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LETTER TO THE EDITOR

Editorial: "Forest Inventories at the European level"

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In 1949, Egon Glesinger, the deputy director of the FAO Forestry and Forest Products Division, published his famous book entitled "The coming age of wood," translated in French in 1951, "Demain l'âge du bois."Glesinger, 1951 This book depicts the technical possibility and the perspective for a massive shift from fossil to renewable resources, mainly from forests, for producing with a low carbon footprint and wide spectrum of end products needed worldwide. As an example he wrote,

> "… forests can be made to produce fifty times their present volumes of end products and still remain permanently self-renewing source for raw materials. Only forests – no other raw material resource – can yield such return. The forest can, and so must, end the chronic scarcities of material goods that have harassed man's experience since the beginning of history."

This early vision formulated by a scientist from the forest and wood science community is nowadays increasingly accepted in the society: the new emerging challenge is to decouple the economic growth from the environmental degradations.

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The world's forests, by their ability to provide renewable products and other social services, have and will have an increasing contribution to this challenge, as soon as they are managed in a sustainable way and face the challenge of climate change. Such perspective implies one very accurate knowledge, understanding, and quantitative description of the forest resources and their evolution and dynamics.

As a consequence, there is an increasing demand on the monitoring of forest resources, on forests statistics, and on projections of future forest resource availability under various scenarios of management and environmental changes, for public policymakers, for industry as well as for scientists. These needs are traditionally fulfilled by the National Forest Inventory (NFI) programs, whose scope and methods have evolved continuously to meet these demands. It is noteworthy that the users of these outputs are not always aware of the underlying scientific achievements and technical complexity.

Information on forest resources is also needed at wider continental scales, in view of the different international reporting processes that aim at orienting forest policies (FAO 2015; FOREST EUROPE 2015, Keenan et al. 2015). Here, the European space faces the basic reality and major difficulty that the NFIs have developed on national bases, with their own purposes and methodologies. As a consequence, NFI data harmonization has been the main topic for two successive European COST actions involving most European NFIs (E43, http://www.metla.fi/eu/cost/e43/, Tomppo et al. 2010), and more recently by the elaboration and launch of the EU-funded research project "Diabolo" (http://diabolo-project.eu). Such effort may also constitute a possible benchmark for future harmonization efforts in other regions of the world.

Annals of Forest Science is therefore proud to lift the veil on what was recently done within the very active European National Forest Inventory community. This issue is based on results gained between 2010 and 2014 within the COST action

FP1001 "USEWOOD" entitled "Improving Data and Information on the Potential Supply of Wood Resources. A European Approach from Multisource National Forest Inventories."

These papers illustrate three main topics:

(i) The needs and approaches for the international forestry reporting (Vidal et al. 2016; Tomter et al. 2016; Kuliešis et al. 2016).
(ii) The identification and analysis of the differences between countries in terms of methods and measurements and directions for harmonization concerning forest volume increment and wood quality assortments (Gschwantner et al. 2016, Bosela et al. 2016, and previously cited contributions).
(iii) The used models and tools allowing a quantitative assessment of forest resources at different scales (McRoberts and Westfall 2015; McRoberts et al. 2015; Mantau et al. 2016) and projections for investigating the different management strategy options for wood production and/or mitigation of the occurring climatic changes (Barreiro et al. 2016; Fortin et al. 2016).

It is noticeable that three contributions (Tomter et al. 2016; Kuliešis et al. 2016; Gschwantner et al. 2016) are dedicated to the estimation of forest volume increment, pointing to the major role of forest growth and its monitoring to assess the sustainability of forest resource supply. Two contributions also focus on uncertainty in the estimates of present (McRoberts and Westfall 2015) and future (Fortin et al. 2016) forest resource attributes, pointing out to a growing need for precision in the assessment of these resources. As original efforts to date, Barreiro et al. (2016) and Bosela et al. (2016) further offers comprehensive reviews across European countries of (1) existing models for wood resource projection and (2) approaches to stem quality assortments and directions for their harmonization.

1 International reporting on forests

The paper by Vidal et al. provides a detailed and comprehensive description of the different reporting processes involving the contribution of the European NFIs, including the Global Forest Resources Assessment, the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change, and its Kyoto Protocol. This paper points the key role of the National Forest Inventory community and the need for a strengthened harmonization process and further efforts to producing comparable National Forest Inventory results and therefore useful at the international level.

Tomter et al. present the methods used for the estimation of gross and net annual volume increments in 30 countries. The authors sent a questionnaire to the UNECE/FAO national correspondents of all European countries and to the members of the UNECE/FAO Team of Specialists on Monitoring Sustainable Forest Management. The results are description and quantitative analysis of the three main groups of methods at use in Europe.

Kuliešis et al. intend to assess the reliability of stem wood increment estimates produced in Europe, by assembling and comparing one significant material resulting from a similar questionnaire, and estimates provided by the FRA report and the State of Europe's forests databases. Estimations appear to be more reliable when resulting from NFI programs than forest management inventories, in particular when permanent plot designs are implemented. Estimates for forest losses remain a weak component of the growing stock budget.

2 Comparison of methods across different countries and prospect for harmonization

Gschwantner et al. provide a comparison of methods used in 29 European National Forest Inventories for the estimation of volume increment. The enquiry was based on previous work from COST E43 and an analysis of literature to provide scientific background to the comparison. Various aspects of volume increment estimate show strong differences among countries. Beyond differences in the inventory design, challenging ones include sample tree selection, sampling thresholds, and tree fractions are considered. In spite of these difficulties, recent developments and implementation of sample-based inventories now set promising perspectives for harmonization of volume increment.

Bosela et al. address the original question of stem quality assessment and assortments structure, from a review of practices among 28 countries. Such information is requested by industrial stakeholders to meet the demand expressed by their customers. For the first time, the authors describe the stem quality assessment used in 19 countries among the 28 European NFIs surveyed. The study concludes that current approaches of stem quality are not comparable, but identifies several promising directions for harmonized stem quality estimation.

3 Tools and models to assess and project forest resources

3.1 Present state assessment of forest resources

McRoberts and Westfall address the issue of uncertainty in large-area volume estimates, such standard statistics delivered for long by national forest inventories. These estimates routinely rely on aggregating tree-level volume estimates based on volume equations, to plot level and wider forest areas. Measurement errors in height and diameter and errors in tree

volume models thus influence the final large-area uncertainty in the growing stock. The contribution highlights that model uncertainty is depending on the sampling scheme and grows significant with stratified sampling. This contribution thus stresses that wide-area statistics delivered by classical NFI come along with errors, and these matter for forest reporting.

In a second contribution McRoberts et al. address an issue related to more recent multi-source forest inventory (MS-NFI) which principle is to use fine-resolution maps as auxiliary information to plot data, in order to gain precision in NFI statistics. Time lags between map and field information indeed often exist, are reinforced by the practice of continuous forest inventory, and can hamper the gain in precision. In a case study in Norway, where forest area changed over the study period, it is shown that precision in the estimate of forest biomass per hectare was strongly affected by a time lag in map-field data of ~10 years.

Previous contributions deal with estimating and harmonizing forest growth and forest growing stock. There are however many obstacles to harvesting forests, so that the sustainable level of forest exploitation does not meet 100 % of volume increment. Further, the growing demand for renewable energy calls for estimating harvestable biomass and at scales wider than that of countries. In this perspective, the contribution by Mantau et al. is a presentation of the "ITOC" model, a tool that combines the multiple purposes of (1) harmonizing national volume increments produced by NFIs, (2) converting this volume into biomass, and (3) defining the sustainable fraction of biomass increment available for supply. Such tools therefore indicate promising directions to evaluate wood biomass available for consumption on a European level.

3.2 Projection of forest resources

In addition to estimating the present state of forest resources, capacities for projecting their future state under specific scenarios are of increased need.

Barreiro et al. offer an original review of models implemented for forest resource projection across 21 countries in Europe. A variety of modeling approaches is encountered, including tree-level models, stand-level models as the dominant paradigm for homogeneous forests, and less frequent large-scale demographic matrix models intended to simulate more heterogeneous forests. The analysis highlights major challenges associated to including climate change forcing and coping with non-stationary management in these models. Coupling these projection models with sector models (representing the economic demand) and assessing projection uncertainty also define perspectives for improvement.

Fortin et al. illustrate the large-scale demographic modeling approach on a region of Spain and address the issue of prediction uncertainty. The contribution of sampling and model-related errors in this uncertainty is explored using Monte-Carlo techniques similar to McRoberts and Westfall, and the study concludes on improving estimators. At the same time, this contribution also shows the technologic advancement of such models where, e.g., site- and stock-dependent processes are not explicitly represented, pinpointing further promising directions to reduce uncertainty in these approaches.

This special issue is also an opportunity to highlight some current major research challenges and trends in the field of forest inventory.

Building on previous COST actions on forest inventory, the recently EU-funded "Diabolo" project (http://diabolo-project.eu/about/structure/) will first focus on essential aspects, such as harmonization of forest statistics, and development of MS-NFI approaches using fine-resolution remote-sensing data required for the delivery of accurate forest information at different scales ranging from local to continental. While statistics on the larger scale remain fundamental to forest policies, obtaining precision in estimates of local forest attributes is a prerequisite to foster the economic use of renewable wood resources. Other innovative aspects will be addressed in the project including the monitoring of forest disturbances, and development of multi-purpose forest inventory, required for informing sustainable forest management through its three societal, economic, and ecological dimensions.

Approaches to projection of forest resources also meet with fundamental challenges that include the integration of possible climate change impacts onto forest dynamics, with various options including hybridization with process-based approaches, as well as the ability to cope with strongly non-stationary forest management, in the renewed context of bio-economy, of CC mitigation, and of the "European forest conversion" aimed at moving forests away from the pure and even-aged forestry paradigm. While a recent effort has been paid on upgrading models for application to a European scale, current technologies remain classical and are not necessarily fit for addressing such challenges.

Also, while forest inventories traditionally estimate forest growing stock, increment, and harvests on a volume scale, the economic context assumes important efforts to be consented to deliver accurate estimates of forest biomass and carbon and their variability across forests, but also to evaluate the quality of wood supply. This implies that appropriate quantifications of stem and wood properties should be encouraged, with NFIs as a measurement support, and calls for a narrower collaboration between forest inventory and wood science.

Sometimes, major progresses in a field are made by one single man. The editors would therefore like to pay tribute to Prof. Tiberius Cunia, passed away later April 2016, who greatly advanced the science of forest inventory, forest inventory design, sampling with partial replacement, the quantification of errors in forest inventory estimates (Cunia, 1989), and in biomass equation estimation for which he received the Humbolt award in 1984.

The editors last wish that the audience of *Annals of Forest Science* will appreciate the content of this special issue.

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