

Uncertainties of a Regional Terrestrial Biota Full Carbon Account: A Systems Analysis

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Abstract We discuss the background and methods for estimating uncertainty in a holistic manner in a regional terrestrial biota Full Carbon Account (FCA) using our experience in generating such an account for vast regions in northern Eurasia (at national and macroregional levels). For such an analysis, it is important to (1) provide a *full* account; (2) consider the relevance of a *verified* account, bearing in mind further transition to a *certified* account; (3) understand that any FCA is a fuzzy system; and (4) understand that a comprehensive assessment of uncertainties requires multiple harmonizing and combining of system constraints from results obtained by different methods. An important result of this analysis is the conclusion that only a relevant integration of inventory, process-based models, and measurements in situ

generate sufficient prerequisites for a verified FCA. We show that the use of integrated methodology, at the current level of knowledge, and the system combination of available information, allow a verified FCA for large regions of the northern hemisphere to be made for current periods and for the recent past.

Keywords terrestrial biota · regional full greenhouse account · uncertainty · verification · certification · Northern Eurasia

1 Introduction

From what we know about interactions between the biosphere and the atmosphere, we can assume that only a full carbon account (FCA) (both in itself and as the informational and methodological nucleus of the full greenhouse gas account) corresponds to the essence and ultimate goals of the United Nation Framework Convention on Climate Change (UNFCCC) (Nilsson et al., 2000a; Schulze, Valentini, & Sanz, 2002). Because of various political and economic constraints and considerations, the Kyoto Protocol and recent documents of the Intergovernmental Panel on Climate Change (IPCC) still operate with partial carbon accounting systems connected to the managed part of the biosphere. We assume from recent developments that transition to full accounting will be put on the climate change science agenda in the near future.

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Perhaps the most appropriate way of providing a transition from a partial to a full carbon account is differentiation between “assessment” (i.e., the actual exchange of greenhouse gases between the biosphere and the atmosphere) and “accounting” (i.e., what parts of this exchange are eligible for inclusion in the Kyoto and post-Kyoto accounting mechanisms).

The full carbon account has two parts that differ in terms of their nature and methodology: (1) assessing emissions caused by the anthroposphere (for example, by industry and energy); and (2) quantifying interactions of terrestrial vegetation with other components of the biosphere, in particular, the atmosphere. The share of emissions that each of these two components has in the summarized fluxes of the FCA at the national level may be of the same magnitude (e.g., for Russia, see Nilsson et al., 2003a). The experiences of some countries (European Union member states and the United States) show that the estimated uncertainties of carbon dioxide (CO₂) emissions from fuel combustion are low, as a rule in the ± 2 –4% range (confidence level 0.95) (EEA, 2005). In spite of the higher uncertainties for other gases (e.g., in roughly the ± 17 –48% range for methane (CH₄) emissions [Monni, Syri, & Savolainen 2004; Rypdal & Winiwarer, 2001]), the overall uncertainties (e.g., expressed on the basis of CO₂ equivalence) of industrial sectors are substantially less than the uncertainties of fluxes resulting from terrestrial vegetation and agriculture (Nilsson et al., 2000a; EEA, 2005). In other words, the uncertainties of the full carbon account will ultimately depend mainly on the uncertainties generated by the biosphere, and the latter is the subject of this analysis.

While the Kyoto Protocol and IPCC documents (IPCC, 1997; 1998; 2000; and 2004b) mention the importance of assessing uncertainty, they do not put this at the center of the problem (e.g., Nilsson, Jonas, & Obersteiner 2000b; Nilsson, Jonas, Obersteiner, & Victor 2001). For instance, the IPCC Guidelines stress that “uncertainty information is not intended to dispute the validity of the inventory estimates, but to help prioritize efforts to improve the accuracy of inventories in the future and guide decisions on methodological choice” (IPCC, 2000: p.6.5). The reliability level of the full carbon account that should be required at the regional and global levels is still being discussed. For the partial account, which is defined by the Kyoto

Protocol and subsequent international documents, Annex 1 countries have a greenhouse gas emission reduction target of 5.2% and the European Union of 8% below 1990 levels by the first commitment period of 2008–2012. This means that the uncertainties for the full carbon account should be minimized to at least a level that is able to provide reliable identification of this reduction. Some scientific discussions (e.g., within the framework of the Global Carbon Project) indicate a presumptive level of ± 20 –25% for required limits of uncertainties for summarized continental carbon fluxes (expressed, for example, as net biome production) caused by terrestrial vegetation; this would obviously be too high if the full carbon account were to become a subject of the post-Kyoto negotiation process. Our tentative results for temperate and boreal regions show that FCA uncertainties for large regions could be decreased to a level of ~ 10 –15% (confidence level 0.9); this level at least seems achievable if the FCA meets a number of system requirements and information improvements. The technical jargon, however, requires two clarifications. First, relative errors depend on the estimated mean, and a definite level of uncertainties implies a tacit prerequisite that net biome production (as an eventual estimate of the terrestrial biota full carbon account) is not zero or close to zero. Second, strictly speaking, the completeness of the FCA cannot be estimated in any formal way, and the knowledge and proficiency levels currently available reduce the chances of finding a solution to this problem. Nevertheless, the philosophy behind the FCA does make it possible to develop an approximate solution.

The full carbon account has two major goals that are equally important and interdependent: (1) quantification of all carbon pools and fluxes included in the account; and (2) reliable estimation of uncertainties. The intentions of the UNFCCC and the logic of recent post-Kyoto developments imply the need to move toward a verified full carbon account. A verified account means, following the IPCC, 2000, p. A3.20), that: (1) uncertainties at all stages and for all modules of the accounting scheme are estimated in a comprehensive and transparent way; and (2) the methodology of the FCA should present guidelines as to how uncertainties can be managed, in particular, if the results of the accounting do not satisfy required (preliminary, defined) uncertainty levels. Verification is basically a scientific notion and is (or should be) an inherent part of any accounting