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GIS-based scenarios of SOC annual change on croplands at subnational level: case studies of Burkina Faso and Uzbekistan

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The Intergovernmental Panel on Climate Change (IPCC) has developed comprehensive methodological guidelines for National Greenhouse Gas Inventories, which aim at estimating and inventorying greenhouse gas (GHG) emissions and sequestration capacity of anthropogenic activities influencing sources and sinks of GHGs. The IPCC approach, applied to the case studies of Burkina Faso and Uzbekistan, was used within a GIS framework to obtain a spatially explicit simulation of C sequestration potential in agricultural soils.

For the simulation, FAO datasets on land use, agriculture, soil and climate were used, together with information on agricultural management and assumptions on potential changes in agricultural management provided by local experts. Potential soil C accumulations from adoption of reduced tillage practices were analysed replacing full tillage and from an increased return of agricultural residues to soil. The estimations obtained represent potentials that do not consider the economic or agronomic feasibility of the proposed agricultural management changes, but provide an indication of the biophysical potential of soil C sequestration that may be useful to policy-makers.

For the purpose of the analysis the following assumptions were made:

- the countries examined used only FAO datasets;
- the extent of areas under croplands in Global Land Cover (GLC) 2000 represents croplands remaining croplands;
- differences in management and levels of input of organic matter between the beginning and the end of the hypothetical inventory period are represented by most likely changes and not by actual changes (C storage potential capacity owing to hypothetical changes in management is simulated).

A number of factors (land use, input and tillage) assigned to each climate and soil type were used to estimate changes in soil C stocks from land-use and land management practices over a 20-year period. Following the methodology, initial soil C stock is a function of soil organic carbon (SOC) under the native vegetation of the area under each combination of mineral soil types (based on World Reference Base for Soil Resources [WRB] classification

[FAO, 2006]), IPCC major climate zones (IPCC, 2006 a,b) and baseline land use and management. Similarly, soil C final stock after 20 years is a function of the area under each combination of soil types, climate zones and, in the case of the present exercise, the simulated scenarios of introduced, improved management practices.

The thematic layers used to estimate spatially defined initial soil C stocks across the study area for each combination of soil, climate and management were derived from: (i) the Harmonized World Soil Database (FAO/IIASA/ISRIC/JRC/CARS, 2008), adapted to the IPCC classification of mineral soil types (in the case study of Uzbekistan); combined with (ii) data on thermal regime and length of growing period provided by the Global Agro-Ecological Zones study (GAEZ, 2008); while in order to define the extent of cropland areas, (iii) the GLC dataset (European Commission Joint Research Centre, 2000) was used. In the case study of Burkina Faso, the HWSD information on topsoil (30 cm) C content was used to determine SOC_{REF}.

Discussion

While FAO global dataset gathering and management posed no technical problems, the following constraints were encountered in the estimations:

- Croplands remaining croplands are difficult to estimate. The land cover map for T_0 and $T_{(0\text{-}T)}$ should be available, but this is not the case when using global datasets. By using aggregated data for administrative units of the country it would be possible to obtain subnational simulations; again, it is difficult to obtain two data points (in many cases, administrative units change over time – polygons change shape or even disappear). For similar reasons, land converted to croplands is even more difficult to estimate.
- Changes in management and levels of input of organic matter as well as the areas involved are difficult to determine.
- Validation of results is difficult because of the lack of locally derived experimental data.
- Detailed data are difficult to obtain. The local statistical databases may not include most of the information required for inventory purposes, namely:

  two time points, on land area in each spatial or administrative unit (municipality/district level) cultivated with: (i) perennial crops; (ii) paddy rice; and (iii) annual crops – except paddy – with details of: *(a)* cropping system (low-, medium- and high-input, high-input with organic amendment); *(b)* tillage intensity; *(c)* irrigation regime; and (iv) set-aside <20 yrs;

detailed data on (i) areas per each typical rotation; (ii) areas under each perennial crops/definition of use of biomass obtained from pruning; (iii) areas under paddy, with detailed water regime specifying application rate of organic amendment; (iv) areas of cultivated (drained) organic soils; (v) areas of croplands with details of crops whose residues are burned in the field as post-harvest practice; (vi) amount of calcic limestone and dolomite applied for soil liming, urea fertilization and N fertilization for each of the rotations or crops listed in (i); and (vii) amount of N input in flooded rice.

Further developments

Given the levels of uncertainty linked to the IPCC default C stock change coefficients,[1] it might be advisable to adopt a conservative attitude, and therefore to assume that the derivation of soil C sequestration rates using the IPCC method, combined with FAO geographically explicit datasets on land use, soil, climate and ecological zones, approximate the upper limit of what might be expected in each given combination of soils, climate, tillage and crop rotation in Burkina Faso and Uzbekistan.

Additional work would be necessary in order to: (i) obtain detailed local data necessary to carry out more precise estimations; (ii) validate the results and determine with more accuracy the uncertainties of the results; and (iii) extend the estimations to grasslands and rangelands, which, particularly in Uzbekistan, might represent an interesting area in terms of soil C storage potential.

For the proposed exercise the default values for estimates of soil C stocks under native vegetation were used together with the base, input and tillage factors contained in the IPCC inventory documentation. The default factors were derived from published literature and intended for application anywhere in the world. Literature-derived values for soil C stocks under native vegetation and the influence of agricultural activities on those stocks are highly variable. This variability may influence how well the default factors represent the soil C fluxes of the specific country under analysis. It could be of interest to select a set of test countries or regions in which to assess the uncertainty of the specific application of the IPCC method to agricultural and/or soils covered by rangeland/pasture, and to develop alternative factors that are representative of the conditions found in those regions. These new data, combined with the IPCC inventory method, could allow identification of a range of locally derived values for current and potential soil C sequestration (which could, at the same time, help improve the IPCC Emission Factor Database).

[1] For example, errors of 4661 percent for long-term cultivated tropical areas, 912 percent for long-term cultivated temperate areas and values of 814 percent and 414 percent for changes of tillage and input levels in tropical and temperate areas respectively (IPCC, 2006c).

One constraint of the IPCC inventory method is that it only accounts for changes in C stocks that result from changes during that inventory period. If there is no land-use or management change during the inventory period, soil C at the site is considered to be in steady state regardless of the tillage and/or management level. It could be useful to use modelling tools, for instance a non-commercial product such as DNDC[2] which include a GIS module that allows the simulation, at regional level, of soil C sequestration over the same agricultural soils with the same crop, rotations, tillage events and climate to provide additional information about the effect of long-term cropping activities (or grassing activities). In addition, a comparison of model and IPCC outcomes in different countries and/or regions may provide insights into areas where the level of accuracy of the IPCC factors is more acceptable or may need further refining.

[2] DNDC is a computer simulation model of carbon and nitrogen biogeochemistry in agro-ecosystems. The model can be used for predicting crop growth, soil temperature and moisture regimes, soil carbon dynamics, nitrogen leaching and emissions of trace gases including nitrous oxide (N_2O), nitric oxide (NO), dinitrogen (N_2), ammonia (NH_3), methane (CH_4) and carbon dioxide (CO_2) (http://www.dndc.sr.unh.edu/).

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