THE CARBON MANAGEMENT DOMAIN IN RUSSIA: APPLICATION OF A COUNTRY-SCALE BIOSPHERIC GREENHOUSE GAS INVENTORY MODEL

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ABSTRACT
Carbon management (CM) domain in Russia is defined by carbon (C) sequestration potentials in vegetation and soil and options for C flux manipulations in line with regional indicators of the carbon cycle (CC).

INTRODUCTION
Traditionally, CM practices in agriculture or forestry considered land management practices that assisted the CC to gain food or fibre. This practice stems from well-established knowledge and experience on nutrients cycles. During the last decade, CM was proposed to become part of the climate regulations through articles 3.3 and 3.4 of the Kyoto Protocol in which biological sinks and sources are introduced to mitigate unappreciated concentration of carbon dioxide (CO_2) in the atmosphere. These new CM goals address the global carbon-climate system and subsequently target the major global C reservoirs. The basis for this practice is a fundamental understanding of the CC processes and mechanisms [*IPCC*, 2000]. However, practical implementation of the CC theory remains unclear. In fact, suggested good practice guidance [*IPCC*, 2003] is centred on countywide carbon account and reporting. This approach provides CM practices that lack a clear link to the overall CC framework. The objective of the study is to illustrate how fundamental knowledge of terrestrial CC can be applied to establish a principal strategy for CM in Russia.

MATERIALS AND METHODS
The study is based on the latest spatially explicit inventory of C pools (biomass and soil C stock) and fluxes (net primary production, litterfall, biomass consumption and disturbances, heterotrophic respiration, riverine discharge) for Russia [*Stolbovoi and McCallum*, 2002]. The CC spatial model incorporates C characteristics. The parametrization of C fluxes (humus mineralization, litter decay, release of dissolved organic C) is done by fitting measured data for the steady CC. The model operates on the mass conservation principle that maintains sizes and intensities of the organic C metabolism in a spatially explicit fashion. For each successive stage of the ecosystem the model computes Net Ecosystem Production (NEP), Net Biome Production (NBP), Ecosystem Carbon Balance (ECB), organic C balances in vegetation, soil and net C-fluxes into the atmosphere, hydrosphere and lithosphere. The analysis operates at the country scale, which aggregates and smoothens the variation of statistical and field data by integrated land-cover/natural zone spatial patterns.

DISCUSSION AND CONCLUSIONS
The model quantitatively describes C reservoir contents, intensity of C fluxes within plant-soil systems, C exchange between reservoirs and C turnover times in a spatially explicit fashion. Expansion of agriculture has resulted in the loss of nearly 4.8 PgC (1 Pg = 1 x 10^{15} g) C of standing biomass from forests. About 4.7 PgC are removed from soil due to cultivation and grazing. Agriculture and forest harvests, direct emissions from wild fires and insect invasion present anthropogenically driven C fluxes and comprise nearly 610 x 10^6 tC (nearly 16% of the annual C uptake by net primary production 3923 x 10^6 tC). The litterfall is the major flux out of vegetation (3142 x 10^6 tC). The remaining in vegetation C (781 x 10^6 tC)

is 80 % balanced by harvest and disturbances and therefore is very sensitive to anthropogenically regulated impacts in spite of relatively large extent of virgin ecosystems in Russia. The input of C into soil through the litterfall is mostly compensated by heterotrophic soil respiration (3067 x 10^6 tC) and methane emission (20 x 10^6 tC). The remaining 55 x 10^6 tC comprise water transport of dissolved and suspended organic C mostly via riverine discharge. Average turnover time of C in vegetation of Russia is about 10 years, ranging from one year in cropland to more than 20 years in forests. Average turnover time of C in soils (upper 1 meter) is about 100 years, ranging from less than 10 years in organic and more than 250 years in mineral horizons. The analysis of CC shows that controls of C balance in vegetation (production, litterfall, consumption, disturbances) are different from that in soil (humification, humus mineralization, release of dissolved organic C) and that both do not always coincide spatially. The loss of biomass due to deforestation and dehumification of soils are selected to establish regions for C sequestration potentials in the country. These regions are further stratified according to the range of CM practices to enhance C sequestration in vegetation, soil or in both. Distribution of C densities in biomass and soil by land cover classes within regions helps to indicate an overall CM strategy for the region. The latter can be applied to introduce relevant policies, socioeconomic C enhancement regimes, etc. It is concluded that indicators of the CC (e.g., Net Ecosystem Production (NEP) and Net Biome Production (NEB)) are too general and impractical to be used exclusively.

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