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Concept Note

Soil properties and carbon estimation of forest ecosystems in Georgia, South Caucasus

Rationale

In the frame of the first National Forest Inventory, NFI, a lot of data about Georgian forests will be generated in 2019 and 2020. Based on these data not only a qualitative and comprehensive description of forest ecosystems will be possible, but also a lot of quantitative calculations i.e. concerning area, spatial distribution of tree species or timber volume will be made. Information about the basal area, height, diameter and the annual increment of the most commercial tree species (Beech, Oak, Hornbeam, Pine, Fir and Spruce) will allow the calculation of biomass and carbon stored in the forests, as well as the forest sequestration potential for carbon dioxide on an annual, or 10-years basis. These figures are important in the frame of international and national efforts of mitigating climate change effects, as forests are the most important terrestrial ecosystem to reduce the CO_2 concentration in the atmosphere.
The NFI is a grid-based forestry inventory. At each sample plot (3.6km x 3.6km), more than 80 forest-stand related parameters will be assessed. For a comprehensive forestry inventory, an additional soil survey delivering i.e. information about ecological site parameters (fertility, water storage capacity) and carbon content is necessary.
As part of the commitment under the United Nations Framework Convention on Climate Change (UNFCCC), the government of Georgia ensures regular reporting of climate-change-related issues in the form of national communications and biennial update reports. In the First Biennial Update Report to UNFCCC the greenhouse gas emission of Georgia in 2013 was about 16.7 M tons CO_2 equivalents without consideration of the Land Use, Land-Use Change and Forestry (LULUCF) sector. Considering the LULUCF sector this value was estimated to approx. 12.6 M tons CO_2 equivalents. This indicates, that forests are considered to have a net carbon sequestration capacity in the range of 3 to 4 M tons CO_2. A net carbon sink is possible, if the annual growth of biomass (mainly in form of wood) is outweighing the loss due to removal of timber and firewood harvested and possible soil degradation processes (e.g. increased humus mineralization) caused by human intervention. But this – simplified - hypothesis is only valid, if the annual harvest in the forests is equal or less than the annual increment. As complete and reliable data about the exact harvested amount per year and the forest above-ground biomass and annual increment are still not existing - but will be generated in the next two years with the implementation of the first national forest inventory and the forest management inventories parallel going on -, the potential of Georgian forests as “net carbon sinks” is not yet clear and has to be proved.

Soil is the largest pool of organic carbon on earth. It interacts strongly with the atmosphere, climate and land cover change (Jobbagy and Jackson, 2000). Soil organic carbon (SOC) dynamics are therefore, among others, driven by changes in climate and land cover or land

use. In natural ecosystems, the balance of SOC is determined by the gains through plant and other organic inputs and losses due to the turnover of organic matter (Smith et al., 2008). Organic carbon stocks in soil depend on the balance between gains and losses of C. Biotic characteristics such as biomass production and microbial abundance, mean annual precipitation and temperature, soil characteristics including texture and lithology and human activities, like land use and management, influence the processes of SOC storage or losses. Concerning the carbon of below-ground biomass and the carbon pool of Georgian forest soils, no comprehensive data are existing and a thorough assessment is needed. Therefore, as a consequence of lacking precise and statistically robust data, Georgia is only able to report on a Tier 1 basis to UNFCCC, i.e. working with default values from similar European forest ecosystems. It must be emphasized here that this does not present a serious problem for Georgia´s commitments in the frame of the FCCC, as CO_2 emissions from above- and below-ground biomass and soil organic matter losses in Georgian forests are and will be relatively low. Forest cover conversation rates or losses are quite small, and in the New Forest Code an ecosystem-based forest management approach is foreseen to be implemented, which will not allow ecosystem disturbances causing dramatic biomass loss.

Nevertheless, with the double purpose to improve ecological data about forest ecosystems as well as the data base for reporting in a near future on a Tier 2 or Tier 3 basis, a project on soil properties and carbon assessment is planned to be carried out in the frame of the NFI from 2019 until 2021.

Objectives

Overall objective of the research project on “soil & carbon” assessment is to broaden the ecological data base about forest ecosystems of Georgia for wise and comprehensive planning and management decisions in the future, following the paradigm shift foreseen in the new forest code from traditional forest exploitation toward ecosystem-based forest management.

Specific objectives are:

- To gather comprehensive information on physical soil properties to describe and evaluate the water regime and cycle and soil oxygen supply in forest ecosystems.
- To gather comprehensive information on chemical soil properties to describe and evaluate the soil-forming processes and the nutrient availability.
- To gather comprehensive information – quantitatively and qualitatively – of the organic surface layer and the mineral soil to describe and evaluate nutrient conditions and cycle in forest ecosystems.
- To gather comprehensive information about the carbon content in the organic surface layer and the mineral soil to describe the carbon cycle in forest ecosystems and for reliable and robust data-based (Tier 2 or Tier 3) reporting in the frame of Georgian government´s international commitments.

Methodological approach of selecting soil sample plots

General considerations:
Due to the big amount of NFI grid-based sample points (more than 2000 for the whole country) it is not possible to take soil samples on all these points. Considering the time for field work and laboratory analysis this endeavor would overstretch the physical and human capacity of the country., In one year only a limited amount of soil sample plots can be managed.
Georgian forests are almost all natural forests. Therefore, as a first step, the description of forest ecosystems by G. Nakhutsrishvili (The Vegetation of South Caucasus) and other relevant literature from forestry and botany is used to identify the major forest ecosystem of Georgia. In a second step, with the support of local knowledge (foresters, farmers, etc.), concrete forest ecosystem sites, which fulfil the criteria showing no or only very few human influences, are selected. Third step is to complement the forest information of these sites with data from the Soil Map and Geological Map of Georgia as a criterion for soil sampling diversification (by example: beech forest on limestone (high pH) soil and beech forest on sandy (low pH) soil). Forth step is the consideration of some additional criteria to build strata for soil sampling i.e. landscape morphology, altitude and exposition. Especially, exposition, or better the different microclimate conditions on North- and South- exposed slopes, are expected to have a considerable influence on humus formation and mineralization rates. When ever possible, soil samples will be taken on these exposures. Final step is to check the similarity of the near-by NFI grid sample points with the selected site. If a high similarity exists, soil sampling will be done at the NFI sample point.

In the book “The Vegetation of Georgia, South Caucasus”, G. Nakhutsrishvili describes the following major forest ecosystems:
Lowland hardwood forests (Colchic lowlands, Riparian forests)
Lowland coniferous forests (Pinus pityusa, Pinus eldarica)

The **Mountain forests** are divided into:
Beech Forests and **Dark Coniferous Forests**
In beech forests, **Fagus orientalis** is the dominant species, associated with Carpinus caucasica or Castanea sativa or Quercus iberica, also with fir and spruce.

In dark coniferous forests, Picea abies, Abies nordmanniana or Pinus kochiana are the dominant species. Dark coniferous forests are found in higher altitudes, they prefer Northern slopes with moist conditions.

In the lower parts of the mountains and often on southern exposure, Quercus sp. forests, associated with Carpinus, Fraxinus or Acer can be found.

Because of the dominance and wide distribution throughout Georgia, beech forests are subdivided into the following associations:
Fageta festucosa, East Georgia, 1100 – 1750 m asl, Carpinus associated, prefer relatively dry climate conditions, in higher altitudes on slopes with southern exposure,
Fageta nuda, Greater Caucasus, 500 – 1200 m asl, northern slopes, poorly developed, acid(?) soils,
Fageta asperulosa, 1100 – 1550 m asl, northern slopes, moist habitats, well drained brown forest soils,
Fageta pachyphragmosa, 500 – 1100 m asl, moist temperate conditions, to be found by example in Lagodekhi protected area,
Fageta rubosa, 1100 – 1600 m asl, moist conditions, Greater Caucasus southern slopes,
Fageta trachystemosa, 100 – 1700 m asl, West Georgia, moist conditions,
Fageta filicosa, mainly West Georgia, abundant presence of ferns,
Fageta luzulosa, upper part forest belt of Svaneti,
Fageta rhododendrosa, everywhere in West Georgia, from sea level to 2000 m asl, high precipitation
Fageta laurocerasosa, typically distributed from 700 to 2200 m asl, well developed at limestones, southern exposition with high precipitation
Fageta ilicitosa, most common from 1000 to 1800 m asl,
Fageta magnovacciniosa, from 900 to 2200 m asl,
Fageta azaleosa, in West Georgia from 800 to 1200 m asl with high precipitation, in East Georgia from 1000 to 1700 m asl, Aragvi and Iori river
Fageta viburnosa, from 900 to 1900 m asl on Northern slopes in East Georgia, in the middle forest belt, 1100 to 1600 m asl, in West Georgia

In **2019,** a total of 20 sites (sample plots) will be selected in undisturbed natural forests. This decision is based on the review of research studies which indicate, that natural forests contain considerably more below-ground carbon than managed forests. The number of sample plots per forest ecosystem is based on the following information from the website of the National Forest Agency, NFA, showing that from the whole forest area of Georgia (100%), approx. 1.200.000 ha (43%) are dominated by Fagus orientalis, approx. 305.000 ha (11%) are dominated by Carpinus caucasica, approx. 290.000 ha (10%) are dominated by Quercus sp., approx. 200.000 ha (7%) are dominated by Alnus sp.. Picea orientalis, Abies nordmanniana and Pinus sp. are dominant on approx. 460.000 ha (16%), and Riparian Forest with no or few human influence can be found only on approx. 50.000 ha (2%).
According to the share of a forest association of the total forest area, the number of sites per association will be selected. The number of soil profiles at each site must be sufficient to estimate carbon stocks precisely and to detect statistically significant differences between the sites. Therefore, a One-Way ANOVA test was conducted. The figures used in this test – e.g. standard deviation – were taken from similar forest soil surveys in temperate climate zones. The test showed a confidence of more than 90% when choosing at least 9 soil profiles

per forest site. Therefore, in each selected site 9 soil profiles will be dug, described, classified and sampled down to a depth of 1 meter or parent material. Calculating that on average in each profile 5 horizons will be sampled, each year (20 forest sites x 9 soil profiles x 5 horizons) 900 soil samples will be analyzed and their carbon content calculated.

In **2020** and **2021**, it is foreseen to assess at least **20** additional forest ecosystems each year, with few and considerable human influence respectively. The concrete site selection will be based on the information generated from the NFI sample plots in the regions Mtskheta-Tianeti, Akhmeta, Guria and Adjara. The number of forest sites in 2020 and 2021 can be doubled, if financial resources are available for the training of field teams! Having this data set of 2700 soil analysis (1 site sampling comprises 9 soil profiles and an average of 45 individual soil horizon samples) after 3 years will allow to calculate the carbon content of Georgian forests at a reliable base and permitting Georgia to report on a Tier 2 basis (perhaps Tier 3) to international environmental conventions and entities. Additionally, it is expected, that the carbon content in undisturbed and disturbed forests are different, which perhaps allow conclusions about future management practice.

On the natural forest sites sampled in 2019, the aboveground biomass should be assessed based on the method described in the NFI field guide. If a soil sample plot coincides with a NFI sample plot, the aboveground biomass is already assessed. If they don't coincide, they have to be assessed, preferable by the NFI task force expert group.

Soil parameters to be assessed

As Georgian forests are almost all from natural origin and forest soil formation did not suffer main disturbances during several thousands of years, a considerable amount of carbon can be expected until a depth of one meter. Therefore, at each sample plot, 9 soil profiles of 1 m depth or until the depth parent material appears (representing upper, middle and lower slope) will be made and soil samples will be taken from each horizon.

Soil profiles will be described identifying horizons, texture, structure, bulk density, color, content of coarse fragments and other important soil parameters.

Samples of the upper soil layer in form of a cube 30 x 30 x 30 cm will be taken to determine Oi, Oe and Oa layers and A horizons (FAO horizon denomination), litter composition (twigs, leaves and needles) and rooting density. This sample approach is in accordance with the requirements of IPCC. Down to 1 m, samples will be taken from every genetic horizon. The total number of samples will be restricted to on average 5 per profile. If necessary, several horizons with similar description will be combined to one sampling horizon, while thick horizons can be subdivided.

Laboratory analyses

Chemical analyses

Type of analysis	Purpose of analysis
Soil pH (H_20 + 1 M KCl)	Nutrient availability, site quality, weathering processes
Carbonates	Information about parent material, site quality, necessary for C-organic calculation
N - total	Nutrient status, site quality
P - total	Nutrient status, site quality
C - organic	Humus and nutrient status, site quality
C/N ratio - calculated	Quality of humus, biological activity
Ca exchangeable	Nutrient status and availability for plants (base saturation)
Mg exchangeable	Nutrient status and availability for plants (base saturation)
K exchangeable	Nutrient status and availability for plants (base saturation)
Exchange acidity	Acid reaction of soil, site quality

Physical analysis

Type of analysis	Purpose of analysis
Bulk density	Calculation of soil volume to assess stocks, rootability
Texture (clay, silt, sand (fine, medium, coarse) fraction)	Total water retention capacity, field capacity calculation, water regime, rootability
Coarse fragments content	Site quality
Hygroscopic water content	Plant-available water

Calculations

The calculation of soil element content (C, N, P, K, Ca, Mg) will be done in kg or to per hectare and specific soil horizon thickness. Carbon values can be aggregated for international reporting by example into: Tons of carbon per hectare and 30 cm, 60 cm or 100 cm soil depth.

Project organizational structure

The soil & carbon project will be realized as a complementary part of the National Forest Inventory project. The following institutions take part in the concept development and implementation of the project.

Institution	Persons	Contribution/Responsibility
MENA, BFD	Koba Chiburdanize, Paata Torchinava	Overall political responsible for the project;
Georgian Academy of Science	Prof. Dr. Tengiz Urushadze	Scientific advice, local knowledge and experience concerning soils of Georgia
ISU, Institute of Botany	Prof. Dr. Giorgi Nakhutsrishvili, Dr. Ketevan Batsatashvili	Scientific advice, local knowledge and experience concerning natural forest ecosystems of Georgia, exploring synergies between “pristine forests” project of ISU and “soil & carbon” project
Scientific Research Center of MENA	Dr. Giorgi Ghambashidze	Chemical and physical analyses of soil samples
Technical University of Munich, Chair of Soil Science	Dr. Peter Schad, Vincent Buness, Marian Walldorf	Scientific advice, training in practical field work, soil description and sampling
Merab Kvaratskhelia, Nika Marsagishvili	Soil Experts	Soil description and sampling (20 forest sites in 2019, at least 10 forest sites in 2020)
ISU, MSc program “Natural resource management”	Students	Support on field work, potential for MSc Thesis
Agricultural University of Georgia, MSc Forestry program	Students	Support on field work, potential for MSc Thesis
Technical University of Georgia, BSc Forestry program	Students	Support on field work, potential for BSc Thesis
National Forest Agency; NFI- and FMP-working groups	N.N. (district forest officers) Zura Janashvili, Jan Staubach	Logistical support during field sampling, local knowledge; Identification of overlapping sample plots to generate comprehensive data sets of above ground and below ground C-pools
GIZ – IBiS/ECOserve	Benedikt Ibele, Dr. Erich Mies, Lasha Khizanishvili, Sophio Devdariani	Teamleader, Financial support, Overall project coordination until November 2019, Local support Akhmeta region; Overall logistic and organization, option for PhD-study

Research & Education

Concerning forestry research and education, the infrastructure and human resources situation is still not very well developed. Therefore, it is foreseen to use in the project “soil & carbon” assessment any opportunity to strengthen these fields, involving lecturers or students in scientific discussions, field activities and laboratory work.

Timetable of activities

Topic	01/2019	02/2019	03/2019	04/2019	05/2019	06/2019	07/2019	08/2019	09/2019	10/2019	11/2019	12/2019	01/2020	02/2020
General preparation, data collection, literature screening, maps, etc.														
Selection of forests for sampling														
Test phase of sampling procedure and laboratory analysis														
Field sampling work														
Analysis of samples and data														
Data interpretation														
Reporting														