microbial decomposition of litter by measuring the mass loss and the changes in chemical composition of litter. A certain amount of litter is placed in a polyester bag, sewed and left on the ground in the forest, collected after a defined time and analysed for mass loss and chemical composition. The experiment is implemented in forest in prevailing climatic conditions.

3 Material for the experiment

Litter types usually include leaf litter, woody litter, and fine roots. In deciduous and semi-deciduous tropical forests, where trees lose an important amount of leaves to limit the water requirements in dry season, leaf litter may be a dominant litter type and a major source of carbon into the soil. When selecting litter types for soil carbon estimation, priority should be given to leaf litter from dominant tree species.

The material we used in our experiment conducted in the Lama forest, in Benin, consists of leaf litter of five dominant tree species: *Afzelia africana*, *Anogeissus leiocarpa*, *Ceiba pentandra*, *Dialium guineense*, and *Diospyros mespiliformis* (Guendehou *et al*. 2014). The following activities are required to implement the experiment:

- Collect senescent leaves ready to fall from the trees by hand; stick can also be used;
- Collect leaves separately by species and mix leaves of the same species;
- Do not collect the leaves on the forest floor as they are considered partly decomposed;
- Dry the leaves at open-air followed by oven-drying at 75 ºC to constant weight; to minimize the loss of material and changes in decomposability likely to occur at high temperature one may dry samples at 40 ºC for which the constant weight is reached after a longer period;

- Use a litterbag made of polyester net fine mesh (we used 0.33 mm); a square 20 x 20 cm bag;
- Place in the bags, between 20 and 30 g of oven-dried leaves. Sew the bag with a polyester string (cotton must not be used since it decomposes);
- Place the bags on the forest floor in 4 or more plots; the distance between plots should be large enough to minimize the spatial autocorrelation between plots (Guendehou et al. 2014) (Figure 1);
- Collect litterbags every 4 weeks (Figure 2) from each replicate (each plot), collect the first row at 4 weeks, the second row at 8 weeks and so on. Our experiment lasted 24 weeks;
- Brush out carefully and clear of foreign material (soil, roots, fauna) the outside of the collected bags;
- Open up the bags carefully to retrieve the remaining litter material;
- Clean the litter carefully of all possible ingrown material (roots or shoots of plants, soil animals);
- Dry the cleaned litter immediately after collection in order to stop decomposition process (dry first in open-air if oven is not available close enough to the study site);
- Dry then the remaining litter in oven at 75 ºC to constant weight;
- Weigh the remaining litter to determine the mass loss, which is reported either as the proportion of mass lost relative to the initial mass:
  $$Mass_{loss}(\%) = 100 * (M_i - M_r)/M_i \qquad (1)$$
  or as the proportion of mass remaining relative to the initial mass:
  $$Mass_{rem}(\%) = 100 * M_r/M_i \qquad (2)$$

where $Mass_{loss}$ = mass loss (%), $Mass_{rem}$ = mass remaining (%), M_i = initial amount of litter placed in the bag, M_r = mass of remaining litter after a certain time of decomposition;

- Keep the remaining litter in a freezer in a plastic bag if the chemical analyses are not done on the same day after having measured the mass loss;
- Implement the chemical analyses in the laboratory to determine the litter quality (Guendehou et al. 2014) (Figure 4).


Figure 1: Litterbags exposure in the field


Figure 2: Litterbag collection

Figure 3: Decomposed leaf litter removed from the bag

Figure 4: Chemical compounds extracted in laboratory

4 Climate data needed for decomposition study

The climate parameters commonly used in the decomposition models (for e.g. Yasso07) include average monthly temperature and precipitation. Data on these parameters can be collected from local measurements especially from the meteorological station located in or closest to the study area. Data can also be obtained from global databases such as the IPCC Data Distribution Centre (http://www.ipcc-data.org/ddc/ddc_about.html). In our study we used the climate data collected by the meteorological stations closest to the study area (Guendehou et al. 2014).

5 Data generated by the experiment

5.1 Litter mass loss

The mass loss was measured every four weeks during 24 weeks for each species studied. Exponential function below was fitted to observations on mass loss to derive the decay models for each species (Figure 5),

$$M_t = M_0 \times e^{-kt},$$

where k = decay rate, M_t = remaining mass at time t, M_0 = initial mass at time t = 0 (Olson 1963).

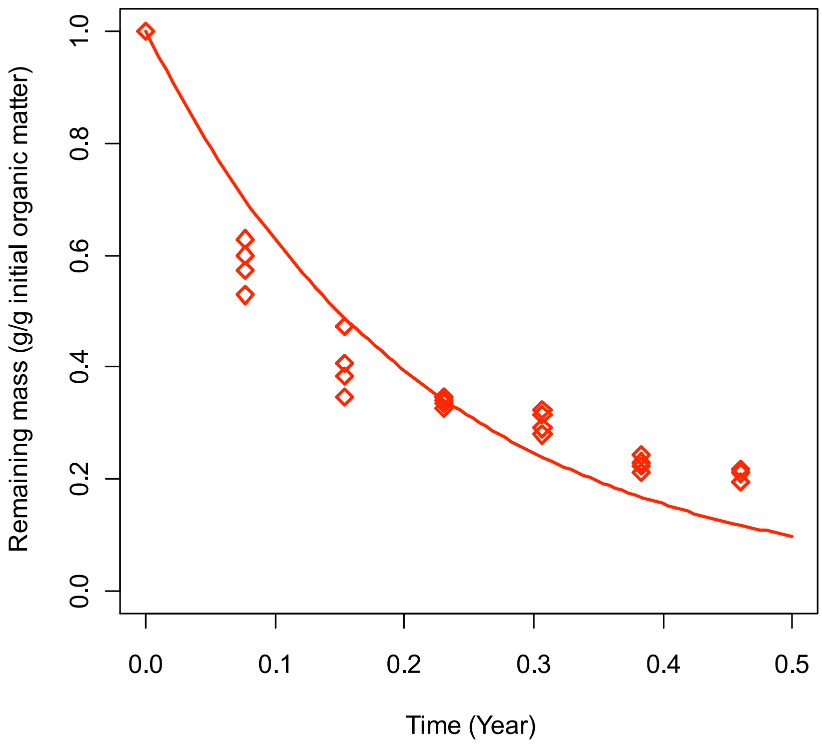

Figure 5: Mass loss relative to time and decay model of *Afzelia africana* as example (according to Figure 5 in Guendehou et al. (2014)).

5.2 Litter chemical composition and its changes

The initial chemical composition and the chemical composition of the decomposed litter were determined in a laboratory (Guendehou et al. 2014). The samples were analysed for C/N-ratio, ethanol-soluble compounds, water-soluble compounds, acid-hydrolysable compounds, and compounds neither soluble, nor hydrolysable.

5.3 Litter decay rate and decay rate of each chemical component

Using the decay functions as indicated above (Figure 5), we determined the decay rate of the litter as a whole and the specific decay rate of each chemical fraction (Guendehou et al. 2014).

6 Applicability of data generated by the litterbag experiment

The data generated by the experiment were used as input to test the validity of the dynamic soil carbon model yasso07 (http://www.syke.fi/projects/yasso). The model was then recalibrated in order to improve its applicability in tropical conditions (Guendehou et al. 2013). The dataset can also be used for testing and development of other soil carbon models.

7 Soil sampling for carbon stock measurement to support soil carbon modelling

- Direct soil carbon measurements provide useful data that can be used to test the validity of soil carbon models and to recalibrate them if needed. It thus increases the credibility of the model results. These measurements can also be used to establish the reference level i.e. the initial soil carbon stock used as starting values for the estimation of changes in carbon stocks using the model application. The following soil sampling approach can be applied in order to estimate soil carbon stock. Consider the 0-30 cm soil layer for sampling as recommended by the IPCC (2006) guidelines, since the sensitivity of this layer to anthropogenic perturbations and the extent of the carbon dynamics therein are more pronounced than in deeper layer (Mäkipää et al. 2012);

- In a square or rectangular plot, collect a vertical column of 30 cm soil in each corner and in the middle of the plot; OR
- In a circular plot, collect a vertical column of 30 cm soil at the main compass point (east, south, west and north);
- Take samples that represent specified area (e.g. cylinder with diameter of 70 mm) from litter/organic layer. Measure the thickness of the litter/organic layer.
- Take samples with known volume (area and height) from the mineral soil which allows to calculate the amount of soil organic matter and soil carbon in the 0-30 cm layer per ha.
- Separate the soil core into layers (e.g., 0-10 cm, 10-20 cm, and 20-30 cm), to find out the depth distribution of soil organic matter and carbon, and for easier sample handling.
-
- Use a ruler and a sharp knife to collect from the soil core sample the first 10 cm, then the second 10 cm and finally the third 30 cm in separate plastic bags;
- Dry the samples in open-air while in the field to prevent them from harmful microbiological activity;
- In the laboratory, keep the samples in a freezer in the plastic bags, if the analyses cannot be done immediately when back from the field;
- Determine the soil carbon of each sample collected separately in the laboratory using the method of loss on ignition or other methods/device such as the CHN analyser.

8 Implications for the development

This technical paper helps to generate country-specific data on soil carbon based on measurements and modelling. These data provide useful information for decision making on forest policies as well as for development and implementation of sound forest management practices contributing to ecological and environmental benefits. The paper also contributes to enhance the technical and scientific capacity of soil researchers and scientists.
Furthermore, the application of reliable country-specific data, provided by methods described in this paper, to estimate the carbon stocks generated by the forest management activities increases the credibility of the carbon credits generated and the participation in the carbon market: Clean Development Mechanism, Nationally Appropriate Mitigation Actions, Reducing Emissions from Deforestation and Forest Degradation in Developing Countries of the United Nations Framework Convention on Climate Change.

9 Conclusion

This study has contributed to fill data gap on soil organic carbon in Benin and the results have improved applicability of the soil carbon model for simulations in tropics. Additional work need to be done on direct soil carbon measurements in order to complement the results generated by the modelling.

10 References

Guendehou, G. H. S., Liski, J., Tuomi, M., Moudachirou, M., Sinsin, B. and Mäkipää, R. 2013. Test of validity of a dynamic soil carbon model using data from leaf litter decomposition in a

West African tropical forest. Geoscientific Model Development Discussion, 6, 3003-3032, doi:10.5194/gmdd-6-3003-2013.

Guendehou, G.H.S., Liski, J., Tuomi, M., Moudachirou, M., Sinsin, B. and Mäkipää, R. 2014. Decomposition and changes in chemical composition of leaf litter of five dominant tree species in a West African tropical forest. Tropical Ecology 55 (2): 207-220.

IPCC. 2006. Guidelines for national greenhouse gas inventories. Kanagawa, Japan, National Greenhouse Gas Inventories Programme.

Mäkipää, R., Liski, J., Guendehou, S., Malimbwi, R. and Kaaya, A. 2012. Soil carbon monitoring using surveys and modelling - General description and application in the United Republic of Tanzania. FAO Forestry Paper 168. FAO 2012, ISBN 978-92-5-107271-4 ISSN 0258-6150 available at: (http://www.fao.org/forestry/32545-078ade939238335dea8570f134cd68fca.pdf).

Olson, J.S. 1963. Energy storage and the balance of producers and decomposers in ecological systems. Ecology 44: 322–331.