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CARBON BALANCE OF WORLD'S FORESTED ECOSYSTEMS: TOWARDS A GLOBAL ASSESSMENT

Proceedings of the IPCC AFOS Workshop held in Joensuu, Finland, 11–15 May 1992

SILMU

The Finnish Research Programme on Climate Change

Painatuskeskus

Contents

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Preface

Our qualitative knowledge of the global carbon cycle is relatively good. However, the current quantitative estimates of sources and sinks do not balance; the atmospheric increase is less rapid than expected from carbon cycle models. Some recent studies suggest that a major part of the uncertainty mentioned above could be related to world's forests. It is evident that at the global level, terrestrial ecosystems play an important role in the carbon cycle. However, at the moment we need quantitative data to assess the role of forests in the global carbon cycle (increase in the sequestering of carbon by temperate and boreal forests vs. the amount of C02 released from tropical deforestation).

The workshop "Carbon Balance of World's Forested Ecosystems: towards a Global Assessment" was held at the University of Joensuu, Joensuu Finland during May 11 to 15, 1992. The main objective of the workshop was to review the current knowledge on the role of world's forests in the global carbon cycle and to discuss methodologies for the development of an assessment of carbon cycle in forested ecosystems, and of the exchange of C02 and other GHGs between atmosphere and forests.

The workshop was organised as a part of the activities of the Working Group III (Response Strategies), Agriculture and Forestry Subgroup (AFOS) of the IPCC. The workshop was hosted by The Ministry of Agriculture and Forestry of Finland in cooperation with The Finnish Research Programme on Climate Change, The Finnish Forest Research Institute and the University of Joensuu. At the workshop, there were 46 participants from 16 countries (see Appendix 1).

The mode of work of the workshop included presentations in plenaries and in two working groups, and voluntary contributions (posters). The working group 1 discussed the data on biochemical cycles and the working group 2 concentrated on biomass estimations and modelling. In addition, an informal group discussed different aspects related to the methodology of greenhouse gas emission inventories developed by the IPCC Working Group I and the OECD.

This volume comprises the contributions presented at the IPCC AFOS workshop "Carbon balance of world's forested ecosystems: towards a global assessment". It also includes the workshop report submitted to the IPCC. On behalf of the organisers I would like to extent my gratitude to all the participants of the workshop for their valuable contributions that made possible to map out the first steps in the way to the assessment of the role of world's forest in the global carbon cycle.

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Country-wide estimates of forest biomass are the major driver for estimating and understanding carbon pools and flux, a critical component of global change re- search. Important determinants in making these estimates include the areal extent of forested lands and their associated biomass. Estimates for these parameters may be derived from surface-based data, photo interpretation or satellite remote sensing, with varying degrees of uncertainty. Ground data are typically aggregated by forest type, stand age, productivity level, and ownership. Survey priority is usually given to regions and forest types with timber of commercial value, such that information on understory biomass and forested lands of low commercial value is either absent or of limited reliability. Furthermore, information on below ground biomass, which is costly and time-consuming to collect, is not generally available. Typically, uncertainty in survey statistics increases as the level of post-stratification increases because of reduced sample size. Likewise, literature-based expansion factors also add to the uncertainty of a final estimate because of the often unknown spatial inference for those factors. Estimates based on modelled processes may provide relatively limited information on uncertainty. The discussions in this paper are based on research funded by the U.S. Environmental Protection Agency, and data provided by the U.S. Forest Service.

Introduction

The major variables requiring consideration in the assessment of uncertainty associated with country-wide carbon budgets include forest land area, the carbon from biomass associated with that area, and the soil carbon. Of these three major areas, we are concentrating here on reliability of biomass estimates insofar as they affect carbon pools. It is essential to understand the effectiveness or reliability of the (biomass) estimation procedures if modelers are to manage the expectations that others may have from their interim and final products. Thus, our goal is not to provide absolute values for error in a particular case, but use some empirical examples to illustrate how one may arrive at estimates of reliability for biomass as the major component in determining carbon pools and flux. Although biomass is the example used for this workshop, the ideas are easily extended to other components of the carbon budgeting process.

As part of the U.S. Environmental Protection Agency's Climate Change Program, we are addressing the area within the U.S.A. that is bounded by the conterminous "lower 48" states. In each state, thousands of photo points from current aerial photographs are used to stratify and compute expansion factors for the field (i.e., located on the ground) sample data (e.g., see Bassett and Oswald 1983). The effectiveness of the estimation procedure for area and volume, that is, how representative the estimates are for the real population, is primarily a function of two important measures: precision (sampling error) and the confidence level. An additional component in variation called nonsampling error (e.g., mistakes in choosing a design, data processing, analytical mistakes, etc.) is usually not known, so we rely on the sampling precision and associated confidence (probability) level to indicate reliability for the survey estimates (Husch et al. 1982). We also recognize that there are many other sources of uncertainty, such as photo/map interpretations, biomass equations, volume equations, and measurement error. Be- cause most of these kinds of uncertainty are not quantified along with their published results, we decided to select the examples used in this paper.

For a U.S. carbon budget, we are using volume and biomass estimates from inventory and resource data that are summarized regionally and derived from a U.S. Forest Service statistically-based survey. Because a major objective is to provide carbon budget information by state, and by types/classes according to ownership, species, and productivity, it is necessary to examine the possible tradeoffs in reliability of estimates when stratifying for those kinds of information. Volume is used instead of biomass as an example, because (i) volume is inventoried nationwide (biomass is not) and (ii) problems of reliability are equally applicable to both measures.

Approach

Precision refers to the variation among repeated sample estimates (e.g., the clustering of observations about the average), and is usually expressed as a standard error of the mean (average) of those estimates. Confidence intervals (Cis), expressed by the sample mean + one or two standard errors, are computed for state resource reports using data sampled from U.S. forested timberlands. Although the Cis vary according to the magnitude of the estimate and variation in the attribute being measured, they provide some approximate reliability for the reported statistics. In this paper, we offer examples of volume and area estimates accompanied by 67% Cis, where the odds are two out of three (67% probability) that the true value (timberland area or volume) will fall inside the range described by the sample mean + 1 standard error. Although confidence intervals vary with both the size of the estimate and the variance of the item being sampled, we have included examples from data published in numerous state reports to illustrate how the width of the confidence band changes with the size of the estimate.

In the procedure for estimating biomass over large regions, we generally obtain data or information from three primary sources:

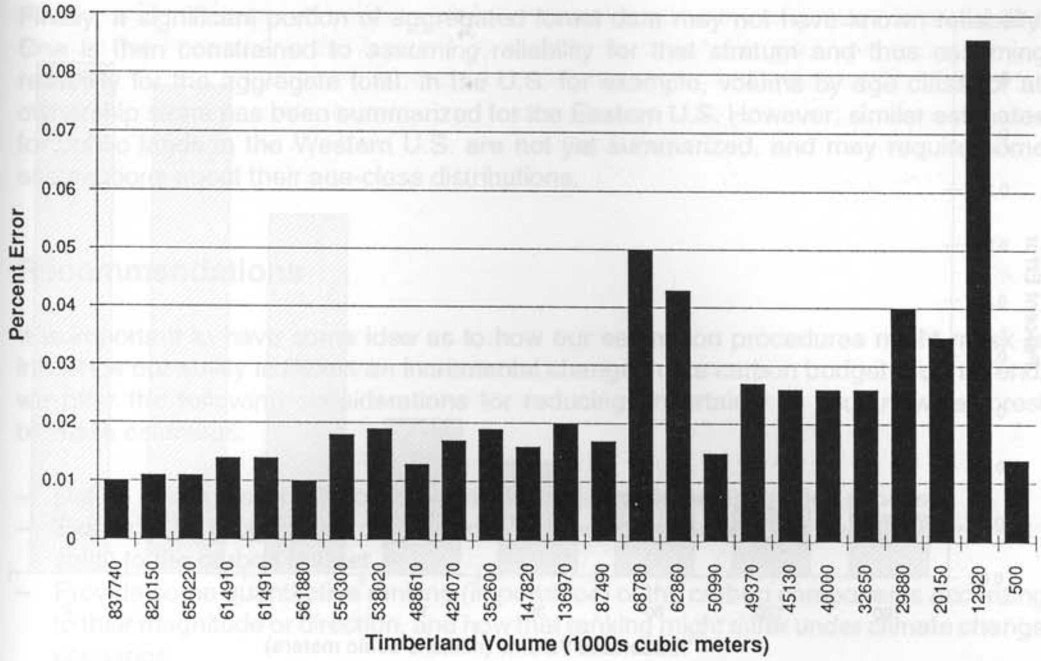

Fig. 1. Percent error (1 standard error divided by the average value, multiplied by 100) associated with state level and sub-state level timberland volume estimates the Eastern U.S.

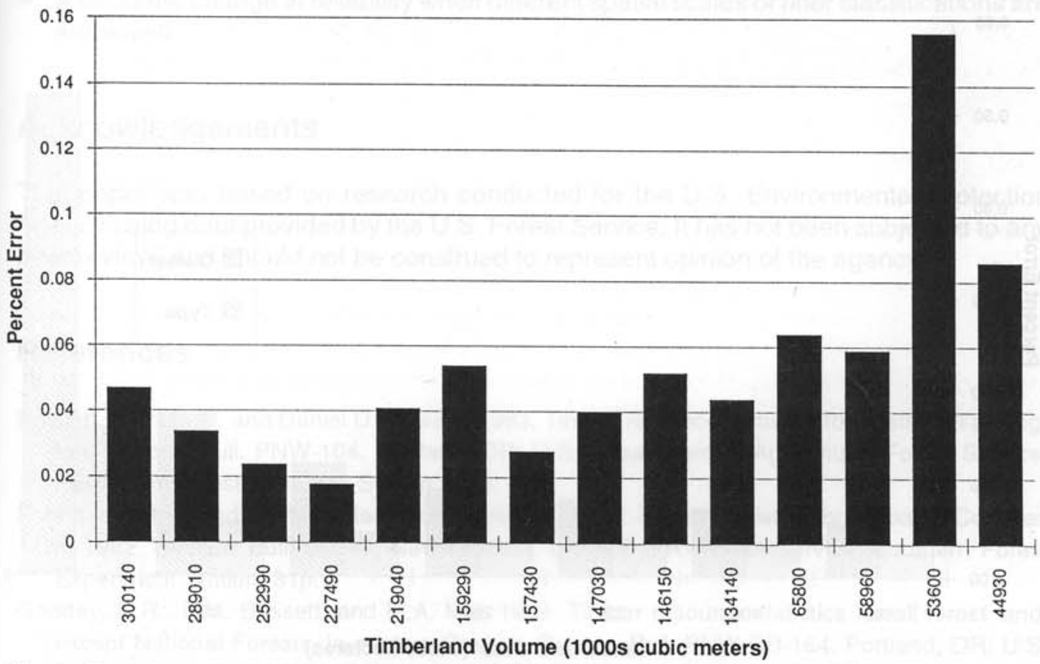

Fig. 2. Percent error (1 standard error divided by the average value, multiplied by 100) associated with state level and sub-state level timberland volume estimates in the Western U.S.

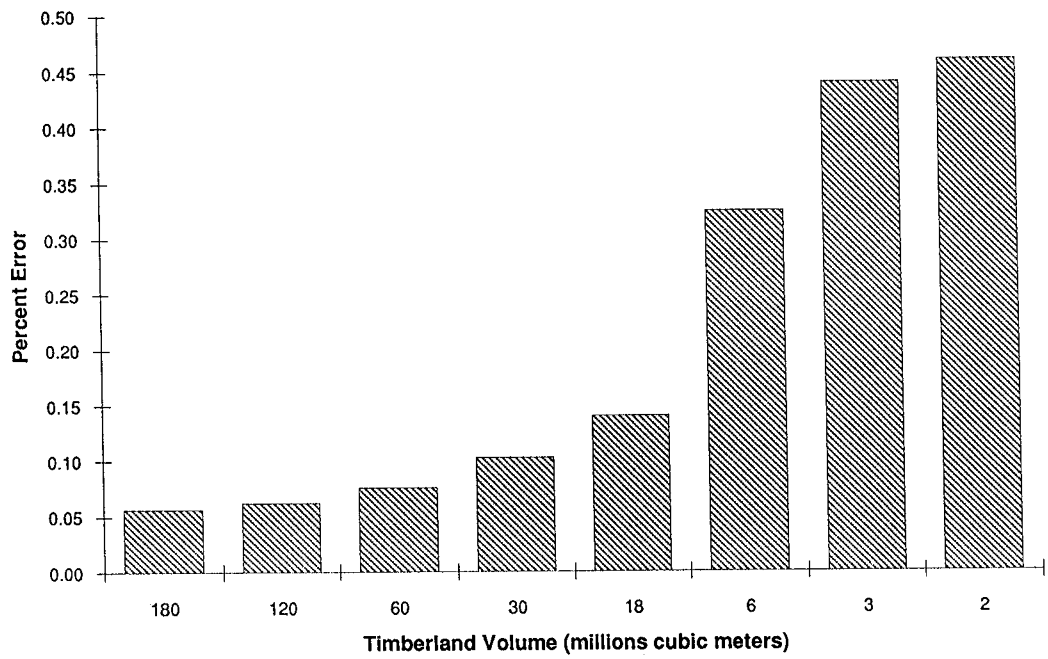

Fig. 3. Percent error (1 standard error divided by the average value, multiplied by 100) associated with timberland volume estimates within a state.

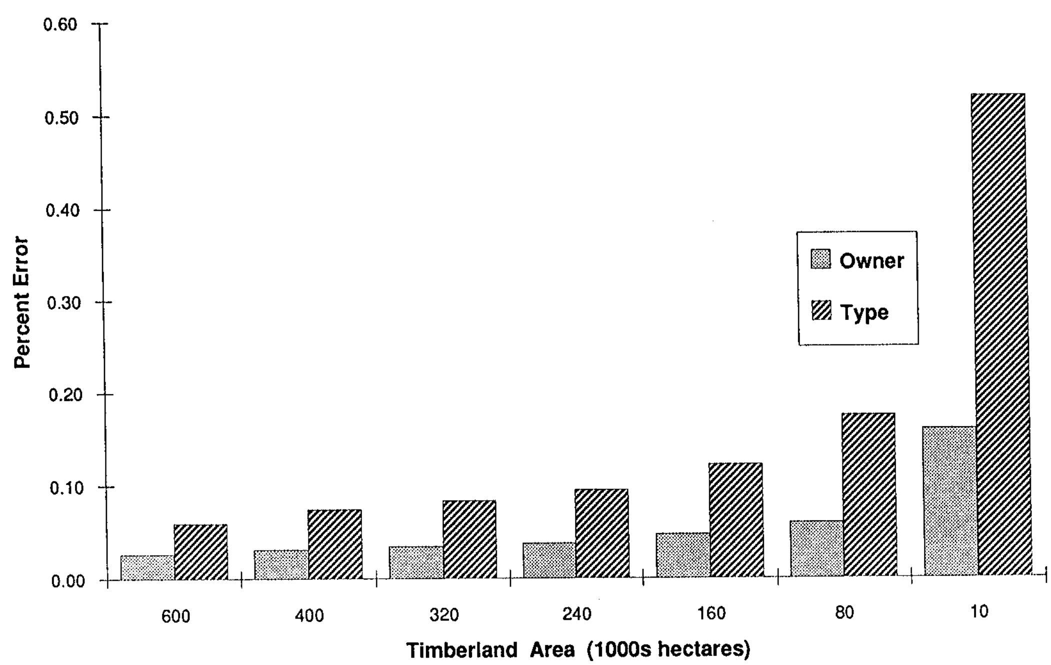

Fig. 4. Percent error (1 standard error divided by the average value, multiplied by 100) associated with timberland area estimates stratified by ownership and type within a state.

(i) Survey -usually statistically based (i.e., data have sampling error) and therefore provides some estimate of regional precision;
(ii) Research -results summarized in the literature and hopefully providing some biological understanding but probably no estimates of regional precision;
(iii) Modeling -may be statistical with some measure of precision, or for understanding or incorporating processes having no precision estimates and perhaps limited generality.

It is important to keep these three sources of information in mind, since they are generally used in combination with each other. As you move from survey information to published literature and finally to model outputs, you generally lose the ability to track or estimate precision. As an example, our biomass estimates for timberlands are a combination of survey (aboveground biomass), literature values (below ground biomass, understory, and forest floor), and modeling efforts (e.g., woody debris).

Results

For the examples of reliability presented here, we are using percent sampling error, defined as one standard error of the mean divided by the average (mean) value. In the Eastern U.S., the percent sampling errors associated with individual state timberland volume estimates are quite low (Fig. 1). The situation in the West is quite similar (Fig. 2), although both the averages and ranges of percent sampling error associated with timberland volume were greater than in the East. In general, for most state reports that displayed 67% Cis, the percent sampling error was around +5% for areas classified by major owner groups, and when timber volumes were lumped as softwoods or hardwoods (e.g., Lloyd, et al. 1986). However, a state-level sampling error of +1.4% might increase up to :t50% when volume is stratified by forest type (FIA Staff 1985).

Further examples of percent sampling errors taken from data reported in Gedney et al. (1989) and Bassett and Oswald (1983), are given in Figs. 3 and 4, to illustrate how reliability changes with the size of the estimate. Note that smaller volume estimates are associated with greater uncertainty (Fig. 3), and in the case of area (Fig. 4), the reliability differs as to whether the data are partitioned by owner or by type, with a trend of increased sampling error by type when estimating strata of smaller forest land area.

Discussion

In the above examples, we have illustrated how the sampling errors associated with forest area and volume estimates from statistically-based surveys are relatively small (i.e., high reliability) for large areas. However, uncertainty increases substantially if volume or area are stratified by forest type (the same result is expected for stratifying by productivity class). Because stratification results in a reduced sampling intensity for some combinations of species type or class, an accompanying decrease in the confidence of the final estimate is expected.

In addition to biomass estimates, most approaches to estimating country-wide carbon budgets will also incorporate results of site-specific studies from the literature and model outputs, neither of which can be characterized with the same kind of reliability that might be expected from a statistically-based survey. A good sensitivity analysis of the models over a range of input values for a variety of scenarios should be employed to assess the reliability of the estimation framework. In order for the end results to be assigned any degree of reliability, even if it is only qualitative, the data origins (i.e., measured or simulated), all assumptions or judgements, and sensitivity analyses, must be fully documented.

Finally, a significant portion of aggregated forest data may not have known reliability. One is then constrained to assuming reliability for that stratum and thus assuming reliability for the aggregate total. In the U.S. for example, volume by age class for all ownership strata has been summarized for the Eastern U.S. However, similar estimates for public lands in the Western U.S. are not yet summarized, and may require some assumptions about their age-class distributions.

Recommendations

It is important to have some idea as to how our estimation procedures might mask or influence our ability to detect an incremental change in the carbon budget. To that end, we offer the following considerations for reducing uncertainty in country-wide forest biomass estimates:

- Define (with glossary) all components identified with the estimation process.
- Examine the proportional contributions of these components, as well as others (e.g., soils) to the carbon budget.

- Provide some quantitative ranking (importance) of the carbon components according to their magnitude or direction, and how that ranking might differ under climate change scenarios.
- Assign some reliability to the estimates associated with each component, drawing a clear distinction between sources such as statistical sampling error, quantitative sensitivity analyses, and "expert opinion."
- Assess the change in reliability when different spatial scales or finer classifications are employed.

Acknowledgements

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