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Issues in forest inventories as an input to planning and decision processes

(With 1 Figure)

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1. INTRODUCTION

Forest inventory in a narrow sense is the technical process of gathering data and providing information. That information is needed and demanded by researchers and decision- and policy-makers in forestry and numerous related sectors. Sustainability of forest management and forest development can only be implemented and monitored on scientific grounds if and when the corresponding information is available at a sufficient level of quality, credibility and resolution.

Forestry has become more and more complex both regarding the management of forest enterprises and regarding the formulation of forest policies. The “one-dimensional” and specific orientation of forest management and policy towards wood production is history for quite some time. Decision making in forestry embraces a constantly increasing set of goals and challenges: while maintaining the production function for wood and non-wood forest products – the majority of the rural poor in developing countries depend on the forest as a resource and the forest and wood sector plays an economically relevant role in a number of countries – the forest ecosystem needs also to be taken care of while considering and maintaining multiple service functions at the same time. It is a complex task to reconcile these partially and seemingly contradictory goals and to achieve sustainability of all forest functions, from both the technical-scientific and from the political point of view. To plan for and to monitor that sustainability, adequate data and information are required as one component.

The demand for forest information for ‘new’ purposes is often substantial; an important example are the requirements for annual information on forests under the UNFCCC (United Nations Framework Convention on Climate Change) and the related legally binding process fixed in the Kyoto Protocol (IPCC, 2003). Recently, the REDD process with its demanding and yet not standardized assessment and monitoring requirements for the forest resource direct the attention of many researchers and political decision makers to for-

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est inventories again (e.g. GIBBS et al., 2007; HOLMGREN et al., 2007, ANGELSEN, 2008; MILES and KAPOS, 2008).

Another important driver of information demands is the United Nations Convention on Biological Diversity UNCBD and the related obligation for national reporting on biodiversity. Conservation groups, both governmental and non-governmental, increasingly have become users of forest inventory data and information, in particular of large area forest inventories such as national forest inventories. Data sets from national forest inventories often constitute the only long term data available for large reference areas.

The history of forest inventories is long and the collated methodological experiences wide. While the beginning of sample-based forest inventories on statistical grounds is fairly clearly occurring in the early 20th century – simply because statistical sampling had been introduced in mathematics at about that time – forest inventory researchers still debate about the first forest resource information collection activity that deserves the name "forest inventory". GABLER and SCHADAUER (2007) mention such activities in Austria as early as in the 17th century, when mining engineers were interested in securing firewood supply for the iron ore processing industry. Obviously, the information need arose from preoccupations about long-term planning for a resource which was recognized to become scarce. In the 18th century the principle of sustainability had been formulated explicitly for the first time by the forester and mining engineer CARL VON CARLOWITZ (1713); again, in the context of wood supply for the mining industry.

About at the end of the 19th century, sustainability became the guiding principle in forest management in Central Europe. The implementation of sustainability as management principle requires and depends on comprehensive information and monitoring efforts, not only in forestry. Therefore, in support to sustainable forestry planning and management, forest inventory research has developed a versatile toolbox of data collection techniques from various data sources, of small area and large area models and of data analysis options. Data sources include field sampling, remote sensing, interviews with forest users and forest owners, expert judgment and former inventory reports, so that this type of inventory is also called multi-source inventory. Forest inventory probably carries the longest and most comprehensive experience in statistical and modeling techniques for the monitoring of renewable natural resources. Principles of forest inventory can straightforwardly be adapted to other monitoring challenges, including the tree resource outside the forest (PANDEY, 2008; KLEINN, 2000) and biodiversity monitoring (WINTER et al., 2008).

However, a review of the current forest inventory research agenda leads to the conclusion that most research efforts continue to be focused on specific technical issues, including optimization of data procurement and precision of estimation. Much less research appears to be carried out to shed light on the link between the data (as provided by forest inventories), the information (as derived by assessment and interpretation of the data) and the utilization of such data and information as decision support. While various studies are there for forest management inventories (for example the review from DUVEMO and LÄMÅS, 2006), very little is found on large area forest inventories. The FAO NFMA Program (Support to National Forest Monitoring and Assessment) has recently started a comprehensive impact assessment for the national forest inventories in that program (CARLE, 2010, pers. comm.).

It is contended that these questions are of fundamental relevance for the planning of forest inventories – at least as relevant as the improvement of sampling, modelling, estimation and remote sensing techniques, and that forest inventory research should include them on a systematic basis. It is a complex issue, though, and requires collaborative efforts of those who generate and those who use the data and information.

This paper addresses issues in the context of large area forest inventories and its planning. Our objective is to identify important links between forest information and its utilization, and to identify important new areas of research in order to bridge current gaps of knowledge and communication. At first, we elaborate on forest inventories as component in decision processes and do then address technical issues that usually receive less attention.

2. FOREST INVENTORIES AND DECISION PROCESSES

2.1 Forest inventories as a component of decision processes

In the Agenda 21 (UNCED 1992), Chapter 40 is specifically on "Information for Decision Making" and paragraph 40.1 there reads "In sustainable development, everyone is a user and provider of information considered in the broad sense. That includes data, information, appropriately packaged experience, and knowledge. The need for information arises at all levels, from that of senior decision makers at the national and international levels to the grass-roots and individual levels." It is important to understand that, while information is required for decision making, it is not the only factor affecting decisions: experience and knowledge are listed in that citation as further important factors. In relatively simple and transparent systems, experience and knowledge may be sufficient for good decision making. However, with increasing complexity of a system, up-to-date information becomes more important to understand at least the most relevant components.

FAO, for example, changed the 10-year interval of the Global Forest Resource Assessment to a 5 year interval since 2005 as it was found that the changes of the forest resource are not any more adequately documented in 10 year intervals. In addition, FAO created a new project in the year 2000 to support governments in the development of National Forest Monitoring and Assessment (FAO-NFMA Project), a project that helps countries to comply both with the international reporting obligations and with the formulation of national policies in forestry and related fields (FAO, 2003).

In general, planning and decision processes are iterative as shown in *Figure 1*: the process typically begins with the definition of goals and the formulation of relevant questions from which the identification of relevant information requirements originates. Such

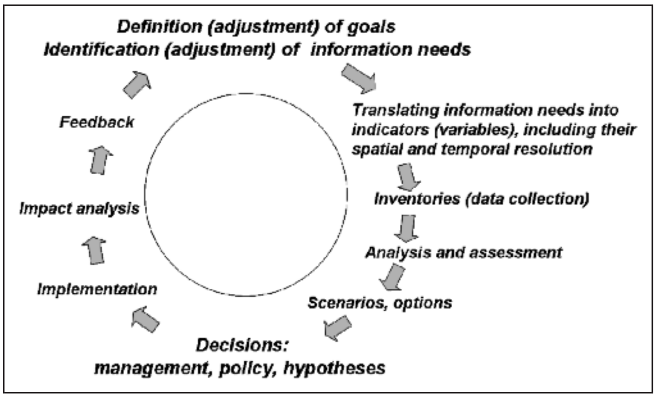

Fig. 1

The circular arrangement of a planning and decision processes illustrates that it is an iterative, continuous, and "learning" process (adapted from FAO, 2000), into which forest inventories are integrated.

Schematische Darstellung eines typischen Planungsprozesses (verändert nach FAO, 2000). Es handelt sich um einen iterativen Prozess, in welchen Waldinventuren als eine Komponente integriert sind.

information requirements need to be translated into measurable attributes; that is: variables or indicators. It is such variables and indicators of which data are collected in the inventory phase. In the subsequent assessment phase the data are interpreted, discussed and eventually translated into information meaningful for the planning process. That information is the basis to develop options of action (scenarios) on the basis of which a decision is eventually taken. After implementation, the feedback phase serves to adjust and fine tune the future planning processes and to adjust information needs (identification of gaps and redundancies). However, for this feedback phase, there does not appear to be a methodology available yet.

In particular for large area forest inventories, important research challenges can be found in all the above mentioned of the planning process and all are relevant for the inventory itself (KANGAS, 2008). It is contended that recognizing and optimizing the role that forest inventories play in planning processes is at least as relevant as the technical optimization of the inventories themselves. This has long been addressed in the large area forest inventory context (JANZ and PERSSON, 2002; GULDIN, 2003), but has also been raised in other disciplines like conservation biology (FIELD et al., 2007; GORDILLO and ANDERSSON, 2004). CROW (2000, cited in GULDIN, 2003) summarize that "our scientific and technical abilities far outstrip our decisionmaking methods and ability to understand the relationship between science and its many outcomes".

2.2 National level forest inventories to support forest related policy processes

Large area forest inventories such as national level forest inventories (NFIs) provide data and generate information that is required to guide and support national policy processes in forestry and related sectors. They do also inform the general public and, for example, the wood processing industry. At the same time NFIs are input to various international processes in which the national governments committed themselves to provide such information on a regular basis. The role of national forest inventories as information source for the UNFCCC (CIENCIALA et al., 2008), in particular in the current specification of the REDD process (e.g. HOLMGREN et al., 2008), or for the Convention on Biological Diversity (WINTER et al., 2008) is considerable and may probably even be enhanced by adjustments in forest inventory techniques and planning.

Given the manifold interested and potentially interested parties, the definition of information requirements to be covered by large area forest inventories is difficult, and this is clearly reflected in the long list of variables that are usually recorded: more than 200 variables area recorded in many national forest inventories. The issue of defining priority variables and their target precision to guide the definition of sampling and plot design development is a methodological challenge.

It may be justified looking at national forest inventories as general information services to the governments and to the general public, shedding light into one of the natural national assets, the forest and tree resources and as such possibly also anticipating potential future information needs and potentially streamlining future decision processes. In many countries, in particular in developing countries, the majority of the rural people depend on the forest as a resource and, therefore, the governments are, in principle at least, obliged to care for the forest which includes being informed on a regular basis on the forests' state and development. In industrialized countries the dependency on natural renewable resources, including forests, is not that obvious and largely not recognized any more, but still the various functions and services of forests are frequently discussed there as well (including water and air protection, tourism and recreation, biodiversity conservation, scenic beauty). We may then see forest inventories and the estimation of forest status and trends in the same way like the governments' estimations of tax income, of labor market data, of indexes of the national economy, of population dynamics, etc. Estimation and quantification approaches for these data are in place in all countries. For practically all fields of policy processes, governments have entities specialized on data and information procurement, data analysis and information management; some information is collated in the publicly accessible national statistics; other data and information, less easy to gather, is collected by so-called intelligence agencies. The usefulness and quality of such information, which is an important input to policy decisions, is judged by the degree to which the expectations of the decision makers are met. Once the decision makers indicate that the information base is sufficient and once they are willing to make the required funds available, we may assume that the information provided is useful and good for their purposes.

An important and typical characteristic of national level forest inventories is the long term documentation aspect: permanent national forest inventories allow building time series on the forest resource and the forest ecosystem for large areas. The value of such long-term time series may not immediately be recognized but they constitute valuable long term data sets offering numerous possibilities for scientific research on the resource forest and on the ecosystem forest.

2.3 Decision making and the relevance of scientific information

"Good information is the basis for good decision making": forest inventory reports and scientific articles on enhancing and optimizing forest inventory techniques frequently begin with statements of that kind. It appears so obvious that it is usually not challenged. However it has more the character of a hypothesis rather than that of factual knowledge as is also discussed in the context of conservation biology: "Good information does not automatically result in good decision-making" (VAUGHAN et al., 2003). And rarely, this hypothesis is tested and proven (or rejected) by means of scientific evidence.

It is, however, not only the scientific data and information itself that needs to be taken into account but the decision makers themselves as well. Decisions result from the assessment and evaluation of data and information (be it from inventories or other sources) through the decision makers, be it an individual or a group. Technical knowledge and professional experience of the decision makers eventually co-determine to what extent the information is used and how. The more professional expertise there is, the less but more specific information is probably required. A series of non-technical factors do also affect decision making (in particular when it is about policy processes), among them the position of the decision makers within their institution, their motivation and values, their cognitive capacities, their social and cultural norms, their advisors, etc. In addition, we may expect interactions between these factors.

Not many studies were found that analyse the weight of scientific information in decision processes relative to other factors. Two examples are given, one from community forestry user groups in Nepal and one of conservation practitioners in England: BANJADE et al. (2006) quantify the contributions of different types/qualities of information in forestry decision making of community forest user groups as follows: experience (47%), stories (18%), enthusiasm (14%), scientific information (12%), images and representation (9%). In that study, anecdotal factors do obviously play a more important role than scientific information. In the context of conservation biology, SUTHERLAND et al. (2004) quantify the sources of information used by conservation practitioners in a protected area in eastern England as follows: common sense (32%), personal experience (22%), speaking to other managers in the region (20%), other managers outside the region (2%), expert advisers (10%), secondary publications (11%), primary scientific literature (2%); although inventory data are not listed here as such, it is also the anecdotal sources that have by far the biggest weight. However, we may assume that scientific information makes also significant contributions in building knowledge and experience (FAO, 2007).

In what follows, we address three further issues in the more technical context of large area forest inventory planning and evaluation.

3. THREE TECHNICAL ISSUES IN FOREST INVENTORIES

3.1 What is adequate precision? A crucial yet unresolved issue

A central question when planning a sampling study is that of sample size because there are immediate cost implications. What we usually teach our students is to calculate sample size in an iterative process from (estimated) population variance s^2, precision requirement A (being half of the confidence interval) and significance level α (as determined from the t-distribution): $n=t^2s^2/A^2$; this formula holds for simple random sampling but the principle holds for other design based sampling techniques as well. While the population variance is characteristic of the population and can be estimated, significance level and precision are to be defined. Frequently, without being much discussed, a precision of 10% is set (some times other values such as 5% or 20%) and a significance level of 5%. And this is usually not done on scientific grounds but following convention and common practice. “There is nothing sacred about the 5% significance level; it has no theoretical justification in either statistics or ecology…” (FIELD et al., 2007); “…there is no cogent reason to prefer this level of confidence…” (GREGOIRE and VALENTINE, 2008). In this context the article by CLAUSER (2008) is instructive who reports about how the 5% significance level has entered statistical analyses in the early 20th century; it does not appear to have had much to do with statistics and science.

In what refers to the width of confidence intervals in estimation , “There are no hard and fast rules for setting the precision level…” says the sourcebook for LULUCF projects (PEARSON et al., 2005) and suggests a 10% precision to be a good choice. It is extremely difficult to formulate criteria for the definition of precision and significance level in technical scientific terms because this would require establishing a researchable link between these two and the value and usefulness of differently precise results.

At the end, it appears that many large area forest inventories are designed and adjusted to the available budget and many different precision levels appear to be acceptable to the users of the data and information. Some national forest inventories work with sample sizes of several thousand, estimating growing stock and forest area with simple standard errors of less than 1% (for example RANNEBY et al., 1987; BMELV, 2008), others resort to small sample sizes (low intensity sampling) accepting simple standard errors in the order of magnitude of 5–20% (among the examples are the inventories that are carried out under the NFMA Project of FAO: THURESSON, 2002; KLEINN et al., 2005). Does that have implications for the usefulness and the use of the data? Where is the “threshold of pain” for the decision makers regarding loosening the precision requirements? Does precision matter, after all? Is it clearly understood by the decision makers what the meaning of a confidence interval or a standard error is? Or is a precision statement only relevant within decision processes when it is about rejecting an undesired result as “not being statistically reliable, anyway”? The issues and questions in this domain are beyond the technical field of forest inventory and require answers from other disciplines, such as forest policy.

3.2 The “magic” 10%

It is striking to see the frequency of the 10% threshold in the context of forest inventory; and not only there. A 10% precision level, for example, is recommended in various forest inventories for the estimation of growing stock or for biomass and carbon estimates (e.g. the mentioned Sourcebook for LULUCF projects, PEARSON et al., 2005). However, in some cases, it does not even become clear whether the suggested 10% refers to half the confidence interval or to the simple relative standard error. 10% are sometimes suggested as sampling intensity in forest management inventories (10% of the area should be tallied in sample plots). 10% is the minimum crown cover in FAO’s forest definition (FAO, 2004), 10% is formulated as an idea and target for multipurpose tree crown cover on farm land in Australia (STEWART and REID, 2006); and a current discussion in Germany has it that about 10% of the public forest in Germany should be taken out of management, as a measure to support biodiversity conservation.

That list could easily be extended. Rarely, however, is the 10% suggestion substantiated by scientific evidence or arguments and it appears to be more an issue of political compromise or “easy acceptance” rather than subjectmatter related criteria that make the 10% so favoured. Maybe, 10% sounds “small enough” but not too small. However, in particular in sampling studies like forest inventories where each adjustment of sample size has considerable cost implications, it makes wonder that these gross rules persist: decreasing, for example, the 10% precision requirement to 11% (simple standard error, simple random sampling, no finite population correction) would mean a reduction of sample size of about 18% – and that brings a reduction of the sample related total cost of about the same order of magnitude. Isn’t that a convincing argument to have a much closer look at the definition of the required precision level?

3.3 What is a “good forest inventory”?

The criteria that govern forest inventory planning are manifold and diverse and not always immediately obvious. General good practice guides are not there yet for forest inventories, albeit countless guidelines. Probably it is not even possible to compose a good practice guide in general terms and on firm scientific grounds. Maybe a “bad-practice-to-be-avoided guide” would be more indicated and more helpful (just like every criminal act lists the bad things that are to be avoided and will be punished instead of specifying a much larger positive list of example behaviour): for forest inventories there are so many good options in terms of technical and organizational design, but there is a probably very well manageable list of clear and repeatedly exercised mistakes that should be avoided. An instructive example comes from an ecological survey textbook where SUTHERLAND (1996) lists in Chapter 11 the “Twenty commonest censusing sins”.

Overall credibility is probably the overruling criterion for inventory planning and implementation; this implies methodological soundness, transparency, precision, accuracy, timeliness and compliance with the defined goals (relevance) and available resources. Unfortunately, credibility is not an objective criterion that can be immediately observed; indicators need to be established to “measure” it. And, obviously, that criterion depends also on the user him-/herself – one and the same inventory may be credible enough for one information user but not for another.

4. CONCLUSIONS

Forest inventories have made tremendous progress in what refers to data collection, estimation, modeling and remote sensing techniques and also in broadening the overall scope of addressed issues towards multi-goal data provision for the sustainable development related to the forest resource. Similar progress should be actively fostered in the lesser statistical domains around planning and analyses of forest inventories. This holds for all types of forest inventories. Regarding forest management inventories DUVEMO and LÄMÅS (2006) state, that the "evaluation of forest data should also include its usefulness in the forest management and decision process". This is true also for large area forest inventories, although the specific questions are different, more diverse and more difficult to formulate. Impact assessments should be conducted on a regular basis and systematic approaches to such impact assessments should be developed giving answers to questions like (KLEINN and STÅHL, 2006): how and by whom are the forest inventory data and information (and which part of it) being further processed and used? Has the data and information made a difference in decision processes? How do information requirements and information usage interact with other relevant factors such as knowledge and experience and political values and aims? How can the results be "packaged" to possibly enhance the use of the forest inventory results and how to optimize the communication strategy? Regarding the latter question, BREWER (2006) states for conservation biology: "The data we continue to collect and report on … may make no difference … if this information is not translated into meaningful stories …".

Of course, there are visible examples of the immediate use of results from large area forest inventories: it is known that the information provided by large area forest inventories is, for example, being used to produce long term regional wood supply scenarios, as done for example by the WEHAM, the projection of forest development and timber harvesting potential, derived from data of the second German national forest inventory (BOESCH, 1995; BMELV, 2008) which form a basis for investment decisions for pulp or saw mills. But the systematic assessment of the role that large area forest inventory results play in these decisions and the systematic assessment of the overall use, utility and eventually impact of large area forest inventory data and information is still missing. Methodological elements of such an assessment will include a systematic follow up on the references to the inventory and the inventory results made in the media and in the information material of different sectors, a follow up with those who ordered copies of inventory results' volumes or use the inventory data from an online information system, an inquiry with professionals in neighboring sectors such as conservation and tourism. It is, of course, a difficult field of research, because the value of that information may also be in the documentation itself of the status at a given point in time and "… the immediate relevance of the results is often difficult to demonstrate …" (VAUGHAN et al., 2003).

Clearly, an interdisciplinary approach is needed. Various disciplines from the social sciences are touched by these questions including political sciences, information economics, sociology, psychology, cultural anthropology, ... Academic teaching of forest inventory should include this as well and should not exclusively be seen as a technical-statistical exercise requiring quantitative skills only. Forest inventory must be seen as a discipline that is embedded in a multitude of other disciplines and requires a considerable amount of communication and analysis skills beyond sampling and remote sensing (KLEINN and STÅHL, 2006). When looking at forest inventory from that generic perspective of decision making, it also becomes immediately clear where the links to other disciplines are that require the same or similar information. Forest inventory sampling and plot design has proven sufficiently flexible in many cases to accommodate the collection of a variety of other meaningful variables and indicators. It is likely, therefore, that the integrative development of forest inventories towards landscape inventories or natural resource inventories or ecosystem monitoring will rapidly further develop. This same discussion on requirements and optimization of monitoring is ongoing in conservation biology for several years as well (VAUGHAN et al., 2003; SUTHERLAND et al., 2004; LEGG and NAGY, 2006; FIELD et al., 2007) and the questions are very close to the ones we discussed here.

5. ABSTRACT

Forest inventories are complex undertakings as they deal with the versatile resource and ecosystem forest and are to support manifold planning and decision processes and research in forest management, forest policy and related fields on local, regional and national level. Despite of this clear orientation towards decision making, research in forest inventory continues to focus largely on technical-statistical problems, mainly towards the improvement of data procurement, modeling and data analysis. The fundamental assumption appears to be that better information leads to better decision processes and eventually to better decisions. Not many studies, however, do systematically research into this assumption by establishing visible and testable relationships between information quantity/quality and the quality of decision processes.

In this paper, we address various issues in this context with particular reference to large area forest inventories. Among the general conclusions is that forest inventory implementation (and also forest inventory research) must develop approaches to systematically include impact assessments that allow evaluating how successful an inventory was, to what extent it answered the formulated questions and to what extent new questions were generated that are relevant to planning and policy processes or for the research agenda regarding the management of forest and renewable natural resources.

6. Zusammenfassung

Titel des Beitrages: *Diskussionspunkte zu Waldinventuren als Input zu Planungs- und Entscheidungsprozessen.*

Waldinventuren sind komplexe Projekte, in denen Walddaten erhoben und zu Information konvertiert werden. Diese Daten und Information dienen als Grundlage für vielfältige Arten von waldbezogenen betrieblichen und politischen Entscheidungen und als Input zur Bearbeitung von Forschungsfragestellungen. Waldinventuren finden auf lokaler, sub-nationaler, nationaler, und überregionaler Ebene statt und betrachten den Wald oft gleichzeitig als Ressource und als Ökosystem. Trotz der klaren Orientierung von Waldinventuren hinsichtlich der Unterstützung von Entscheidungen konzentriert sich die Waldinventurforschung weitgehend auf statistische und technische Fragestellungen zur Effizienzsteigerung der Datenerhebung, zur Verbesserung von Datenqualität und -quantität und zur Verbesserung von Modellen. Die grundlegende Annahme dabei scheint zu sein, dass bessere Information zu besseren Entscheidungsprozessen und auch zu besseren Entscheidungen führt. Es gibt nicht viele Studien, die diesen Zusammenhang tatsächlich systematisch untersuchen. In diesem Beitrag besprechen wir eine Reihe von Aspekten, die in diesem Zusammenhang relevant sind und beziehen uns dabei auf großräumige Waldinventuren. Eine der Schlussfolgerungen ist die Empfehlung, dass sich die Inventurforschung auch (!) mit Ansätzen befassen möge, wie eine systematische Wirkungsanalyse von großräumigen Waldinventuren umzusetzen ist. Nur dann kann beurteilt werden, in welchem Maße eine Inventur die gesetzten Ziele erfüllt hat und zu welchen weiteren – möglicherweise ungeplanten – Verwendungen der Information es schließlich kam. Es ist anzunehmen, dass ein solches regelmäßiges „impact assessment" auch die technische Entwicklung von großräumigen Waldinventuren befördert.

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