ATTEMPTING A VERIFIED REGIONAL TERRESTRIAL BIOTA FULL CARBON ACCOUNT: EXPERIENCE FROM CENTRAL SIBERIA

S. Nilsson[1], A. Shvidenko[1], I. McCallum[1], C. Schmullius[2], H. Balzter[3], A. Kadiyev[1], M. Korets[4], W. Lucht[5], S. Quegan[6], V. Skudin[4], V. Sokolov[4], A. Sukhinin[4], T. Letoan[7], L. Vaschuk[8]

[1]*International Institute for Applied Systems Analysis (IIASA), A-2361 Laxenburg, Austria, nilsson@iiasa.ac.at*

[2]*Friedrich-Schiller University, Jena, Germany, c.schmullius@uni-jena.de*

[3]*Climate and Land Surface Systems Interaction Centre, Monks Wood, UK, hbal@ceh.ac.uk*

[4]*V.N. Sukachev Forest Institute, SD RAS, Krasnoyarsk, Academgorodok, Russia, institute@forest.akadem.ru*

[5] *Potsdam Institute of Climate, Potsdam, Germany, wolfgang.lucht@pik-potsdam.de*

[6] *University of Sheffield, Sheffield S3 7RH, UK, s.quegan@sheffield.ac.uk*

[7]*CNES-CNRS-Universitt Paul Sabatier, 31401 Toulouse, thuy.letoan@cesbio.cnes.fr*

[8]*Irkutsk Regional Forest Management Agency, Irkutsk, Gorky str., 31, Russia, leonid_vaschuk@mail.ru*

ABSTRACT
The paper presents major results of the terrestrial biota full carbon account (FCA) for a large region of Northern Eurasia based on a semi-empirical ecosystem-landscape approach and taking into account major requirements to a verified FCA. The average net ecosystem production (NEP) and net biome production (NBP) for the entire region are estimated for 2003 at 59 and 33 g C m^{-2}, respectively. It is shown that uncertainties of the regional FCA can be reliably estimated and decreased to an acceptable level if the information base and methodology used are based on a consistent systems approach.

INTRODUCTION
A *verified* FCA means that (1) completeness of the account is provided in all ramifications, at all stages and for all modules of the FCA; (2) uncertainties are assessed in a comprehensive and transparent way and they do not exceed a preliminary defined level; and (3) the methodology used presents an explicit guidance, which is the optimal way to manage the uncertainties. Verification generates prerequisites of transition to certification of the FCA which seems obligatory for the further progress of the post Kyoto international negotiation process. The research covers a large (above 3 million km^2) area of Central Siberia, which includes all major bio-climatic zones of Northern Eurasia (from arctic deserts through tundra, taiga and the temperate zone to semi-deserts in the south). The region is typical for polar and boreal domains and is under increasing anthropogenic impacts (oil and gas extraction, harvest, air pollution). The most dramatic climatic change over the globe is expected in the region.

METHODS AND INFORMATION BASE
The most important features of the methodology used are *inter alia*: (1) as comprehensive as possible systems approach is used as an overall methodological basis; (2) the need to fuse ground data, remotely sensed indicators, results of measurements *in situ* and regional ecological models; (3) the need to assess the uncertainties at all stages of the account; (4) the relevance to use a combination of different approaches and ecological models of different types. The study examined two well known Dynamic Global Vegetation Models (DGVMs) — the Sheffield model and LPJ, which have been regionalized to a possible extent, and the semi-empirical landscape ecosystem approach elaborated by IIASA. This presentation considers results of the latter approach.

The FCA is a typical fuzzy system that defines specific features of expedient methodologies of the FCA and ways in which the uncertainties should be assessed. The information base is presented by (1) an Integrated Land Information System in the form of multi-layer geographic information system (GIS; the basic scale is 1:1 million), which contains a possible comprehensive description of individual ecosystems and landscapes and numerous attributive databases; (2) multi-sensor remotely sensed data of different types and resolutions; (3) results of physical

measurements in situ; (3) and sets of semi-empirical models, e.g., those which connect remotely sensed indicators and "hidden" ecological parameters. A relevant combination of these sources resulted in a GIS layer "relevant for the FCA". This layer includes about 30,000 homogeneous polygons corresponding to a unified hierarchical classification of land cover. The polygons have been comprehensively parametrized (e.g., about 120 indicators for each forest polygon). The FCA is carried out in two interconnected ways: (1) analysis of carbon pools and fluxes by polygon for 2003; (2) assessment of inter-annual variability of the FCA by ecoregion and land class for 1988–2003 based on seasonal climatic characteristics, accounting for disturbances and land cover dynamics. NBP was defined as NBP = NPP – HR – DEC – ANT – FHYD – FLIT, where NPP is net primary production, HR is soil heterotrophic respiration, DEC is flux due to decomposition of aboveground and onground coarse woody debris (CWD), ANT is fluxes due to anthropogenic impact (harvest, consumption of agricultural products) and disturbances, and FHYD and FLIT are carbon transport to the hydrosphere and lithosphere, respectively. Indicators derived from process-based models are used for independent comparisons and "closing" the FCA.

RESULTS AND DISCUSSION

The paper presents georeferenced quantification and systems analysis of all components of the FCA (estimates of carbon pools, NPP, HR, emissions caused by disturbances, NEP, fluxes to lithosphere and hydrosphere, NBP). The total area of vegetative land of the region of 299.4×10^6 ha is presented by forests (57.9%), shrubs (2.6%), disturbed forests (6.3%), grassland (mostly tundra) 22.0%, wetland (8.7%), and agricultural land (2.5%). In addition, the region includes 6.2×10^6 ha water bodies and 5.2×10^6 ha of non-vegetative land. The average density of live biomass (LB) is 37.2 Mg C ha^{-1} (here and below all estimates are given for vegetative land), of which 65% is in aboveground wood (AGW), 7% in green parts (GP) and 28% is belowground (BG) LB. The maximal value of LB is in forests: 52.1 Mg C ha^{-1}, of which 69.6% are in AGW. The region has a substantial amount of CWD (the average density is 3.66 Mg C ha^{-1}) and dead roots (7.56 Mg C ha^{-1}). The average vegetation to soil carbon ratio is 1:3.7 (organic soil carbon is defined for aboveground organic layer plus 1m top layer for mineral soils). Major carbon fluxes for 2003 are presented in Table 1.

Table 1. Major carbon fluxes for 2003 (average values, Mg C $ha^{-1}yr^{-1}$, by major land classes)

Land classes	NPP-AGW	NPP-GP	NPP-BG	NPP-T	HR	DEC	FHYD	FLIT	NEP
Total for the region	0.365	1.083	1.043	2.491	1.679	0.151	0.053	0.019	0.589
Including forest	0.553	1.323	1.251	3.137	2.120	0.224	0.050	0.018	0.725
disturbed forest	0.175	1.038	0.491	1.704	1.375	0.338	0.050	0.018	-0.076
grassland	0.027	0.345	0.597	0.969	0.613	0.001	0.057	0.018	0.280
wetland	0.163	1.009	0.867	2.039	1.417	0.001	0.064	0.022	0.534
shrubs	0.216	0.829	0.947	1.992	1.413	0.001	0.064	0.023	0.491
agricultural land	0.063	2.617	2.258	4.938	2.649	0.001	0.037	0.010	2.240

T = total.

There are evident zonal and altitudinal gradients of major components of the FCA. On average, 15% of NPP is allocated in AGW, 43% in GP, and 32% in BG LB, although the structure of NPP substantially depends on land classes. Average NEP for the region is rather high and comprises of 23.6% of NPP. However, 2003 was a year of high disturbances (e.g., wild fire enveloped an area of 3.137×10^6 ha with the consumption of 43.3 Tg C, of which 37.8 Tg C has been emitted into the atmosphere in gaseous form, 2.6 Tg C as particles and 2.9 Tg C has been stored as charcoal). A possible complete account for fluxes due to consumption (including import/export of major vegetation products) and disturbances allowed estimating an overall average NBP at 0.333 Mg C ha^{-1} yr^{-1}, or ~13% of the total NPP. Vegetation of the region served as a carbon sink of 99.8 Tg C yr^{-1} in 2003. Substantial seasonal variability (up to 30%) of the carbon sink in 1988–2003 was mostly driven by natural disturbances. The impacts of seasonal weather specifics and land use change were substantially lower. The uncertainties of the results were estimated taking into account the fuzzy character of the FCA [*Nilsson et al.*, 2004]. The uncertainties of major fluxes of the FCA for 2003 are 7–10% (confidential interval is 0.9), NBP is about 25%, although these results are true under the assumption that the data and models used have no unrecognized biases.

REFERENCE

Nilsson S., A. Shvidenko, and M. Jonas (2004), Uncertainties of the regional terrestrial biota full carbon account: A systems analysis. Proceedings of the International Workshop "Uncertainties of the Full Carbon Account", Warsaw, Poland, 25–26 September 2004, pp. 1–15.