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Review

Contribution of large-scale forest inventories to biodiversity assessment and monitoring

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ABSTRACT

Statistically-designed inventories and biodiversity monitoring programs are gaining relevance for biological conservation and natural resources management. Mandated periodic surveys provide unique opportunities to identify and satisfy natural resources management information needs. However, this is not an end in itself but rather is the beginning of a process that should lead to sound decision-making in biodiversity conservation. Forest inventories are currently evolving towards multipurpose resource surveys and are broadening their scope in several directions: (i) expansion of the target population to include non-traditional attributes such as trees outside the forest and urban forests; (ii) forest carbon pools and carbon sequestration estimation; (iii) assessment of forest health; and (iv) inclusion of additional variables such as biodiversity attributes that are not directly related to timber assessment and wood harvesting.

There is an on-going debate regarding the role of forest inventories in biodiversity assessment and monitoring. This paper presents a review on the topic that aims at providing updated knowledge on the current contribution of forest inventories to the assessment and monitoring of forest biodiversity conditions on a large scale. Specific objectives are fourfold: (i) to highlight the types of forest biodiversity indicators that can be estimated from data collected in the framework of standard forest inventories and the implications of different sampling methods on the estimation of the indicators; (ii) to outline current possibilities for harmonized estimation of biodiversity indicators in Europe from National Forest Inventory data; (iii) to show the added value for forest biodiversity monitoring of framing biodiversity indicators into ecologically meaningful forest type units; and (iv) to examine the potential of forest inventory sample data for estimating landscape biodiversity metrics.

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1. Introduction

Statistically-designed inventories and biodiversity monitoring programs are gaining relevance for biological conservation and natural resource management. Mandated periodic surveys provide unique opportunities to identify and properly satisfy natural resource management information needs. However, this is not an end in itself but rather is the beginning of a process that should lead to sound decision-making in biodiversity conservation.

From this perspective, forest inventories can be regarded as effective tools for estimating the kind, amount and condition of forest resources over large areas. The use of statistical sampling coupled with periodic re-measurements of permanent sample units provides the basis for measuring changes in forest conditions and constructing models to estimate trends (Lund et al., 1998). The information is generally reported for management and/or administrative units (e.g. district, province, country) and/or for thematic or resource classes (e.g. forest type, age).

Large-scale forest inventories, such as National Forest Inventories (NFIs), have gained ground over the last decades as mandated programs for providing the information necessary to fulfill reporting obligations under international agreements such as the FAO Global Forest Resource Assessment, the Kyoto protocol, the United Nations Convention on Biological Diversity (CBD), the Ministerial Conference for the Protection of Forests (MCPFE–Forest Europe), and the Montréal Process. For this purpose, the use of data from stand-wise inventories has often been discontinued in favor of regional and national forest inventories where plots are the primary sampling units rather than forest stands (Motz et al., 2010).

All sample-based inventories over large areas share a common methodological feature: sample units are objectively selected by rigorous probabilistic rules as a means of guaranteeing the credibility of estimates (Olsen and Schreuder, 1997).

Traditionally, large-scale forest inventory data are analyzed in the framework of design-based inference which assumes population values are fixed constants; the randomization distribution resulting from the sampling design is the basis of the inference. In this framework, the bias and variance of an estimator of a population parameter are determined from the set of all possible samples (the sample space) and from the probability associated with each sample. Usually, forest inventories adopt sampling schemes in which a set of points is randomly selected from the study region in accordance with a spatial sampling design. Subsequently, plots of adequate radius or angle-counts with a predefined basal area factor are established with centers at the selected points, and forest attributes are recorded for the trees included in the plots, or in the angle-counts (e.g. De Vries, 1986; Schreuder et al., 1993; Fattorini et al. 2006).

Forest inventories are currently evolving towards multipurpose resource surveys (Lund, 1998; Corona and Marchetti, 2007; Tomppo et al., 2010) and are broadening their scope in several directions: (i) expansion of the target population to include non-traditional attributes such as trees outside the forest and urban forests; (ii) forest carbon pools and carbon sequestration estimation; (iii) assessment of forest health; and (iv) inclusion of additional variables such as biodiversity attributes that are not directly related to timber assessment and wood harvesting.

Biodiversity monitoring is an essential prerequisite to support management decisions to maintain multiple forest ecosystem functions in the long term. Thus, assessing and monitoring biodiversity status should be regarded as strictly tied to sustainable forest management (see Criterion 4, Forest Europe, UNECE and FAO, 2011). In particular, the ecosystem approach fostered by CBD (2000) brings into sharper focus that the many components of biodiversity control the stores and flows of energy, water and nutrients within ecosystems, and provide resistance to major perturbations. Hence forest resource inventories must expand from traditional variables related to wood and timber production to the assessment of the composition, structure and function of forest ecosystems, and must provide a better understanding of the roles of the components of biological diversity in the provision of multiple forest ecosystem functions.

Forest inventory and biodiversity survey methods are similar in many ways, but also have multiple differences (Newton and Kapos, 2002). The debate regarding the potential role of forest inventories in biodiversity monitoring is still open. Some authors argue that the actual capability of forest inventories to directly support biodiversity management is still generally poor around the world (Lindenmayer et al., 2006). However, Tomppo et al. (2010) demonstrate that despite the timber-oriented approach that largely prescribes the information collected by European NFIs, a substantial proportion of forest biodiversity attributes can be estimated from NFI data (Winter et al., 2008; Chirici et al., 2011). Additionally, several studies and exercises have been carried out in the last decades to find ways of effectively integrating biodiversity issues within forest inventories (e.g. Corona et al., 2003; Motz et al., 2010). Recently Chirici et al. (submitted for publication) demonstrated that NFIs can report comparable or harmonized estimates of indicators for multiple biodiversity features (forest categories, deadwood, forest age, forest structure and naturalness), but for others (ground vegetation and regeneration) NFIs should invest more in harmonization efforts (see also Web references, COST Action E43).

Building on the premise that forest inventories have the potential to make substantial contributions to the large-scale assessment and monitoring of forest biodiversity, this paper provides a review of issues that lead to a more complete realization of that potential, with major focus on European NFIs. The remainder of the paper is organized into three sections: Section 2 includes the previously mentioned review; Section 3 includes a brief follow-up discussion with several recommendations; and Section 4 includes a brief summary and comments on future prospects. The main review part of the paper, Section 2, consists of a sequence of sub-sections that begins with a brief general discussion of biodiversity indicators and progresses to the estimation of meaningful landscape-level biodiversity metrics. Section 2.1 focuses on selection of forest biodiversity indicators that can be estimated using standard forest inventory variables; Section 2.2 focuses on sampling issues and includes two relevant examples; Section 2.3 focuses on harmonized estimation of forest biodiversity indicators to facilitate and enhance international reporting; Section 2.4 focuses on the utility of estimating forest biodiversity indicators by forest habitat types; and Section 2.5 focuses on sample-based estimation of landscape metrics that contribute to identification of critical changes in the spatial pattern of forest habitat types that lead to biodiversity loss.