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Sjur Baardsen, Tron Eid, Hans Fredrik Hoen (eds.)

Festschrift in honor of professors
Ole Hofstad and Birger Solberg

Editors:

Sjur Baardsen, Tron Eid, Hans Fredrik Hoen

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Forestry, forest economics, forest management planning, forest policy, REDD+, forest sector modelling, bioeconomy, climate change

BIOGRAPHIES

Birger Solberg

Birger Solberg was born 07.07.1946 in Målselv, Norway and graduated (Examen artium) from Troms Public Secondary School in 1965. In 1972 he finished his M.Sc. studies in Forest Economics at the Agricultural University of Norway (AUN). This year he also finished studies, equivalent to B.Sc., in Mathematics, Physics and Chemistry at the University of Oslo. From 1972 to 1973, he worked 8 months as research assistant at the Department of Forest Economics (DFE) at AUN, before joining in 1973 the Norwegian Peace Corp working as forest economist in the Ministry of Natural Resources, Kenya. From 1975 to 1979, he had a graduate research scholarship at DFE, AUN. Solberg then worked as researcher (1980-1982) and Associate Professor (1982-1990) at DFE, AUN. In the fall of 1988, he successfully defended his Dr. Agric.-degree in Forest and resource economics with the title "Choice of technology in less industrialized countries with particular reference to forestry and sawmilling".

From 1990 to 1992 he was full professor in Resource economics at the Department of Economics and Social Sciences, AUN, before he took up the position as Chief director of research/full professor in Forest and resource economics at The Norwegian Forest Research Institute (NISK). In 1993 he was appointed the first Director General of the European Forest Institute (EFI) in Finland. Solberg returned from Finland in 1996 to NISK, and in 1998 he got the position as Professor in Forest economics at the Department of Forest Sciences (DFS), AUN, a position he held till 2016.
In 1987-1988 Solberg was Visiting fellow and in 2005-2006 Visiting Professor at University of California, Berkeley, USA. In 2012-2013 he was Visiting Professor at North Carolina State University, Raleigh, USA.

Solberg has had a large number of appointments in boards and committees at the university as well as in various national and international organizations, such as: Member of the Executive Board of IUFRO (1995- 2000), member of the Board of AUN (2002-2005) and the Board of the Norwegian University of Life Sciences (UMB, now NMBU) (2005-2010), Norway's member in the Timber Committee of the European Commission for Europe (2000- 2006), member of the Global Change Committee of the Research Council of Norway (1999-2004), and member of the Board of EFI (2000-2004). Solberg was involved as Review editor for IPCC's (Intergovernmental Panel on Global Climate Change) main report WGIII chapter 4 on mitigation of climate change (1998-2000) and was Lead author for IPCC's Special Report on Land Use Changes and Forestry (1998-2000). He has participated in numerous doctoral committees, evaluation teams, research committees and advisory teams worldwide as well as done consultancies for

FAO, Nordic Council of Ministries, NORAD, FINNIDA/SIDA, EU, CIFOR and the World Bank. He has received several recognitions for his work, like First fellow of the European Forest Institute (1997), the Wilhelm Pfeil Preis (Germany 1998), Honourable member of the Finnish Forest Research Association (1998), Doctor Honoris Causa University of Joensuu (2004), and the IPCC award for "Contributing to the award of the Nobel Peace Price for 2007 to the IPCC" (2008).

Solberg has been teaching various courses at both BSc.-, MSc.- and Ph.D.-levels, and has been main supervisor for 20 students who have fulfilled their Ph.D.-degree. He has been a very active researcher and led numerous research projects with national as well as international funding. Many of these projects have involved close and extensive collaboration with prominent research groups worldwide within the field of forest sciences. He has published widely, both scientifically (more than 130 peer-reviewed scientific articles in international journals) as well as through popular science contributions and via participation in the public debate.

His main research field has been forest economics, and comprises a wide range of topics including forest sector modelling, the forest-based sector and climate change, forest-based bioenergy, stand management optimization, timber supply, global demand for forest industry products, forest policy - to mention a few. A selected list of 25 of his most important scientific works since 2003 is as follows:

Bergseng, Even; Ask, Jon Andreas; Framstad, Erik; Gobakken, Terje; Solberg, Birger; Hoen, Hans Fredrik 2012: Biodiversity protection and economics in long term boreal forest management — A detailed case for the valuation of protection measures. Forest Policy and Economics 2012. Vol. 15:12-21.

Bolkesjø, T. F., Buongiorno, J. & Solberg, B. 2010: Joint production and substitution in timber supply: a panel data analysis. Applied Economics 42(6):671-680.

Bolkesjø, T. F., M. Obersteiner, and B. Solberg 2003. Information technology and the newsprint demand in Western Europe: A Bayesian approach', Canadian J. Forest Research 33:1644-1652.

Kallio, A.M.T, A. Moiseyev & B. Solberg 2006. Economic impacts of increased forest conservation in Europe: a forest sector analysis. Env. Science & Policy 491:9-18.

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Raymer, Ann Kristin; Gobakken, Terje; Solberg, Birger 2011: Optimal forest management with carbon benefits included. Silva Fennica .Volume 17(3):395-414.

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Solberg, B., A. Moiseyev, A.M.I. Kallio & A. Toppinen 2010: Forest sector market impacts of changed roundwood export tariffs and investment climate in Russia. For. Policy and Economics 12(7):489-496.

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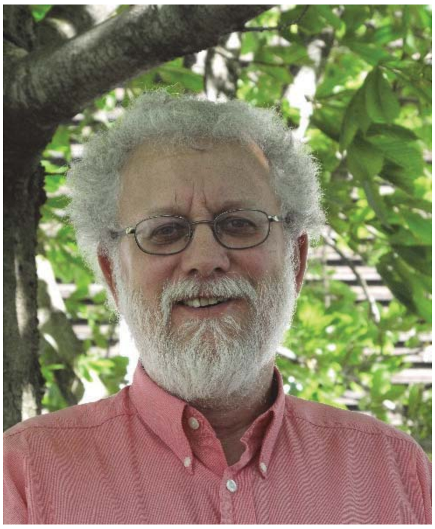
Ole Hofstad



Ole Hofstad was born 19.03.1949 in Trondheim, Norway and graduated from Ringve High School in 1968. In 1973 he finished his Msc. studies in Forest Economics at the Agricultural University of Norway (AUN). The same year he was employed as research assistant at the Department of Forest Economics at AUN. He successfully defended his Dr. scient thesis in Forest Economics at the same department in 1977. The title of his thesis was “Conflicts in multiple-use forestry”. Subsequently Hofstad spent two years in Morogoro, Tanzania as lecturer at the University of Dar es Salaam (later Sokoine University of Agriculture) and one year as lecturer at the Department of Forest Mensuration and Management, AUN. From 1980 he was employed for two years as director of planning for MADEMO (Post-independence state forest enterprise) in Mozambique. In the period 1982- 89 he was lecturer and associate professor (from 1985) at the Department of Forest Mensuration and Management, AUN. He was elected as Head of Department for 1988 and 1989.

After the merger of all forestry departments at AUN in 1990 he was elected as the first Head at the Department of Forest Sciences, AUN. From 1991 to 1993 he was on leave from the department and spent two years as Woodland Management Advisor to Zimbabwe Forestry Commission on contract with the Danish Ministry of Foreign Affairs. Hofstad was appointed as professor in Forest economics and planning (Skogbrukets ressursøkonomi og planlegging) at the Department of Forest Sciences in 1993, and was later elected as Head of Department for two three-year periods (1996-1998 and 2000-2002). In 2002-2003 he spent his sabbatical at College of Natural Resources, University of California at Berkeley. Since 2003 he has been professor at the Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences.

In addition to his administrative duties as Head of Department, Hofstad has been member of boards and member of professional working groups for the department, at the university level as well as for external institutions. He has over the years done numerous consultancies, especially related to forestry and development issues in Africa. Hofstad has been teaching extensively at both Bsc.. Msc. and Phd. levels. He has been responsible for the development of many courses within a wide range of topics, and has implemented his teaching through conventional lectures, and exercises in data laboratories and in field. Hofstad has been main supervisor for 8 Phd-students. Hofstad has been very active and visible on the public scene through numerous popular science articles, chronicles, debate contributions, speeches and presentations on forestry topics as well as on more general policy challenges, both at the national and international scene.

His main research field has been forest economics, but comprises a wide range of topics including multiple-use forestry, bio-economic modelling, forest management planning and forest policy, to mention a few. A selected list of 15 scientific works is as follows:

Hofstad, O. 1976. Konflikter ved flersidig bruk av skog. (Conflicts in multiple-use forestry). Unpublished Dr.Scient. thesis, NLH. 173pp.

Hofstad, O. 1984. Still større krav til driftsplanen. *Skogeieren*, (10):36.

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Wam, H. K, O. Hofstad, E. Nævdal and P. L. Sankhayan 2005. A bio-economic model for optimal harvest of timber and moose. Forest Ecology and Management 206:207-19.

Preface

The professors Ole Hofstad and Birger Solberg are about to step down after more than 40 years of service. Each of them has, in their own ways, given great contributions to research, teaching and dissemination in forest economics and forest policy in the broad sense, nationally as well as internationally. This Festschrift is a celebration of, and a thank you for, the effort. We are many who have had the pleasure of having Birger and Ole as teachers, colleagues and collaborative partners.

The Festschrift is the result of a great response to an invitation we sent to a selection of people in the spring of 2016. Because Birger and Ole have contributed to a wide range of topics, and in many different ways, we allowed the contributors to choose the form and degree of scientific formalism of their respective contributions, within proposed themes. The Festschrift is therefore broad in its selection of themes, and we are happy to present contributions of original character, as well as presentations of a more review- and discussion-like nature. We have made an effort to present the articles in a thematic order.

We thank all authors for their response and contributions. Thanks go to Cathrine Glosli for effective and excellent editing.

Ås, August 2016

Sjur Baardsen Tron Eid Hans Fredrik Hoen

Forord

Professorene Ole Hofstad og Birger Solberg er i ferd med å trappe ned etter mer enn 40 års tjeneste. På hver sin måte har de gitt store bidrag til forskning, undervisning og formidling innenfor skogøkonomi og skogpolitikk i vid forstand, nasjonalt så vel som internasjonalt. Dette festskriftet er en markering av, og en takk for, innsatsen. Vi er mange som har hatt gleden av å ha Birger og Ole som lærere, kolleger og samarbeidspartnere.

Festskriftet er resultatet av en gledelig stor respons på invitasjoner sendt til et utvalg av personer våren 2016. Fordi Birger og Ole har gitt bidrag innenfor mange temaer og på mange måter, åpnet vi for at bidragsyterne kunne velge form og grad av vitenskapelig formalisme på sine respektive bidrag som de selv ønsket, innenfor foreslåtte tema. Det er derfor stor spennvidde i valg av temaer, og vi er glade for å kunne presentere bidrag av så vel original karakter, som mer oversikts- og diskusjonspregede framstillinger. Vi har forsøkt å presentere artiklene i en tematisk orden.

Vi takker alle bidragsyterne for deres bidrag. Takk også til Cathrine Glosli for effektivt og utmerket redigeringsarbeid.

Ås, august 2016

Sjur Baardsen   Tron Eid   Hans Fredrik Hoen

Contents

1. The EFI-GTM model: past – present – future

A. Maarit I. Kallio[1], Alexander Moiseyev[2]

[1]Natural Resources Institute Finland (Luke)
[2]Norwegian University of Life Sciences

Introduction
The EFI-GTM is a spatial partial economic equilibrium model of the global forest sector. The model's first version was launched in 1997 and the model has been in use since then, furnished with updated data and modifications needed to address the various research questions. The model building was initiated by professor Birger Solberg, then the director of the recently founded European Forest Institute, and was carried out together with Solberg and the authors of this review.

The use of forest sector models integrating dynamics of forest resources, timber supply, forest industry, and forest product markets was well established before the EFI-GTM. Yet, at the time EFI-GTM was started there was no global model active and available that could be used to analyze the European forest sector. Among the most well-known early models combining round wood markets to forest industry production are the Timber Assessment Market Model/TAMM for North America (Adams and Haynes 1980), the PELPS model (Buongiorno and Gilles 1984, Zhang et al. 1993) that was later modified to the Global Forest Product Model/ GFPM (Zhu et al. 1998, Buongiorno et al. 2003), and the global forest sector model GTM (from "Global Trade Model") developed at the International Institute for Applied Systems Analysis in the 1980s (Kallio et al. 1987). The structure the EFI-GTM resembles the GTM in many aspects, for which reason it was named "GTM".

The EFI-GTM depicts a group of competing price-taking market players that are producing, consuming and trading forest sector commodities in various regions whenever these activities increase their economic welfare. For each region, the model includes demand functions for the final products (mechanical forest industry products, paper and paperboard, energy commodities), supply functions for waste paper, round wood and logging residues, as well as a set of technologies for producing intermediate (pulp, chips) and final forest industry and energy products.

The EFI-GTM is a *partial* equilibrium model, because the existence of the sectors or production factors in the economy other than those more or less directly linked to forests and wood based market chains are only accounted for indirectly, via exogenous specification of demand functions and prices of exogenous production factors such as labor, energy and capital, and via predictions on possible technological change and economic growth. The model is *spatial* because it gives, for each period and region, an equilibrium solution which includes trade between all regions in the model.

The theoretical basis for the model is that of spatial equilibrium in competitive markets as first solved by Samuelson (1952) for several commodities. The competitive market equilibrium is found via maximizing the sum of producers' and consumers' surpluses net of transportation costs subject to material balance, trade, and capacity constraints.

The EFI-GTM model is multi-periodic. It is solved for one period (year) at time and the solution is used to update the timber supply specifications and the existing production capacities for the subsequent period. Also, the given periodical data describing the exogenous sector factors like demand functions for final products are then updated according to their assumed development in the studied scenarios. Thereafter, a new equilibrium is computed subject to the new demand and supply conditions. As such, the dynamic changes from year to year are modeled by recursive programming, meaning that the long run spatial market equilibrium problem is broken up into a sequence of short run problems, one for each year. Hence, the model assumes that the decision makers in the economy have imperfect foresight, while they adapt to the new prevailing market conditions period after period.

The basic logic of the model is explained in Kallio, Moiseyev and Solberg (2004), though there are some extensions made to the commodities considered (e.g., logging residues and energy commodities) in the later applications.

Past uses of the model

The EFI-GTM was developed with the aim of having a tool for making consistent projections on the questions of how and by how much production, consumption, imports, exports, and prices of various categories of wood biomass and forest industry products might change over time as a response to changes in external factors like economic growth, forest biodiversity protection, energy prices, trade regulations, transport costs, exchange rates, forest growth, consumer preferences and various policies. Indeed, the various applications of the model prove its usefulness to these purposes. The EFI-GTM has been used for several consulting studies (e.g., EEA 2006 and 2007, Indufor 2008, European Forest Sector Outlook Study II (UN, 2011), Kallio et al. 2015) as well as to academic research published in peer-reviewed scientific journals. The latter is briefly reviewed below.

The first peer-reviewed application of the EFI-GTM model (Solberg et al., 2003) addressed the impacts of climatic warming on the European forest sector. The climate change was brought in to the model projections by assuming that forest growth in Europe accelerates due to warmer climate and CO_2 fertilization. The forest sectors' reactions to climate change in Western Europe were mostly found to be positive in the sense that more roundwood and sawnwood could be produced at lower costs making both the profits of the forest industry and the income of the forest owners increase in Europe. While the results are plausible given the assumptions, in the future work it would be of interest to consider the heterogeneous responses of forest growth to climate change in various regions. The climatic warming is not beneficial to forests in all regions even in Europe - and climate change brings in several risks to the wood supply (forest fires, insect outbreaks, etc.).

Kallio et al. (2006) considered the economic impacts of potential increases in forest conservation in Europe. In the EFI-GTM, the assumption of increased forest conservation was operationalized by constraining the growing stock available for timber supply by certain percentages, by 3% and 5%, more precisely. It was found that conservation is beneficial to the forest owners in Europe because the round wood prices increase more than the harvests decline. While profits of the forest industries decline due to increased wood prices, the production quantities are affected mostly in sawmills and pulp mills. The leakage of harvests from Western Europe in particularly to Russia takes place due to forest conservation.

A leakage impact is relevant also in other contexts, like e.g., in that of a EU Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan, which was considered by Moiseyev et al. (2010), or in that related to Russia's policy for setting tariffs for its round wood exports, as analyzed by Solberg et al. (2010). Modeling with EFI-GTM the various policy options proposed by the EC to combat illegal logging and to prevent the imports of illegally harvested timber or products derived from such timber was a part of the assessment carried out by Indufor (2008). Moiseyev et al. (2010) considered two EU trade policy options in addition to the baseline policy, VPA (Voluntary Partnership Agreement). It was found that an option, which requires a licensing scheme for all wood and wood products placed on the EU market by all sellers including internal EU operators, would lead to the lowest negative consequences, including leakage of forest sector's value added in favor of high risk regions. This option was chosen by EC as a basis for its EU timber regulation (EUTR) policy implemented since 2013.

Solberg et al. (2010) considered the impacts of the Russian Federation's policy decision to set considerable tariffs on its roundwood exports. As can be expected, the tariffs were found to decrease harvest and roundwood prices in Russia. The decreasing wood prices could give some help to the development in the Russian sawnwood and pulp industry. Yet, it was found that, for the Russian forest industry to develop favorably, policies improving the investment climate in Russia would be more vital than attempts to constrain wood exports.

In Eriksson et al. (2011), the EFI-GTM was used as a part of integrated modeling framework for studying the potential impacts of the increased use of sawnwood and plywood for construction in Europe. Increasing the share of apartment flats built of wood instead of non-wood materials gradually so that most new flats in Europe would be built of wood by 2030 was found to have surprisingly small effect on the wood market and consequently on forest management. The reason for the meager effect was due to the relatively small amount of wood that is needed to construct one apartment flat. Considerably higher increases would be required to cause more significant market impacts. Eriksson et al. also considered a case where the sawnwood consumption would increase in European countries to 1 m^3/capita, i.e., to the level where it is more or less in Finland. This development would have drastic effect on the wood market and possibly on forestry. The latter would largely depend on whether the forest owners are able to anticipate such development or not.

Several recent applications of the EFI-GTM (Moiseyev et al. 2011, 2013, 2014) reflect the fact the wood based bioenergy is coming more and more important factor in shaping the development of the wood using sectors in Europe. Moiseyev et al. (2011) addressed the effects of increasing energy wood prices on the EU forest sector and on the use of wood biomass for energy in the context of the storylines of A1 and B2 of the world economic development by IPCC. The results predicted that rising energy wood prices in Europe would lead to increasing wood imports and reallocation of wood from competing industrial users such as board manufacturers or the pulp and paper industry to energy sector. Nevertheless, for that to take place in a considerable manner, relatively high energy prices would be needed. Results in Moiseyev et al. (2011) were to a large extent based on EEA (2006, 2007) report with the EFI-GTM analysis being part of the study.

In Moiseyev et al. (2011) the demand for energy wood was driven by the assumed mill gate price that an energy plant could pay. In the European Forest Sector Outlook Study II (UN, 2011), where the EFI-GTM was used to consider the “Reference” and “Promoting wood energy” scenarios, the use of energy wood was fixed to a given policy based target quantity that had to be met regardless the price. Both these approaches for modeling energy wood demand (setting fixed price or fixed quantity) suffer from arbitrary external assumptions. Consequently, Moiseyev et al. (2013) took a step forward. In that study, production technologies for heat and power were introduced to the EFI-GTM in order to examine the effects of different coal, natural gas and carbon emission prices and market situations on the use of wood for electricity and heat production in the European Union. Also, this study suggested that rather high costs of using the other fuels competing with wood would be needed in order to boost the wood demand to the level that would cause so much rivalry over wood that it would affect the production of the forest industries. Yet, it is possible that the prices of CO_2 emission will increase to the levels considered (e.g., 100 €/t), when the EU energy sector is being decarbonized. However, even then the impact on the forest sector and energy wood supply may be relatively modest without subsidies for wood fired energy.

Finally, Moiseyev et al. (2014) considered the question of how subsidies for wood-fired heat and power plants and wood with coal co-fired power plants influence the use of wood biomass for energy in the short (2020) to medium (2030) term in the European Union. The results suggest that without subsidies wood-fired electricity will take only a marginal market share due to limited availability of low-cost wood from logging residues. One important result of the paper is the notion that subsidies for co-firing wood can be harmful as they help maintain the coal power, which could otherwise be reduced at high carbon emission price level.

Future prospects

There is no reason to believe that the EFI-GTM model would not be actively used in the future as well. Interesting questions arising will likely deal with the new wood based commodities entering the market, whereas the questions related to climate change mitigation, energy, environmental protection, carbon leakage, forest product market development and trade can be expected to remain strongly on the agenda in the future as well.

Regarding the methodological development of the model, the question of how to address uncertainties better than before is an interesting issue. Also, the EFI-GTM could be improved to consider the forest owners' behavior and timber supply in the more sophisticated manner. Last but not least, one of the major challenges in the use of the EFI-GTM model is that of furnishing it constantly with fresh and recent data. The model is rather detailed regarding the forest industry production technologies (more detailed than any other global forest sector model), which is one of the strengths of the model. But at the same time, that is a weakness considering the resources needed to keep the model updated. There are no public statistics or ready data available for the forest industry technologies divided to various vintages or data on all the input cost categories covering all of the many EFI-GTM regions. Therefore the data collection requires lots of resources. The lack of good statistics of the wood prices and forest resources in the various countries at a usefully detailed level of product categories also poses a problem to any (global) forest sector modeler.

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2. Global forest sector modeling: application to some impacts of climate change

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Abstract

This paper explored the potential long-term effects of a warming climate on the global wood sector, based on Way and Oren's synthesis (Tree Physiology 30,669-688) indicating positive responses of tree growth to higher temperature in boreal and temperate climates, and negative responses in the tropics. Changes in forest productivity were introduced in the Global Forest Products Model (GFPM), using Way and Oren's equations in accord with the rising temperatures projected in the IPCC scenario A1B, A2, and B2. Projections of the forest stock, production, prices, and trade of wood, and value added in industries were obtained with the GFPM for each scenario, with and without temperature changes from 2012 to 2065. In the three scenarios, the projected global growing stock of forests in 2065 was hardly changed by the rise in temperature. However, the forest stock was 2% to 6% higher in developed countries while it was 3% to 4% lower in developing countries. There were significant attendant changes in wood production, prices, trade, and value added in forest industries benefiting developed countries and harming the developing countries.

Keyword*s*: Climate change, wood, supply, demand, prices, international trade.

Introduction

The temperature of the earth has been rising steadily, and by nearly 1°C from 1950 to 2014 (NASA, 2015 and Figure 1). This trend is expected to continue. The International Panel on Climate Change projects that the earth surface temperature could increase by 1.8°C to 4.0°C over a century, depending on different scenarios concerning economic growth, demographic trends, and mitigation policies (IPCC 2007). This rise in temperature matters for global forests that are sources of wood and carbon sinks (Woodbury et al. 2007). Accordingly, past studies have addressed the effects of climate change in forest economics (see Kirilenko and Sedjo 2007 for a review), using projections of biological consequences of climate change to alter the wood supply in forest sector models (McCarl et al. 2000, Perez-Garcia et al. 2002, Solberg et al. 2003, Sohngen and Sedjo 2005).

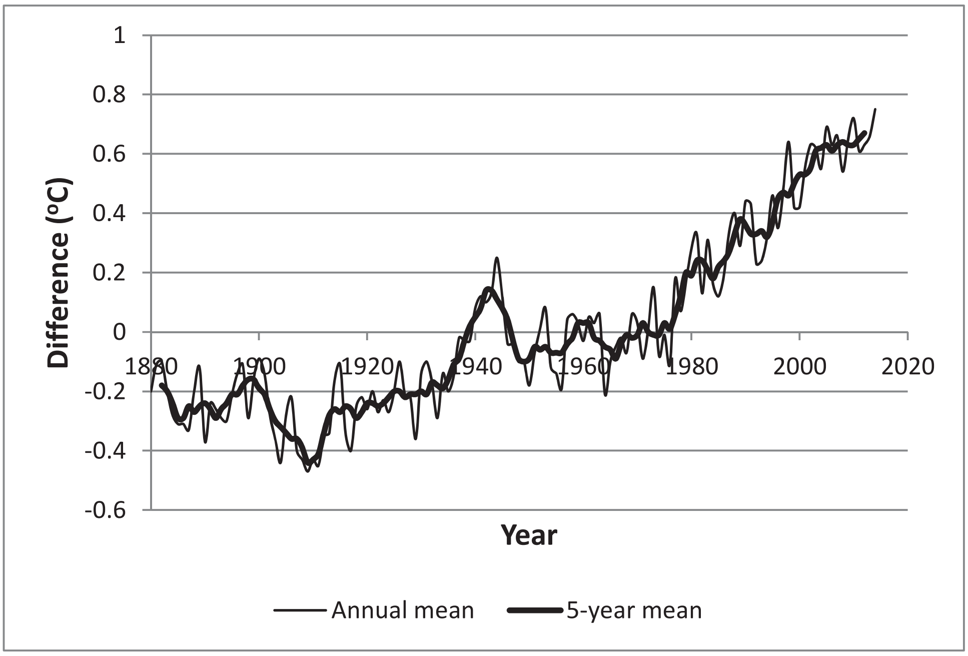

Figure 1: Difference in mean average temperature relative to the average 1951-1980 (NASA 2015).

Although some studies assume higher growth of forests due to higher temperatures and longer growing seasons (Nabuurs et al. 2002), predicting the effects of climate change on forests is extremely complex as it depends on future nutrient availability, especially water, carbon dioxide fertilization, and the adaptability of various trees to environmental changes (Boisvenue and Running, 2006). Nevertheless, Way and Oren (2010) have produced a very useful synthesis (Ryan 2010) of the effects of temperature on tree growth, in the form of equations linking changes in growth to temperature changes, differentiated for boreal, temperate, and tropical ecosystems. Accordingly, this study aimed at using the findings of Way and Oren (2010) to predict their long-term consequences for global forest stock and wood markets. Special attention was given to the possibility that the impact could vary considerably depending on the chosen scenarios concerning world economic and demographic growth, and policy, with their attendant differences in global temperatures.

The next section of the paper describes the theory, models, and data used in the study. This is followed by the projections for the main world regions of the changes due to increased temperature on forest stock, and consequently on roundwood production and trade, world wood prices, and value added in forest industries. The conclusion summarizes the main results, especially the differential impact on developed and developing countries.

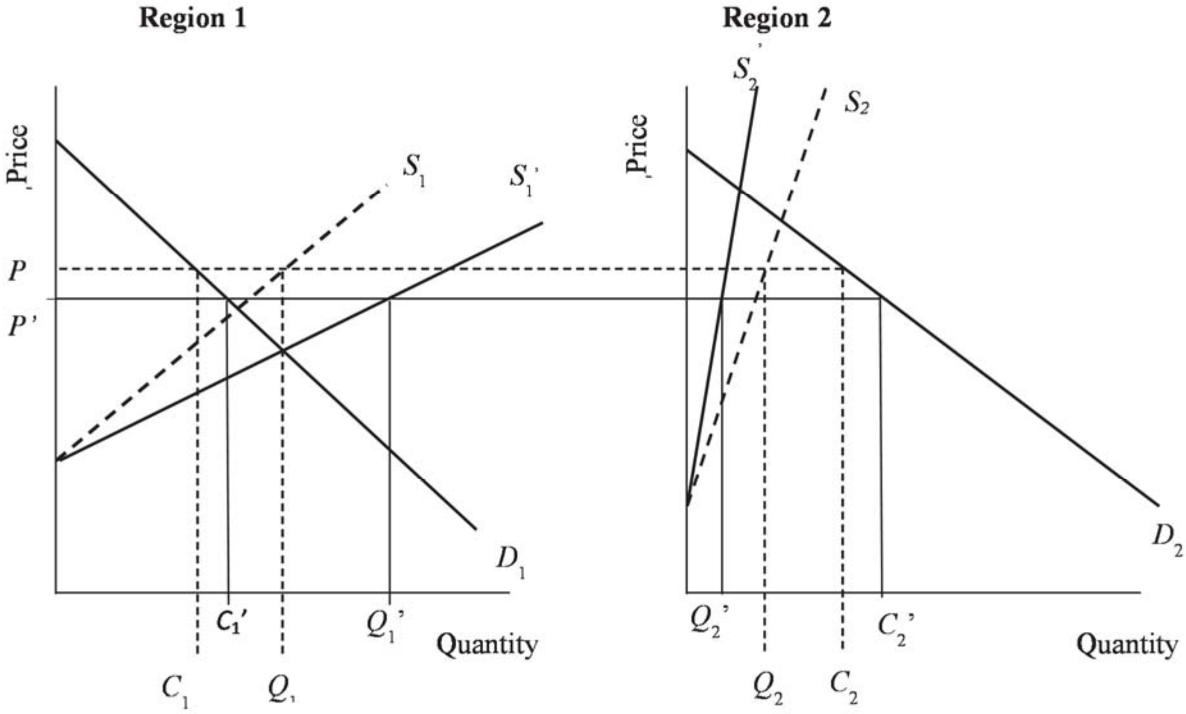

Figure 2. Theoretical impact in two trading regions of wood supply shifts induced by changes in temperature on production, consumption, net trade, and price of wood.

Methods

Theory

The general principles of the analysis are symbolized in Figure 2. The figure outlines the demand, supply, trade, and price of wood, with and without impact of temperature change on forests, in a world divided in two regions. Without temperature change Region 1, with demand schedule D1 and supply schedule S1, exports the quantity Q1-C1 and Region 2, with demand schedule D2 and supply schedule S2 exports the quantity C2-Q2=Q1-C1. Ignoring the transport cost, which is not critical for the reasoning, the price, P, is the same in Region 1 and Region 2. With the change in temperature Figure 2 assumes that forest growth is stimulated in Region 1, so that the wood supply shifts to the right to S1', while forest growth is hampered in Region 2, and accordingly the wood supply shifts to the left to S2', but by less in absolute value than the positive supply shift in Region 1. Other things being equal, the demand is unchanged by the temperature change and remains D1 in region 1 and D2 in region 2. However, the net increase in supply leads to a decrease of the equilibrium price, from P to P'. In accord with the lower price the quantity consumed increases from C1 to C1' in region 1 and from C2 to C2' in region 2. The lower price together with the negative supply shift induces lower production in region 2, from Q2 to Q2'. Meanwhile in region 1, the positive effect of the supply shift exceeds the negative effect of the price decrease, and leads to increased production from Q1 to Q1'. For trade, in this Figure, the net result of the increase in temperature is an increase of exports from region 1, and a matching increase of imports in Region 2.

Although Figure 2 is very abstract it reveals the complexity of the response to changes in temperature that may stimulate forest growth in some regions and reduce it in others. Even considering the supply side only, the direction, let alone the magnitude of changes in consumption, production, trade and price may differ considerably depending on the effect of temperature change and the elasticities of demand and supply. For example, given a positive effect of temperature increase on forest growth, production may still decrease in a region if the price effect (movement along the supply curve) exceeds the effect of the supply shift. Thus, in a multi-region, multi-products situation, the adjustment of the global equilibrium due to changes of temperature requires a more elaborate model of the forest sector.

Global Forest Products Model (GFPM)

The GFPM adapted for this study is a recursive dynamic equilibrium model of the global forest sector. The formulation and the computer software, available freely to researchers, are described in Buongiorno and Zhu (2016). The current model deals with 180 countries, forest area and stock, and 14 commodity groups, ranging from fuelwood to paper and paperboard.

For each projected year the model simulates a spatial economic equilibrium as a quadratic programming problem. The objective function is the "social surplus" in the global forest sector (Samuelson 1952, Takayama and Judge 1971). The constraints equate demand and supply for each country and product. The primal solution gives the quantities consumed, produced and traded while the dual solution gives the prices by product and country. The quadratic program is solved with the BPMPD interior point solver (Mészáros 1999).

Between years, the demand equations shift in accord with the expected gross domestic product (GDP). The shifts of roundwood supply are determined by the changes of forest stock. The changes in forest area depend on the level of income per capita, according to a Kuznet's curve (Koop and Tole 1999, Buongiorno 2014). The national forest stock changes over time according to a growth-drain equation:

$$I = I_{-1} + G_{-1} - S_{-1} \qquad (1)$$

where I and I_{-1} are respectively the level of the forest stock at the beginning of the current and previous year, S_{-1} is the harvest during the previous year and G_{-1} is the change of forest stock during the previous year, given by:

$$G_{-1} = (g_a + g_u + g_u^*))I_{-1} \qquad (2)$$

Where g_a is the forest area growth rate, and g_u is the rate of forest stock growth on a given area, without harvest. In this application g_u* is the relative change of the annual rate of forest stock growth due to temperature change. The forest growth rate, g_u, is an inverse function of the stock per unit area (Buongiorno 2014). Equation (1) then gives the rate of change of forest stock net of harvest, which determines the shift of the wood supply curves. Other dynamic elements include the changes in the input-output coefficients describing technologies, and the associated changes in manufacturing cost (Buongiorno and Zhu, 2015a).

The input-output (I-O) coefficients and manufacturing costs of the GFPM used in this study were calibrated for the base year 2012 with FAOSTAT data (FAO 2015) averaged from 2011 to 2013 (Buongiorno and Zhu 2015b). Together with data on local prices the calibration also gives estimates of the manufacturing costs. With input-output coefficients and manufacturing costs determined in this way, and the end-product demand and wood supply equations positioned with the price and quantity in each country, the solution of the global equilibrium closely replicated the base-year input data (production, consumption, net trade, and prices).

The parameters of the demand equations were estimated with panel country-year data from 1992 to 2013, using the fixed-effects method (Buongiorno 2015). The environmental Kuznets curve for forest area change and the equation of the growth rate of forest stock were both estimated with data from FAO (2010) as in Buongiorno (2014). The elasticities of fuelwood and industrial roundwood supply with price and growing stock were based on Turner et al. (2006). The freight cost between countries was estimated as the difference between unit value of imports and exports. Data on import tariff duties came from the World Trade Organization data base (WTO 2013).

IPCC scenarios

Three global scenarios, A1B, A2, and B2 were used in the projections from 2011 to 2065. The scenarios are based on the IPPC scenarios (Nakicenovic et al., 2000), extended and modified for the purpose of the United States Forest Service 2010 RPA Assessment (USDA Forest Service 2012). Each scenario makes different assumptions about future global social, economic, technical and policy changes. Scenario A1B assumes continuing globalization with attendant to high incomes and low populations, and thus the highest future income per capita. Scenario A2 assumes a slowdown of globalization, leading to lower incomes than scenario A1B, higher populations, and thus lower income per capita. Scenario B2 has economic and demographic assumptions between scenarios A1B and A2.

For the GFPM simulations, the three main exogenous variables taken from these scenarios were the growth of GDP and population, and the rise in temperature. National GDP growth was deducted from the regional growth available from the IPCC with the assumption that the growth of individual countries converged towards the regional growth rate (Buongiorno et al. 2012, p. 117). Table 1 shows the resulting annual growth rates of GDP for each scenario, by world regions. The corresponding rises in temperature over a century are in Table 2. The highest projected increase is for scenario A2, with an expected value of 3.4^{o}C over 100 years, and the lowest is for scenario B2, with an expected warming of 2.4^{o}C.

Table 1. Projected annual percent GDP growth rate in world regions, by scenario.
Source: Adapted from Buongiorno et al. (2012).

Table 2: Projected global average warming over one century (°C).

	Scenario A1B		Scenario A2		Scenario B2	
	2012-2030	2030-2065	2012-2030	2030-2065	2012-2030	2011-2065
AFRICA	7.1	5.4	3.4	4.1	5.0	5.9
N/C AMERICA	2.6	2.3	1.9	1.8	1.7	1.4
SOUTH AMERICA	5.3	3.3	2.0	2.5	2.7	3.4
ASIA	5.5	3.8	2.5	2.4	3.7	2.8
OCEANIA	2.9	2.1	2.2	1.6	2.2	0.9
EUROPE	2.3	2.0	1.2	1.1	1.3	1.3
EU-28	1.9	1.7	1.2	1.0	1.1	0.9
DEVELOPED	2.3	2.0	1.5	1.4	1.4	1.2
DEVELOPING	6.7	4.2	3.1	3.0	4.6	3.7
WORLD	3.9	3.2	1.9	2.0	2.4	2.4

Scenario	Likely range	Best estimate
B2	1.4 - 3.8	2.4
A1B	1.7 - 4.4	2.8
A2	2.0 - 5.4	3.4

Source: IPCC (2007)

Table 3: Regression coefficients for relationship of total tree mass versus a change in growth temperature. Equations are of the form $y=a+bx+cx^2$, where x=temperature change in °C, and y is the response relative to the control.

Line	*a*	*b*	*c*
Boreal	0.90(+-0.088)	0.091(+-0.014)	
Temperate	0.87(+-0.041)	0.053(+-0.00645	
Tropical	0.98(+-0.052)	-0.0067(+-0.0087)	-0.0064(+-0.0013)

Source: Way and Oren (2010).

Temperature change and forest growth

Way and Oren (2010) find that trees in boreal, temperate, and tropical zones respond differently to increased temperature. The response is positive and largest in boreal ecosystems, much lower but still positive in temperate ones, and negative in tropical zones. Table 3 shows the parameters of linear and quadratic equations reported by Way and Oren (2010) to summarize the results of numerous experiments dealing with tree growth in total mass. In these equations the response to a change in growth temperature (assumed here over the growing season) is measured by dividing the treatment value by the control value. Thus, response of 1 means that the temperature change has no effect on tree growth, a response <1 means that the change in temperature reduces growth, and a response >1 means that the temperature change increases growth (Way and Oren, 2010).

For example, with the equations in Table 3, a rise in temperature of 2.8°C implied by the A1B scenario led to a response of 1.1548, i.e. an increase in total mass of 15.48 percent in boreal forests. Since the 2.8°C rise in temperature was over 100 years, the annual increase in growth rate in total mass was $1.1548^{1/100}-1=0.0014$ or 0.14 percent per year. This was then the predicted impact of the temperature change on the forest growth rate used in the GFPM, the value of the parameter g_u^* in equation (2). In contrast, in tropical forests the same temperature increase of 2.8°C led to a response of 0.9111 i.e. a decrease in total mass of 8.89 percent over a century, and a $g_u^* = -0.09$ percent per year. Figure 3 shows the adjustments of the forest growth rates g_u^* for the temperature changes in the three scenarios and for the boreal, temperate and tropical forests. As the GFPM only deals with national statistics, countries were broadly classified as having mostly forests of the boreal, temperate, or tropical type according to their mean monthly annual temperatures (MAT) from 1961 to 1999 (World Bank 2011). For the 180 GFPM countries, those with MAT≤1.5°C were classified as Boreal, those with 3°C ≤ MAT≤19.7°C as temperate and those with MAT≥20°C as tropical.

Results

Effects on forest stock

Table 4 summarizes the long-term effect of the rise in temperature on the forest stock, by scenario, for major world regions and selected countries. For each region, the effect was measured by the difference in projected forest stock in 2065 between the simulations with and without temperature increase. Globally, the largest predicted effect was a decrease in total forest stock of 4.2×10^9 m^3 (approximately 1%) under scenario B2. This was due to a 10.7 $\times 10^9$ m^3 (3%) decrease in growing stock in developing countries, which was only partially compensated by a 6.5 $\times 10^9$ m^3 (2%) increase in growing stock in developed countries. The main negative regional effect was in South America, where the growing stock was 6.2 to 8.2 $\times 10^9$ m^3 (4% to 5%) lower depending on the scenario, largely due to decreases in growing stock in Brazil. Other large negative impacts were in Africa where the growing stock was 3.1 to 4.3 $\times 10^9$ m^3 (4% to 6%) lower depending on the scenario.

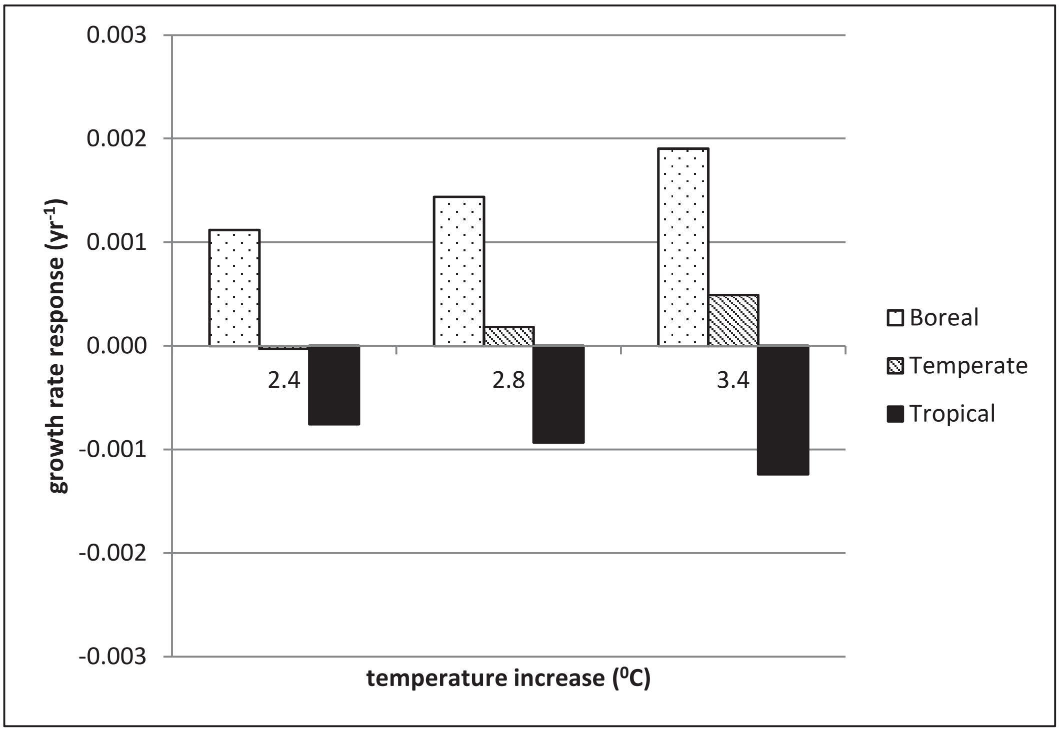

Figure 3: Projected response of forest stock growth rates to temperature changes of 2.4 °C (scenario B2), 2.8 °C (scenario A1B) and 3.4 °C (scenario A2).

In contrast, the rise in temperature led to higher growing stocks in 2065 principally in Europe, and mostly due to the positive impact in Russia: 4.6 to 8.4 x10^9 m^3 (5% to 10%). The growing stock was also higher in North America, but by lesser amounts (1.5 to 4.8 x10^9 m^3 or 1% to 4%), mostly due to changes in Canadian forests, and secondarily to those in the United States. In Asia, the changes in growing stock were negative under scenarios B2 and A1B due principally to changes in India and Indonesia, but under scenario A2 this was totally compensated by the increase in growing stock in China.

Effects on wood production

The differences in annual roundwood production (fuelwood and industrial roundwood) in 2065 due to rising temperatures are in Table 5. The changes were due to the shift of wood supply induced by the changes in growing stock in conjunction with movements along the wood supply curves due to the price changes described below. Globally, production was higher in all three scenarios. The largest increase occurred with scenario A2 (20.1x10^6 m^3/year or 1% difference). But there was a sharp contrast between developed countries where production was 75.2x10^6 m^3/year or 4% higher, and developing countries where production was 55.1x10^6 m^3/year or 3% lower with the A2 scenario.

The major increases in wood production took place in Europe, especially in Russia where it was 25.6 to 41.4x10^6 m^3/year (10% to 17%) higher depending on the scenario due to the rise in temperature. There were also notable rises in production in Canada: 15.2 to 28.1x10^6 m^3/year or 10% to 13%, and in Scandinavian countries: 6% to

12% in Finland and Sweden. Changes were much more modest in temperate regions. In the United States for example, production was slightly lower, due to lower prices, even though growing stock was somewhat higher in conjunction with higher temperatures.

Rising temperature induced major decreases in roundwood production in South America where in Brazil in particular production was 13.5 to 27.5 $x10^6$ m^3/year (5% to 9%) lower depending on the scenario. In Asia production decreased by 16 to $24x10^6$ m^3/year mostly due to the effects in India and Indonesia. Lesser negative changes occurred in Africa and Oceania.

Effects on wood prices

As indicated above and in Figure 1, the price changes induced by a rise in temperature depend on the magnitude of the positive and negative shifts of wood supply induced by changes in the growth rate of forest stock stimulated or hampered by global warming. Figure 4 shows the GFPM predicted differences due to temperature increases for the world prices of fuelwood and industrial roundwood, and the price of one derived product, sawnwood, from 2012 and 2065, according to the three scenarios. In all cases the world price was defined as the unit value of world exports.

For all three scenarios the prices were lower in 2065 than they would have been without temperature change, in accord with the global increase in growing stock induced by the rise in temperatures (Table 4) and the attendant wood supply shift. In all cases, the relative price impact was similar for fuelwood and industrial roundwood, and substantially less for sawnwood, an end product for which a substantial part of the manufacturing cost is due to non-wood inputs: capital, labor, and energy. Regardless, under the B2 scenario, the price impacts in 2065 were hardly noticeable, about -1% for industrial roundwood, and -0.5% for sawnwood.

The largest predicted price effects were observed with scenario A2. As shown in Figure 4, the price differences increased steadily over time as global temperatures increased. By 2065, the prices of fuelwood and industrial roundwood were both approximately 5% lower than they would have been without changes in temperature, and the price of sawnwood was 2% lower.

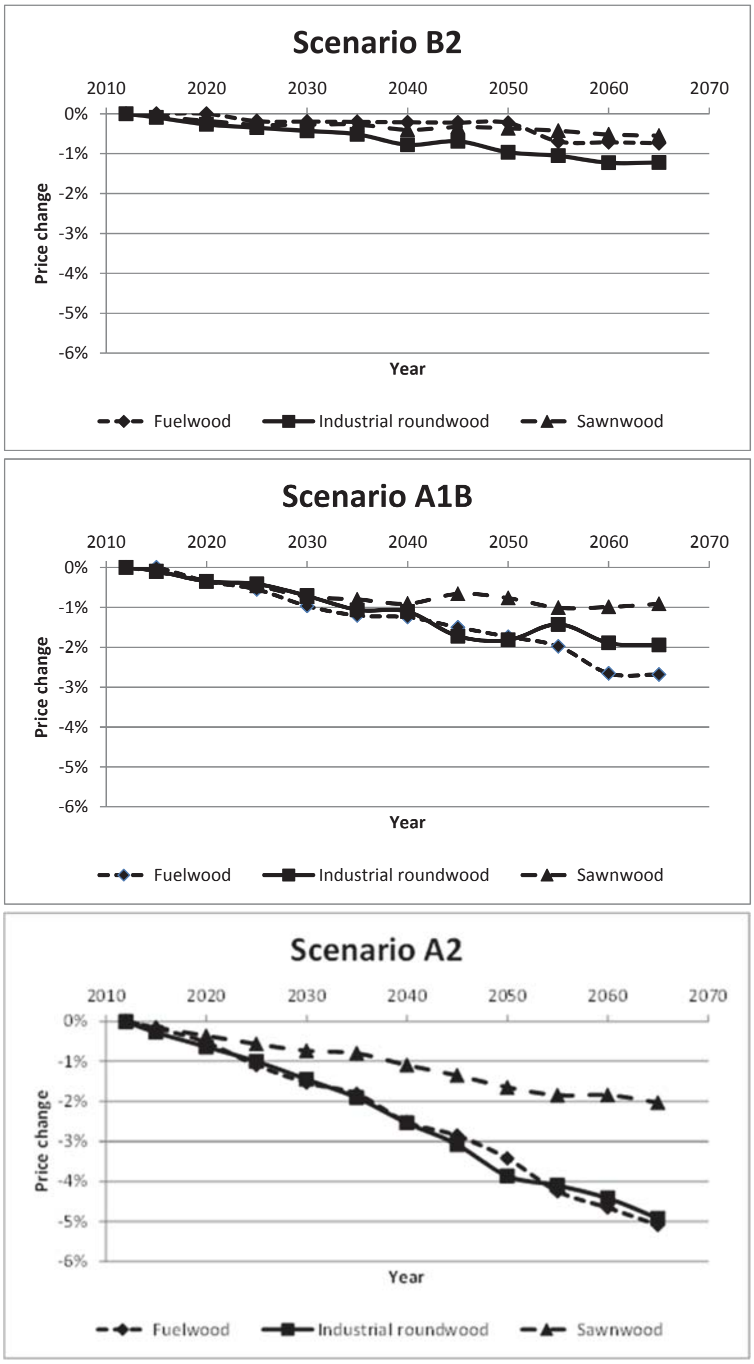

Figure 4. Projected changes in world prices of roundwood and fuelwood due to temperature changes, by scenario.

Table 4: Projected differences in forest growing stock in 2065 due to temperature changes, by region and selected countries (10^6 m^3).

	Scenario					
	B2		A1B		A2	
AFRICA	**-3081**	**-4%**	**-3550**	**-5%**	**-4269**	**-6%**
South Africa	12	1%	20	2%	49	4%
N/C AMERICA	**1523**	**1%**	**2588**	**2%**	**4817**	**4%**
Canada	1637	5%	2096	7%	3116	10%
Mexico	-131	-4%	-145	-5%	-179	-7%
United States	152	0%	808	1%	2070	3%
SOUTH AMERICA	**-6232**	**-4%**	**-6852**	**-4%**	**-8193**	**-5%**
Argentina	3	0%	34	1%	60	3%
Brazil	-4968	-4%	-5546	-4%	-6792	-6%
Chile	15	1%	37	2%	96	4%
ASIA	**-948**	**-1%**	**-620**	**-1%**	**41**	**0%**
China	47	0%	318	1%	1050	2%
India	-360	-3%	-368	-3%	-497	-4%
Indonesia	-336	-4%	-385	-5%	-459	-6%
Japan	7	0%	25	1%	75	3%
Korea, Republic of	3	0%	31	1%	68	2%
Malaysia	-186	-3%	-205	-3%	-240	-4%
OCEANIA	**-398**	**-3%**	**-400**	**-3%**	**-491**	**-3%**
Australia	-306	-4%	-323	-4%	-446	-5%
New Zealand	12	0%	43	2%	104	3%
EUROPE	**4928**	**4%**	**6517**	**5%**	**10111**	**7%**
EU-28	204	1%	474	1%	1238	3%
Austria	6	0%	18	1%	41	3%
Finland	27	1%	22	1%	92	3%
France	26	1%	63	1%	160	3%
Germany	31	0%	91	1%	217	3%
Italy	1	0%	30	1%	77	2%
Russian Federation	4625	5%	5828	7%	8374	10%
Spain	5	0%	12	1%	48	3%
Sweden	45	1%	45	2%	139	4%
United Kingdom	3	1%	7	2%	18	4%
DEVELOPED	**6456**	**2%**	**9220**	**4%**	**15143**	**6%**
DEVELOPING	**-10665**	**-3%**	**-11535**	**-3%**	**-13125**	**-4%**
WORLD	**-4209**	**-1%**	**-2316**	**0%**	**2018**	**0%**

Table 5. Projected differences in roundwood production in 2065 due to temperature changes, by region and selected countries (10^3 m^3).

	Scenario					
	B2		A1B		A2	
AFRICA	**-3887**	**-1%**	**-4624**	**-1%**	**-7452**	**-2%**
South Africa	-171	0%	270	1%	34	0%
N/C AMERICA	**7227**	**1%**	**24367**	**2%**	**14092**	**2%**
Canada	15251	10%	28066	13%	19873	14%
Mexico	-825	-2%	-1269	-3%	-1189	-3%
United States	-6722	-1%	-1101	0%	-3771	-1%
SOUTH AMERICA	**-14563**	**-4%**	**-28319**	**-6%**	**-20496**	**-5%**
Argentina	-73	0%	-175	-1%	141	1%
Brazil	-13535	-5%	-27540	-9%	-19962	-8%
Chile	-255	-1%	325	1%	215	0%
ASIA	**-15937**	**-1%**	**-23769**	**-2%**	**-24222**	**-2%**
China	-1114	0%	1754	0%	4376	1%
India	-3690	-1%	-11027	-3%	-13250	-4%
Indonesia	-5197	-5%	-7460	-6%	-6189	-6%
Japan	-106	-1%	80	0%	63	0%
Korea, Republic of	-81	0%	10	0%	-104	-1%
Malaysia	-2468	-7%	-4135	-9%	-3739	-13%
OCEANIA	**-3012**	**-5%**	**-4811**	**-5%**	**-4345**	**-7%**
Australia	-2195	-8%	-3881	-10%	-3633	-14%
New Zealand	-270	-1%	50	0%	128	1%
EUROPE	**33794**	**3%**	**51097**	**4%**	**62498**	**6%**
EU-28	7334	1%	15389	2%	19472	3%
Austria	-160	-1%	79	0%	73	0%
Finland	5040	6%	6059	8%	9144	12%
France	-843	-1%	133	0%	-402	-1%
Germany	-848	-1%	322	0%	-615	-1%
Italy	-3	0%	-13	0%	61	1%
Russian Federation	25638	10%	33390	11%	41431	17%
Spain	-27	0%	238	1%	36	0%
Sweden	5998	7%	7546	8%	10684	12%
United Kingdom	-75	-1%	94	1%	42	0%
DEVELOPED	**39585**	**2%**	**74592**	**3%**	**75214**	**4%**
DEVELOPING	**-35963**	**-2%**	**-60651**	**-3%**	**-55139**	**-3%**
WORLD	**3622**	**0%**	**13940**	**0%**	**20074**	**1%**

Table 6. Projected differences in roundwood trade in 2065 due to temperature changes, by region and selected countries (10^3 m^3).

	Exports			Imports		
	B2	A1B	A2	A2	A1B	A2
AFRICA	**-814**	**-1239**	**-3031**	**136**	**278**	**94**
South Africa	-507	-254	-2254	0	0	0
N/C AMERICA	**5689**	**16079**	**10431**	**54**	**-102**	**-110**
Canada	13915	21578	16401	-98	-113	-135
Mexico	0	0	0	84	1	3
United States	-8034	-5162	-5614	0	0	0
SOUTH AMERICA	**-373**	**-25116**	**-2172**	**4**	**5**	**18**
Argentina	0	2	0	0	0	2
Brazil	0	-24759	0	1	0	10
Chile	-289	197	-373	0	0	0
ASIA	**-3644**	**-1333**	**-4510**	**574**	**3559**	**1895**
China	0	-2	0	-9	-2803	-9430
India	0	-1	0	2	6888	10773
Indonesia	0	0	0	1	76	76
Japan	0	0	0	150	-618	89
Korea, Republic of	0	0	0	-3	30	0
Malaysia	-1729	-228	-1160	0	0	0
OCEANIA	**-3471**	**-5425**	**-5308**	**4**	**28**	**8**
Australia	-2289	-3972	-4081	4	4	6
New Zealand	-667	-513	-223	0	0	0
EUROPE	**-2039**	**3341**	**-488**	**-5423**	**-17459**	**-6983**
EU-28	-2332	3226	-1377	-5429	-17559	-6993
Austria	0	0	0	810	1130	1927
Finland	0	0	0	-4509	-8168	-8978
France	-508	126	-600	0	0	0
Germany	0	0	0	427	-258	-3108
Italy	0	0	0	-2	-197	-30
Russian Federation	-43	-2898	0	0	0	2
Spain	-25	-1	-5	80	-1126	530
Sweden	0	0	0	-5097	-12378	-451
United Kingdom	-76	493	32	0	0	0
DEVELOPED	**379**	**15020**	**3742**	**-5370**	**-18168**	**-7018**
DEVELOPING	**-5031**	**-28712**	**-8820**	**719**	**4476**	**1940**
WORLD	**-4652**	**-13692**	**-5078**	**-4651**	**-13692**	**-5078**

Table 7. Projected differences in value added in 2065 due to temperature changes, by region and selected countries ($\$10^6$).

	Scenario					
	B2		A1B		A2	
	($\$10^6$)		($\$10^6$)		($\$10^6$)	
AFRICA	**8**	**0%**	**132**	**1%**	**646**	**8%**
South Africa	113	3%	191	6%	599	17%
N/C AMERICA	**934**	**1%**	**4185**	**2%**	**3096**	**2%**
Canada	461	3%	2535	12%	1292	10%
Mexico	-25	0%	-214	-2%	-176	-2%
United States of America	505	0%	1887	1%	1981	2%
SOUTH AMERICA	**-2001**	**-4%**	**-283**	**0%**	**-1097**	**-3%**
Argentina	-21	-1%	-31	-1%	40	2%
Brazil	-1936	-5%	-206	0%	-1502	-5%
Chile	17	1%	50	2%	67	3%
ASIA	**-951**	**0%**	**-4366**	**0%**	**-906**	**0%**
China	363	0%	-514	0%	89	0%
India	-258	-1%	-370	-1%	432	2%
Indonesia	-749	-4%	-1353	-4%	-725	-4%
Japan	45	0%	-442	-1%	235	1%
Korea, Republic of	-46	0%	41	0%	-108	-1%
Malaysia	-158	-2%	-1318	-5%	-489	-6%
OCEANIA	**255**	**2%**	**283**	**2%**	**314**	**3%**
Australia	52	1%	64	1%	134	2%
New Zealand	200	4%	212	2%	148	3%
EUROPE	**3188**	**1%**	**3422**	**1%**	**5555**	**2%**
EU-28	2310	1%	2972	1%	3888	2%
Austria	464	1%	779	2%	655	2%
Finland	208	2%	474	4%	567	6%
France	-65	-1%	-113	-1%	70	1%
Germany	993	2%	1150	1%	561	1%
Italy	-5	0%	-75	-1%	-3	0%
Russian Federation	820	2%	565	1%	1547	5%
Spain	-66	0%	-664	-3%	243	2%
Sweden	144	1%	39	0%	1033	10%
United Kingdom	27	1%	-30	0%	32	1%
DEVELOPED, ALL	**4555**	**1%**	**7875**	**1%**	**9941**	**2%**
DEVELOPING, ALL	**-3122**	**0%**	**-4501**	**0%**	**-2333**	**0%**
WORLD	**1433**	**0%**	**3374**	**0%**	**7608**	**1%**

Effects on trade

Table 6 summarizes the projected effects of temperature changes on imports and exports of wood (fuelwood and industrial roundwood), in major world regions and selected countries. Depending on the scenario, the total world trade was approximately 5 to 14 million m^3 lower in 2065 than it would have been without temperature change. The largest change was in developing countries where with scenario A1B exports decreased by nearly 29 million m^3 while imports increased by 4.5 million m^3. In contrast, the balance of trade improved for developed countries, as exports were 15 million m3 per year higher in 2065 and imports were 18 million m^3 lower. The main increase in exports was in North America where Canadian exports in particular were, depending on the scenario, 14 to 22 million m^3/year higher in 2065 than they would have been without the increase in temperature. Symmetrically, countries in Asia tended to have lower exports and larger imports. India's imports in particular increased by 7 to 11 million m3/year under scenarios A1B and A2. The net trade of Europe improved with higher temperatures mostly due to lower imports, especially in countries of the European Union. However, there was generally little change in Russian imports and exports, despite the rise in production of 10% to 17% induced by temperature increase in 2065 (Table 5).

Effects on value added

The impact of the rises in global temperatures on forest industries are summarized in Table 7. For the purpose of this paper, value added was defined as the difference between the value, at local prices, of the products considered in the GFPM minus the cost of the wood and fiber inputs used in production.

At world level, there was practically no change in value added under scenario A1B and B2. With scenario B2, the world value added was only $1.4x10^9$ (0.1%) higher with the rise in temperature than without it. The largest world increase in value added was with scenario A2, but still no more than 1% higher than without temperature change. However, with all three scenarios there was a marked difference between developed and developing countries. For scenario A2 value added increased by approximately $10x10^9$ (2%) in the developed countries while it decreased by $2.3x10^9$ (3%) in developing countries. For scenarios B2 the increase in value added was nearly the same as the decrease in developing countries.

The largest regional increase in value added was in Europe under scenario A2, due in large part to positive changes in Russia and Scandinavian countries. The largest decrease was in Asia under A1B, stemming from changes in Indonesia and Malaysia in particular. Due to differences in manufacturing cost and resulting competitive advantage of countries, there was only a rough correlation between the changes in value added in Table 7 and the changes in production in Table 5, R^2=0.69 for the relative changes under A2. For Russia for example, while production was 11% higher due to temperature change, value added was only 5% higher, and in Germany value added actually increased despite a small decrease in production.

Summary and conclusion

The objective of this paper was to explore the potential effects of future global warming on the forest sector. Way and Oren's (2010) synthesis provided quantitative estimates of the effects of temperature changes on tree growth, suggesting a positive and largest response in boreal climates, a slightly positive effect in temperate conditions, and a strong negative effect in tropical environments.

This change in productivity was applied to national forest growth rates in the Global Forest Products Model in accord with the rises in temperature projected by the

International Panel for Climate Change scenarios A1B, A2, and B2, together with the different growth rates of gross domestic product and population attendant to the three scenarios.

For each scenario, projections of forest stock, wood production, wood prices, trade, and value added were obtained with the GFPM for the years from 2012 to 2065, with and without temperature changes.

According to the results, in the three scenarios, the projected global growing stock of forests in 2065 was hardly changed by the rise in temperature. Thus, globally, the temperature change would have little effect on carbon sequestration. However, the forest stock was 2% to 6% higher in developed countries while it was 3% to 4% lower in developing countries.

Consequently the wood supply, the harvest, and the net trade (export minus imports) increased in Europe and North America, but decreased in Asia and South America. In conjunction with this higher supply, world wood prices were lower with global warming, and the value added in wood industries increased in Europe and North America while it decreased in Asia and South America.

These findings rely on strong assumptions; in particular that the effects of rising temperature can be summarized over very different forest types by the equations suggested in Way and Oren (2010). Although the patterns of response that they observe are striking and useful in large spatial scale models like the GFPM where more detailed data are lacking (Ryan 2010), much work is still needed to quantify the effect of temperature apart from or in conjunction with changes in related factors, such as precipitation (Zickfeld et al. 2012). In addition, the methods used in this study require good estimates of current forest growth rates in different countries. This will mean further improvement of the global forest inventory and harvest statistics, which are currently subject to substantial errors due to infrequent and unequal sampling, and differences in definitions and classifications (FAO 2015).

Despite these limitations, an important result of the present study was to show that the impact of temperature, and thus of climate change in general, depended strongly on the economic and demographic scenarios in which it occurred. But regardless of scenario, the study predicted that while temperature change had a neutral effect on global carbon sequestration, it had a series of strong beneficial effects in developed countries, from increase in growing stock to more value added, but harmful effects in developing countries for the same components.

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3. The economic viability of biofuel production based on wood biomass

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1. Introduction

Bioenergy comprises a large diversity of technologies for generating heat, electricity and transportation fuel. Bioenergy used for heating and electricity generation may provide energy security and flexibility in electricity systems with large shares of intermittent renewable energy (RE) such as wind and solar (IEA 2013). In the transport sector, biofuels are one of the few alternatives to fossil fuels for heavy transportation and aviation, and the renewable share (RES) in the transport sector is still very low. The transport sector represents 31.6% of the final energy consumption in EU-28 (2013 figures) and had a RES of 5.4% - far below the 25.4% share in electricity and 16.5% in heating and cooling. Biofuels have been the main contributor to the increased RES in the transport sector and the biofuel share increased from 0.4% in 2003 to 3.8% in EU-28 in 2013 (European Commission 2015). The global production of biofuels have increased 7-9 fold since 1995 and represents between 3 and 3.5% of the energy consumption in the transport sector (BP 2016; REN21 2015).

Biofuels are regarded a promising renewable option in the transport sector for multiple reasons. They can be blended with fossil fuels and can be used in existing storage and distribution systems. There are, however, several technical, environmental and economic challenges in production and use of biofuels. The current production is mainly based on corn and sugar cane for bioethanol and on vegetable oil and fat containing waste for biodiesel, which imply that biofuel production may come at the cost of reduced food production. The food versus fuel issues are to a large extent avoided in second generation (SGB) or advanced biofuels based on cellulosic biomass. SGB is already available, but it is not yet commercially competitive for fuels for transport. While cellulosic biomass reduces the direct fuels versus food competition, it may impact land use, biodiversity and GHG emissions. The competition for biomass for production of heat, power, biofuels pulp and paper as well as integrated, combined or cascading production rises issues related to markets, comparative advantages, location, energy system benefits, synergies and competition.

The objective of this paper is to assess and discuss potentials for biofuel production, with emphasis on the Norwegian setting. The analysis is based on assessments of the resource potential, the future driving forces for reduced use of fossil fuels, technological prospects for SGB, and GHG effects of biofuels. Finally, we discuss energy system effects of alternative use of biomass for energy.

2. Biomass supply – potential role of biofuels

Global and European potentials

Biomass is currently providing about 10% of the global energy supply of 571 exajoule (EJ) (European Commission 2015). IPPC's special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN) estimated the global technical potential of energy from biomass to be from 50 to 500 EJ/year (Chum et al. 2011). The market potential in the SRREN refers to the part of the technical potential that can be produced given a specified requirement for the level of economic profit in production. This depends not only on the cost of production but also on the price of the biomass feedstock, which is determined by a range of factors such as the characteristics of biomass procurement technologies, the price of competing energy technologies and the prevailing policy regime.

The European baseline biomass potential by 2030 is estimated by Chum at al. (2011) to be 18 EJ/yr and the high potential 27 EJ/yr. The current final consumption of petroleum products in the EU is 14 EJ. The annual supply of wood is 9 EJ/yr below a cost of 2005-US$9/GJ, about 25% of the current market price for the cheapest wood for energy purposes delivered roadside. The European Environment Agency (2013) estimated the European potential of delivered bioenergy in three different scenarios where feed stock prices varied from 3to 6 €/GJ. The potential varied from 5.3 to 6.7 EJ/yr of which about 20% origins from imported biomass and 10-20% from wood. These estimates indicate that bioenergy can provide about 10% of the current energy consumption in Europe.

The Norwegian case

Forest resources represent in the short and medium run the major potential for increased biomass utilization in Norway. The annual sustainable yield with current environmental regulations and certification was estimated to be 17 mill m^3 by Bergseng et al. (2012). The annual harvest level has been stable around 10 mill m^3 since statistics become available around 1920. The roundwood harvest is hence about 60% of the technical sustainable yield. The nominal timber prices have been relatively stable but with a falling trend, hence real timber prices have been falling. The current market price in Norway for wood chips delivered plant is 70-85$/GJ.

Numerous timber supply analyses have been conducted in Norway dating back to 1964 (Baardsen et al. 1997) – both at forest owner level and at the aggregate level. Studies at the micro level (forest owner) have identified a wide range of factors affecting the timber supply (Bolkesjø & Baardsen 2002; Bolkesjø & Solberg 2003; Bolkesjø et al. 2007; Bolkesjø et al. 2010; Løyland et al. 1995; Rørstad 1990; Rørstad & Solberg 1992; Størdal et al. 2008). These factors include current and expected timber prices, operation costs, rate of return, various socio-economic factors (e.g. age of the owner, education level, wealth and non-forest income), factors related to the forest property (e.g. size of productive forest, standing stock, sustainable yield, annual increment and management plan) and tax rate. For a closer review, see Vennesland et al. (2006). The factors mentioned above are to a large degree the same as found in the international literature (Amacher et al. 2003; Beach et al. 2005; Bolkesjø & Solberg 2003; Conway 2003).

Harvest residues are only to a limited extent demanded by the traditional forest industries in Norway, and thus represent an unutilized resource for increased production of renewable energy. However, the utilization of the residues is closely integrated with traditional forestry, and the volume and location of timber harvest is the decisive factor for their economic availability. The costs of collection, transport, chipping and storage and the demand for the residues decide the actual supply, within the potential given by actual roundwood harvest. In addition to a price that covers the direct costs involved in the production process, the forest owner might also demand a "stumpage fee" to compensate for perceived non-market costs of deliveries, like potential loss of soil productivity. Rørstad et al. (2010) combined GIS and forest modelling
in estimating regional supply of harvest residues in Norway and the results were used in Bergseng et al. (2012) to estimate national biomass potentials. The techno-economic potential for extra biomass utilization from forestry is around 70 PJ. 15-20 PJ of additional biomass could be available by 2020 at current biomass prices. The current pulpwood export is of the same magnitude, hence 30-40 PJ of biomass is in principle available for biofuel production at current prices.

The energy consumption in the Norwegian domestic transport sector was 193 PJ in 2015 of which 75% is in road transport, 15% coastal shipping, 8% domestic air transport and 2% railways (Statistics Norway 2016). With a conversion efficiency from biomass to biofuel of 50%, about 10% of the current fuel consumption in the transport sector could be supplied by biofuels produced from domestic forest resources.

High transport costs for forest biomass and the spatial nature of the market makes it important to incorporate price-quantity relations for biomass supply, and the results in Trømborg et al. (2014) show how sensitive the bioenergy production is for differences in biomass costs. Price influences biomass supply, but other factors are also important. Technological development and attitudes towards use of forest resources can affect future biomass supply, and can give price-quantity relations different from the current situation. More studies of supply drivers would reduce the uncertainty connected to this type of analysis.

3. Technology developments and prospects

The global biofuel production is currently mainly based on edible crops (i.e. starch, sugar and vegetable oil). Bioethanol production in Brazil – based on sugarcane – and in USA – based on corn – make up about two third of the global production in energy terms. The production of FAME (fatty acid methyl ether) accounts to 30%, while the rest is production of hydrotreated vegetable oil (HVO) (REN21 2015). Norway produces about 20 million liters/year bioethanol (Borregaard in Sarpsborg, based on a hemicellulose) and about 110 million liters/year FAME (Perstorp in Fredrikstad, based on imported rapeseed oil).

Globally, there are only a few producers of so-called advanced biofuels or SGB. SunPine and Preem are producing HVO-diesel from talloil which is a pulping byproduct (Ekbom 2016) and in Crescentino bioethanol is produced from lignocellulosic feedstock. There are some plants in USA under construction, but they are not in full commercial production (Schwab et al. 2016). In the short term, there are no signs that cellulosic biofuel will take a large share of the biofuel market.

Biofuels can be made from forest biomass in various ways, and both virgin fiber and by-products from the forest industry may be used. Gasification of the biomass, followed by catalytic synthesis, e.g. Fisher-Tropsch process (F-T) is not a new invention, but it is still subject to considerable interest. This process was developed in the 1920-ies to produce liquid fuels from coal (CtL), and it has been adapted to produce liquid fuels from gas (GtL). Commercial plants exist for both these feedstocks. The ash melting behavior and slag properties in the gasifying step of the process and the subsequent purification of the syngas is currently the major challenge when applying the process to biomass (BtL) (Haarlemmer et al. 2014). The cost estimates of BtL are uncertain since no commercial plants exist. Recent techno-economic assessments show a large variation in the cost estimates (see e.g. Sunde et al. (2011)). Due to the complexity, BtL will not be competitive against CtL if only the production costs are included. There seems to be no large economies of scale for BtL and expected learning rate seems low (Daugaard et al. 2015; de Wit et al. 2010).

Another thermo-chemical route is (fast) pyrolysis followed by bio-crude upgrading (cracking, hydrotreatment, etc) (Brown et al. 2013). There is commercial production of heating oil utilizing the pyrolysis process (e.g. the Fortum Otso bio-oil, see also (Bridgwater 2012)). Thus, this technology is closer to being a viable biofuel process than F-T. Also, this is a milder process operating at 400 – 600 degrees C, and thus, ash melting and slag seem to be of less concern than for the F-T process. This means that the use of low quality feedstocks such as harvest residues is more likely for this type of biofuel production.

In addition to the two pathways mentioned above, there are also numerous biochemical ways to produce biofuels, i.e. using microorganisms to produce liquids or gases from lignocellulosic biomass. The main challenge is the lignin that act as glue in the biomass and makes the cellulose (i.e. the sugars) less available. Different technologies exist, but so far none seem to compete with first generation bioethanol produced from corn and sugarcane (Kumar et al. 2016).

The current producer prices on biodiesel and bioethanol is about NOK 8.7 and 6.9 per liter fossil fuel equivalent, and prices are projected to remain fairly constant the next ten years (OECD/Food and Agriculture Organization of the United Nations 2014). These prices roughly equal 0.8 NOK/kWh. Chum et al. (2011) presents expected production costs towards 2030 for different fuels and technologies. For biofuels based on F-T and pyrolysis, they estimated production costs to be in the range 14 – 30 US$/GJ. With a conversion efficiency of 0.5 and feedstock costs accounting for 40% of total costs, the cost of wood chips delivered plant must be between 3 and 6 US$/GJ. The current price for wood chips delivered plant in Norway is about 8 US$/GJ.

The opportunities for feedstock costs reductions in Norway is uncertain, especially in combination with increased supply. Our previous estimates (Bergseng et al. 2012; Rørstad et al. 2010) imply that currently, the cheapest resources are not available even at the upper level of the estimates based on Chum et al. (2011) (6 US$/GJ). Other low quality assortments than pulpwood do exist, but in relatively small quantities. There is potential for cost reductions by learning and scale, but a main challenge remains: A biofuel plant will need large biomass quantities at rather low costs.

4. Best use of forest biomass

Alternative use of forest biomass

As discussed above, the costs of SGB is well beyond the corresponding costs of fossil fuels and the market prices. This implies that substantial biofuel policy support is needed for wood-based biofuel market shares to rise. Such policy support should consider the societal benefits and costs of different options for utilization of forest biomass. Unlike other renewable energy sources such as solar, wind and hydro, biomass have several alternative applications, both for energy (power, heat and transportation fuels) and other commodities. While the current use of bioenergy in Norway is limited to 16 TWh (58 PJ)/year (Trømborg 2015), a transition towards a fossil free energy system may cause substantially higher production levels - both in Norway and the rest of Europe - and this may cause increased competition for biomass for different energy purposes as well as environmental impacts.

Energy system impacts

In the 2050 carbon neutral scenario (CNS) of IEA (2016) bioenergy is by far the largest energy source with a total primary energy supply of 4.5 EJ (or approximately 1250 TWh/year). Given a limited and price sensitive biomass supply it may be necessary to prioritize different bioenergy options in the long run, and in this context the societal benefits of different types of bioenergy (heat, power and transportation fuels) in the future energy system is highly important. The main advantage of biofuels over bioheat and biopower, in this context, is that there are few, if any, renewable alternatives in heavy duty transportation and aviation. This is particularly important in the Norwegian setting where the power and heat sector have very low fossil fuel shares already (Statistics Norway 2016). Bioenergy may, however, provide substantial positive energy system benefits in stationary use as well. Besides bioenergy, the major growth in renewable energy is expected be solar and wind power, having a highly variable supply not easily regulated (intermittent). These intermittent technologies will replace mid-merit easily regulated gas and coal plants and cause a power production mix which is less able to adapt supply to demand. This development will imply larger short-term variations in power prices and cause challenges in balancing the energy system, and the need for flexible demand and supplying the energy system will increase. Bio-power is dispatchable and may hence provide such flexibility. Bio-power or –heat with carbon capture and storage is also one of very few alternatives for net sequestration of carbon. The third main option, bio-heat, is currently the most competitive alternative. Since a large share of electricity in Norway is used for heating, the advantages of bioheat are to some extent similar to those of bio-power, mentioned above. District heating plants with both a bio-boiler and an electric boiler are system friendly options in several respects (Lund et al. 2014 and Kirkerud et al. 2016). They can use electricity in excess power situations while maintaining security of supply by using biomass (or other sources) when there is low electricity supply. More renewables in the European heat and power sector will hence increase the demand and competition for biomass.

Green-house-gas effects

More than 90 % of the flux of GHG between terrestrial ecosystems and the atmosphere occurs in forests, and global forests is a net carbon sink despite rather large emissions due to deforestation (Trømborg et al. 2011). The standing stock in Norway has tripled during the last 100 years, and the net annual increment in stored carbon in Norwegian forest is roughly 25 million tons CO_2-equivalents.

Large scale SGB plants in Norway will use large volumes of wood fiber and this will affect both harvesting levels, net wood import and the profitability of other forest industries (Trømborg et al. 2013). Increased wood demand would, *ceteris paribus*, increase the domestic harvest level and hence affect the carbon cycle. A range of studies at different scales with a variety of approaches has been carried out to assess the climate change mitigation possibilities in the forest sector. Prolonged rotations, afforestation, intensified planting, improved plant materials, changes of species, more fertilization and less thinning are all changes in the forest management that might enhance carbon sequestration and storage. Use of bioenergy can reduce fossil GHG emissions by replacing fossil fuels directly, and wood materials can substitute GHG-intensive materials such as concrete and steel. Studies of such substitution effects generally find a reduction in the GHG emissions when biomass systems are compared to fossil reference systems, as long as the permanent reductions in terrestrial carbon pools are small. However, the majority of these case studies assume carbon neutrality in the meaning that as new trees grow where the old ones were harvested, an amount of CO_2 similar to the quantity emitted during combustion will be sequestered over the next rotation period. This assumption of carbon neutrality is in line with the approach taken by the Kyoto Protocol, i.e. biogenic carbon flows are summarized without regard to the timing of each flow.

Since combustion of wood usually is less energy efficient / more carbon intensive than combustion of oil and natural gas, using wood instead of these fossil fuels for energy will in the short term lead to increased CO_2 concentration in the atmosphere, creating a carbon debt and a corresponding CO_2 pay-back time. If wood energy replaces power produced from coal, the net GHG emissions in the combustion process are approximately zero. The length of the pay-back time from increased harvest in Norway is mainly determined by the following factors: (i) the foregone sequestration in the harvested stand, (ii) how large share of the harvested biomass in the stand is utilized and the substitution effects of this utilization, and (iii) the initial growth of the new stand. With the present biomass utilization, forest growth and management in Norway, the length of this payback time is relatively long. A positive carbon price implies longer rotations for forest stands, the more if the sequestration in the existing stand is high, re-growth is slow and substitution effects low. However, at a certain point in time, a forest stand will reach a state of slow and eventually negative growth, and in this situation, harvest to replace fossil fuels followed by regeneration is more likely to improve the GHG balance also in the short run.

If harvest in Norway increases and the use of oil and natural gas is replaced by forest bioenergy, the GHG emissions will increase in the short to medium run. However, given that increased use of biomass substitute fossil fuels or materials, increased use of biomass will reduce GHG accumulation in the atmosphere in the long run. An important question is therefore what the relevant time horizon for global warming mitigation efforts is. The optimal mitigation strategy will depend upon this chosen time horizon.

To assess the forcing effects of forestry in both the short and the long term, we need to broaden the scope from pure GHG emission calculations to the entire climate system. This means that we need to take into account also non-GHG effects like reflections from the forest surface (albedo), evapotranspiration, aerosols, etc (Trømborg et al. 2011). For example, the albedo effects may imply shorter rotations, more broadleaves and less afforestation compared to what is optimal when considering GHG effects only. The important point here is that we need to link the biogeophysical climate forcing effects to forest management in order to get a more complete picture.

5. Opportunities and challenges for biofuel production in Norway

The Norwegian forest industry was a large net importer of pulpwood from 1990 to 2010. Due to a 60 percent reduction in the domestic pulp and paper production, the Norwegian forest sector is currently exporting a large share of the harvested roundwood. From a forest sector value chain perspective, a higher domestic utilization of energy wood, pulpwood and harvest residues would be beneficial, since it reduces the vulnerability of exchange rates, changes in foreign demand and reduces transport costs.

The transport sector, both in Norway and globally, is energy intensive. It has a low share of renewable energy and there is currently no renewable alternative to biofuels in aviation and parts of heavy transport and shipping. As such, the resources potential and future demand indicate promising opportunities for forest-based biofuel production in Norway. However, in the long-run, biomass may be demanded as substitute to fossil resources for multiple applications, and the competition for biomass both within and outside the energy sector should be accounted for. There are also major economic barriers in wood-based biofuel production per se. Current biofuel retail prices in the US are about 20% higher for ethanol than for gasoline and 50% higher for biodiesel than for diesel. Biofuel costs will likely reduce through learning effects, but still, due to the heterogeneous chemical properties of biomass and the low energy density, it seems unlikely that wood biofuel will be fully cost competitive to fossil alternatives without a substantial CO_2-price. On the other hand, blending requirements will continue to increase the global production of biofuels.

Future biomass prices predicted in international biofuel research are low compared to Nordic market prices for forest-based biomass, and the magnitude of cost reductions by learning through reallocation of biomass from pulp and paper to biofuel is uncertain. Hence, like for the power sector, a transformation from a fossil to renewable transport sector will require political commitments and will come with substantial costs. Large scale forest based biofuel production in Norway requires strong and targeted political support and/or strong and clear commitments from large consumers in order to be economically viable.

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4. The Role of Forest Sector Models in the Policy Process – The US Experience

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Forest sector models (FSMs) of varying degrees of sophistication have been employed to analyze forest policy proposals in the US over at least the last 50 years. In most cases the characteristics of emerging policy questions have acted to drive the development of new types or features of FSMs to provide more focused and useful information. Using Latta, Sjølie and Solberg's (2013)—LSS--taxonomy of FSM types, however, it's not clear that the particular policy issue (e.g., public lands management or climate change) has favored the application of either their dynamic recursive or intertemporal optimization model forms. Both forms have found use in almost every type of policy question, though there may be differences between the two in terms of flexibility in dealing with new or unique policy proposals.

The extent and complexity of what LSS term "model features," in contrast, do seem to be linked more closely with the types of policy questions under consideration and the policy outcomes that are of importance. Three broad classes of features are of interest: (a) product and spatial market detail, (b) extent and biological complexity of the forest inventory (biological) representation, and (c) links to other sectors through land use decisions. For example, the number of products and market levels and the extent and detail of product flows represented in a model has usually depended in part on the geographic scope and product specificity of the policy(ies) under examination. Detailed biological modeling is more common in studies concerned with a policy's silvicultural or broader ecological implications or where policy provisions are directed at specific silvicultural actions. Inclusion of explicit (and often endogenous) land use decisions has varied with the geographic and sectoral scope of policies (e.g., carbon taxes in forestry and agricultural sectors) and the time horizon of analyses (e.g., effects of land use shifts may become more important with longer projection periods). In general, these added features act to extend the boundaries of the partial equilibrium system being modeled, expand the number of endogenous variables, and raise issues of model validation and control.

The following sections consider five broad groups of policy issues that (in our view) have attracted significant attention and debate in the US forest sector and which have been analyzed using FSM's: i) public lands management, ii) international trade policy, iii) private forestry practices, iv) changes in the private forest land base, and v) forest products market behavior. In each section we characterize the types of policy questions that have been posed and describe the features (per LSS) of the FSMs that have been used to provide information to policy makers. Citations provide examples of current and past approaches, but space does not allow an exhaustive review.

Public Lands Management

The ubiquitous policy issue on most public forest lands in the US relates to levels of timber harvest and how public harvests impact the behavior of other forest owners (through market linkages). Prior to 1990, federal planners were required to consider effects of federal harvest on other owners. FSMs emerged to assist in this process. The USDA Forest Service had used crude national sector models since the early 1960's to examine future price and timber harvest prospects. These were elaborated in the Timber Assessment models developed pursuant to the 1974 Renewable Resources Planning Act (RPA), including TAMM, NAPAP based on PELPS, and linked versions of these models to allow endogenous interactions between solidwood and fiber products markets (this history is reviewed in Adams and Haynes, 2007). These were all spatial equilibrium models employing LSS's dynamic recursive form with endogenous capacity (capital input) decisions. They explicitly considered interregional and international trade (in varying degrees of detail) and allowed flexibility in examining alternative macroeconomic, trade policy, and exchange rate scenarios. As needs grew in policy debates for more detailed information on the characteristics of the forest over time, models were elaborated showing more resource detail (e.g., age classes, forest types, productivity classes) and specificity in defining silvicultural regimes. The most recent models used in the Forest Service's Timber Assessment process follow the same recursive dynamic form but have retreated from the regional, product, and resource detail of earlier assessments, while embedding the US forest sector in a more elaborated analysis of global trade (Ince et al. 2011).

The 1989 court decision requiring federal agencies to consider habitat conservation for the northern spotted owl led to major harvest reductions in the western US. Models in the Timber Assessment suite were employed in the policy process leading to the NW Forest Plan for management under the court order. A wide array of national FSMs have been developed or adapted to examine the effects of these changes, including both national dynamic recursive (Wear and Murray, 2004) and intertemporal optimization forms (Adams et al. 1996). Regional FSMs have also found application in examining public harvest impacts, though primarily in the West (Adams and Latta, 2007a).

Public timber harvest has recently reemerged as a policy issue as public forests consider restoration thinning and fire hazard reduction. Prestemon et al. (2008) employ a national recursive dynamic FSM to examine the effects of expanded harvest associated with hazard reduction programs on western and southern federal lands. Adams and Latta (2005) use a regional intertemporal optimization FSM to look at restoration thinning options in eastern Oregon. Ince et al. (2008) examine the western US impacts of federal lands hazard reduction with a recursive dynamic form based on the PELPS framework.

Model features, following LSS's categories, vary widely across analyses of public lands. One distinction that clearly divides the studies is the treatment of aspects of public policy decisions as either endogenous or exogenous elements in the model structure. Examples would include Adams et al. (1996) and Ince et al (2008), both of which involve simulated exogenous timber supply shifts. Other studies include parts of the public policy under consideration as explicit, endogenous activities in the FSM. Prestemon et al. (2008), for example, determine the extent of federal land restoration thinning activities within their national dynamic recursive model. Adams and Latta (2005) determine the maximum area of thinning on federal lands in eastern Oregon within the limits of hypothetical policy delivery schemes. Im et al. (2010) endogenously vary levels of public timber harvests to achieve a policy of maximum carbon sequestration across all owners in the western Oregon region.

International Trade Issues and Modeling

The oldest continuing international trade issue in the United States relates to the softwood lumber imports from Canada, dating from the 1800's. Despite its longevity, active trade restrictions were not adopted until the early 1980's when a series of tariff, tariff-quota, and self-imposed (by Canada) taxation measures were begun to limit lumber flows. These restrictions have continued to the present. The sources of Canada's comparative advantage in lumber exports to the US have been the subject of some controversy, but it is clear that both differential wood costs and shifting exchange rates play a role.

Within the US, regional export issues have often raised clamorous debate. In the PNW states, emergence of softwood log exports following the Columbus Day storm of 1962 raised strong complaints from regional mills. These concerns quickly precipitated legislation to prohibit log exports from federal (and most other public) lands. More recently, export of wood pellets from the South to Europe has brought objections about associated environmental effects from NGOs and other groups, though no trade legislation has yet emerged.

And at the broadest scale, the US (like all traditional forest products producers) has faced a continually changing and expanding array of new global sources of wood fiber and product supplies that compete with domestic producers. In the 1970's these included Australia and New Zealand in softwood logs and Southeast Asian countries as sources of hardwood panels. In more recent decades, Brazil, Chile, and other South American countries have assumed major roles as suppliers of processed paper and wood products as well as logs. Domestic US trade restriction efforts have been limited with respect to these suppliers, but domestic producers and policy makers have frequently sought information on the market share implications of trade policy changes in world regions that are jointly supplied by the US and emerging production regions.

Policy concerns for international trade and global wood supply developments have had a significant impact on the form and development of FSMs in the US. The treatment of trade in each modeling effort has varied widely, however, depending on the focus of the specific analysis. For some studies it has been sufficient to represent trade via a “rest of world” (ROW) net demand/supply process in a kind of quasi-spatial model. In other cases a global spatial model with high detail in trading regions, products, and product flows has been required. Examples of the former approach are legion and include the USDA Forest Service’s Timber Assessment model system and FASOMGHG which combine explicit regions and flows for key trading partners and aggregate net supply/demand relations for ROW regions.

Perhaps the earliest US model with an explicit global spatial context was the Timber Supply Model developed by Sedjo and Lyons (1990) using an intertemporal optimization format to explore impacts of emerging plantation-based supply regions. Spin-offs from the global trade model developed in the Forest Sector Project at IIASA (Kallio et al. 1987) have been employed in many countries, including the CGTM adapted at the University of Washington (Cardellichio and Adams, 1987). The most detailed extant forestry trade model, GFPM developed by Buongiorno, et al (2003), has become the basis for the current USDA Forest Service Timber Assessment process (USFPM, Ince et al. 2011).

Modeling private forest management

Modeling of private forest management behavior in the US is usually conducted at the regional or finer geographic scale because of the market, land ownership, and public policy differences across regions (e.g., the PNW or Southeast). Working at these finer scales allows the modeler to optimize local data utilization to address distinctive local issues. Conversely, unless the model is linked to a broader modeling framework, global and national market linkages are ignored or are based on exogenous assumptions with attendant partial-equilibrium concerns. Typical regional policy questions include the market and resource impacts of mill openings or closings, storm damage, tree planting incentives, new silvicultural practices or genetic material, BMPs or other harvesting restrictions, and changes in ownership.

Examples of regional studies of private management behavior employ both recursive dynamic and intertemporal optimization frameworks. In the US Southeast (SE) analysis is complicated by the labile nature of the private land base. Though private timberland area has remained relatively stable, the flux between timberland and agriculture land is significant and related to relative land rents between the two sectors (Alig 1986, Lubowski et al. 2006). This occurs at both the active margin where marginal agricultural land transitions to intensive forestry, and the passive margin where abandoned land quickly reverts to forest. Additionally, the industrial ownership structure has changed from integrated (forestland and mills) pulp dominated ownership to Timber Investment Management Organization (TIMO) and Real Estate Investment Trust (REIT) lands owned by independent investors.

The Sub-Regional Timber Supply (SRTS) model (Abt, et al., 2000) uses a dynamic recursive framework in which a supply region, or multiple supply regions, faces a demand projection based on exogenous shifters. Prices, regional allocation of harvest, and inventory by log product are endogenous. SRTS was built as a simulation system that can be used for strategic resource planning. It models only private land and allows modification of log product definitions, supply and demand elasticities, growth rates, and demand scenarios. Private harvest is projected based on timber supply curves. Land use change can be exogenous or endogenous. Applications include the Southern Forest Resource Assessment (SOFRA-Wear and Greis 2002) in which the land base is endogenous and the analysis of biomass in the Southern Futures Project (Wear and Greis, 2013). More recently, applications have focused on regional implications of EU pellet demand [Galik and Abt (2016) and Abt, et al. (2012) that looked at linked market interactions].

In the western US, shifting of the private land base between forest and agricultural uses is limited and analysis of private owner behavior commonly addresses questions of response to change in public timber harvest. Examples include work on timber trends in western Oregon and Washington (Adams and Latta, 2007a) which employ intertemporal optimizing models with subplot-level inventory and detailed management intensity classes. Private harvest and silvicultural regimes are determined so as to maximize land value. The demand side is spatially explicit and based on empirical demand relationships derived from a profit function analysis for regional industry. Adams and Latta (2005 and 2007b) project private timber harvest and regional industrial changes in eastern Oregon using an intertemporal optimizing model that allows mill locations to both shut down and start up during the simulation. Variations and extensions of this framework have been used to address how forest policy affects carbon sequestration (Im et al. 2010) and the impacts of carbon offset programs on forest management (Latta et al. 2016).

Two recent regional assessments by the USDA Forest Service for the North and South employ somewhat different biological representations (Wear and Greis, 2012; Shifley and Moser, 2016). Forest dynamics were based on plot-imputation techniques. Growth, harvest, and land-use changes were based on historical plot level assessments. Plots were grouped into homogenous groups based on regression trees and conditional transition matrices were used to control plot evolution over time. These data-driven techniques take full advantage of plot level variability. In the future they are likely to become more robust and, when combined with geospatial analysis, provide a powerful tool for linked local, regional, and national assessments.

Changes in Private Forestland Area

Before the 1980s, changes in private forestland area, or the more restrictive timberland subset, were projected by means of expert opinion. Systematic methods and models for projecting area changes for private forestland were first introduced in land base assessments for the USDA Forest Service's Resources Planning Act Assessments and *The South's Fourth Forest* (USDA Forest Service, 1988). Early land base assessments by the USDA Forest Service typically focused on one "business as usual" future, with variations generally limited to alternative income and population projections. With growing interest in emerging markets for carbon and other ecosystem services, methods have evolved to allow analysis of land base changes under markedly broader ranges of policy and economic scenarios.

Methodological changes have involved both analytical approaches and access to expanded land use data. Early econometric land-use models relied exclusively on Forest Inventory and Analysis data for forestland. The first national cross-section of National Resources Inventory (NRI) data allowed creation of models to explain interactions of urban and forest area change (Alig and Healy 1987). Over time, combined time series/cross-section panels of NRI data have been used to create more comprehensive econometric land use models for RPA Assessments and other applications (Lubowski et al. 2006; Alig et al. 2010a). With the availability of sufficient amounts of spatial or georeferenced data, models have also been developed at regional and subregional levels (e.g., Latta et al., 2016), especially to help inform finer-scale ecosystem management planning.

Land use decisions have also been incorporated directly as endogenous elements of some FSMs. FASOMGHG, an intertemporal optimization model, links models of the US agriculture and forest sectors (Adams et al. 1996). The sectors can interact in the provision of substitutable products (e.g., biomass feedstock) and also share a portion of the land base that can be employed in either agriculture or forestry. This joint land base is allocated across the two sectors based on relative land rents. Conversion of land from agriculture and forest sectors to developed land uses, however, is exogenous. Latta et al. (2016) employ a combination of an intertemporal optimization model of forest markets and an econometric land use model to simulate endogenous shifts to urban or developed uses and associated impacts on the forest sector.

Dynamic recursive FSMs have incorporated land use change by linking a network of econometric land use models with forest products market models. Solutions for the network are obtained using recursive Gauss-Seidel iterations in each projection period. This was first illustrated with the TAMM-NAPAP-ATLAS-AREACHANGE network of models in the 2005 RPA Timber Assessment Update. A similar approach was employed in the Southern Forest Resource Assessment linking SRTS and a land use module (Wear and Greis, 2002).

Both econometric and FSM approaches have been used in recent years in forest area change studies to examine a variety of forestry and agricultural policies, as well as simulations of interactions with developed uses. Policies, such as tax changes or forest carbon offset sales, can affect the allocation of land to major uses, including afforestation of agricultural land, as well as the allocation of private timberland to different forest types in the process of reforestation (Alig and Butler 2004).

In the future, increased availability of spatial data could enable researchers to explore alternative specifications of land-use models (e.g., Lewis and Alig 2014). This could improve the spatial properties of empirical models and any corresponding landscape simulations. A related improvement could be use of finer-scale data on independent variables that drive land-use decisions, such as parcel-level land-use regulations. However, adding such detail can result in trade-offs between increasing spatial specificity and the scale at which a model can be estimated and applied in simulations or projections. Additional work on forest fragmentation is also warranted (Alig et al. 2005), including more attention to soil types and proximity to developed areas.

Forest Products Markets

While they are typically the FSM output of primary interest, forest products markets can also be the focus of policy stimulus. These policies have ranged from the indirect effects of interest rates on housing starts or increased efforts at recycling to the more direct efforts to increase forest biomass use in energy to promote domestic energy independence and rural economies.

In solid wood markets the single biggest driver is housing starts. As such, expectations of future levels of housing starts have been the focus of RPA alternative future scenarios on multiple occasions looking at either higher or lower levels (e.g., Haynes, 2003). Recent work by Ince and Nepal (2012) uses USFPM to evaluate the impact of the US housing crisis on the long-term forest outlook.

Pulp and paper markets have likewise seen considerable attention in both RPA assessment and other modeling efforts. Early work focused on the resource and market effects of efforts to increase recovery and use of recycled fiber in paper production. By the turn of the century the focus had shifted toward incorporating the effects of increased adoption of electronic media and its impact on newsprint and paper demand.

The forest sector has long been associated with the use of both waste (e.g., bark, mill residues, and black liquor) and dedicated (e.g., firewood or wood pellets) biomass usage in energy generation. It has likewise been considered within multiple RPA Assessment analyses. Recent years have seen many other FSM analyses internationally with GTM (Daigneault et al., 2012) and GFPM (Raunikar et al., 2010), nationally with FASOM (White et al., 2013) and USFPM (Ince et al., 2011), and regionally with SRTS (Abt et al., 2012) all with results as varied as their approaches. Latta et al., (2013) use FASOM and attempt to construct a range of scenarios evaluating the impact of demand, feedstock and market response levels and find some consistency in the prior studies. Galik et al., (2015) go one step further coordinating SRTS and FASOM scenarios finding further consistencies between approaches with differing temporal dynamics.

As better log product delineation allows evaluation of particular silvicultural practices, models are also employing greater detail in both market drivers as well as forest manufacturing processes in both primary products and byproducts. Inclusion of macroeconomic drivers as well as additional products and processes can add significant complexity to a FSM. In general, modeling wood as a fuel for energy presents a number of obstacles for traditional FSMs. First, biomass for energy typically involves small trees, defect, and tops. These biomass elements are often underrepresented in FSMs, which tend to focus on higher value products. Additionally, this biomass is not usually part of the “growing stock” component of the Forest Service’s Forest Inventory Analysis inventories typically used in FSMs as the forest resource base. Also, a larger proportion of biomass harvested for energy, such as firewood, comes from non-timberland forests and thus would likewise not be represented directly in most FSM resource data. Finally, given the low value of biomass as an energy source, a larger component of the delivered feedstock cost is associated with transportation and thus the spatial representation of forest products markets will play a greater role.

Summary and Outlook

Recent FSM developments in the US are characterized by expansion of virtually all the “boundaries” of traditional model forms. New modeling efforts now regularly include considerably more spatial detail than earlier approaches. This reflects improved computing capabilities to handle large, dynamic databases and analysts’ attempts to better represent spatial considerations (e.g., impacts on landscape characteristics) that are critical in some policy issues. Greater spatial detail has also allowed the integration of other types of forest management decision models (e.g., econometric land-use models) with the more traditional components of FSMs. Models have also employed biological representations of the forest resource that are increasingly detailed. This reflects expansion of markets for products beyond traditional sawlogs and pulpwood and the importance of recognizing the details of silvicultural treatments in some policy studies. Finally, the sectoral boundaries of FSMs are being stretched in recognition of the interrelationships across economic sectors and the spillover effects of many types of policies. Thus we see integrated land-use models (e.g., agriculture-forestry and forestry-urban interface), FSMs with extensive energy sector representations, and models with expanded representations of feedbacks of forest sector responses into construction and other end-use sectors traditionally taken as exogenous.

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5. Future of forest-based sector – state of the art and research needs

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Introduction

The history of studies in the forest sector for predicting consumption, production and prices of forest products dates back to early 1950's. Especially, since the beginning of 1980s the sophistication of research methods and geographical and product coverages of the analysis have progressed significantly (Solberg and Moiseyev 1997). Simultaneously, however, the speed of changes in consumer tastes, products, and geographic re-location of production and markets at global level are making the task of tracking possible future trends and prospects in the sector a challenging task. This is a concern for both the academic research as well as for the practical decision making and policy planning in the forestry sector.

In this article, we discuss the academic challenges related to long-term forest sector outlook studies, as well as some of the implications to practical decision making. We discuss the role of complementing quantitative analysis with qualitative foresight approaches and conclude by pointing main research gaps and ways forward. Our purpose is not to write a review of the existing literature, as recent reviews of the topic exist (e.g., Toppinen & Kuuluvainen 2010, Hurmekoski & Hetemäki 2013, Latta et al. 2013). Instead, we wish to give a brief look at alternative approaches in order to identify main research voids and challenges especially from the long-run forecasting perspective.

Before any assessment, it should be noted that there is no established definition for an "outlook study". According to FAO (2016), outlook studies "*highlight long-term trends in the sector and identify emerging opportunities and challenges. […] By taking into account economic, social, institutional and technological changes, outlook studies support policy reviews and strategic planning, depict the range of choices available to forest sector policy makers and describe the alternative scenarios that might arise as a result of these choices*". In practice, the focus and implications of the outlook studies have been on forest products consumption, production and trade flows, and on the forest resources being able to meet the demand for roundwood (Hurmekoski and Hetemäki, 2013).

When quantitative analysis and forecasting of the long-run development of forest products consumption and production began to emerge in 1950's, this work was based on time series econometrics. Since 1980's numerical partial equilibrium models have gained ground, although econometrics is still used, especially in detecting the required behavioral parameters for the numerical models. Presently, expectations of forests to meet increasing environmental, social and economic demands are maybe higher than ever. In addition to increasing energy and raw material needs, utilization of forests has to address challenges such as climate change, protection of biodiversity, and providing space for recreation and leisure (UNECE, 2011).

At least in retrospect, the development of the sector up to 21st century may have been more "predictable" with rather well established relations between consumption of forest products, population and economic growth, and the prices of the products. The Figures 1 and 2 show the world graphics paper (newsprint + printing and writing paper) and sawnwood and veneer products production for two 15 years periods: 1985-1999 and 2000-2014. Clearly, the pattern for graphics paper consumption has changed from increasing trend to stagnating and decline. Yet, the major traditional drivers of the consumption, i.e., the global GDP and population growth have continued their past trends. On the other hand, the sawnwood and plywood production has been more volatile in the latter period compared to the 20th Century patterns.

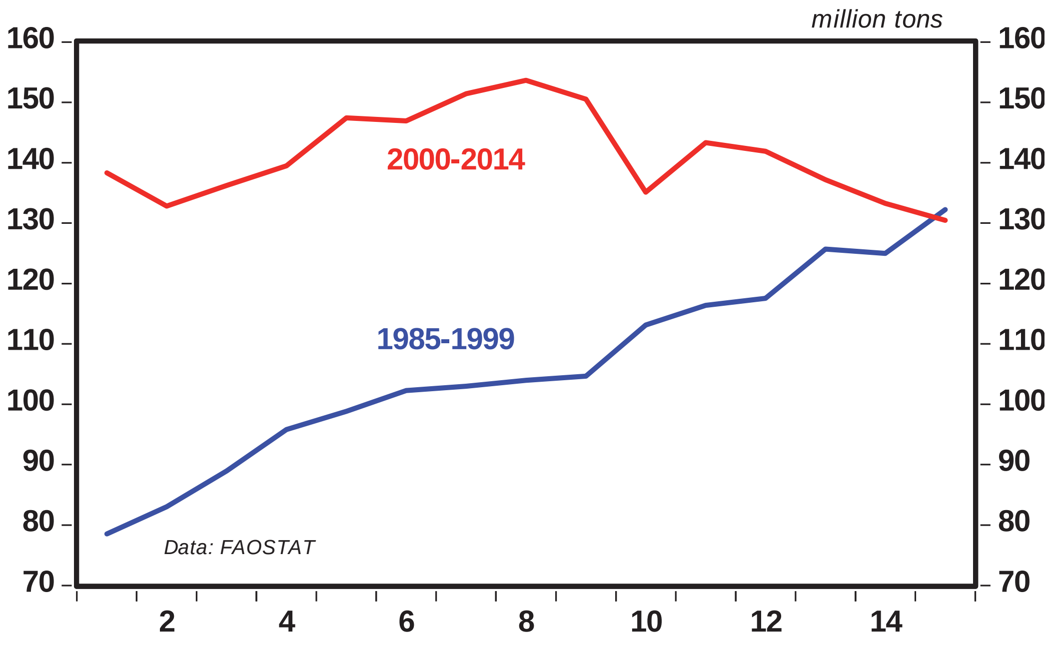

Figure 1. World graphics paper production in 1985-1999 and 2000-2014

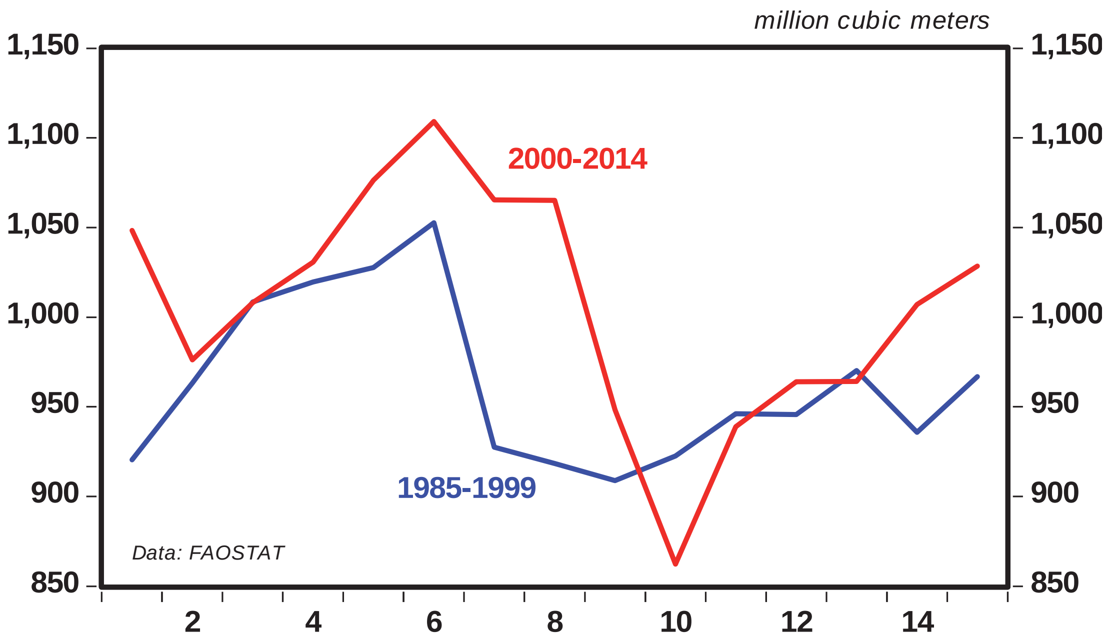

Figure 2. World sawnwood and plywood production in 1985-1999 and 2000-2014

According to a review by Latta et al. (2013, p. 357) "*the dynamic recursive models in use today provide reliable short-term projections yet lack the ability to endogenously adapt to expected future conditions. Likewise, the intertemporal optimization models capture the optimal adjustment to expected future conditions but can produce short-term results that may not conform to recent market developments*". But the fundamental dilemma related to all future-oriented research is: ***How can the future be studied, as it does not yet exist***? No method can yield "correct" or even *reliable* information of the future. Therefore, the more relevant question may be: how *useful* these methods and studies are for practical decision making?

Forest sector outlook studies

The first ECE/FAO European timber trends and prospects –study was published in 1953 and the last in the 1990s (European Timber Trends Study V 1996). These have been followed by European Forest Sector Outlook Studies, EFSOS I (UNECE 2005) and the EFSOS II (UNECE 2011). Especially, since 1980's the theoretical basis, statistical methods and the quality and coverage of data have improved considerably. According to Latta et al. (2013), forest sector models (FSMs) that are used today are related to, or have been developed from, four models constructed in the 1980s: (1) TAMM – the Timber Assessment Market Model (Adams and Haynes,1996) covering North American solid wood products markets; (2) PAPYRUS on the North American pulp and paper markets (Gilless and Buongiorno,1987); (3) IIASA GTM – the International Institute for Applied Systems Analysis Global Trade Model covering global forest products and trade (Kallio, et al. 1987).; and (4) TSM – The Timber Supply Model (Lyon and Sedjo, 1983). While these "first generation" FSMs can be characterized as "dynamic recursive" models, with the exception of TSM, the models developed more recently may be labeled "intertemporal optimization" models (Latta et al. 2013).

Latta et al. (2013) discusses in detail the "intertemporal optimization" models, FASOM (The Forest and Agriculture Optimization Model, Adams & Haynes, 1996), PNW-RM (The US Pacific Northwest Regional Model, Shillinger et al. 2003), EUFASOM (The European Forest and Agriculture Sector Optimization Model, Lauri et al., 2012; Schneider et al., 2008) and NorFor models (Sjolie et al. 2011). However, the most recently developed model in the area, FinFEP (Finnish Forest and Energy Policy model, Lintunen et al. 2015) must also be referred to. FinFEP is a policy analysis tool for the Finnish forest and energy sector. Typically, timber supply in FSMs is based on the dynamics of forests under present value maximizing management, and econometrically estimated short-term supply elasticities (especially in the boreal forests with long rotations). In contrast, FinFEP includes an explicit description of forest owners' decision making as utility maximizing agents deriving utility from consumption of goods and services as well as from non-marketable amenities of their forest, constrained with the dynamics of their growing forest stock (Lintunen et al 2015). In addition, the forest and energy sector markets are more detailed and disaggregated in FinFEP than in other existing forest sector models.

The past forest sector long-term projections have often turned out to be rather accurate at the aggregate or global markets level. Hurmekoski and Hetemäki (2013) note, as an example, the pattern of the global aggregate paper and paperboard consumption, projected by FAO (1999), which follows closely the actual development, and the observed 2010 consumption differs by only around 2% from the predicted. However, especially at the level of individual products or regional markets, the projections have often left much to desire. Moreover, in the context of outlook studies, it is important to ask the question that Toppinen & Kuuluvainen have proposed (2010, p.7): "*Do the empirical work and outlook studies respond to the questions that decision-makers are interested in, or are they focusing on those markets and research problems, for which established methods and data sources exist?".* In short, the outlook studies should provide informative, internally consistent and plausible analysis and scenarios, and not perhaps even aim to be "reliable" or "accurate predictions", since this criterion can only be assessed in hindsight. Forest sector outlook studies are applied research, and therefore, the usefulness of the analysis and results for the decision makers and stakeholders should be an important criterion for the studies.

The above mentioned FSMs are often, and increasingly, used for scenario, or "what if" analyses, i.e., to analyze the possible consequences of different economic, environmental or social policy changes, and the aim is not to present "traditional forecasts" or economic outlook results (Hetemäki et al. 2010). However, the usefulness of the outlook studies as well as the scenario analyses are still crucially dependent on how well the "business as usual" scenario is able to track the most likely development without policy changes or structural shifts. In addition, and in spite of the impressive technical development of the analytical tools and increased academic interest in scenario analysis, the most commonly used methods and approaches in the outlook studies, such as UNECE/FAO outlook series

(UNECE/FAO, 2011), have actually changed relatively little (Hurmekoski & Hetemäki, 2013). Therefore, the question is whether these models are able to aid decision makers in policy and investment planning under the rapidly changing social, economic, and technical environment.

Effects of innovation and structural changes in outlook studies

It is said that economists stand on the edge of the time. The only information we have about the future is based on our experience of the past. Still, there are phenomena for which the expected future development is, or at least seems to be, easier to "predict" than for others. This, of course, depends also on the desired forecasting horizon. For example, looking 5 to 20 years into the future (e.g. in the EFSOS II study the outlook horizon expands to 2030), population growth, and the growth of the forests, are unlikely to experience dramatic turns in the trends. In contrast, new product innovations or the changes in consumer tastes, may be difficult to observe and measure, even if the change has already happened. Even if the observed behavior might indicate that something is changing, the number of available observations maybe too small for firmly confirming it, and even less so to run statistically reliable inference. However, the past evidence may provide information on how innovation cycles typically evolve, such as an S-curve model (e.g., Schilling & Esmundo 2009), and this information could be used as an approximation of possible future development. Alternatively, one may use qualitative expert information to capture possible future developments, and even try to quantify these, by e.g., applying Bayesian econometric models (Hetemäki & Obersteiner 2001, Bolkesjo et al. 2003). Consumer behavior is also affected by the changes in citizens' values, e.g. related to media format (print vs. digital) or environment (Kuznets curve), or due to economic and environmental policies. Yet, the effects of these changes, or their timing, can be unpredictable, and subsequently their inclusion in a formal model structure and/or in parameters is difficult.

In spite of the level of sophistication in methods used, the outlook studies are in principle partial equilibrium market models, and are composed of rather similar elements or "sub-models". Some of these elements seem to be more vulnerable to the structural changes in the industry or changes in consumer tastes and habits than others. First, the driving force for industrial roundwood production is the demand for final forest products and energy. This must be described in any FSM. Demand for forest products and energy were earlier often modeled using econometric methods. Even today, the maintained hypothesis is that the demand depends on population, economic growth and prices. The consumption of energy is often forecasted by using simple trend projections and policy targets, as the data for more rigorous statistical analysis is often not available.

Secondly, long-run development of forest resources and wood supply must be described and predicted. Development of forests resources is obtained from the dynamics of growing timber stock under given (present value maximizing) management schemes (in EFSOS II, EFISCEN model; see e.g. Schelhaas et al. 2007), and the actual timber production is obtained from the equilibrium of wood demand (sub-model (1)) and the supply of timber from existing growing timber stock (sub-model (3), see below). Forest owners' timber selling decisions from the existing forest stock can be modelled using econometrically estimated supply elasticities (however see, Lintunen et al. 2015 for an alternative approach). The obtained equilibrium volume of wood is then used to calculate and to project (regional) wood resource balances (see Mantau et al., 2010 in case of EFSOS II). Additionally, the supply for other woody biomass can be taken into account (e.g., in EFSOS the EUwood study, Mantau et al., 2010), and also the estimates of carbon stocks and sequestration can be obtained (e.g., Carbon and Decomposition model Yasso built in the EFISCEN is used in EFSOS II, see Liski et al., 2005).

Thirdly, the price-quantity equilibrium both in the wood markets as well as in the end products and energy markets must be solved. In EFSOS II, the EFI-GTM model (Kallio et al., 2004) developed from the above mentioned IIASA GTM model is applied to analyze how the market adjusts in order to reach the equilibrium. This sub-model requires a description of the production technology of the industries, and is usually based on engineering data and some way of projecting the technical change.

Finally, after determining the effects of the computed supply and demand conditions on trade, the effects of the prospective market conditions on forestry can be determined. In EFSOS II this is done using again the EFISCEN model. In this way, the approach considers the whole value chain from the forest to the consumers and back to the forest. Some models (e.g., FASOM and EUFASOM) also include the resource allocation between agriculture and forestry, which is an essential aspect to understand land use competition and dynamics in the long run.

Projecting consumer demand

The development since already the mid-1980s, and especially this century, indicates that, when considering the regional consumption and/or individual product categories, structural changes in consumer tastes or consumption habits have been difficult to model. Therefore, even if the forecasts at the aggregate level work reasonably well, more detailed projections of the development can be rather uncertain. Still, it would be important to analyze and project these for the strategic planning of the industries, forest owners and policy planning. The new bio-based products will also impact the structure and competitiveness of the whole forest-based sector, and will be discussed in the final section.

As an example of the impacts of structural changes, Hetemäki (1999), Hetemäki and Obersteiner (2001), Kuuluvainen (2004), and Hetemäki (2005) have shown how newspaper consumption started to stagnate and then to decline in the US after 1987, even though the US GDP had continued to increase trend-wise. Hurmekoski and Hetemäki (2013) point out that a similar development has taken place also in the European Union, where the connection between economic growth and consumption of newsprint and printing and writing paper began to break down around year 2000, and more recently, also for the aggregate paper products markets (Hetemäki & Hurmekoski 2014 and Hänninen et al. 2014). Interestingly, the FAO statistics (Figures 3 a & b) indicate that the world largest graphics paper market, China, has perhaps started to follow similar pattern. That is, the growth of graphics papers is also there starting to saturate or even decline, despite of the still continuing relatively fast growth in Chinese real GDP. This conclusion is supported both by the long run patterns (Figure 3a) as well as the changes in the 3-year moving average growth rate in consumption (Figure 3b). From about 2004 onwards, the growth rates have started clearly to decline for printing and writing paper and newsprint. For the latter, it is currently even negative, i.e. the consumption declines. Thus, the structural changes due to digital media observed already in high-income countries, have started to impact markets also in China. Given that China's consumption of global printing and writing paper consumption is about a quarter, this will have implications also to global market equilibrium and price development.

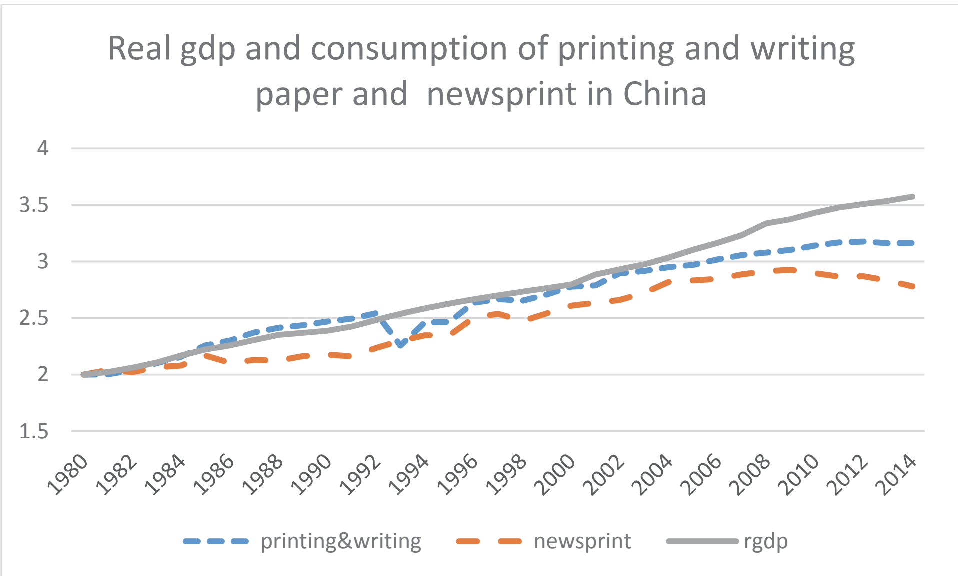

Figure 3a. Real GDP and consumption of newsprint and printing and writing paper in China during 1980-2014. Index, 1980=100, log scale.

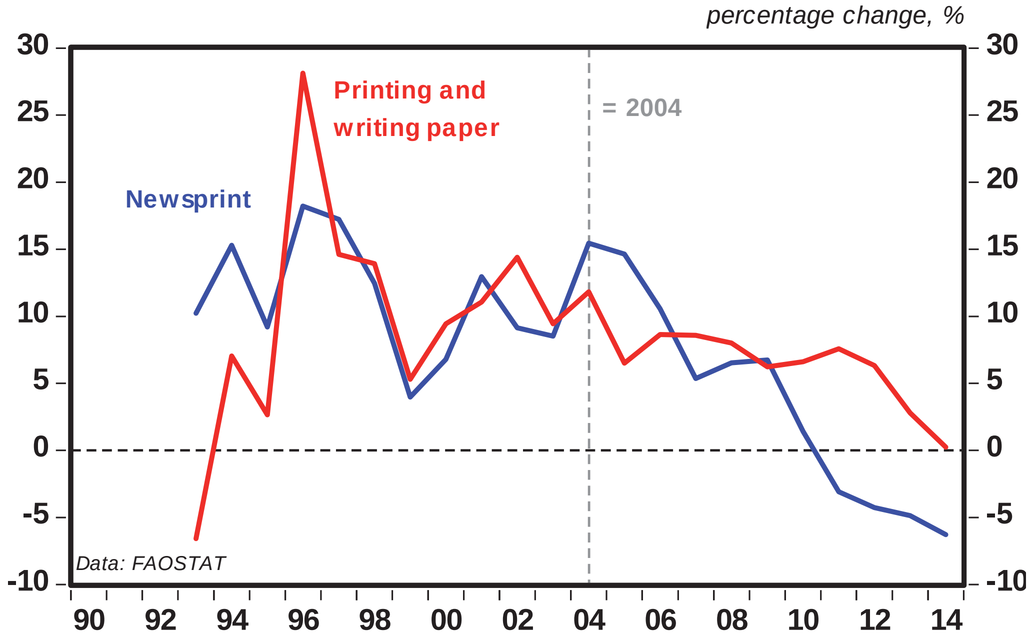

Figure 3b. The 3-year moving average annual growth rate of newsprint and printing and writing paper consumption in China 1990-2014.

Another example of unpredictable changes, given by Hurmekoski et al. (2015), is the consumption of sawnwood in Finland, which experienced an unexpected expansion after 1996 but has returned almost to the mid-1990s level after 2007 depression. The factors behind the development are not apparent from the statistical analysis, and many reasons have been given (e.g. government wood construction promotion policy, changes in way data has been collected, consumers' tastes, etc.) (see also Hetemäki et al. 2004). In spite of the decline followed by modest increase in construction activity in 2008–2012 in Finland, the sawnwood consumption per capita in Finland has still remained three times higher than the European Union average per capita consumption.

Although these kinds of structural changes can already be detected from the observed data, it is not a straightforward matter to take them into account in a large model system like EFSOS II, or any of the other dynamic optimization or recursive dynamic FSMs used in forecasting and policy analysis. Should the structure of the model be changed, or is it sufficient to change the behavioral parameters, and/or production technology in the model? Where may we get the information of the relevant substitutes, and relevant elasticities of demand with respect to disposable income and price, if we are not even sure whether there has been a structural change or not? Ideally, each country should have its unique parameter values, but do we have data for this?

Role of econometric market analysis and structural changes

Econometric analysis provides important behavioral parameters, e.g., supply and demand elasticities, needed in the numerical models used for policy and outlook analysis. In case of a large number of countries and products, but relatively short time spans of data available, panel data analysis is often the only feasible solution. For example, econometrics was used to obtain behavioral parameters for EFSOS II, where the EFI-GTM (Kallio et al. 2004) was used for finding the equilibrium in the forest products markets. Also in the Global Forest Sector Model (Buongiorno and Zhu 2014, Buongiorno 2015b), demand and supply elasticities were estimated using econometrics. Both of these models make numerical projections for (European and global) consumption, production and trade of forest products in the future.

However, econometric models are also still used to actually produce forecasts, for example, concerning some of the key drives of the future use of forest resources (e.g. Jonsson 2013). They were used in an earlier UNECE outlook study, ETTS V, (Kangas & Baudin 2003) and were also applied in the first EFSOS (UNECE, 2005) to produce country-specific projections for consumption, production and trade of forest products. Montgomery (2001a and b) reported a structural model of the U.S. housing sector based on annual time series data from 1953 to 1998, and predicted housing demand for 1996 through 2050. These were then used as the basis for housing assumptions in the 2000 Resources Planning Act timber assessment in the United States.
We have already drawn attention to the difficulty in observing and foreseeing structural changes. What is a structural change? In econometrics, a structural change is considered to have occurred, when a statistically significant shift in the estimated parameters is observed. Not being able to capture such a shift, can lead to large forecasting errors and unreliability of the model in general. Although presence of such a shift can in principle be statistically tested, if enough data observations are available after the break, the econometric model maybe be unable to indicate the reason for the change explicitly. Often, this requires updating the model, and including new variables that explain the change, as in the case of digital media impacts to graphics paper (Latta et al. 2016).

In the 1980's, econometric modelling of economic time series developed rapidly. Hendry and Richard (1983) advocated their "general to specific" modelling approach, Engle and Granger (1987) published the representation theorem for error correction models with non-stationary but co-integrated time series, and Johansen (1988) developed a maximum likelihood method to estimate co-integrated vector autoregressive time series models with non-stationary data. Along with the development of these methods, empirical econometricians were provided with tools to avoid spurious results when modelling macroeconomic time series, which often are trended, and where the standard ordinary least squares methods have difficulties in reliable statistical inference. However, modern time series analysis requires large numbers of observations for statistically reliable results. Therefore, econometricians prefer to work with quarterly or monthly data. When this type of high frequency data is used, the equilibrium or the *long-run* behavioral parameters refer to reactions of the agents over or during the business cycles (typically less than few years). In contrast, the types of structural changes relevant in numerical partial equilibrium FSMs discussed above, can normally be observed only if the analysis can be extended over several decades. From a statistical point of view 50 observations, often the maximum available for econometric analysis using annual data in the forestry sector, can be insufficient for statistical validity. Yet, from the point of view of the behavior of economic agents, the observations dating back twenty years may not be relevant anymore for predicting the future. A solution advocated by many working with FSMs is the panel data. However, even this route needs to be followed with caution, as following examples illustrate.

Buongiorno (2015a) studied the effects of the income and price elasticities of different forest products (seven major product groups) on international forest sector projection using GFPM, the Global Forest Products Model, (Buongiorno and Zhu 2014). The price and income elasticities were estimated using panel data and comparing high-income and low-income countries, and recent (2004–2013) and older (1992–2003) observations. The elasticities by Buongiorno (2015a) were obtained using the annual changes of the levels data (first differences over time of multi-country and multi-year panel data). This eliminates unobserved differences between countries which, as stated by Buongiorno (2015a), might affect consumption apart from GDP and price. While the approach is statistically sound, the interpretation of behavioral parameters obtained from this type of econometric analysis in parametrization of a numerical FSM model requires caution. By definition, an econometric model estimated using first differences, produces "short-term" elasticities. As stated by Buongiorno (2015a), first differencing in panel data eliminates unobserved factors that might affect consumption in individual countries. However, it also eliminates possible long-run information contained by the data. Thus, we get statistically valid information on the short run behavior, but the long term behavior must be captured through the structure and other behavioral parameters of the numerical model, where these elasticities are used (Buongiorno 1996).

Hurmekoski and Hetemäki (2015) also used panel data to study the demand for sawnwood in the European Union. They used a fixed effects specification with lagged dependent variables and report both the short run and the long run elasticities. However, both were based on the time-section variation in the data. They did not report elasticities estimated from cross-section variation in the data. Their results indicate, that it may be rather difficult to obtain statistically and theoretically acceptable behavioral parameters that could be directly used in numerical analysis (Buongiorno, 1996). The Finnish case study also shows, that differences between countries can be considerable.

The above suggests, that it is not straightforward to statistically estimate the behavioral parameters, or to obtain information of the structures of the market, consumer tastes, or emerging technologies, required for long-term forecasting or scenario analysis using FSM with tens of regions and products. Econometrics may still help, in addition to obtaining the elasticities, in detecting some of the weak signals already available in the observed market behavior. Annual time series data can be helpful in detecting structural changes, in spite of the small number of observations, and in spite of the fact that the statistical properties of the models do not necessarily turn out as good as we would like them to be (Hetemäki and Obersteiner 2001). Unstable parameters and unstable long run relationships are also important information and can be used, if not directly as model input, at least as means to evaluate the model output and long term projections produced by FSMs.

Qualitative information based on foresight studies

According to Hurmekoski and Hetemäki (2013, p. 17), "*there are potential advantages in complementing the current modeling approach dominant in the forest sector with other methods from the field of foresight*". The use of qualitative information can be vital in constructing the structure of forest sector models in changing industry strategies and market environments, and eliciting expert views may in some cases be the only way to get around this challenge.

Among various foresight approaches, the Delphi methodology has established a position as an effective tool to gather expert opinions on a variety of problems in different domains under market and technology forecasting, especially in situations where expert opinions and views are the only source of information. Iteration, participant and response anonymity, controlled feedback, and group statistical response have been identified as the key characteristics of a Delphi study (Blind et al. 2001, Landeta 2006). Some variants of the methodology (such as Policy Delphi or Argument Delphi) highlight the importance of finding reasons for dissensus rather than striving for consensus among the Delphi-panelists. The Delphi approach has also received criticism, and clearly its reputation has been tarnished due to examples from the literature where careless selection of experts, poorly formulated questions or lack of time to carry out the study, have resulted in problems with accuracy of the method (for a review, see e.g. Landeta 2006).

Although the use of Delphi approaches is more recent in forest economics, and can lack in empirical rigor and depth, there are some recent studies worth pointing themes and directions of this line of research. For example, Pätäri (2010) explored the future of forest bioenergy in the interface between forest and energy industries. Näyhä and Pesonen (2012) studied current forest industry change features required for a strategic shift towards a biorefining business in Scandinavia and North America using the Delphi approach, concluding that concerns over raw material prices, sustainability and traditional industry mind-set act as barriers for changing the strategic focus in the forest industry. In a recent work aiming for packaging industry foresight, Olsmats and Kaivo-oja (2014) mapped the general trends and drivers and evaluated potential future demands, opportunities and threats for packaging. Sjolie et al. (2015a) used expert information in analyzing the future development of Norwegian forest industry and found that short-term shifts in economic and policy factors (such as lower emphasis on environment and cheaper fossil fuels due to global recession) may crucially impact respondent's assumption about their significance for the forest sector in the future. Pätäri et al. (2016) used industry expert Delphi panel to identify a greater demand for energy, volatility in the fossil fuel markets and increasing material resource scarcity as the most significant sustainability megaforces shaping European PPI until 2030. We believe that in the future, qualitative foresight applications will emerge more commonly in our field, for example on mapping the future territory in the transition to the forest bioeconomy with new products and services lacking market data.

Conclusions and way forward

With the influence of international policies, global market and technological changes, and other drivers, such as the increasing global competition over arable land and natural resources, the forest sector is experiencing a myriad of structural changes. Company production portfolios are becoming more diversified than in the past, and the boundaries between forest, chemical, energy and construction industries are becoming more blurred than in the past. In evolving forest bioeconomy, new products, such as advanced wood-based biofuels, biochemicals and prefabricated wood elements and modules, emerge from niche products to industry mainstream. Along with this, industries' structural reorganization continues. These are all factors which make the long-term country-level projections for the future all the more important, but also more complicated and difficult than ever.

First, based on the past experiences, one might suggest that the most challenging part for any outlook or foresight study is to try to capture the future development of the demand for final products. Even the demand for existing products can be difficult to predict because consumer tastes are heterogenous, actors have bounded rationality, and substitution from products that do not even yet exist cannot be measured statistically. Second, there has been a growing pace in the forest industry globalisation, and the strategic (investment) decisions of global multinationals have a capacity to influence local and regional markets (and institutions), and are influenced by these (see Zhang et al. 2015). Aggregate market approaches are not very powerful in capturing these types of changes. Third, the rapid transmission of information is clearly affecting on how markets (also in forest sector) behave in the short term. The fourth difficult area is the speed of diffusion in technological innovations, such as capturing the effects of digitalisation and changing media habits. Finally, addressing the changing value orientations and lifestyle patterns in developed countries is not well captured with any aggregate level analysis.

In conclusion, it seems evident that the focus of future research should be targeted in particular to the above mentioned areas with most obvious gaps in current knowledge, particularly on the demand side, and by acknowledging the parallel use of different (sometimes conflicting) methodological approaches. Doing so, it is elementary that careful consideration is given to issues such as validating the **quality of data used** and focusing on the use of **rigorous and transparent analysis** to most effectively benefit practical managerial and policy decision-making. Issues with multicollinearity and non-stationarity of data in econometric models, sufficient rigor in testing out-of-sample forecasting capability of models, and conducting sensitivity analysis seem essential elements. **Crossing bridges with the use of forest sector models, econometric tools**

and various qualitative methodologies may in the future be essential for building a sharp picture of the future of forest based sector and to better understand the influences of many interlinked policies, as well as the multitude of other drivers.

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6. Forging ahead: The demand for and delivery of forest ecosystem services

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Challenges of the 21st century

Forests provide a number of goods and services, which are essential for civilizations and crucial for economic development. Forests are also home to at least 80 per cent of terrestrial biodiversity and constitute a major carbon sink regulating global climate. Over 1.6 billion people worldwide depend on forest resources for parts of their livelihoods, e.g. for food, shelter, medicine, and water (Angelsen et al. 2011). Here at the start of the 21st century, the impact of humans on the biosphere is ever more pronounced. Expanding populations and rising living standards increase demands for goods and services from forests, land for farming and grazing, fish and other resources from the sea, minerals from soils and rocks, and fuel from biomass and hydrocarbons. At the 1992 Rio Earth Summit, intense negotiations among governments resulted in an authoritative, but non-legally binding statement of "Principles for Global Consensus on Management, Conservation, and Sustainable Development of All Types of Forests". This declaration affirmed the sovereign rights of states over their natural resources, but also recognised that many aspects of forests and other natural habitats represent ecosystem services of global value and significance. In consequence, broader concepts and criteria of sustainable forest and nature management emerged.

Valuing forest biodiversity and ecosystem services

Since the late 1990s, the number of scientific publications dealing with the concepts of ecosystem functions and the value of their services has increased (Fisher et al. 2009). Particularly two publications, Gretchen Daily's "Nature's services"(Daily 1997) and Costanza et al. (1997) in Nature on "The value of the world's ecosystem services and natural capital", seeded public interest in how ecosystems affect the quality of human life. Costanza et al. estimated the value of the annual supply of services as 50% higher than global GDP.

Critics of these and similar studies have subsequently questioned whether the calculation of the total value of ecosystems makes sense. A more appropriate question, they argue, is to address if we have the right provision of ecosystem services. This redirects the research lens to focus on methods for assessing how the total value of ecosystem services is affected by changes in existing ecosystems (Toman 1998). The Millennium Ecosystem Assessment, MEA, (2005) reinforced this interest by developing and implementing a conceptual framework for assessing the world's ecosystems, ecosystem services, and their impact on people's livelihoods and well-being (MEA 2005; Daily et al. 2011). The main objective of MEA was to assess the consequences of ecosystem change for human living conditions and provide a scientific basis for conservation and sustainable use of ecosystem services. MEA estimated food production to constitute only 3% of global GDP, while perhaps nearly half of the global workforce is employed in the agricultural sector. A study of forest ecosystem services in the Mediterranean area found production values to be less than half of the forest ecosystem services value flows, including carbon storage, recreation, and water (MEA 2005). Approximately 60% of ecosystem services examined had either been heavily influenced by human activities or were subject to unsustainable utilisation (MEA 2005). Despite environmental degradation and a decline in most ecosystem services worldwide, human welfare has increased in the last 50 years (MEA 2005; Raudsepp-Hearne et al. 2010). This does not, however, imply that ecosystems are optimally managed in relation to people's welfare. Many analysts and policy-makers consider the loss of biodiversity and degradation of ecosystem services a global challenge (Sachs et al. 2009) likely to have significant and adverse consequences for future generations and achieving the Sustainable Development Goals.

Livelihoods and forest ecosystem services

As the interest in valuing ecosystem services increased in the 1990s, so did the interest in understanding rural livelihoods in developing countries, including the economic importance of forest ecosystem services in total household incomes. While a string of classic livelihood studies were published throughout the 20th century (Scoones 2015), livelihood perspectives in research and development was only mainstreamed with the Chambers and Conway (1992) working paper operationalizing the sustainable livelihood definition and subsequently the development of the sustainable rural livelihoods framework (Carney 1998) that allowed a structured approach across disciplines and sites. It remained difficult, however, to link quantitatively livelihoods and forest ecosystem services due to the huge number of forest products and services, many of which were challenging to value. William Cavendish (2000, 2002) provided a methodological breakthrough that was further developed and applied across 8000 households in 24 tropical and sub-tropical countries by the international research consortium Poverty Environment Network (Angelsen et al. 2011). These studies showed, among other things, that 28% of total household income derived from environmental products, with 77% coming from forests (Angelsen et al. 2014). This was comparable to crop income, making up an average of 29% of total household income. These advances also allowed studies combining income surveys and biophysical data (Meilby et al. 2014), quantitative analysis of livelihood strategies based on environmentally augmented income data (Nielsen et al. 2013), and the generation of panel data sets that allowed analysis of the role of environmental products in households' movement in and out of poverty (Walelign et al. 2016).

While a set of general challenges to livelihood studies have been identified (Scoones 2015), three areas appear particularly interesting in relation to improving our understanding of the relationships between households and forest ecosystem services: (i) develop the PEN approach so that environmental modules become available in connection to standardized national-level household surveys; (ii) develop the method tool box to allow estimates of environmental resources that are important but typically excluded from household-level valuation studies, such as water; and (iii) initiate studies that move inside the household, e.g. to generate understanding of the relative importance of income from forest ecosystem services to individual household members.

Enhancing the provision of ecosystem services for social gains

The opportunity to supply forest ecosystem services, including protection of production sites, may be influenced at multiple-policy and administrative levels (Dallimer and Strange 2015) by numerous socio-political factors, available budgets, and forest owners' willingness to be involved in the provision of ecosystem services (Barrett et al. 2001; Knight and Cowling 2007). In particular, from a social planner perspective, it is important to improve our understanding of the relationships between forest owner preferences and the spatial distribution of ecosystem services. This will inform the design of regulation and instruments enabling society to target the right forest owners when pursuing changes in ecosystem service provision. An increasing number of studies attempt to reveal forest owners' perceptions of forests, their reasons for owning forests, their willingness to participate in environmental schemes as well as their attitudes towards the contents of such voluntary agreements. These studies demonstrate that forest owners' preferences are highly heterogeneous (Boon et al. 2010). Some owners focus on managing the forest as a timber resource while others are primarily concerned with nature and environmental values. Many owners emphasize the importance of the forest as a place for personal use, leisure time and hunting (Boon et al., 2004). A number of choice experiment surveys in the Nordic countries have revealed forest owners' management objectives, in particular, their views on various forms of ecosystem service provision agreements and contracts. Horne (2006) was the first to study preferences over contract attributes in the Nordic countries and documented that provider and initiator of such contracts mattered for Finnish forest owners when providing enhanced biodiversity protection. Broch et al. (2013) found that Danish farmers are more likely to accept afforestation contracts (and require less compensation) if the objectives of the contracts, e.g. protection of particular ecosystem services, match their own preferences. Additionally, they found that farmers are more likely to accept a contract, and have a lower reservation price if the contract has a time limited exit option, and if they have previously accepted similar contracts. Furthermore, the monitoring policies may affect land owners willingness to accept contracts (Vedel et al. 2015a). Some forest owners may be willing to participate at a lower compensation level for activities they already plan or implement (Vedel et al. 2015b). What is most notable from the above research is the vast heterogeneity in land owners' willingness to accept, and views on, various contract variants. Importantly, the existence of this heterogeneity is not exploited deliberately in standard conservation policies designed to underpin regulation such as the EU Habitat Directive and Natura 2000 forest schemes. Across Europe such measures are mainly focused on offering owners compensations based on direct cost and income foregone measures (Jacobsen et al., 2013), mainly to avoid 'overcompensating' forest owners. Furthermore, the conservation contracts, which land owners are offered, are often modest menus of contracts and designed as equalitarian flat rate schemes in the hope of keeping costs and potential overcompensation at a low level. This is unfortunate for two reasons: This kind of contract does not effectively solve the coordination problem across land owners, as variation in true opportunity costs are not reflected in the way land owners opt into the program or their compensation. From a welfare economic point of view, rents represent a transfer, which may imply some degree of distortionary losses. However, avoiding any sort of rent should not be a social objective in itself. The cost of rents should be balanced against the social cost and benefits of ecosystem service provision (Anthon et al. 2007).

Another approach to regulation is to elicit the owners' true preferences in a reverse auctioning scheme. In a reverse auction, the buyer calls for bids from potential sellers subject to a transparent selection and pricing scheme. This is opposed to a traditional auction where the seller calls for bids from potential buyers. In reverse actions, the social planner asks for bids from private forest owners on their required compensation for providing specified actions to enhance ecosystem services on their land. Such market-based instruments have been advocated for more than two decades, yet only implemented a few times. The available cases, mainly from the US and Australia (Latacz-Lohmanm and Schilizzi, 2005) merely represent pilot experiments. Interestingly, reverse auctions are common in the public procurement of numerous other services (Carter et al. 2004).

Designs of the few existing examples do not meet central criteria to comply with a good auction design, such as transparency about the pricing rule or sufficient competition for the tendered contract types (Latacz-Lohmanm and Schilizzi, 2005; Klemperer 1999). Yet there are positive experiences from existing experiments, which suggests that well-designed reverse auctions do not have greater administrative costs than the existing flat-rate grants schemes (Juutinen and Ollikainen, 2010). We suggest that implementation of further auctioning experiments be improved and advocate for a general change in the design of conservation schemes within the EU.

Forest management for ecosystem services in the Nordic countries – multiple use at what scale?

Thus, in recent years, the research community has made considerable progress in the development of methods for valuing ecosystem services. The number of studies is increasing, also in a Nordic context (Lindhjem 2007). Filyushkina et al. (2015) present a comprehensive review of ecosystem service studies in the Nordic countries and their integration into decision-making models. They find there is a need for (i) wider coverage of non-market ecosystem services and evidence-based modelling of how forest management regimes affect ecosystem services; (ii) improved natural scientific and ecological knowledge of "stock and flows" and the resulting changes in ecosystem services due to changes in environmental policies and initiatives; and (iii) robust economic estimates for the derivative effects and their marginal values (value per unit), and knowledge of how changes in flows affects the marginal values of the service.

Importantly for forest management, the value of the ecosystem services is highly context and scale dependent and varies over time and space. One example is the value of recreational attributes of a forest ecosystem, which clearly depends on their spatial location, in particular proximity to cities and accessibility. Forests located close to cities have a higher recreation value than forests in sparsely populated areas. Other services, e.g. the value of carbon storage, a true global public good, may be less sensitive to the spatial location . Some spatial and management sensitive trade-offs between land uses, e.g. biodiversity and forest management, may indicate that multiple-use forestry – in the sense of pursuing all uses in a supposedly optimal mix on all forest land - as a general concept underpinning modern forest management, is questionable. The management of the multiple services of forests is important but very complex (Bennett et al., 2009). Biodiversity protection may imply very steep or even infeasible trade-offs at the stand or ecosystem level, or require landscape level decisions making a stand or even forest property level optimization an infeasible approach in social planning. Therefore, regulatory design has to consider such spatial and temporal trade-offs to avoid sub-optimization of land use decisions.

Sustainable management and improved decision-making at local scale

Sustainable forest management has for centuries been described as the achievement of meeting Society’s future demand for forest products and its benefits. The multi-functionality of forests entails that forestry should not compromise the need for preserving biodiversity, maintaining intact ecosystems, and fulfilling social functions at all spatial and temporal scales (Davis et al., 2001). Sustainable forest and nature management planning are complexity planning. For forest and nature managers, sustainably managing a particular forest or nature area means determining, how management actions ensure sufficient future delivery of ecosystem services from the forest. This implies that forest and nature managers usually must assess and integrate a large number of sometimes conflicting factors. Modern forest and nature planning requires a new framework for understanding planning and policy. Trends of expert driven, and rationality based, decision processes are being replaced by nonlinear, socially constructed processes engaging both experts and stakeholders. This is taking place in countries throughout the world. Trends in appropriate knowledge, where practice expert knowledge is dominant, is replaced by an understanding that knowledge is a social construction and not only experts but lay people possess valid inputs. Therefore, forest and nature managers develop and implement forest action plans in consultation with citizens, businesses, organisations, and other interested parties in and around the areas being managed. Within this complexity of managing forest and nature resources avoiding making biased judgements (Tversky et al., 1974; Kynn, 2008) a value-based focus (as opposed to an alternative based focus) suggests a structured step by step decision framework. The Structured Decision Making (SDM) framework (Gregory et al. 2012) is an organized approach to developing and evaluating creative alternatives and making defensible choices. It has been particularly useful for helping groups work productively together on decisions marked by technical uncertainty and controversial trade-offs. It combines analytical methods from decision analysis with insights into human judgments and behaviour from cognitive psychology, group dynamics, and negotiation theory and practice. The primary purpose of an SDM process is to aid and inform decision makers, rather than to prescribe a preferred solution. Such approaches may provide a sound way to emphasize the quantification of impacts of alternative actions/alternatives on the achievement of objectives in forestry.

Perspectives

The role of forests and their many ecosystem services for social welfare is increasingly recognized, both in the global north and the global south. Safeguarding and enhancing the role of forests for social welfare poses challenges for research in forest policy, economics, and management planning around the world, including the need to change research approaches and develop new methods. This is also an opportunity for forest research communities to reach out and engage with strong non-forest research environments, e.g. in social science areas such as public and regulatory economics, political science, behavioural sciences, but also natural sciences with critical insights into the role of forests, e.g. in the fields of biology and climate science.

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7. Developing MSc education in nature-based tourism

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Powered by nature. This is the pitch made to attract more people visit Norway – and that is of course no coincidence. One in fifteen people in Norway work in the tourism sector, which had 30.3 million commercial bed-nights in 2014 (Innovation Norway, 2015). When asking people living abroad about their perceptions of Norway as a holiday destination there are fjords, nature, mountains, cold, snow and scenery at the top of their minds (ibid), and a national inventory estimate between 2000 and 3000 firms offering nature activities and experiences against payment in Norway (Stensland et al., 2014). In a global perspective, nature is a key attraction factor for tourism in the Nordic region and nature-based tourism is one of the fastest growing sectors of tourism in Europe. Such a demand has created opportunities for nature-based tourism to develop as an economic diversification tool within regions rich in natural amenities (Fredman & Tyrväinen, 2010). Nature-based tourism is a land-use activity involving a diversity of entrepreneurs, many of which are small, located in rural areas and challenged by seasonality in demand. It is also common that nature-based tourism businesses are combined with other natural resource uses, such as forestry and agriculture (ibid).

The growth of tourism in general, and the growing significance of nature-based tourism as an economic sector in particular, call for new and more integrated knowledge to management and use of natural resources. Studies in tourism is primarily social sciences – its' about people visiting places outside their ordinary neighborhood. In nature-based tourism however, management of natural resources interact with opportunities to recreate in the outdoors and successful development of tourist destinations. To meet the demand for such an integrated knowledge field, the Department of Ecology and Natural Resource Management at the Norwegian University of Life Sciences established a two-year master program in nature-based tourism in 2004. This paper tells the story of the program – how it emerged, was designed and concludes with some future outlooks.

Travel for nature

In Norway, nature-based tourism has a relative long history due to the country's abundance of natural resources and attractive landscapes. Since the Romantic period in the nineteenth century, foreign and domestic visitors have treasured the countryside and its natural / wild environments. English lords were pioneers of nature-based recreational activities such as mountaineering, hiking, and sports fishing (Aas, Stensland & Baardsen in press). Inspired by these impulses, the Norwegian Trekking Association (Den Norske Turistforening, DNT) – was established in 1868 by the social elite, and has over the years developed into one of the bigger outdoor organizations in Norway with 240 000 members. In 1904, the climber William Cecil Slingsby published the book *Norway: The Northern Playground*. As the title indicates, the English alpine explorer perceived Norway as a source of enjoyment and recreational activity due to the country's magnificent natural attributes.

The tourist appreciation of natural resources in present-day society has several additional antecedents. After the First World War, the quest for naturalness became a fashion in European culture. The rural idyll and closeness to nature turned out to be attractive elements; the modern life styles embraced the suntan as the new status symbol in sharp contrast to the aristocracy's former protection of the whitish skin. The genuine *friluftsliv* tradition, based on common access to public and private land – *allemannsretten* – also played an important role in the development of nature-based tourism in Norway. Polar explorers and extensive travellers like Fridtjof Nansen (1916) emphasized the social and personal benefits of outdoor recreation in the public debates of his time. The Norwegian Outdoor Recreation Act (1957) finally warranted and formalized the common people's right to practice a simple way of life in natural surroundings (LOV 1957-06-28 nr 16). In the 1950's and 60's, mass tourism based on private cars and improved accessibility to natural areas took off and the members of an ever more industrialized, urbanized and affluent society demanded a variety of tourism products to be consumed in natural settings.

Experiencing nature is also a primary travel motive among contemporary tourists (Fredman & Tyrväinen, 2010; Gössling & Hultman, 2006; Haukeland & Rideng, 1999). Healthy life style trends with focus on activities and physical exercises have continued to grow in nature-oriented tourism. A fast growing "outdoor recreation industry" also offers well-designed outfits and sophisticated gear, which are spot-on as regards the creation of trendy identities in the consumer society (Fredman & Haukeland, 2015). Various nature-based events generate increased public attention and the extensive use of social media in the nature-based tourism context confirms and co-creates ever more diversified and specialized consumer identities.

This quest for outdoor recreational activities has created multiple business opportunities for locals and entrepreneurs, and the building of supplementary infrastructure (second homes, commercial accommodation, ski resorts etc.) and additional services (food and beverage provisions, boat rentals etc.) has significantly influenced local and regional economies over the last decades. The traditional "landscape of production" (i.e. the production of basic outputs like food and fibre) loses ground with the decline in primary resource based industries like farming, fishing and forestry. The transformation process of the production system turns the countryside more and more into a "landscape of leisure and consumption" (Butler, Hall, & Jenkins, 1998; Groote, Huigen, & Haartsen, 2000; Hoggart, Buller, & Black, 1995).

Studies in nature-based tourism

As an academic inquiry, tourism knowledge is a synthesis of fact-oriented positivist methodologies and critical theory, and since much tourism research takes place in the form of a multi- and post-disciplinary study field, tourism scholars often identify themselves with "learning outside of established disciplinary agendas" (Tribe 2006; Coles et al. 2006). As an example, the PhD program in tourism studies at Mid-Sweden University has a three-pillar framework – tourism related resources, consumer behavior, and tourism management – which provides an interface between individual disciplines and the study field of tourism (Fuchs et al., 2014).

Turning the focus to nature-based tourism, it can be defined as recreation activities occurring when people visit nature areas outside their ordinary neighborhood, and the nature-based tourism sector represents services directed to meet the demand of nature-based tourists (Fredman & Tyrväinen, 2010). Methodologically, researching nature-based tourism comprises three main approaches – demand (participation), supply (service providers) and resources (nature areas). In addition, there are many external factors having large impacts in the nature-based tourism production system (regulations, seasonality, infrastructure etc.). Current research agendas in nature-based tourism worldwide typically include studies in motivations and benefits, consumer markets, entrepreneurship, impact (economic, social, environmental), non-market valuation, recreation conflicts, physical planning, visitor monitoring, interpretation, protected area management, accessibility, aesthetics and wildlife management. The lack of more integrated knowledge on nature-based tourism is, however, problematic given the special features of this sector including e.g. nature-based attractions, commercialization of natural heritage, seasonality and climate dependence.

This gap was addressed in the research project "*Nature based tourism in Norway – companies, recruitment and education*" where Fossgard and Stensland (2013) made a content analysis of higher education study programs in Norway with respect to the relevance for nature-based tourism. Collecting data from webpages, 52 one-year bachelor and master level study programs were classified using current theories for curriculum design. The study programs were analyzed to which extent they included modules in the above four categories. Findings showed that a majority of the programs had a single topical focus, while only a few programs had an integrated, multi-topical approach to nature-based tourism. The latter may become an issue for the small-scale

Norwegian nature-based tourism sector, where companies with few employees struggle to cover all the four competence fields identified. Fossgard and Stensland proposed to continue the development of nature-based tourism practitioner programs, with the goal to educate more graduates as managers or advisors for the tourism sector. Furthermore, the nature-based practitioner should also be educated for work tasks within public administration and management of natural resources of relevance to nature-based tourism.

Breaking the grounds

About ten years earlier, in December 2002, the Agricultural University of Norway received a letter from the Norwegian Farmers' Union, which expressed the need for new and more holistic competence among current natural resource managers (Stensland, 2005). The background for this was multifaceted. Income and employment in traditional agriculture and forestry had been shrinking and to counteract this the Government wanted the sector to be able to increase commercial use of their wildland resources (Landbruksdepartementet, 1999). Tourism and energy production were two important pillars mentioned. At this time, politicians also expressed an optimistic view that increased possibilities for landowners to develop nature-based tourism will strengthen the interest to protect environmental values like wilderness and biodiversity (Nærings- og Handelsdepartementet, 1999). A true child of this mind-set was "The Mountain Text" (Fjellteksten) which was delivered in 2003 and stated: "If we manage to protect the natural and cultural historic assets of the Norwegian mountain areas, not least in protected areas, the Government sees a large potential for increased environmentally adapted tourism in our mountain areas" (Finansdepartementet, 2003).

Some of the first to take on these challenges were the Norwegian Farmers' Union and the Norwegian Forest Owners Association. Starting in the late 1990s, they managed several national and regional projects focusing on organization of landowners, planning and business development. These projects were successful on the two first tasks, but did not create much business development among landowners. According to an evaluation by the Norwegian Institute of Nature Research, NINA (Aas et al. 2004), a reason for this could be that people involved in these projects had training in the natural sciences as natural resource managers/biologists, but lacked competence in the social sciences, such as tourism and entrepreneurship. A further paradox was that landowner organizations often collaborated with someone "greener than themselves" such as the Norwegian Hunter and Fisherman Association instead of seeking tourism competence. Similar needs were also identified at a seminar in November 2002 about competence and research needs in the outfield businesses arranged by the Norwegian Research Council. The minister of agriculture at that time, Lars Sponheim, concluded that there was a need for investments in new knowledge in this area.

Based on a request from the Norwegian Farmers' Union, a working group started to assess the need for a master program to fill this educational gap. The group consisted of representatives from the Norwegian Farmers Union (Finn Erlend Ødegård), and the Norwegian Forest Owners Association (Vidar Holthe) and NORSKOG (Haaken Christensen). From the Agricultural University of Norway Anne Marte Tronsmo (leader), Chrstina Qvam Heggertveit (secretary), student representative Espen Fjeldstad, and the professors Birger Solberg (Department of Forest Sciences), Ole Hofstad (Department of Forest Sciences) Olav Hjeljord (Department of Biology and Nature Conservation), Hans Sevatdal (Department of Spatial Planning), and Anders Lunnan (Department of Resource Economics). The 2003 report from the group concluded that a two-year master program was appropriate to fill the abovementioned educational demand. They also emphasized that the candidate should be able to start his/her own business, or work as manager/advisor within the private or public sectors. Further, small-scale rural, nature-based tourism/outdoor recreation should be the core, and not heavy infrastructure /mass tourism. A potential challenge identified was that there existed no specialized bachelor program leading up to this master. The late fall of 2003 a new group was formed to plan the master program for a start up the following year. This group included Ole Hofstad, Svein Dale, Anders Lunnan, Sølve Bærug, Hans Fredrik Hoen and Birger Vennesland.

An emerging program

In August 2004 the first student started at the master program named "Outfield Businesses and Development" (Utmarksbasert næringsutvikling). There were three study options to start with – Renewable Energy (Fornybar energi), Land Use Planning (Arealbruk), and Outfields and Nature-based Tourism (Utmark og naturturisme). The reason for the single 2004 student was that the program received approval just before the summer and there were no time or resources to market it. The first real cohort of 11 students started the fall of 2005. The following years, student numbers were in the range of 5-12 per year, but has since then steadily increased to around 20 at present time (Figure 1). Initially the admission requirements were a Bachelor degree in natural sciences or economics/tourism. In 2009, the program changed the name to "Nature-based Tourism" (Naturbasert reiseliv) to better reflect the core content, as well as for marketing purposes. The more technical and economic oriented renewable energy option, which attracted very few students, was re-organized into its own master program. The change of name also reflected a change towards the social sciences as a viable bachelor option for applicants, including tourism and business development programs. Over the years, about two thirds of the students entered the program with a bachelor from a different institution than NMBU (former NLH and UMB). Around 80 percent of the students have been recruited about equally from bachelor programs in natural resources management/ecology/biology, outdoor recreation (friluftsliv), tourism or economics from many different institutions. Since the language primarily used for teaching is Norwegian, around 90 percent of the students are from Norway, with the remaining originating from other Scandinavian countries, the Netherlands, Germany, Mozambique, and Russia

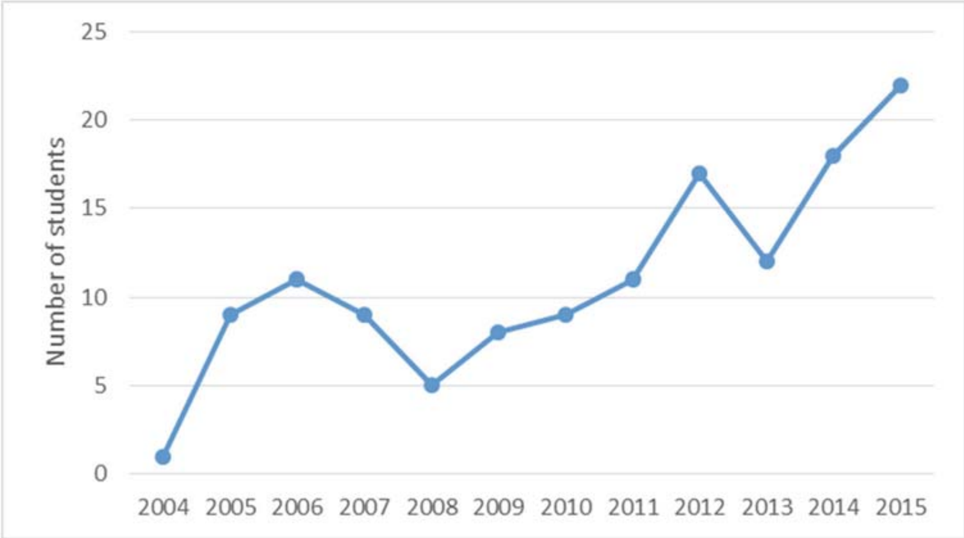

Figure 1. Number of students entering the program since the start in 2004.

A two-year master in nature-based tourism

The current program content aims to meet the requirements of the nature-based tourism practitioner (Fossgard & Stensland, 2013) by including elements from four main areas; tourism, nature management, activities/experiences and society (Figure 2). Tourism and nature management subjects are combined with economics, entrepreneurship and innovation, land use planning, and qualitative and quantitative method courses. The students learn to adopt a holistic approach to the management of nature, and the opportunities, challenges and conflicts that lies in increased commercial use of natural resources. The candidates will gain skills in entrepreneurship, product and resource management, and sales of nature-based tourism products. Relevance to the nature-based industry is important and through projects and master tasks, field trips and lectures the candidates get contact with tourism companies, NGOs and administrative authorities (Figure 4). For admission to the program, a bachelor degree, or equivalent, with specialization in one of the following fields are required: Tourism, recreation, forest sciences, agricultural sciences, environmental sciences, biological sciences, natural and wildlife management, economics, innovation and entrepreneurship, social and marketing communication.

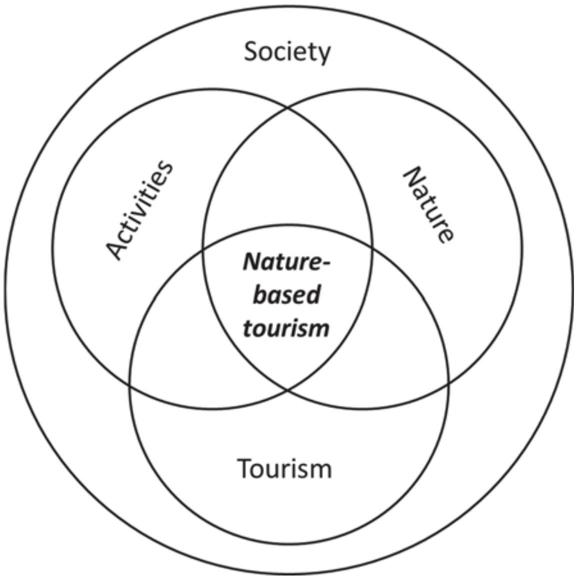

Figure 2. Thematic illustration of the main topic areas in the nature-based tourism master programme.

Current compulsory courses cover tourism as a phenomenon and industry and nature-based tourism; conservation and management of Norwegian nature; business establishment, economic development, innovation and entrepreneurship; regulation and environmental law; and research methods. In addition to the compulsory courses, the student have about 25 credits of elective courses. Depending on educational background, students are required to use some of these credits to secure that all competence areas are included in their degree. For the remaining credits, candidates pick freely from the rich palette of different subjects at NMBU or at other universities, even abroad.

The first year spring term is relatively open to facilitate specialization and exchange. Students are encouraged to do some of their studies abroad in order to gain new professional and cultural perspectives. Previous students have traveled to Alaska, New Zealand, Canada, Tanzania, Sweden, Iceland and Svalbard. The program concludes with a master thesis of 30 credits on a nature-based tourism topic. As of May 2016 there were 72 completed theses registered. Of these, 33 used a quantitative approach (surveys mostly) and 31 a qualitative approach – mostly interviews. Eight theses used a combination of methods. Thematically, topics vary widely from analyses of specific tourism/recreation activities like biking, photography, kiting and fishing, to more place-oriented studies of recreation areas such as national parks, often with a tourism-planning approach to the topic. In general, the thesis topics are influenced by the research portfolio of the supervisors with, for example, 22 theses on protected areas and 6 about recreational fishing. Topics at the boundary between agriculture and tourism/entrepreneurship counts for nine theses.[1]

In addition to the educational activities, students at the program are also involved in several social activities related to their studies. There is a student network "Natura Innova" and the nature-based tourism research group organizes an annual two-day study tour open for present and former students. Starting in 2014, there has also been an annual nature-based tourism research seminar organized in the fall, involving both students and representatives from the industry.

Table 1: Current (2016) content of the two-year nature-based tourism master program at NMBU

Term	Subject	ECTS	Comment
Year 1: Autumn	Introduction to the Master Program in Nature-based Tourism	10	Compulsory
	Tourism as Phenomenon and Industry	5	Compulsory[1]
	Environmental Governance and Law	5	Compulsory
	Management Accounting	10	Compulsory[2]
	Qualitative Methods	5	BSc dependent[3]
Year 1: Spring[4]	Nature Interpretation	5	Compulsory
	Idea and Business Development	5	Compulsory
	Nature Conservation and Management in Norway	5	Compulsory
	Quantitative Methods	5	BSc dependent[3]
	Elective courses	10	BSc dependent[3]
Year 2: Autumn	Business development, policy and innovation	10	Compulsory
	Nature-Based Tourism	10	Compulsory
	Elective courses	10	BSc dependent[3]
Year 2: Spring	Master's Thesis	30	Compulsory

[1] Non-compulsory for students with BSc in tourism. [2] Non-compulsory for students with BSc in economics.
[3] Requirements will vary according to BSc. [4] Term free to facilitate specialization and exchange

Scholars involved in the program

Over the years, several persons have been involved in the development of the program, teaching and supervision – from NMBU as well as other organizations. These include;

- *Ole Hofstad*, professor in forest economics. Member of the working group planning the program. Has been involved in teaching, administration and thesis supervision since the start-up to present time.
- *Stian Stensland*. Employed in 2004 to help plan and start the program, and have been involved in administration and development since then. Responsible for the introduction course and lectures in several other courses, supervision and marketing. PhD completed in 2011. PostDoc position 2011-2017.

[1] See link for a full overview of theses' titles/themes: http://statisk.umb.no/ina/studier/moppgaver/moppgaver.php?sprx=M-UN&fraaarx=&tilaarx=&enkaarx=&forfx=&tittx=&veilx

- *Sjur Baardsen*, professor in forest economics. Program development, responsibility for tourism course, lecturing and supervision 2004 to 2015.
- *Birger Vennesland*, researcher in entrepreneurship and rural development. Program development, responsible for nature-based tourism course, supervision 2004-2010.
- *Øystein Aas*, adjunct professor in nature-based tourism on a 20 percent basis since June 2005, 10 % 2010 - 2014. Main employee NINA. Responsibility for nature-based tourism course, lecturing, MSc and PhD supervision.
- *Jan Vidar Haukeland*, associate professor, 40 per cent part time position since April 2012. Main employer: the Institute of Transport Economics (TØI). Program development, responsible for nature-based tourism course, supervision 2009 to present time. . PhD completed in 2011.
- *Knut Fossgard*, lecturer in tourism. Teaching assistant in several of the tourism courses. PhD student in nature-based tourism since August 2015.
- *Peter Fredman*, professor in nature-based tourism. Head of research group and program development. Responsible for tourism and nature interpretation courses, lecturing in nature-based tourism and supervision since 2014 to present time.
- Torvald Tangeland, PhD completed in 2012.
- Monica Breiby, PhD completed in 2015.
- Georg Kamfjord, senior lecturer at BI - Norwegian Business School. His book Reiselivsproduktet (The Tourism Product) has been used since the program start, and Kamfjord has given annual lectures based on the book.

Integrating higher education with research

A key success factor for the program and research group has been externally funded research projects on different nature-based tourism topics, also including cooperation with other research institutions. With two of the part-time researchers in the group also holding positions at TØI and NINA, respectively, these have been central partners in this respect. However, the group has also had significant benefits from cooperation with the institute of landscape planning at NMBU and Centre for Rural Research (CRR) as well as with several international partners – especially Mid-Sweden University/ETOUR, Natural Resource Institute of Finland (LUKE), University of Iceland, University of Alaska, University of Otago (New Zealand), and Oregon State University. Some of the major research projects include;

- Tourism business development based on nature (cooperation with NINA and funding for Phd of Torvald Tangeland)
- The LOVIT project – Salmon sport fishery management and tourism (cooperation with NINA, funding for Stian Stensland’s PhD and two master theses)
- The SUSTOUR project on national park tourism in mountainous areas (cooperation with TØI, Centre for Rural Research and NINA, and funding for Jan Vidar Haukeland’s PhD and six master theses)

- The PROTOUR project concerning national park tourism and management challenges (Ten master theses)
- SALMONCHANGE – Sustainable salmon angling tourism in a changing world (funding for Stian Stensland's postdoc, cooperation with NINA, Iceland, and Alaska, four master theses)
- NATURE BASED TOURISM – firms, competence and recruitment. (Cooperation with TØI, Mid-Sweden University. Four master theses).
- BIOTOUR – From place-based natural resources to value-added experiences: Tourism in the new bio-economy. Project which started in April 2016 and will last until year 2020 (funding for two PhDs, two postdocs and several master theses)

Other projects with close cooperation and use of master students include several NINA lead projects on mountain recreation and tourism, wildlife tourism and ecotourism. Key themes have been understanding marked preferences, attractive product development, policy challenges and opportunities in the interface between biodiversity conservation and tourism development, and monitoring ecological and social impacts from tourism and recreation, to mention a few. These projects have been important for a range of reasons. First of all the projects have funded PhD and Postdoc scholarships, which have significantly contributed to the growth of new, highly qualified researchers in the field. Secondly, the success of bringing in new projects give strong signals to decision makers and other key persons both at universities and the Norwegian Research Council that nature-based tourism is an attractive and relevant field for research and academic education. Thirdly, it has linked NMBU better with existing and new cooperative institutions – an important aspect for developing the field further, as documented in the recently funded BIOTOUR project.

Future outlook

During the first years of the program, there were relatively few students and the job market was very favourable for those students who left the university with this new and innovative mixture of courses. Looking back and judging from job surveys conducted we see that the graduates get interesting jobs within or related to the tourism industry. The most recent job survey sent all graduates showed that 50 per cent work in the private sector, but only a few have started up their own businesses. Most common is to work as advisor or project manager. One out of three students work directly with experiences/tourism and development. Although many graduates already get jobs outside of the core tourism sector, most of the positions are indirectly related to tourism (e.g. national park management, nature interpretation). With more students graduating in the future, it is likely that even more graduates will end up outside the traditional tourism sector[2].

[2] Job examples are listed at https://www.nmbu.no/om/fakulteter/miljotek/institutter/ina/student/yrkeseksempler/naturbasert-reiseliv-y

Looking further ahead, the overall vision is to be the leading master curriculum in nature-based tourism in the Nordic region. The first full-time professor associated with the program took office in 2014, and a second full-time position is announced during 2016. The successful funding of the BIOTOUR project implies that both the research portfolio and the study program are well positioned for the future. This will not only be the arena for additional PhD and post doc positions, but also an excellent opportunity to introduce master students to research, in particular through their thesis work. This could be one mean of making the study program more attractive so that the number of students remain at the target of at least 20 each year.

It takes time to establish a new study program and to get the word out, but several indicators are now looking bright. Former students increasingly take on the role as ambassadors, media coverage is more frequent, and there appear to be relevant job opportunities. Future development plans of the program include more international exchange opportunities, annual seminars with the industry, a new website and social media actions to reach out better, as well as more interactions with Alumni. There is also a need for further elaboration of the curriculum as an integrated part of the long-term research strategy in nature-based tourism at NMBU. Topics of special interest are nature interpretation, ecotourism, visitor monitoring, tourism and recreation behavior, quantitative research methodologies, wildlife tourism, entrepreneurship and innovation in a nature-based tourism context.

Figure 4. Immediately after the formal establishment of the program, the main Norwegian newspaper Aftenposten wrote a piece about the coming study program. This initiated a request from Oddvar Skråmestø (rector at Ål high school) and Randi Frellumstad (Skandinavisk reiselivskompetanse in Geilo) who invited the program to "come to where the outfield (utmarka) is". Hence, since 2005 the new master students as a jump start of their study have gone on a five day field trip in August to the Hallingdal region to meet and talk to tourism actors and try activities like rafting, milking cows, fly fishing, and mountain biking. Similarly the second year field trip to Fulufjället National Park in Sweden which is the first National park in Scandinavia to specifically facilitate for visitors, has been an important part of the program since start up too.

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8. REDD+: From idea to reality - and back?

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Introduction

Forest economists – even economists in general – should be pleased with the idea of REDD+: Reducing Emissions from Deforestation and forest Degradation. In many respects, REDD+ takes as its starting point the basic economics insight as to why environmental problems arise. Forests produce climate services in the form of carbon sequestration and storage; these are public goods that currently have no large-scale markets or market-like mechanisms to incentivize the forest owners and users to factor the value of these services into their land use decisions. The textbook solution is simple: pay them to sequester and store carbon, and the problem is solved. The initial REDD+ idea was therefore to create a multilevel (global → national → local) system of payments for environmental services (PES).

Implementing the textbook solution in the forest is challenging, and the REDD+ concept has evolved in several distinct ways. The purpose of this chapter is to discuss how the REDD+ idea has changed at three scales: global, national and local (with Tanzania as a case), and along three dimensions: objectives, funding, and policies/means of implementation.

The changes described are driven by both practical considerations and political forces. Designing and implementing a market-based multilevel PES system has proven much more difficult than anticipated by many. Creating national and local PES systems presents a number of design and practical challenges (Angelsen 2014). Throwing a simple REDD-PES idea on various policy arenas, with prospects for big money as well as significant reductions in forest use in the near future, also mobilized a number of forces. Some wanted to modify the REDD+ idea to fit their agenda, for example, to modify the objectives to fit a more traditional biodiversity conservation agenda promoted by some environmental NGOs, or to dilute the proposal such that business-as-usual could continue and generate profits for palm oil and timber companies. The current REDD+ idea and emerging practice is therefore quite different from the one that entered the international scene in 2005.

REDD+ as an idea

When REDD+ was placed on the agenda of the global climate negotiations (UNFCCC) in 2005, it was envisioned as a mechanism whereby developed (Annex I) countries would incentivise and compensate developing (non-Annex I) countries for reduced emissions from forests. Initially promoted by Brazilian environmentalists and scientists (Santilli et al. 2005), it was a proposal about "compensated reduction". The voluntary nature and national discretion were stressed: "Compensated reductions is a voluntary mechanism that offers tropical countries access to substantial market incentives for reducing emissions, while respecting their sovereignty in selecting means and investing returns" (Santilli et al. 2005: 50). Nevertheless, increasingly the idea became that an international results-based payment mechanism should be mirrored within countries; local forest owners and users should be incentivised and compensated for the carbon sequestered and stored in their forests.

After a two year consultation period, REDD+ became an integral part of the global climate negotiations at the 13th Conference of the Parties (COP) of the UNFCCC in 2007 (UNFCCC 2007). In the meantime, the second D (degradation) had also become included after much pressure from African countries (but with some opposition from Brazil, among others). The scope of REDD+ has indeed been contested all along, but gradually expanded. The "+" part, slowly being inserted in 2008-9, is a diplomatic silver bullet allowing different parties and actors to insert their own agenda items into the concept of REDD+.

The primary source of funding was supposed to be from REDD+ credits sold in a compliance carbon market. The Bali Action Plan was, in the view of key actors, a plan of a global Cap and Trade (CAT) system in which REDD+ credits could be used as offsets (Guizol and Atmadja 2008).

The key features of the original REDD+ idea, as expressed through the COP decisions and mainstream actors, are summarized in column two in Table 1. The REDD+ idea was, in short, about achieving lower carbon emissions through an international (and national) PES mechanism, funded by a global carbon market. The idea then changed both at the level of international (global) negotiations (column 3), and in national and local developments – using Tanzania as case (columns four and five).

Table 1: Key ideas of REDD+ and their evolution and status at different scales.

Element	Idea (2)	Global (3)	National (4)	Local (5)
Objectives	Carbon	Development, Biodiversity (synergies)	Development + carbon	Carbon + development
Funding	Carbon market	Development aid	Aid + own resources	Voluntary carbon markets
Implementation	PES Measure results	RBA, PAM MRV dev. Safeguards (SIS)	PAM; Green growth/LED	PES, hybrid

Notes:

LED: Low Emission Development
MRV: Monitoring, Reporting and Verification
PAM: Policies and Measures
PES: Payment for Environmental/Ecosystem Services
RBA: Result-Based Aid
SIS: Safeguard Information Systems

What happened to the REDD+ idea internationally?

We argue that the single most important factor that has changed the REDD+ idea is the fundamental change in the nature of the climate agreement. For years, the aim of the international climate negotiations were to realize a CAT model, similar to the Kyoto Protocol of 1997, but with more countries included. Countries commit to binding emissions targets (caps), and flexible mechanisms – including trade – permits these to be achieved in a cost-efficient way. REDD+ credits generated by developing countries would be part of the CAT system, in a similar way as Certified Emission Reductions (CER) are under the Clean Development Mechanism (CDM) of the Kyoto Protocol. COP 15 in Copenhagen (2009) failed to deliver that agreement, but the ambitious idea survived. A major breakthrough of the CAT idea – encompassing all countries – happened two years later at COP 17 in Durban (2011): all countries agreed in principle to take on some sort of legally binding commitments. The consensus was short-lived.

In the lead-up to the Paris conference of 2015, it became clear that an agreement with legally binding commitments in the form of emission targets was simply unacceptable for most key countries outside EU. COP 21 in Paris (2015) gave us a very different agreement, with a bottom-up approach based on each country's (Intended) Nationally Determined Contributions ((I)NDCs). In short, each country submit what they intend to do, either in form of a specific reduction target (compared to a base year or to a more or less specified business-as-usual scenario), or as a set of policies and actions. The current contributions are far from being compatible with the 2 degree target. Ironically, the parties in Paris tried to address this emission gap by making the target even more ambitious (1.5 degree)!

UNFCCC has provided a global arena for REDD+ discussions and decisions, culminating in the Warsaw framework (COP 19, 2013). The majority of the actions have been undertaken by multilateral and bilateral donors, national and state governments, NGOs and the corporate sector. Donors – led by Norway and Germany – have tried to implement the PES idea through result-based aid, which raises a host of challenges related to defining performance criteria, setting reference levels and playing hard-ball with developing countries (Angelsen 2016).

Another significant development is the efforts – not at least by Norway – to engage the private sector as a key partner in REDD+. In the New York Declaration on Forests (2014), signatories (countries, states, companies and indigenous peoples groups) committed to doing their part to halve current deforestation rates by 2020 and to end deforestation by 2030[3]. They also agreed to ensure that the production of four key commodities (palm oil, soy, paper, and beef) did not add to deforestation. "Zero deforestation" initiatives have resulted in several global companies making significant efforts in greening their value chains.

At the project level, hundreds of REDD+ local initiatives present a diversity of approaches, best seen as hybrid projects with traditional conservation approaches such as Integrated Development and Conservation Projects (ICDPs), community management, and tenure reforms. The results-based payment or PES concept has survived and is still seen (in different versions) as a key component of REDD+ policies and projects, but alongside other instruments (Sills et al. 2014).

REDD+ has in this process changed in three significant and interlinked ways, cf. Table 1. First, REDD+ has moved from single to multiple *objectives*. Initially (from 2005 to 2008), the principal objective of REDD+ was to contribute to the UNFCCC aim of "stabilisation of greenhouse gas concentrations in the atmosphere". Since then, other objectives (referred to as "co-benefits" or "non-carbon benefits") have been added to the debate: protecting biodiversity, reducing poverty/enhancing local livelihoods, strengthening indigenous rights, improving governance, and expanding capacity for climate adaptation. REDD+ is also increasingly linked to an agriculture-climate agenda.

Second, the *funding* for REDD+ was initially supposed to come mainly from an international carbon market. But that market is yet to emerge, as no demand has been created through a CAT climate agreement. As a result, 90% of the international funding is currently coming from public sources, mainly official development aid (ODA) budgets (Norman and Nakhooda 2014). In the future, international funding might increasingly come from the Green Climate Fund, although REDD+ will have to compete with other adaptation and mitigation mechanisms. Moreover, domestic contributions – by

[3] http://www.un-redd.org/portals/15/documents/ForestsDeclarationText.pdf.

integrating REDD+ into national green or low-carbon/emission development strategies – is covering major costs, probably outweighing international contributions.

Third, the *implementation* focus has moved from results-based payments to a portfolio of policies. Creating a market for forest climate services presupposes a demand (created by emission caps), a well-defined commodity in the form of verified emission reductions (measured emissions, and a credible reference level), well-defined sellers (carbon rights clarified), and a marketplace with associated rules and regulations (Angelsen 2014). These elements are not yet in place in most countries. REDD+ must therefore be pursued as a broader set of national forest conservation policies, as we have argued for some years (Angelsen 2009), including command and control (e.g., establish and better enforce protected areas) and addressing drivers (e.g., remove agricultural subsidies).

What happened to the REDD+ idea nationally: The case of Tanzania

Tanzania was among the first countries to embark on the REDD+ idea. A bilateral agreement between Tanzania and Norway was signed on 21. April 2008; the first one for Norway and before the NICFI secretariat was established. Norway was to support national capacity building, development of a national REDD+ strategy and pilot activities at local level. We present an overview of main elements of the REDD+ strategy and some of the key challenges in establishing it.

Drafting the Tanzania REDD+ strategy started in 2009. The Vice President's Office (VPO) was responsible, while an interim National REDD Task Force (NRTF) operated as the secretariat. Initially, NRTF included three members from the VPO and three members from the Forest and Beekeeping Division under the Ministry of Natural Resources and Tourism (MNRT/FBD). In 2012, the number of ministry representatives expanded to also include agriculture and energy, as well as a member from civil society – the Tanzania Forest Conservation Group (TFCG) (URT 2013).

This expanded representation reflects the understanding that reducing deforestation demanded engagement across several sectors. It also reflects pressure from NGOs where TFCG took a leading position early on. While there had been consultations with a wider set of actors, including civil society (URT 2010), NGOs involved in forest management criticized the process for being slow and increasingly closed and centred on the NRTF. NGOs therefore organized public protest events (Rantala and Di Gregorio 2014). A key issue regarding REDD+ in Tanzania concerns ownership of forest land. The Land Act (URT 1999a) defines three main categories: reserved, village and general land. The government is responsible for managing the first and last categories. General land is, nevertheless, typically accessed by local communities that consider it their own by custom. While the Land Act defines general land quite extensively to include more than 50 % of all forests, the Village Land Act (URT 1999b) uses a definition where most of this area is defined as village land. This ambiguity creates legal uncertainty: who has the right to be compensated for the opportunity costs of forest conservation? The position on this issue has changed during the development of the REDD+ strategy. The last version (URT 2013) accepts that most general land is village land, while noting that there is "insecurity" to the definition.

The Tanzania REDD+ strategy is multi-objective. It reflects the general trend emphasized in Section 3 above, and views REDD+ as part of a broader development strategy. The goal of the strategy "is to facilitate well coordinated and effective implementation of REDD+ related policies, processes and activities so as to contribute to climate change agenda and overall sustainable human development" (URT 2013: ix). Other benefits that REDD+ might bring include "maintenance of forest dependent communities' rights, improved community livelihoods, technology transfer, sustainable use of forest resources and biodiversity conservation" (URT 2013: xxi).

At the time the strategy was concluded, there was great uncertainty regarding funding. The strategy favours a fund-based financing arrangement and includes a proposal for a Tanzania REDD+ Trust Fund. It notes, however, that the solution has to be adapted to the UNFCCC framework and decisions. The choice of a national fund has been criticized by a coalition of NGOs (Tanzania Civil Society Organizations 2012). Their main argument is that the government has not been good at devolving resources to local communities. In an early proposal on key elements of a national REDD strategy, the arguments for a REDD Fund was exactly to keep money at an arm-lengths distance from the government and ensure that money are channelled to those that reduce forest emissions (Angelsen and Hofstad 2008).

The strategy places REDD+ administratively under the general climate change policy organizations, in particular a National Climate Change Steering Committee (NCCSC) and a National Climate Change Technical committee (NCCTC). The NCCSC is an inter-ministerial committee while NCCTC includes directors of various departments and agencies of the ministries represented in the NCCSC plus some external representation, e.g., from NGOs and businesses. It is clear that the ministries will play a key role in REDD+. At the same time, links are made to the local government, acknowledging that regional and district authorities are important for implementation. The relation between these structures and the REDD+ fund is unclear. The same goes for how responsibilities are to be allocated between the central and local level. It is not clear to what extent payments will be distributed through sector programmes or directly paid to local initiatives.

The national REDD+ strategy is based on broad policies and measures (PAM), and less on PES. A key element of the strategy is so-called participatory forest management (PFM). This system was developed around the turn of the century (URT 2002) and includes both community based forest management (CBFM) and joint forest management (JFM). In CBFM, village forests are formally established and land use plans – including forest management bylaws – are created. JFM supports the joint management of reserved, government-owned forests, based on the idea that including local communities will ensure more sustainable forest management. The REDD+ strategy notes that the issue regarding revenue sharing under JFM is still not settled. It also notes that the development of PFM in Tanzania has been slow and the hope is that REDD+ can offer needed resources for speeding up the process.

The strategy reflects the idea that payments to the country, via the REDD Trust Fund, will be result-based. Substantial work has been put into establishing a reference level, a requirement under the Warsaw framework. The establishment of a National Carbon Monitoring Centre (NCMC) is also part of the strategy, fulfilling another Warsaw prerequisite for accessing future international funds. Due to the uncertainties regarding future payments for REDD+, the establishment of the NCMC has been slow but is now established at the Sokoine University of Agriculture.

What happened to the REDD+ idea locally: REDD+ in Tanzanian villages[4]

The agreement between Tanzania and Norway also included the funding of pilot activities to test ways of organizing REDD+ locally. Nine pilots were contracted with various NGOs. While Norway supported the government to develop a national strategy, NGOs were contracted directly by the Norwegian Embassy to run the local pilots. The reason was ongoing issues regarding mismanagement by MNRT of Norwegian aid funds. We highlight some key experiences from two pilots; one in Kilosa District run by TFCG in partnership with the Community Forest Conservation Network of Tanzania (MJUMITA), and one in the Kondoa District (Kolo hills) led by the African Wildlife Foundation (AWF). While the former included only village forests, the latter covered mainly (central and local) government forests (Vatn et al. 2016).

The NGOs based their activities on participatory forest management following standard Tanzanian strategies for including villagers through either CBFM or JFM. In Kondoa, some CBFM activities had already been initiated by AWF. In Kilosa, there were no such engagement before the TFCG/MJUMITA pilot started. As district authorities play a key role in establishing CBFM and JFM in local government forests, the NGOs partnered with them early on. Nevertheless, the NGOs were clearly in charge. Districts were "door openers" to the villages as well as being service providers for the NGOs.

Establishing REDD+ activities implied formalizing rights to forests and potential payments for lost income from forest conservation. There were still conflicts early in the process. In Kondoa, five out of 21 invited villages were hesitant to join. In the end 19 enrolled, but one of them withdrew during the land use planning phase. Another one was "put on hold" by AWF as it did not commit itself to the rules defined for forest

[4] This section is based on extensive fieldwork in the two districts under various projects and funding sources. The authors will especially thank prof. George Kajembe and prof. dos Santos Silayo at Sokoine University of Agriculture, PhD Maria Nantongo and a series of master students for their engagement in developing research instruments and participating in fieldwork.

protection. A key factor explaining the reluctance of some villages was variation in local trust in AWF. REDD+ implies great uncertainty for the villages regarding, for example, how great the restrictions on forest use and how large the compensations in the end will be. The most forest dependent – especially on charcoal – were typically also the most critical.

In Kilosa, all 13 invited villages joined initially, while one withdrew during the land use planning phase. The level of conflict was lower, even though there were conflicts regarding defining some village borders, and around the fact that some families had to move as nobody were allowed to live in forests set aside for REDD+. Also in Kilosa many charcoal producers opposed REDD+, but some felt it was difficult to voice their disagreement. Conflicts were as much internal in villages as between NGOs and local people, e.g., between those supporting REDD+ and those that had to resettle.

Both NGOs followed a three step procedure: (i) inviting villages to join REDD+, (ii) land use planning including a forest management plan and bylaws, and (iii) trial payments. In Kilosa, none of the villages had land certificates, so defining village borders was necessary. In Kondoa, all villages seem to have land certificates dating from 2007.

While the focus was at building institutions and creating plans to ensure increased carbon storage, the NGOs coached the projects largely in the language of conservation. But both pilot programs were multi-objective, with distinct development component: intensifying agriculture, sustainable charcoal making, and bee keeping. These activities can be seen both as compensations for lost livelihoods and as means to expand them.

Both pilots were financed by the Norwegian government. AWF did not seem to have any clear plan for ensuring financing beyond the pilot period. TFCG/MJUMITA developed a system to make it possible for the villagers to access the carbon markets. Key components of this strategy was to establish so-called “carbon enterprise” within MJUMITA to support villagers in the process of trading carbon credits. The purpose is to bundle emission reductions across villages and thereby increase volumes and reduce transaction costs (MJUMITA 2012). The system also includes validating, monitoring, reporting and verification components. It is yet not fully operational in Kilosa, while it is so in a TFCG/MJUMITA pilot in Lindi (MJUMITA 2012). TFCG has been leading an NGO advocacy group arguing that such a “carbon enterprise” system will be preferable to Tanzania as a national system (see Section 4 above). We note that this is also a system that offers most opportunities for NGOs to engage in REDD+.

Land use planning has in both pilot areas resulted in defined “REDD+ forests” with a set of restrictions on land use. Agriculture and timber harvesting is not allowed in any of the REDD+ forests. In Kondoa, grazing is allowed in some periods for a restricted number of animals and against a payment. In Kilosa, all grazing in forests is prohibited. Some villages also established utilization forests besides the REDD+ forests allowing, for example, sustainable charcoal making and timber harvesting. Collecting firewood may still be allowed, but part of the programme has been to establish woodlots to compensate for lost access to forests.

The compensation (of opportunity costs of forest conservation) has partly been in the form of creation of new livelihoods. The capacity to do so has, however, been limited. There has also been "test" payments in cash, named "trial payment". TFCG/MJUMITA agreed with the villagers to pay per person a fixed sum (up to five people per family). This reflected the argument that forests were common and that the majority of villagers looked negatively at those using forests extensively, e.g., charcoal makers. These people were seen to make private gains from a common resource. This payment system also reduced transaction costs substantially.

TFCG/MJUMITA tried to mimic a market deal when paying, i.e., the present carbon price and a calculated level of change in carbon stocks formed the basis. Most villages decided to let a certain fraction of the payment go to village projects. Given the low carbon price at the time, payments to villagers became low, in the order of USD 5 per person.
AWF used a different system. JFM dominated in the project area, and a key issue was to agree on a benefit sharing rule between the state/district and villages. In the end, a 20/80 rule was accepted, compared to a 40/60 solution initially proposed by the state. The payment to the villagers was split in two; one part was kept by the organization established for the REDD+ villages (JUHIBECO) and the rest to the villages themselves. The transfer to the villages depended on how well they followed the rules. Calculated as compensation per person, compensations were lower than in Kilosa. Payments were in all villages allocated to various village projects.

An interesting observation is thus that the PES idea, the initial core REDD+ idea, seems more alive among NGOs operating at the local level than among government actors at the national level in Tanzania. The initial prospects of significant cash transfers remain attractive to many villagers and NGOs alike. For NGOs, it opens up opportunities to act as 'middle-men', while national authorities might be reluctant to make systems that transfers most of the funding to the local level. Moreover, REDD+ projects have created high expectations in many villages, not just in Tanzania. Recent signals about a significant slowdown in REDD+ funding, and a possible end of the Norwegian REDD+ involvement in Tanzania, is concerning. For outside observers, it is another conservation fad that has faded. For the villagers, it is another example of broken promises, which will make future forest conservation even more challenging.

Norway as the global rainforest saviour?

> *«There are surely ten thousand economists in the world that can describe all the hindrances in the struggle to save the rainforest»* (Erik Solheim, Dagbladet, December 2007)

> *«The climate-forest initiative fits into a series of international efforts where Norway, with great courage aims to create peace, reduce poverty and save the environment. Some wonder whether the idealism has resulted in a lack of realism and therefore effectiveness of the efforts.*» (Arild Angelsen and Ole Hofstad, Dagbladet 25. January 2008 (our translations).

Norway is the REDD+ superpower. Norway's International Climate and Forest Initiative (NICFI), launched at COP 13 in Bali (2007), is the single largest REDD+ initiative to date with more than 40% of the international REDD+ funding (Norman and Nakhooda 2014). A succinct story of NICFI and the political process leading up to the initiative is given elsewhere (Hermansen and Kasa 2014, Hermansen 2015).

Almost ten years on, we still maintain that Norway has suffered from lack of will to critically examine the strategy and results. Rather, the political efforts seems to be focussed on high political ambitions and portraying this is a success story. Two reasons stand out to explain this.

First, Norwegian policy makers – and parts of the REDD+ community – has been blinded by the apparent simplicity of result-based aid (RBA) and the "we only pay for results" postulate. Erik Solheim, the former Norwegian minister of environment and development cooperation, and a key player behind NICFI states in his biography: "But with results-based payments I cannot see any large risk." (our translation) (Solheim 2013). Elsewhere, we have questioned whether Norwegian funding, including the USD 1 billion to Brazil can be characterized as result-based aid (Angelsen 2016).

Second, REDD+ plays a political role in the domestic policy arena, which makes policy makers less interested in questioning its effectiveness. The NICFI initiative has served as a "political offset", i.e., the funding of REDD+ activities and their alleged effectiveness has been used to respond to critiques regarding the lack of domestic efforts to reduce emissions (in particular, the missing link between Norwegian petroleum activities and climate change). The government budget proposal for 2016 for the Ministry of Climate and Environment states: "The government's domestic policy must be viewed together with Norway's international commitments and efforts" (our translation).[5] At the same time, in public debates, governments of different colours have repeatedly claimed that the support to Brazil has been effective and contributed to reducing emissions.[6]

Climate change is real, and achieving the 2 degree target is virtually impossible without eliminating most of the current emissions from tropical forests, and even turning them into carbon sinks. Because of the urgency of the problem, we need to be extra critical

[5] https://www.regjeringen.no/no/dokumenter/prop.-1-s-kld-20152016/id2455649/?q=&ch=2

[6] https://www.regjeringen.no/no/aktuelt/regnskogsatsingen-har-effekt/id2466007/

and make sure that the billions spent actually have an impact. Retired professors are sorely needed in that debate!

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9. Bio-economic modelling approaches for forest management in developing countries: opportunities and challenges

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Introduction

The term *bio-economic model* is generally used to define models that contain two main components, a biophysical component, which represents the natural resources (natural constraint), and a socio-economic component that describes resource users (Knowler 2002, Kragta 2012). Bio-economic models have increasingly been used as decision support tools. They have been widely applied in different sectors including forestry, typically to determine the optimal level of resource extraction that maximizes economic profits (Kragta 2012). Bio-economic modelling has developed significantly since the end of the 1950s, owing to a number of factors such as the growing demand for multi-disciplinary approaches for integrated assessment (Prellezo et al. 2012).

Bio-economic modelling approaches

Bio-economic models can be grouped into simulation and optimization models (Prellezo et al. 2012). Simulation models are designed to evaluate the dynamics of a system and its components under different policy and/or management alternatives, or to make *ex-ante* assessment of the impact of new technologies, policy interventions or other exogenous variables such as climate change on natural systems or human welfare and behaviour (Sankhayan et al. 2003, Upadhyay et al. 2006, Flichman 2011). Simulation models are particularly suitable for non-linear systems that contain stochastic components (Flichman 2011). They may also be useful for system analysis in developing countries with high rates of population growth and deforestation (Sankhayan et al. 2003). Some attempts have also been made to apply bio-economic simulation models in developing countries for analysing the dynamic processes of deforestation and forest degradation (e.g.Sankhayan and Hofstad 2001, Sankhayan et al. 2003, Namaalwa et al. 2007, Gera et al. 2010) and for analysing management alternatives (e.g.Soltani et al. 2014, Soltani et al. 2015a, Soltani et al. 2015b). Optimization models, on the other hand, are designed to find an optimum (best) solution to a given problem or system under certain constraints. These models are widely used in natural resource management, particularly in the forest planning and decision making process. Optimization models in forest management are typically used for developing optimal harvest strategies that will best meet the objectives of the landowners/land managers in terms of maximum economic benefits (e.g.Wam et al. 2005, Buongiorno et al. 2012, Hofstad and Araya 2015, Soltani et al. 2015a). Normally, the net present value of the flow of outputs up to the planning horizon is used for selection of optimal plans.

Optimization bio-economic models can further be classified in to static (equilibrium) and dynamic models. A static bio-economic model represents systems at a particular point in time whereas a dynamic bio-economic model represents systems as they change over time. Static models are at equilibrium or in a steady state, while dynamic models can change with time, which makes the modelling of them relatively flexible. A familiar form of a standard static bio-economic model is known as the Schaefer-Gordon model, which contains stock growth, harvest and a profit function (Knowler 2002). Static models are more practical than dynamic models as they are easier to develop and may allow natural resource managers to adjust fast to new policy interventions or regulations (Brown et al. 2015). However, they do not allow analysis outside an optimal steady state. Richard Bellman developed the dynamic programming method during the 1950s (Flichman 2011). A dynamic model is a representation of the behaviour of the static components of a system. The theoretical basis for a dynamic bio-economic model is the optimal control theory. Hence, in this type of model, variables such as harvest and stock are specified as functions of time (Knowler 2002). Natural resources are stocks of natural capital that provide a flow of services. In this case, the problem of optimization (optimal allocation of resources to maximize the benefits obtained from the flow of resources through time) that accounts for the impact of the current use of resources on the future availability is a dynamic problem. Therefore, dynamic modelling provides the right approach to natural resource management, particularly to renewable resources such as forests (Flichman 2011, Kragta 2012). Developing these models is however, computationally demanding and constrained by data, time, financial resource and expertise. Dynamic bio-economic models can be sequential or non-sequential regarding the decision-making process (Flichman 2011). In the first type, decisions are made sequentially allowing for progressive adjustments. In the second type however, the sequence of optimal decisions is determined at the beginning of the decision process with no room for further modification. Dynamic models that contain random variables as inputs are referred to as stochastic dynamic models. Those that has no random variables are categorized as deterministic dynamic models. Natural resource problems generally involve sequential, uncertain and irreversible decisions. This indicates that the use of sequential stochastic dynamic modelling approaches may be appropriate. However, stochastic programing methods have a problem of dimensionality, since the model grows explosively as the number of variables increases (Flichman 2011).

Opportunities of using bio-economic models for forest management

Policy makers and natural resource managers (individuals, communities or governments) generally face the need for a mechanism to make ex-ante assessments of the outcomes of their choices in terms of policy and resource use plans (Bouman et al. 1999). The assessments usually require an interdisciplinary modelling approach that links biophysical and socio-economic factors. Bio-economic models are therefore important tools in providing the required interdisciplinary analysis allowing integration of biophysical and socio-economic dimensions of the problem in a consistent way. They also allow the required ex-ante assessments at different scales and over a range of geographic and climatic conditions (Janssen and Van Ittersum 2007). Another benefit of these models is that they can provide an improved and more comprehensive indication of the feedback effects between human activities and natural resources. Moreover, bio-economic models provide the required arena for different disciplines, e.g. it lets economists and ecologists to interact and cooperate (Wam 2010). Ecologists and economists often analyse the same natural resources from different perspectives. The ecologist analyses the interaction among different organisms in forests, while the economist studies the production and consumption functions of various goods obtained from forests such as timber and charcoal. Furthermore, bio-economic models may be useful in identifying critical knowledge gaps and in providing guidelines to identify research priorities. This feature is particularly important for developing countries where the knowledge gap regarding resource management in general is huge.

Challenges related with the application of bio-economic models for forest management

The use of bio-economic models especially in developing countries are limited in extent due to the several complexities and challenges. A general challenge is related to the extent to which both biophysical and socio-economic components and the interaction between them are incorporated in the model. Some of the existing bio-economic models are biophysical process models with simple socio-economic components added to them, while others are economic optimization models that include few biophysical components. A good bio-economic model should be in between these extremes and should capture the interaction between the biophysical and socio-economic processes. However, it is challenging to integrate both components successfully, without losing their important properties or strong features. Another challenge is related to the availability of required and reliable information. In developing countries in particular, sufficiently detailed biophysical data is often limited to enable an appropriate representation of the dynamic interrelationships between natural processes and socio-economic systems. Moreover, the required human and financial resources are very limited.

Using bio-economic models for forest planning and decision-making requires consideration of the property rights regime that governs the management of the forest. Under open access regimes, for example, the economic returns to forests cannot be maximized. Since the forest tenure in most developing countries may be characterized as unclear and is often overlapping between traditional (*de facto*) and legal (*de jure*) rights, the application of bio-economic modelling is challenging.

A well-integrated bio-economic model must capture the dynamic nature of the biological systems and allow for feedback effects between human decisions, biological processes, and the range of possibilities available for future decisions. This requires a big computational effort. In addition, most of the forests in developing countries are of a multi-species and multi-sized nature. This makes the biological modelling process more complex as compared to when a model is applied to a single species and even aged forest. Moreover, there has been an increasing demand for environmental services such as carbon sequestration provided by forests in tropical developing countries owing to the recognition of payments for environmental services. Consequently, there is a growing need to consider such benefits when developing forest management plans. Incorporating such benefits however, also complicates the model.

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10. Bio-economical Models: Tools for analyzing Forest Degradation Processes

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My association with Professor Ole Hofstad dates back to the beginning of year 1996. I was briefly unemployed at that time. I was invited to join a team of NORAGRIC researchers for seminars to be held at Dar es Salaam and Morogoro in Tanzania. The purpose was to publicize the findings of just concluded research project: Ecology and Economics, of which I was a part for four years. During our stay at the NORAD guest house in Morogoro, Professor Hofstad mentioned about the launching of a newly EU-funded research project – Woodland Degradation Processes in Open Forest Lands in Sub-Saharan Africa. He also talked about his search for a researcher in that project who could develop a model for analyzing the woodland/forest degradation processes. Later during the summer of 1997 when I was already employed in a research project funded by the Research Council of Norway at the Department of Economics of the Agricultural University of Norway (now known as Norwegian University of Life Sciences), that the vacancy of a researcher was announced by the then Department of Forest Sciences. Apart from being the coordinator of the project, Ole Hofstad was also the Head of the Department. I was at that time in India doing fieldwork for my research project. On my return to Norway, I got the information about the vacancy announcement. My first reaction was total reluctance. I thought the position carried lower status than the one that I had already been holding or held in the past. The only strong basis for making an application was the longer duration of three years of the EU project. I, therefore, made up my mind, though half-hearted, to send my application for the position. Up to the last moment, I was not sure if I was really interested in it. However, the destiny was very different. I was offered the position. I accepted it, even though at the ire of my project manager at the Department of Economics and Business Management, and started working on the research project sometime from October that year, on 50% basis for three months and full time later on. That summarizes the beginning of my journey on a long road with Professor Ole Hofstad and the forest economists. This journey has been continuing until this day, even after I got retirement at the age of 62 years in 2006.

Besides enjoying excellent personal rapport, my association with Professor Hofstad and the forest economists turned out to be quite productive scientifically. Professor Hofstad's great understanding and friendly behavior encouraged me to discover newer avenues in research. But for his supporting and friendly behavior, I would probably have given it up. After all, it was not easy for me to work on the position of a researcher after having held the position of a professor at a reputed Agricultural University in India for several years before my arrival to Norway in 1992. I am glad that I did not have to repent for my decision of joining the fleet of forest economists whom I found friendlier and more accommodating than the other economists with whom I had worked until that time in different places and countries.

As already mentioned, I was mainly responsible for developing a mathematical model capable of analyzing the forest degradation processes in Africa. In spite of my long experience of working with linear programming models in the field of agricultural economics, I initially found it hard to make a successful beginning. Professor Hofstad constantly kept pressing me hard to go beyond the static economic models and instead develop a dynamic programming model. Though familiar with the theoretical aspects of such models, I had until that time never used any software to solve the dynamic models. It was, therefore, a great challenge. Luckily, my previous expertise with GAMS during my employment at the Centre for Sustainable Development at this university proved helpful. I took up the challenge. The path was rather painful. There was absolutely no help available from any one on the university campus. At times, I often got frustrated when I found myself stuck up with a problem for several days. During those difficult moments, Professor Ole Hofstad came to my rescue with a lot of inspiration and useful ideas. That kept me going. Over time, we together developed expertise in the field of Bio-economic models capable of analyzing the woodland/forest degradation processes – their development and empirical applications in different geographical locations, in Africa and Asia. Such models followed a holistic approach and helped explaining the complexities of real world in a much better way. By incorporating biological-economic-social interactions, these models proved more useful in analyzing the system behavior in totality as against partial efforts in the past.

Following are some of the examples of such efforts:

1. A few M.S. and Ph.D. students successfully adopted the models developed by us with some variations in their research to study not only forest degradation but also related aspects, at different geographical locations.
2. We were able to win a few more research projects, both from the EU and the Research Council of Norway. These projects were located in India, Nepal and Pakistan. One such major research project funded by the European Union that is worth mentioning is:
   An Interdisciplinary Approach to Analyze the Dynamics of Forest and Soil Degradation and to Develop Sustainable Agro-ecological Strategies for Fragile Himalayan Watersheds. Obviously, this research project aimed at analyzing the dynamics of forest and soil degradation in the Himalayan region covering Nepal, India and Pakistan and was built on our expertise gained during the first project in African countries of Tanzania, Uganda and Senegal.

3. Publications of the results of our research work in international scientific research journals.

Focus of various studies of woodland/forest degradation

The major focus of research studies conducted in collaboration with Professor Ole Hofstad has been on the analysis of woodland/forest degradation and land use changes under different biological, economic and social environments, both in African and Asian countries.

Methodology Used

Dynamic linear/non-linear programming bio-economic models constituted the methodology of most research studies. These models have been applied at village and watershed levels in several countries. Suitable variations were incorporated in the models to account for the variations in biological-economic-social environments characteristic of different study areas.

Broad conclusions on forest degradation

Though the conclusions of various studies vary from one geographic and bio-economic-social environment to another, the broad conclusions of our studies can be broadly summarized as follows:

Growth rate of population aggravated the woodland/forest degradation processes.

Introduction of improved agricultural technology, higher product prices, increased rural wages, and reduction in prices of forest products such as charcoal helped slowing down the process of forest degradation.

The state controls, traditional rules as well as biological feedback mechanisms proved effective in keeping the animal population within the carrying capacity.

Even in the absence of state controls, villagers managed to preserve forest resources through traditional institutional arrangements.

Best promise for sustainable use of land and raising per capita incomes lies in developing off-farm employment opportunities; intensive farming and research-based scientific management of forests.

A well-implemented system for taxes or quota restrictions would enhance sustainable resource use in the remaining woodland areas. These interventions are highly limited by implementation and enforcement problems that need to be properly addressed by policy makers and planners.

The role of policy makers in devising appropriate demographic and economic policies to retard the process of woodland/forest degradation appears to be important. Family planning policies aimed at reduction of population growth, quota restrictions on forest products and increase in prices of major agricultural crops at locations where there are no more possibilities for land clearing can be effective policy instruments for slowing down the process of forest degradation or even in reversing it completely to regeneration.

List of some important research publications

Following is the list of some the important publications on which the various conclusions outlined in the earlier section were made:

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Sharma, Rakesh Kumar; Sankhayan, P. L.; and Hofstad, O. 2008. Forest biomass density, utilization and production dynamics in a western Himalayan watershed, International Journal of Forestry Research, 19(3):171–180.

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11. The potential role of forests and the forest–based sector in climate change mitigation – experiences from the last three decades.

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Introduction

Forest economics and policy issues related to climate change began to emerge as in the research literature in the mid-late 1980s. Early research focused on the impact of climate warming on biological systems, especially agriculture and forestry. Organizations like the Resources For the Future and the United States Environmental Protection Agency, among other organizations globally, examined how forested ecosystems could be affected by climate change, and how markets would respond to these changes. At the time, global timber harvests were increasing, and there was considerable concern that climate change would put pressure on the world's timber resources, and consequently on important ecological resources.

Around the same time, forests were recognized as a potential source of climate change mitigation through both the growth of forests and the reduction of emissions due to deforestation. A mature forest can be thought of as a carbon silo, holding a fixed stock of carbon. A growing forest, which is increasing its biomass, can be thought of as a silo in the process of being filled. A large number of important research questions have addressed questions such as how much carbon can be accumulated in new forests, how much carbon is already accumulated in mature forests (full silo), and how quickly is the full silo of carbon, especially in tropical areas, being deforested.

Economists of course have been compelled to analyze the costs of these activities, using a variety of techniques and tools. Politically, international negotiators recognized the potential of forests to help mitigate climate change and they wrote forest mitigation options into international treaties like the United Nations Convention on Climate Change and later the Kyoto Protocol. There was also the potential that these forests could enter into hoped for carbon trading markets as offsets for fossil fuel based emissions. Not surprisingly, questions about the costs and benefits of utilizing forests for sequestration have continued to occupy economists for years, and not surprisingly, our colleague Birger Solberg has been at the center of analyzing these issues over much of that time.

The policy issues have become more complicated over time. For example, landowners and policy makers have wondered whether timber harvesting and carbon sequestration are substitutes or complements. They have also addressed the role of forest management and silvicultural practices, and whether new or traditional techniques can be deployed to affect the levels of carbon sequestered. Furthermore, questions arose about carbon captured in long-lived wood products, such as lumber, and how to assess the amount of carbon captured. Finally, what types of incentives could be created to promote the management of forests for carbon sequestration and how these incentives might be captured and distributed. More recently, policy makers in Europe and the US have considered whether forest biomass is indeed carbon neutral.

This paper provides an overview of the work that has emerged in the last 30 years in the area of climate change and forests addressing a range of issues that have been identified as important and addressed over the years by economists.

Ecological vs. the Economic View

When addressing either climate change impacts or the use of forests as a source of mitigation for climate change, ecologists and economists have spent considerable time disagreeing. The differences tend to reflect the different world views of the two disciplines.

Ecologists tend to think of the forest system as a stand-alone biological system. They recognize that the system is affected by humans either directly through harvesting, management, or introduction of invasive species, and also indirectly affected through impacts on nutrient cycles such as for carbon, nitrogen, or phosphorus. But ecologists tend to view anthropogenic changes from historical norms as negative consequences for forested ecosystems and the services they provide. Suppose the system is affected by climate change, which causes increases in the amount of disturbance such as forest fire incidence. Ecologists often view these changes as having negative consequences, with the solution being to try to reduce the source of the impact, namely climate change.

In contrast, economists recognize the underlying biological system as part of a broader bio-social system that has been managed either intensively or in a limited way, for centuries in many cases. The biological system is integrated with the social system, and in particular economics. The easiest set of human responses climate perturbations occur through market factors because market outputs can be privatized and sold. Rather than relying only on the reduction in forest fires by hard working global politicians endeavoring to slow down carbon's rise, forest managers simply have to respond. They do so by managing differently, planting differently, and potentially fighting forest fires more aggressively.

When market outputs are at stake, foresters can be expected to respond vigorously to the challenges presented by climate change, carbon sequestration, biofuels, or any number of human intrusions on ecosystems. These responses, however, are harder to achieve when the goods at stake are public instead of private goods that can be sold. Obviously there are a large number of institutions that have evolved globally to help provide public goods from forests through governmentally sanctioned protection on public and private land, or community based forest institutions, but these institutions may or may not be able to adapt to the large scale impacts that climate change is likely to bring.

A Role for Modeling

Modeling has played a role in forestry for a long time, going back more than 100 years to the "informal" models of Faustmann (1848) and Ohlin 1922). Early work focused on clarifying the question of the optimal forest harvest rotation that individual landowners should use to maximize land value (e.g., Samuelson 1976). As computer programming evolved, forest economists and engineers began developing models, such as FORPLAN (Johnson and Scheurman 1977), that included timber stocks over larger areas and allowed for a wider variety of management options than just cutting at a given age (thinning, changing the type or density of forest planted, fertilizing, etc.). These broader models allowed individual landowners, or in many cases, government agencies, to compare tradeoffs among timber and environmental values.

More recent models, like TAMM (Adams and Haynes, 1981) and EFI-GTM (Kallio et al., 2004) have expanded the scope of modeling to include a demand side, whereby timber prices can be determined endogenously. This has been an important development for modeling broader areas of forests and large-scale trends in development of forest stocks over time, particularly as they are influenced by demand side phenomena, like income, housing starts, and technology change. Current models, such as the TSM (Sedjo and Lyon, 1990; Sohngen et al., 1999) and FASOM (Adams et al., 1999), similarly model widespread trends in forest stocks using optimization techniques that treat the price of timber as endogenously determined with forest stocks, harvesting, and investments in forest stocks.

Climate Change Impacts

The important link between forest investments as affected by prices and the determination of those prices in optimization approaches like TSM have allowed foresters to begin analyzing both climate change impacts and carbon sequestration efforts. Climate change is such a widespread phenomenon that is likely to affect every corner of the earth, it is important to attempt to determine the effect of climate change on prices in order to understand the potential adaptive response landowners will undertake.

According to the ecological view, climate change is likely to cause large scale changes to forested ecosystems over the next century. While climate change has already been occurring and affecting forests, the speed of the changes is projected to increase in the future, as we experience faster temperature and precipitation changes in the future than we have experienced in the past. Some of the changes include changes in the growth rate of trees, shifts in the distribution of trees, and changes in forest disturbance patterns.

Economic studies have found that the economic implications of these changes could be quite large, although the welfare impacts have largely been to be positive (Joyce et al., 1995; Sohngen and Mendelsohn, 1998; Sohngen et al., 2001; Perez-Garcia, et al. 2001, Solberg et al., 2003). Foresters, it turns out, have been pretty good at adapting to changes historically, and while climate change presents new and unique challenges for foresters, they can use many existing tools to adapt relatively efficiently to potential change.

Most of the existing economic studies have focused on the provisioning of timber resources. As a good sold in private markets, it is perhaps not surprising that adequate incentives exist for land managers to work to adapt their forests to new climate conditions. It may or may not be as easy to adapt forests to continue providing other ecosystems services that are currently provided by forests, such as carbon sequestration (absent market incentives), water quantity and quality, and habitat. This represents a useful area for continued research in the future.

Forest Carbon Sequestration

Some of the earliest estimates of forest carbon sequestration suggested that a large amount of carbon could be sequestered in forests globally for relatively low costs (Sedjo and Solomon, 1989; Richards and Stokes, 2004). Integrated assessment analyses suggested that forests could efficiently provide up to 30% of total carbon abatement over the coming century (Sohngen and Mendelsohn, 2003). As estimates of the potential damages from climate change have increased, the scope for forest carbon sequestration has increased.

Many studies have considered important activities like afforestation (e.g., Stavins, 1999 and Plantinga et al., 1999) and avoided deforestation (Kindermann et al., 2008). Other studies have considered the efficiency of increasing the management of forests in order to increase forest carbon sequestration (Hoen and Solber, 1994). While there has been considerable policy discussion about the potential for forest carbon sequestration, there are still many road blocks out there for implementing these proposals.

Incentive systems to use forests to control carbon

Because carbon is an externality, political systems have to create the incentive to discourage emissions or to capture forest carbon. If an industry releases carbon it could be taxed. In addition, many have suggested that forests be included in the policy system as offsets. Offsets are credits for the net reduction in carbon emissions that occur as forests grow or as deforestation is abated. Trading systems have been proposed to facilitate trades between carbon emitters and those who develop credits based on forest carbon sequestration.

A number of complications and concerns with forest carbon offsets have been identified, however, limiting their role in actual policy applications to date (Murray et al., 2007). For instance, carbon in forests might only persist for a limited time period due to logging, biological decline or natural and manmade disasters. Given that the offset credits should be adjusted if events occur that reduce the carbon, the value of offset credits is reduced and their cost is higher. Without higher carbon prices, this lack of permanence reduces the widespread adoption of forest carbon credits.

A related issue is the concern with leakage. Conceivably, forestland owners could receive credit for managing one forest sustainably, while simultaneously clearing a separate forest for agriculture. Alternatively, the leakage need not be done by the same person, since the implementation of wide-spread forest carbon projects will change prices and cause behavior change across a broader area. This issue suggested that monitoring a site or even a number of sites where carbon projects are located is not adequate and measurement must be done over a wider area. The implication is that comprehensive monitoring systems are required, with monitoring conducted at the regional, national and potentially global level.

Monitoring Forest Carbon

Forest carbon monitoring could be accomplished either with satellites or with on-the-ground measurement efforts, or some combination of the two. Satellite technology has improved over the years and can be used to measure the extent of forest cover, but it cannot yet be reliably used to measure the extent of carbon content (Macauley and Sedjo, 2011). This increases the costs of forest carbon monitoring, which range from $0.11 per ton CO2 to around $2 per ton CO2. If the costs of monitoring are included with other transactions costs, as well as the costs of insuring contracts, total transactions costs appear to range from $2-$8 per ton CO2 for forest carbon projects around the world (Pearson et al., 2012).

Biofuels: Some Issues

In recent years the question of the potential role of bioenergy and biofuels and especially the role of wood has come to the fore. When providing energy statistics bioenergy is treated by both the IEA and the US EIA as a renewable fuel along with solar and wind. Wood can be used as biomass for boilers to produce electricity and heat. This use is currently occurring in many applications and locations. Also, wood can be used to produce liquid biofuels, such as ethanol, that can be substituted for petroleum in many uses, although this technology is somewhat expensive today. However, despite desire to reduce and eventually eliminate fossil fuel use, the question of the role wood has created a controversy. The burning of biomass or wood for energy releases carbon, sometimes more than fossil fuels to produce the same amount of energy.

The Bioenergy Controversy

The degree of the controversy surrounding the widespread use of wood for energy has become very controversial. In 2010 two letters were sent to the US Congress (Sedjo 2011). The first was signed by over a hundred academics strongly criticizing the use of wood for energy. They made three basic arguments. First, they argued that the burning of wood for energy was counter-productive since the burning of wood would release carbon just like fossil fuels. Hence, it is argued, there are few carbon reducing advantages to using wood. To the extent that harvests are replaced by regrowth due to natural regeneration or tree planting, it would be decades before forest regrowth would have captured a carbon volume equal to the releases of carbon from the earlier energy uses. Second, they argued that harvesting wood would reduce the current stock of forest thereby causing an emission of currently stored carbon. Finally, there was the concern that the harvests of wood for energy would compromise the long-term viability of the forest and its other functions.

The second letter was followed in a couple of months by a letter from almost one hundred forest scientists. They argued that forests are renewable and that in the long run, especially with good management, wood could substitute for substantial amounts of fossil fuel energy, preventing their release of carbon. Finally, since reforestation would offset the early carbon releases here would be no net release of carbon emissions over the long-run. Furthermore, forest management could both reduce the time of regeneration and expand the forest stock, thereby reducing net carbon emissions.

This debate about whether forests as a biofuel are carbon neutral continues. One of the biggest concerns of the biological view is that the standing stock of trees will quickly and costlessly be converted into biomass energy, and these subsequent emissions will take years or decades to be made up with new forest plantings. Some are concerned that these forest stocks will never be fully replaced.

A number of dynamic forestry models have now been widely used to address these questions (see for instance, Daigneault et al., 2012, Favero and Mendelsohn, 2014). These studies have found no evidence that forest carbon will be released, even with fairly large biofuel consumption. There are two reasons for this. First, consumption of biofuels is not free. Thus the existing stock will not just be decimated as many fear because it is not free to attain. Second, forest investments can relatively quickly increase forest stocks by encouraging faster growth.

Summary and Conclusions

The first part of this paper reviewed the work, primarily of economists, on some of the early issues related to the role of forest in climate change. This body of work has been substantial. The second section has focused on the relation between forests, bioenergy and carbon. This section suggests that releases in forest carbon can be offset though future forest growth or sustainable management. Thus, forest can contribute to global carbon stabilization even to overall relative carbon reduction.

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12. European cooperation on renewable energy, circular economy and climate policies. Possible implications for Norwegian forest policies and programs.

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Introduction
Forests amounted to around 32% land area in Europe (excluding Russia) in 2010 (Pülzl et al. 2013, FOREST EUROPE 2015). If other wooded land is added, the area of forests and other wooded land exceed 40% of the total land area in Europe. Growing stock has increased substantially in recent years.

Forests contribute to a number of societal, environmental and economic benefits in our region. The forest sector employs more than 3 million people in Europe. The social, economic and environmental values of the forest resources are strongly affected by forest policies and policies and governance issues in other sectors. Simultaneously, the forest sector itself is undergoing profound changes. These developments are about to create a more complex governance environment for the forest sector in the future, demanding more knowledge about the impacts and increased research intensity in order to mitigate risk and uncertainties.

Current national and European developments in renewable energy, environment and climate change policies have the potential for significant implications in the Norwegian forest policy development and implementation. This paper discusses some elements of these developments and their possible implications for forest policies and programs.

Forest policies in the European Economic Area
EU member states and Iceland, Lichtenstein and Norway constitute the European Economic Area, EEA. Through the EEA agreement, Norway is an integral part of the internal market in the EU. Agricultural-, forest- and fisheries policies are not covered by the EEA agreement.

Forest policies in the EU is within the competence of member states. EU has a Common Agricultural Policy (CAP). Nothing similar exists for forest policies. Financial support for various forest activities however, exist within the so-called second pillar of the CAP, namely rural development. EU has recently launched a revised forest strategy, building on the previous forest strategies and a forest action plan (European Commission 2013). Developments in forest policies are evolving at national levels in Europe. A number of countries have revised their forest legislation in recent years and most countries in Europe have launched national forest programs (FOREST EUROPE 2015).

An increasing number of policy decisions in other sectors, i.e. energy, climate change, environment, trade and industry, impacts forest policies in Europe and elsewhere. Forests are expected to contribute to economic and environmental objectives, in particular the emerging bioeconomy and to biodiversity protection and climate change mitigation.

Bioenergy in the EEA

In 2009, the European Union adopted the Renewable Energy Directive (2009/28/EC), hereafter labelled RED (European Council 2009). RED is EEA relevant, meaning that the directive regulates the renewable energy policies in the EEA. The European Commission plans to table a revised renewable energy directive during 2016.
Biomass from forests constitutes approx. half of the renewable energy in the EU. Hydropower is the dominant renewable energy source in Norway, where biomass counts for 8% of the renewable energy.

According to National Renewable Energy Plans, prepared in accordance with the RED, bioenergy will supply 42% of the 20% renewable energy target in the EU in 2020. If this is achieved, the amount of wood used for energy purposes in the EU in 2020 will be equivalent to today's total wood harvest (European Commission 2013).

EU member states and Norway have established national policies in support of bioenergy and other renewable energy sources. These measures may include feed-in tariffs and simplified rules to include bioenergy (i.e. Germany) or subsidies for use of bioenergy (i.e. Finland, Germany, Norway, Slovenia and Spain among others). These are examples of a variety of measures introduced in order to encourage renewable energy use in general, and more specifically bioenergy (Lindstad et al. 2014).

National bioenergy policies vary throughout Europe. At EU/EEA-level, the RED will provide the overall legislative basis and determine the development of the renewable energy sector for the future. RED and national policies constitute complex horizontal and vertical interlinkages between energy, environment and natural resource policies and may influence forest policies in Europe.

An exercise of particular significance for future forest policies in Norway and EU member states will be the considerations of sustainability of bioenergy. The European Commission recently launched a public consultation on this issue (European

Commission 2016). Previous attempts to introduce sustainability criteria on biomass stalled, but sustainability criteria are operative for biofuel. A legislative proposal due late in 2016 will most likely include a form of sustainability criteria for biomass.

Different types of «sustainability criteria» exist. The sustainability criteria for biofuels are performance standards required to be counted towards the eligible share of biofuel according to the RED. Criteria for sustainable forest management, however, are strategies for sustainable management. Indicators for sustainable forest management are used to measure the development according to the criteria.

The European Commission adopted a revised forest strategy in 2014 including an ambition to establish EU criteria and indicators for sustainable forest management. These criteria and indicators utilize the pan-European set of criteria and indicators developed within the Forest Europe process. This is a different approach from establishing criteria based on end-use, like biomass for energy.

Climate policies in Europe

The EU framework for climate and energy adopted in October 2014 set out targets for the year 2030. The overall target for 2030 is at least 40% reduction in greenhouse gas (GHG) emission from 1990 levels. The emission trading system (ETS) sectors have to reduce their emissions by 43% compared to levels in 2005. Non-ETS sectors, including the forest sector, should reduce their emission by 30% compared to 2005. The climate and energy package also envisage an EU wide target of 27% renewable energy by 2030 and at least 27% improvements in energy efficiency (European Council 2014).

The Norwegian targets for the year 2030 were presented in a white paper to the Parliament (Stortinget) in 2015 (Klima- og miljødepartementet 2015). The white paper mirrors the targets from EU's climate and energy package. The Parliament endorsed the white paper that also explains Norway's ambition to enter into a joint fulfilment of the commitments with the EU.

National emission reduction targets in the Non-ETS sectors will be set within the range of 0-40% in the Burden Sharing Decision (BSD) based on agreed criteria, such as GDP/capita.

For non-ETS sectors, flexibility within the EU system will make it possible to achieve some of the GHG emission reductions through the purchase of EU emission allowances or the implementation of measures in other EU countries.

Norway has participated in the European emission trading system (ETS) since 2005. Joint fulfillment in the ETS sectors is therefore nothing new. This is different for the Non-ETS sectors, such as transport, building sector, agriculture, land use and forestry.

Circular economy
EU policies relevant for natural resource management in Norway are not limited to climate- and energy policies. Recently the European Commission presented the Circular economy package. In a circular economy the value of products and materials is maintained for as long as possible; waste and resource use are minimized, and resources are kept within the economy when a product has reached the end of its life, to be used again and again to create further value (European Commission 2015). Included in the action plan is further work on biomass, food waste and recirculation. Legislative proposals will follow.

The circular economy action plan includes important elements for future use of biomass and bio-based materials. Particularly, the ambition is to provide guidance and dissemination of best practice on the cascading use of biomass and to support innovation in this domain through Horizon 2020, and to ensure coherence and synergies with the circular economy when examining the sustainability of bioenergy under the Energy Union (European Commission 2015). The first action is scheduled for 2018-2020 and the synergies with the circular economy when examining the sustainability of bioenergy is included in the current work in preparing for a revised Renewable Energy Directive scheduled for 2016.

Cascading principle is frequently mentioned in the context of circular economy in general and in relation to biomass, bio-based materials and bioenergy in particular. There are, however many theories and opinions of the cascading principle. In general, it is understood as biomass first should be used for the options with the highest "value". The most recent 4th SCAR Foresight report is particularly attracted to the principle, but end up admitting that the concept is easier to handle in theory than in practical implementation. The report is highlighting two main challenges; 1) What value is considered and who decides about this, and 2) how can these rules be implemented if they run against market logic (Barna Kovacs 2015).

If implemented in any form, the cascading principle could influence allocation of biomass and divert revenues from its production in a way that can have significant influence on the utilization of biomass. Particularly so, since similar principles most likely never will be considered in the competing sectors, notably in the extraction of fossil energy.

EU policies in transition - uncertain future influences on Norwegian forest policies
The future regulatory framework for the previously mentioned sectors will all affect the development of the forest sector and management of forest resources in Europe. Energy policies, regulatory framework for adaptation and mitigation of climate change and circular economy are major factors for all aspects of natural resource management. For all these policy areas, legislative proposals are in the pipeline and it is therefore too

early to determine the directions. This creates uncertainty. The combined effect of these uncertainties is significant.

Merely all significant regulations in the EU on energy and climate change are now in transition. Given the importance of biomass, land use, land use change and natural resource management for the climate- and energy policies, the result will determine the management and utilization of natural resources in EU for decades to come.

The forest sector in Europe is currently undergoing a profound change and structural development that is adding to the uncertainty provided by changes in other sectors. Structural changes in the traditional forest industries and development of new products and markets in the emerging bioeconomy add complexity to the governance of the forest sector.

Possible implications for Norwegian forest policies and programs

Forest policies in Norway and other European countries is susceptible to influence and developments in other sectors. For Norway, the consequence of this is that our national forest policy is influenced by EU regulations even if forest policy is not within the scope of the EEA agreement. The implications of this should be studied more thoroughly in order to provide a better basis for policy decisions in Norway.

The Norwegian government's ambition to jointly fulfill the ambitions on climate change with the EU will make the developments of these policies in the EU similarly significant for Norway. Other policy areas in the EU, such as renewable energy, are already well positioned to strongly influence Norwegian policy development through the EEA agreement.

In addition to climate and energy, future regulations on circular economy, other environmental issues, agricultural policies and trade might influence management of natural resources in Norway.

Transition to a bioeconomy will increase the range and complexity of products and services from the forest sector and will have the potential to gradually shift the influence and governance of forest resources in Norway. While forest resources will maintain its place within the national sovereignty, the framework for national forest policies will increasingly depend on forest related policies made elsewhere.

Risk and uncertainty can be investigated and mitigated by research and knowledge creation. A number of studies on the development of energy policies and climate change policies in Europe exists, but future policies and programs for forest management in Norway will increasingly depend on research and development taking into account the regional and global aspects of policy formation. This will require a much closer attention to the governance of other sectors, influencing the forests sector – and developed and decided outside the Norwegian borders.

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13. Forest policy in Norway - for new owners in a new climate

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1. Introduction

In order to be effective, forest policies need to be adapted to the forest owners and their attitudes towards and objectives for the use of their forest. Forest owners take short-term and long-term decisions based on the economic, political, biological and technological frames that surround them as well as their personal objectives and attitudes. This framework, or the climate that consists of the extended operating environment for forest owners, is changing. In addition, the physical climate is changing, with bidirectional interactions between forests and climate. Thus, designers of forest policies ought to consider these changes in order to define and develop policies that are well suited for the current and the future climate for forest owners.

In this short review, we first discuss impacts of physical climate change on forests, and synergies and trade-offs between climate change mitigation and adaption. We then look into one specific change in the political climate for forest owners in Norway that is underway (The Norwegian Ministry of Food and Agriculture 2014; 2016): Liberalizing regulations on property trade and its possible impacts on an important characteristic of the Norwegian forestry sector, namely the ownership structure. In the last chapter, we discuss the findings and draw conclusions.

2. Physical climate change

2.1. Biological effects and economic consequences for forest owners

Temperature and precipitation are the main climatic factors controlling tree growth in Norway. Climate model projections for Norway (Engen-Skaugen, Haugen, & Hanssen-Bauer, 2008) predict increased temperature, precipitation and wind, but with large regional variance. Figure 1 shows an example of climate change projections for an arbitrary geographical point in Gjøvik municipality in Hedmark county. The figure shows three different model projections of temperature and precipitation under different assumptions on GHG emissions, along with the normal observations (average over the period 1960-1990). Although not very pronounced in the figure, the general prediction is that winter temperatures will increase more than summer temperatures and most of the increase in precipitation will be in winter (quite pronounced in the figure).

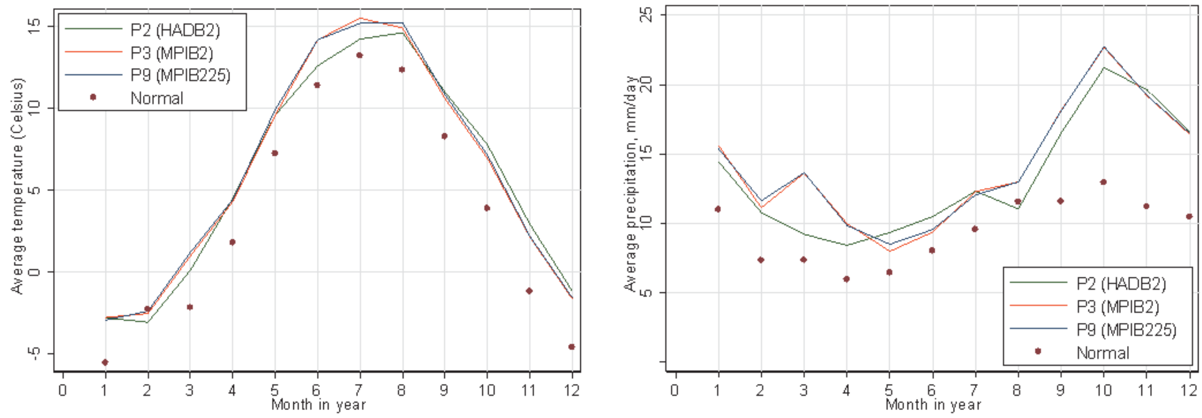

Figure 1. Predicted change in temperature and precipitation for an arbitrary location in the municipality of Gjøvik (Hedmark fylke, Norway) for three different emission scenarios. Data from (Engen-Skaugen et al., 2008).

Thus, the largest increases in temperature and precipitation are outside the growing season. Increasing temperatures during winter combined with moist and wet soils that are susceptible to increased wind, we are clearly heading for a future with increased risk of both abiotic and biotic risk. The operating conditions will also be more challenging and difficult.

There is a lack of research on climate change impacts on Norwegian forests (exempts are (Zheng et al., 2002)), but there is a growing Nordic literature (Kellomäki & Väisänen, 1995; 1996; 1997).

In general, it seems that an increase in productivity is expected: 7-49% in net primary production (NPP) for *Picea Abies* in south-east Norway (Zheng et al., 2002), 5-27% increase in NPP for Nordic coniferous stands (Bergh et al., 2003) and ~38% increase in NPP for European boreal zone (Morales et al., 2007). Subsequently, models suggest varying effects on growing stock and timber yield (Briceno-Elizondo et al., 2006; Jordi Garcia-Gonzalo et al., 2007; Kellomäki et al., 1997; Nabuurs et al., 2002; Talkkari, 1996). Unpublished material from Norway suggests one site class increased growth (Bergseng et al., 2014). Based on this literature it seems conservative to suggest an average increase in timber yield of 20%.

Along with increased wood production there will most certainly be increased risk, both biotic and abiotic. Increased wind and storm frequencies will be a problem (Blennow & Olofsson, 2008; Peltola, Kellomaki, & Vaisanen, 1999), especially in combination with less days with frozen soil. Growth is restricted by water availability in parts of Norway (Andreassen, Solberg, Tveito, & Lystad, 2006), and as such there is probably an increasing risk for drought. Changed seasonal variation may affect frost hardiness and cold acclimation, and yield more spring and autumn frost injuries. Although not very common in Norway, forest fires may become more frequent in the future (Spring et al. 2005).

Insects will likely profit from climate change, especially increased temperature, and become an increasing risk factor in forestry (Lange et al., 2006; Seidl et al., 2008; Vanhanen et al., 2007; Zhang, et al., 1999). Pests will react in the same way (La Porta et al., 2008; Percy et al., 2002).

2.2. Mitigation of climate change in the forest sector

Norwegian forests sequester approximately half of the national anthropogenic emissions, with a potential for more (Astrup et al., 2010). Current mitigation as well as potentials for increasing offsets lie in both forest carbon sequestration and from using woody biomass to substitute products that emit fossil-based carbon in production or use.

There is an intensive debate on how to use forests to mitigate climate change, both within the research community and in the general public/political debate. The debate may be summed up in one simple question: To use biomass from forests as carbon stocks or as products? Although it might seem as a straight forward question whether a tree should be cut or not to provide the best effect for mitigation of climate change, there are several climatic, ecological and biological processes which we lack information about that influence the climatic result of either choice.

First, and maybe somewhat surprising, we lack information on how very old forests grow and behave. Despite very long traditions of management and measurements in forestry, interest has mainly been in young and rapidly growing forests. Related to this are different kinds of biological risks, especially insects and pests, which are more probable to occur in old and weak forest than in young forests in good health. Secondly, we know little about how carbon is stored in the soil, especially in old forests. Third, the climatic effects of forest management seem dependent on the albedo effect (Bright et al., 2012) where more insight about the dynamics is needed.

2.3. Adaptation to changing climate

Although not as intense as the debate over forests role in climate change mitigation, there is a growing interest and concern related to adaptation of forests to a future climate. Large areas will only experience moderate climate change, with increasing temperature and precipitation, which at least for biomass production in the boreal forests is favorable. In some areas however, there is certainly a need to plan future forests and their management given the expected changes in risk. The most obvious and urgent challenges is the choice of species and tree density of new stands both at the time of establishment and throughout the rotation. However, this has not been much researched.

Due to increased growth, shortened rotations are often suggested (Briceno-Elizondo et al., 2008; Garcia-Gonzalo et al., 2008; Kellomäki et al., 1997; Nuutinen et al., 2006) and more intensive thinnings (Briceno-Elizondo et al., 2008, 2006; Jordi Garcia-Gonzalo et al., 2007; Nuutinen et al., 2006). An increase in share of broadleaves (Kellomäki et al. 2005) is also suggested. Furthermore, as conditions for spruce seem to become less favourable, less spruce on medium site type/index is suggested and more southern provenances should be used (Kellomäki et al., 2005). Wind risk suggests lower stand density. Subramanian (2016) gives a recent overview of risks and adaptation to climate change in forestry.

3. Social/economic/policy and new forest owners

3.1. Forest ownership structure

There are about 128 000 forest properties in Norway, of which 94% are owned by non-industrial private individuals. The property structure is highly heterogeneous in size, with more than 60% of the properties being smaller than 25 hectares (Figure 2). On a per-hectare basis, smaller and larger properties harvest about the same (Figure 2); however, harvest potentials are greater on smaller properties due to more accumulation of growing stock caused by relatively less harvest and better productivity than on larger properties (Hobbelstad & Ørnelund Nilsen, 2006).

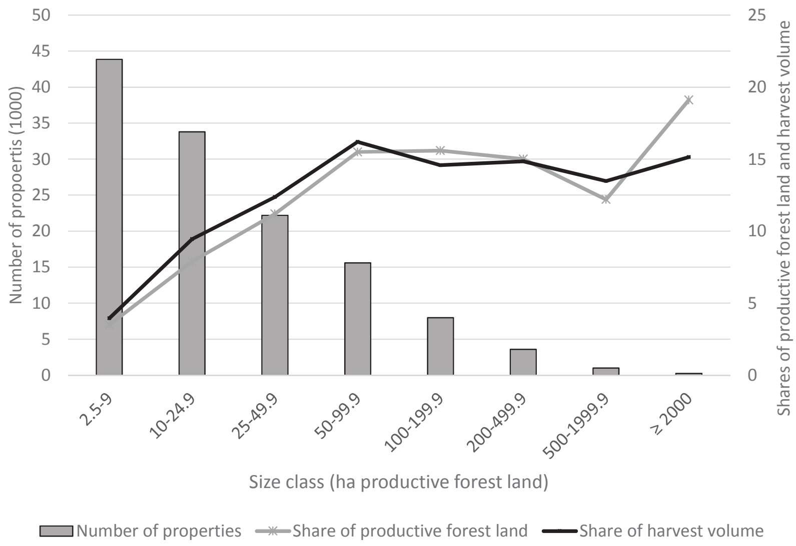

Figure 2: Forest ownership structure. Number of properties in 1000 per size class (left axis, bars); shares per size of productive forest land and harvest volumes in 2014 (right axis, lines). Source: Statistics Norway, 2015.

The total harvest volume in Norway has remained remarkably stable over the last century, of about 10 million cbm timber harvested for sale (Statistics Norway, 2015). However, growth has increased about 150%, from 10 to 25 million cbm in the same period. With timber price declines and salary growth, harvest revenues are gradually constituting a smaller share of the forest owners' income. In parallel, harvesters and forwarders have completely changed the way wood is harvested; from the small start in the end of the 1970s, almost all timber is today felled by harvesters (Steinset, 2015). Over the same period, the share of forest properties that are run in combination with agricultural production has declined from 62% in 1979 to 30% in 2010 (Rognstad & Steinset, 2012). One trend that is likely to partly originate from these changes, is the declining number of forest properties that harvest for sale. While 45% of all forest properties harvested timber for sale over the period 1996-2005, this share was reduced to 36% in the period 2005-2014 (Statistics Norway, 2015). On average, the forest contributes to 6% of the total income of forest owners; 41% is made up of salaries (Steinset, 2015).

3.2. Political climate

Forestry and the forest sector are currently topics high on the policy agenda in several countries. EU has released its bioeconomy strategy (European Commission, 2012) where the forest sector is supposed to play an important role for meeting objectives such as climate change mitigation, reduced loss of biodiversity and create jobs and increase value-added. The Norwegian forest sector has been through a decade where more than half of the capacity in the pulp and paper sector has been shut down and the industry struggles with low competitiveness and low profits. As a response to this, the Norwegian government appointed a committee for providing advices on how policies could be shaped in order for the sector to fulfill some of its potentials, called Skog22 [Forest22]. The report was finalized in January 2015 (Forest22, 2015), and provides lists of measures that could increase the competitiveness of the sector as well as actions that could increase the sector's total production and value-added. In the following, we will take a look at one of the policy changes that also outside this report has been received considerable attention lately, namely regulations of forest property trade.

The trade of forest and agricultural properties in Norway is highly regulated. As a general rule, such properties cannot be divided; if sold, one purchaser has to buy the whole property (Lovdata, 1995). The buyer needs concession from the authorities for acquiring the property; elements such as price, the buyer's knowledge and intentions for running the business are considered (Lovdata, 2015), and it is not uncommon that the authorities react on some of these elements and deny concession. In addition, Norway has as the only western country, maintained the thousand-year title of farmland that the heirs have the priority to acquire the property when it is being transferred, independent of the seller's intentions (Lovdata, 2014). One result of these regulations, and strong culture for inheritance of farmland in Norway, is that only a small share of the forest properties are sold out of the family, and that only marginal changes in the forest property structure take place. Debates and voting on abolition of, or changing, several of these laws have been going on in the Government and Parliament throughout the last year; however, no considerable changes have yet passed the Parliament.

As liberalizing property trade often is put forward as an action that can make forest owners on average more interested and professionally oriented towards their property, and decrease costs, it is of interest to investigate how forest owners look upon these issues. Are forest owners interested in increased forest property trade?

3.3. Interest among forest owners
In 2014, the Norwegian University of Life Sciences did a survey among more than 3000 randomly selected Norwegian non-industrial private forest owners (Sjølie et al., 2016). Questions in the survey centered around ownership objectives and views on the use of their forest. The survey was sent to two different populations, properties with harvest for sale the last 15 years, and properties with no such harvest. The sizes of the two populations were about 72 000 and 56 000, respectively. The survey, administered by Statistics Norway, yielded response rates of 56% for the first sample ("active owners") and 49% for the other sample ("inactive owners).

Owners were asked how they acquired their property, and if they were interested in selling or purchasing forest land. Almost 90% of the active forest owners had acquired the property from the family, as opposed to 80% of the inactive owners (Figure 3). The main other means of purchasing the property was from outside the family.

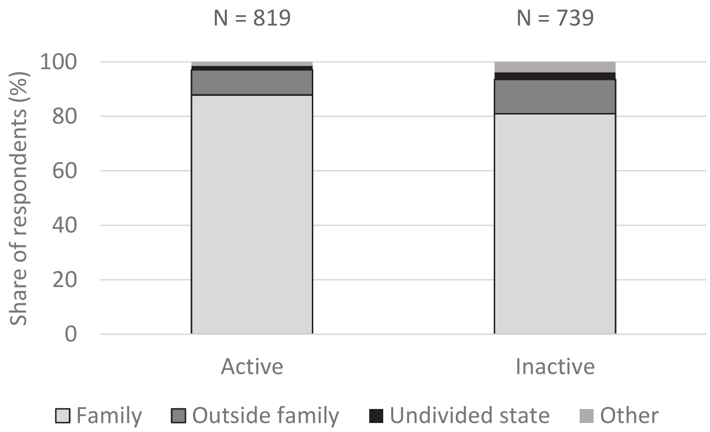

Figure 3: Form of acquiring forest land when becoming forest owner. Percent of total respondents.

On direct question, 18% percent of active owners stated they are willing to sell their forest land, contrasted to 22% of inactive owners (Figure 4). The difference between the two owner groups is thus relatively small.

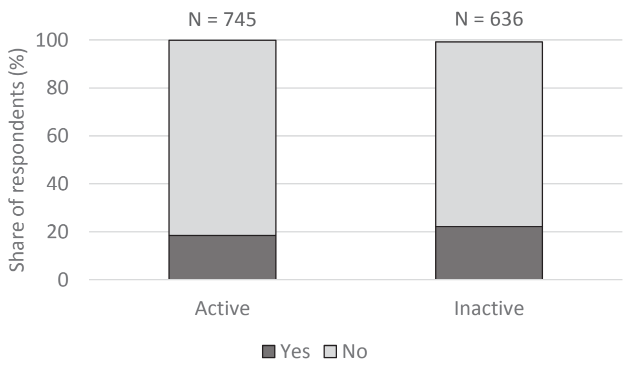

Figure 4: Willingness to sell forest land. Percent of total respondents.

Not surprisingly, active owners were more interested in acquiring more forest land than inactive owners (Figure 5). Among active owners, 33% were a little interested in acquiring more forest land, 10% very interested and 57% not interested. The corresponding numbers were 19% (a little interested), 5% (very interested) and 76% (not interested) for inactive owners.

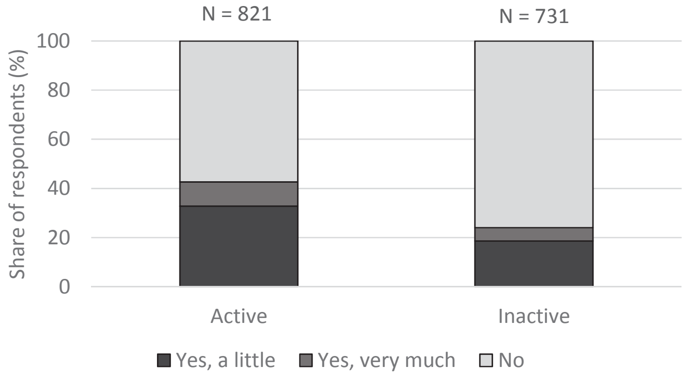

Figure 5: Interest in acquiring more forest land. Percent of total respondents.

4. Discussion: Which policies are adapted to the new climate?

Any policy that aims at influencing the use of forest resources and the long run development of forests, is dependent on forest owners managing their forests and have the knowledge abilities to act upon that policy. In the ongoing discussions of liberalizing forest property trade in Norway, advocates for liberalization refer to the need for larger properties that are run more professionally by individuals who receive a significant share of their income from their property. It might also be easier to stimulate more professionally oriented forest owners to act upon the current policies. Thus, a restructuring of forest ownership may aid in policies being more effective.

However, our findings indicate that there is only moderate interest in more trade among current forest owners. Ten percent of active forest owners are very interested in buying more forest land, and 33% are a little interested. One might think that the latter are mainly interested in buying forest land that is within a reasonable distance from their current property and/or home, which requires interested sellers within a given geographical area. However, only around 20% of forest owners are interested in selling their forest land; it is interesting to notice the small difference between active and inactive owners in this regard. Also, a certain share of inactive owners are interested in buying more forest land. These owners seem to have other objectives than profiting from timber production; it would definitely be of great interest to look deeper into what are the driving motives of this group. Since this group is also increasing in size (Steinset, 2015), their ownership objectives are increasingly important for the whole forest sector and policy-making.

Other factors in forest owners' social climate, that we have not discussed here, are also changing. For instance the pressure from NGOs regarding biodiversity conservation.

Recently, the Parliament decided to increase the protected forest area to 10% within 2025, in line with suggestions from NGOs. More specialized use of forest land, with larger set-asides and more intensive production on other sites, have been put forward as a strategy to improve multiple output from forests (Vincent & Binkley, 1993; Y. Zhang et al., 2009). However, this strategy has many barriers and would require substantial political changes in order to be implemented. Also, if schemes for more conservation and land specialization are to be implemented, the bidirectional interactions between these schemes and physical climate change should be considered for measuring total costs and benefits to the society of this strategy. Current forestry regulations in Norway do not really (in practice) consider environmental issues, as these have been taken care of by the forest sector and NGOs through certification. Another question is whether that will continue in the future, or whether standardization/certification will become part of public regulations?

The findings suggest that even if forest trade is being liberalized as suggested, no significant changes in ownership structure will take place in the short to medium term. Forest policies will most likely also in the future need to be based on a large inactive owner base, which may increase further given the trends of declining timber values compared to salaries. Adapting forests to climate change and using a larger share of forestry's potential to mitigate climate change require active forestry. If forest owners are not becoming more active, policies might need to be adopted to stimulate more active ownership. Another policy strategy would be to stimulate private enterprises and markets for long-term forestry contracts, where forest owners to a larger extent than today outsource forest management to professionals. This way, forest owners retain ownership, which may be important to them, while forests can be managed according to both private ownership objectives and public objectives related to i.a. climate change mitigation and adaptation.

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14. Innovation in the forestry-based sector – what activities may make a difference?

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Abstract

Questions I care about: Which theories can best explain the changes that are taking place in the forest sector? Which factors are crucial to explain the changes and why is innovation an useful concept when discussion these changes? Which competencies are useful in an innovative company and can some of these competencies be learned in a university setting?

Approach: Literature study, conceptual article.

Results: Innovations are important for the forestry sector to remain competitive. Innovations take place in all parts of the value chain. Examples of radical innovations in the forestry sector are rare, most innovations are incremental and build upon more radical innovations from other sectors. Both theories of networks and learning have proven to be useful in explaining innovativeness and innovation activity.

A case study from the firewood production industry shows that lack of public policy does not necessary hamper innovation. A state of the art study analyzing 28 articles on innovation in the forest sector in North America in the period 2000-2013 concluded that a conservative innovation culture in the forest sector lead to low investment in innovation and innovativeness and low performance in the sector. To improve the innovation culture is a long-term task, the educational system is certainly a key factor in doing that.

1. Introduction

The most important thing I learned from my teacher in economic history, professor Stein Tveite, is that in every time period there has been major changes in society. Tveite had a dispute with his collegue, professor Sverre Steen, about this. Steen wrote a book which he called "Det gamle samfunn (The old society)" and Tveite argued strongly against the idea of some old (static) society. This was only a romantic, nostalgic idea often used to discuss negative aspects of the current development. However, the negative effects of technological development for forest workers and rural communities was the first project I worked with after finalizing my M.Sc. in forestry. More about that later.

Later on I was introduced to the literature about rural development and the fact that rural citizens could do a lot themselves to develop their communities, not only by political interventions, which at that time was very popular in Norway. Business retention and expansion is one of the techniques used to address barriers, we used this approach to study how the wood-working industry in the mountain region of Hedmark and Sør-Trøndelag could increase their value creation (Lunnan and Underdal 2000).

From rural development I continued to the literature on innovation and entrepreneurship and developed courses for students on these topics. Innovation is often used as a political buzzword and in many ways in the daily language. There are also many different research traditions within innovation research and some research applied on forestry and forest industries is also done within these traditions. Innovation is considered to be important for economic growth and especially for high cost countries like Norway, innovation and knowledge are key factors to remain competitive at the world market. One example is that the shipyards in western Norway now stop outsourcing large part of the shipbuilding process. By introducing robot technology they can produce as cheap in Norway as in Poland or South Korea, and they have full control over the whole production process.

In this article I will reflect on the term innovation and its usefulness to study the development in forestry. Many interesting questions arises: Which factors can explain why the innovations take place? Do the innovations take place in the forestry-based sector or are they simply diffusion of innovations taking place in other sectors? What role does research in forestry play? I will also make a comment to the discussion if skills in innovation and entrepreneurship is something innate or if it is possible to learn, and how it eventually can be learned.

2. The technological development

I started my professional career as a research assistant on the project "The technological development – effects for forestry, agriculture and rural communities". In this project the idea was to document the rapid technological changes going on in agriculture and forestry and its effects on the rural communities. Economics of scale and new logging technology would lead to a rapid decrease in employment, and if this trend could be slowed down a bit, the adaption would be easier and the negative effects would be reduced. In agriculture there already were regulations in this direction. One question was if this also would be a good idea in forestry. I summed up the literature and wrote some reports (Lunnan 1978, 1979). Based on a report I wrote to the Ministry of Agriculture in 1977, a two year pilot project on concessions for harvesters was implemented in Norway. This project was no success and regulations were not put into practice. Even if there might have been some short run economic benefits to the forestry communities, the long run effects of trying to regulate the technology in an internationally competitive sector was not a good idea.

Birger Solberg studied similar problems in his dr. agric-thesis. He found that pitsawing under given conditions in Tanzania could compete with commercial sawmills. Also oxen-logging was able to compete with tractor logging. In the developing country context the situation was that technology was often subsidized by donors, and more appropriate and local technologies were not able to compete (Solberg 1988).

Both he and I emphasized the dynamic effects and that new technologies would have a tendency to get cheaper over time because of learning effects.

Looking back on my first project with the glasses of 2016, it seems obvious that I underestimated the influence of the oil sector and the coming rapid changes in the Norwegian economy. Rapid increase in wages and scarcity of labour did increase the cost and made technological solutions more competitive.

In spite of that, the negative demographic development in the forestry dependent communities remained, and from 2000 to 2004 I was leading a strategic institute project on rural development at the forestry research institute (NISK). Our ambition was to examine the possibilities for a synthesis and cooperation between research in wood technology and social science (Lunnan et al 2004). This proved to be more difficult than we originally anticipated, but we managed to hold a conference and invite faculty and ph.d. students within technology and social science in forestry and produce a special edition of Scandinavian Journal of Forestry.

3. Innovation research and its application to forestry

Professor Eric Hansen at Oregon State University organized a workshop on innovation and entrepreneurship in forestry at the IUFRO World Congress in Brisbane in 2005. A nice state-of-the-art article was written by him and three other authors as a follow-up of this event (Hansen et al 2007). In this article the authors use a threefold typology: organizational innovativeness, new product development processes and innovation systems. Although each of these areas were somewhat covered in the forestry literature, the new product development literature was clearly underdeveloped. Very little research was found on how forest sector firms approach new product development, or why they do very little new product development at all.

From the same workshop Niskanen et al 2007 produced a state of the art article concerning entrepreneurship in forestry. In this article case studies from six countries were included. Few examples on policies directed towards entrepreneurship were found. The policies identified were intended to correct market failures and promote sustainable forestry. At the same time the policies were often found to be bureaucratic and limit the opportunities for forestry entrepreneurship. Nybakk et al 2009 did a follow-up study building on the previous cited studies. They found that social networking and learning orientation positively impacted landowner innovativeness, but entrepreneurial climate did not.

Hansen et al 2014 made a review article where they analyzed 28 journal articles on innovation in the forest sector originating in North America in the period 2000-2013. "Seven important themes were identified and discussed: defining innovation and innovativeness, measuring innovativeness, factors influencing innovativeness, new product development, climate/culture, innovation systems, and innovativeness and firm performance". They especially focused on the innovation culture, which they found conservative in the forest sector, leading to low investment in innovation and innovativeness and low performance in the sector. Nybakk 2012 and Nybakk and Jenssen 2012 studied innovativeness in the Norwegian wood industry and found that learning orientation, innovation culture and an innovation strategy possibly effected performance within the industry. On the other hand, there has historically been relatively close connection between the forest research institutions and the forestry sector. There is, however as far as I know, little research done on how these contacts have led to innovations (incremental or in some cases radical) in the forest industry. The lack of innovation culture in the forest sector might be a barrier (Hansen et al 2014), lack of entrepreneurial orientation in the universities and research institutions might have been an even more significant factor (Lunnan 2011a).

The driving force for innovation in the forest sector might also come from outside the sector, from consumers (user-led innovation, von Hippel 2005) or from suppliers. In some cases suppliers are large multinational companies. A study of the wood treatment industry found that managers in chemical companies did not find the wood treating industry as particularly innovative (Nybakk et al 2015). The study found that the chemical company managers had a key role in innovation in this industry and that strong relationships between the chemical industry managers and key innovative customers played an important role in creating and implementation of innovations in the wood treating industry.

A question much discussed in the literature is if education in innovation help people to be more innovative. There are examples of successful business people like Olav Thon and Kjell Inge Røkke which have limited education in innovation methods and innovativeness, but several studies the last decade show that education in innovation have a major positive influence(see e.g. Hovne et al 2014). At NMBU school of economics and business we have especially worked with development of new teaching methods in innovation and entrepreneurship and the results of this work so far is high satisfaction among the students and improved perceived employability (Kubberød and Pettersen 2016a, 2016b). We believe that some of the main results of this work is transferable also to other university programs.

4. Innovation in the firewood production sector

In the project «Bioenergy Markets» from 2009-2012 financed by NFR, Erlend Nybakk and myself did a study on firewood producers in Norway (Nybakk et al 2013). Most of the bioenergy in Norway still originates from firewood. We do not know exactly how much of the firewood is traded at the market and how much is chopped by the consumers directly, but our impression is that the percentage sold at the market has increased the last decade and we estimate the percentage to be around 50%. An interesting fact is that this sector has got very little public attraction. There is no section on wood production at bioenergy conferences and there are very few examples of research projects and cooperation between research institutions and this industry.

In the project we sent a survey to 3000 firewood producers (including one persons firm) and got a response rate of 30,5 %. From theory and literature we hypothesized a positive correlation between social network size, innovation and firm performance among firewood producers in Norway.

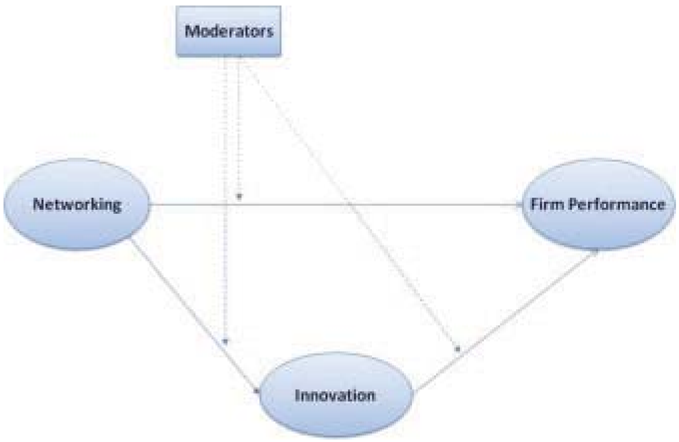

Fig. 1.

Theoretical model. Moderators: tie strength and variation within a network. Nybakk et al 2012.

The findings showed that social network size had a positive effect on firm performance via innovation by firewood producers. Furthermore, the results showed that firewood producers with fewer involved family members and more variation in occupation and entrepreneurial experience in their networks benefitted more from larger social networks than other producers do. In another study, which is not published yet, we were able to show that actors with a strong learning orientation had higher performance.

The interesting part of this study is that no radical innovations have taken place in this industry. Many public programs support innovation in renewable energy. There are no programs supporting firewood producers, still the industry has been able to implement incremental innovations and keep the costs relatively low. In the project we were able to identify some possible factors that could explain this. Another important factor we did not consider is the development of cost-efficient and clean wood stoves, major innovations in this field could be explained by close cooperation between industry and research institutions (see e.g. the ongoing WoodCFG-project at SINTEF in Trondheim led by Øyvind Skreiberg, Georges and Skreiberg 2016).

The data in this study was also used for a study of growth drivers in low technology firms. Rasmussen used this data in his ph.d. study and found that customer orientation, innovativeness and tenacity had a significant effect on growth in the wood production companies (Rasmussen and Nybakk 2016).

Another theoretical starting point for studying the wood producers, if we have had sufficient time series data, would have been the theory of induced innovation (see e.g. Binswanger & Ruttan 1978). This theory states that rising prices of a production factor would lead to a technical change (innovation) and more efficient use of the factor becoming more expensive. There are many publications using induced innovation in the agricultural development literature. Concerning forestry and bioenergy, I find that the study on woodland deforestation by charcoal supply to Dar es Salaam by Ole Hofstad (Hofstad 1997) would have been an interesting starting point for a study using the induced innovation perspective.

5. Bioenergy innovation

In 2011 I did a literature study on bioenergy innovations (Lunnan 2011b) and in the following I give a brief summary of what I found. If Europe is going to succeed with reduction of GHG emissions, many different measures are necessary. One of them is increased use of biomass for energy purposes. Most innovations are incremental and a better understanding of how incremental innovation and learning takes place in companies is an important research task. Radical innovation is R&D-driven and here (case-)studies using the Technological Innovation System (TIS) methodology have given much insight. Innovation takes place in all parts of the bioenergy chain, but there are few studies of innovation processes in bioenergy systems. More research is needed to understand innovation drivers, what makes innovation go fast in one field and less fast in another. Public policy is an important factor, consumer preferences and awareness another, environmental factors is a third important factor. The involvement of end-users and environmental groups in innovation (user-led innovation) is another very interesting research topic, especially because IT-technology, social media and innovation in logistics seem to be an important part of at least the incremental innovations. There is more and more trade with biomass and biomass technology, and this has an impact on domestic innovation. Markets get more and more transnational. EU policy is a strong driver in Europe, and policy measures will probably in the future be coordinated in different countries.

Uncertainty about future public policy is influencing investment in new renewable technology and hampering innovation. Case-studies from Canada, Norway and Germany illustrates this point quite clearly (White et al 2013).

6. Discussion

The last decade many innovation studies have been undertaken in forestry and forest industries. One very central point, highlighted by Hansen et al 2014, is that the innovation culture seem to be conservative in the forest sector, leading to low investment in innovation and innovativeness and low performance in the sector. Innovation culture has something to do with traditions in the sector, the educational system and the links between the sector and other parts of the innovation system (R&D, suppliers, customers, competitors etc.). As far as I know, there is no good empirical study of this available, more a set of hypothesis based on theory and anecdotal evidence.

We know something about what might explain innovativeness and which actors are most innovative in the forest sector, but there are certainly room for more studies, also studies of educational programs and how they could be made more innovative, how they can motivate students to learn and contribute more in the future.

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15. Cost structure of Norwegian sawmilling

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Abstract
The study evaluates cost structure and operating efficiency of Norwegian sawmilling. The data set includes all Norwegian sawmills in 2012, it is based on data from income statements collected by Statistics Norway Structural business statistics for manufacturing. In total 351 production units were included in the data set. The mills were grouped according to size (in five size classes). The results indicate that the cost structure of Norwegian sawmilling diverges between mills of different size, suggesting a more effective production and management of large production units. There was, however, not a consistent connection between mill size and operating efficiency.
Keywords: Sawmilling, cost structure, operating margin, operating efficiency

Introduction
The study evaluates cost structure and operating efficiency of Norwegian sawmilling. Costing and analysis of production costs is of substantial importance to companies with respect to production efficiency and forms the basis for pricing of products. Knowledge of cost structure is therefore of relevandce to improve profitability. Previous Norwegian studies on cost accounting and production costs in Norwegian sawmiling have been conducted by Tunes, Nyrud and Eikenes (2008), Baardsen (1998 and 2000).

Method and data
The study includes variable costs from income statements collected by Statistics Norway and reported in the Structural business statistics for manufacturing (SSB 2016). Statistics Norway Industrial area 10 collects data on the enterprise and corporate level (cf. SSB 2012 and SSB 2016). All companies that are included in Statistics Norway's structural statistics are anonymous. Disaggregated data for individual enterprises (i.e. production units/sawmills) enables the analysis of costs directly associated with production in manufacture of solid wood products. Based on the data from individual production units, the data resembles income statements, and thus on the aggregated level national accounts (cf. Rodriguez 2012). Costs are grouped in relevant cost groups, the following cost groups are used in the report: Wage costs, raw material cost, sales and administrative costs, depreciation.

Statistics Norway classifies industries according to international industry categories. Group 16 includes manufacture of wood and products of wood, cf. Table 1 below. A distinction is made between primary production of sawn wood (16.1) and wood and wood-based panels, and various forms of processing (production of parquet, buildings, packaging and other products) (16.2). This study includes data from group 16.1.

Table 1. Industry Group 16 Manufacture of wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials, except furniture (SIC 2007)

Level 1	Level 3	Group
16.1		Sawing and planing of wood
	16.100	Sawing and planing of wood
16.2		Manufacture of products of wood, cork, straw and plaiting materials
	16.210	Manufacture of veneer sheets and wood-based materials
	16.220	Manufacture of assembled parquet floors
	16.231	Manufacture of wooden prefabricated buildings
	16.232	Manufacture of builders' carpentry and joinery
	16.240	Manufacture of wooden containers
	16.290	Manufacture of other products of wood; manufacture of articles of cork, straw and plaiting materials

The data set included all domestic production units in 2012 (n = 749), most of them are autonomous enterprises. The data were grouped according to mill size (i.e. number of employees). A large share of the companies were small businesses with less than six employees (n = 620). For a substantial share of the production units, the data entries were incomplete, and these records were therefore excluded from the data set. The truncated data set consisted of 351 production untis, cf. Figure 1.

Figure 1. Number of sawmills in the sample.

Results

Average costs for each size group are presented in Figure 2 and Table 2. The data implies that large production units has a relatively high proportion of raw material costs and lower wage costs, indirect costs as well as sales and administration costs. Furthermore, except for the smallest production units, depreciation increased with company size. This can be considered as indicative of higher, more modern and capital-intensive technologies in large production units.

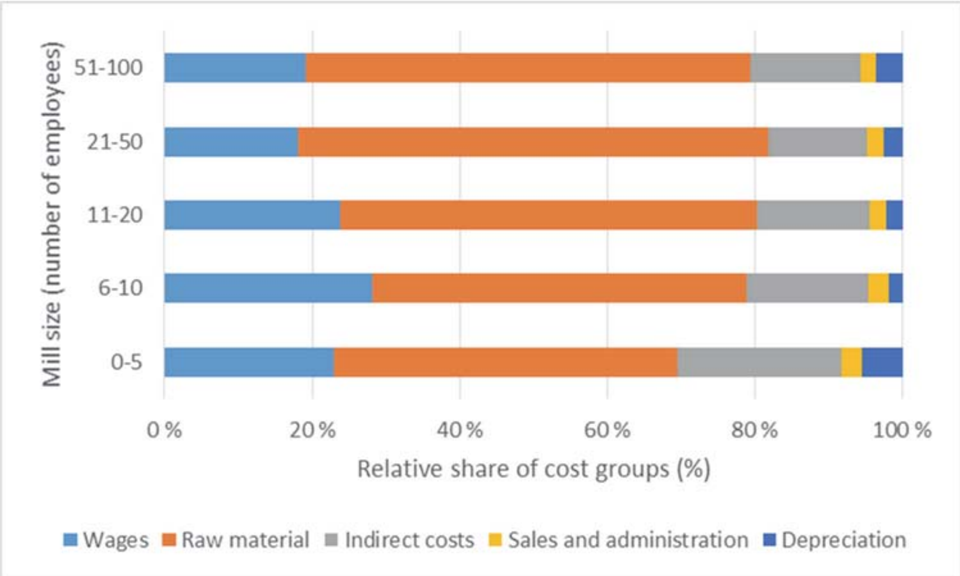

Figure 2. Relative costs divided on cost groups.

Table 2. Relative costs divided on cost groups.

	Mill size (number of employees)				
Cost category	0-5	6-10	11-20	21-50	51-100
Wages	23,0	28,1	23,8	18,1	19,2
Raw material	46,5	50,8	56,4	63,7	60,3
Indirect costs	22,3	16,5	15,3	13,4	15,0
Sales and administration	2,9	2,7	2,2	2,2	2,1
Depreciation	5,4	1,9	2,2	2,6	3,5

Average operating margins[7] for the five size groups are reported in Figure 3. The largest production units (51-100 employees) had the highest average performance (12,9 %), the smallest production units (0-5 employees) also performed well (7,5 %). In average, companies with 6-10 and 21-50 employees achieved negative operating margins.

[7] Operating margin = Operating profit/Revenue

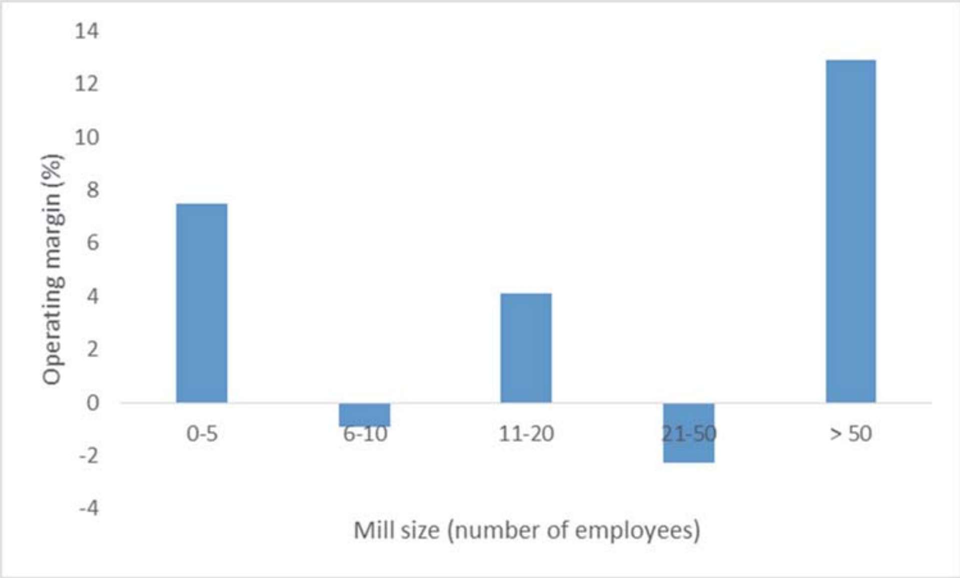

Figure 3. Operating margin relative to size of company.

To analyze what constitutes success in sawmilling, production units' cost structures related to operating margin are reported in Figure 4 and Table 3. From the 351 production units included in the data set, 11 units achieved operating efficiency above 50%. It is evident that depreciation and administrative expenses increase with operating margin. It can be interpreted as modern technology and intensive sales and marketing activities as success factors. The relative share of raw material and wage costs decerease with rising margins.

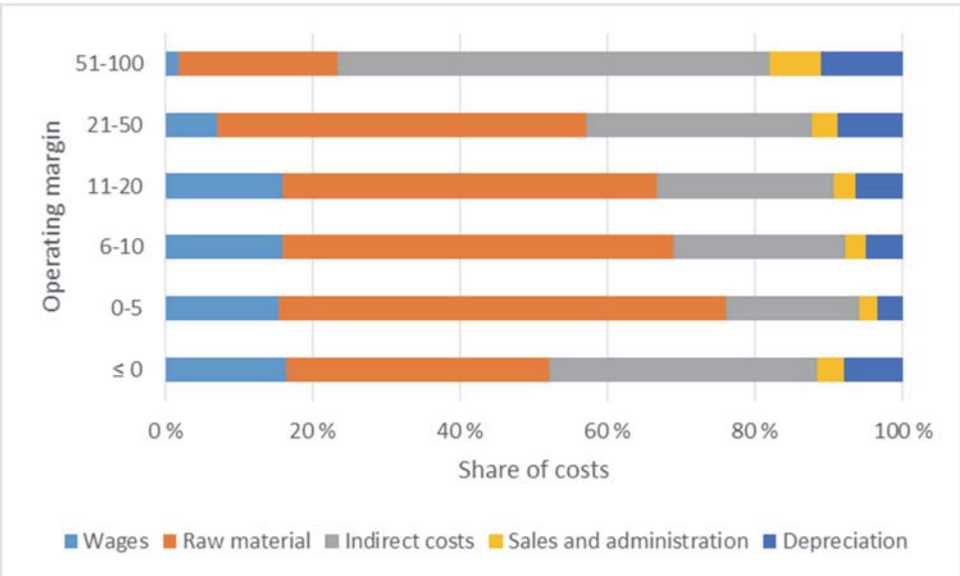

Figure 4. Costs relative to company operating efficiency.

Table 3. Costs relative to company operating efficiency.

	Operating margin					
Cost category	≤ 0	0-5	6-10	11-20	21-50	51-100
Wages	16,4	15,4	15,9	16,0	7,1	1,9
Raw material	35,7	60,5	52,9	50,6	50,0	21,6
Indirect costs	36,3	18,2	23,3	24,1	30,6	58,6
Sales and administration	3,7	2,4	2,8	2,9	3,4	6,9
Depreciation	7,9	3,4	5,0	6,4	8,9	11,1

Discussion

The results indicate that the cost structure of Norwegian sawmilling diverges between large and small mills. The relative share of raw material costs increases with size, whereas wage costs and indirect costs and costs related to sales and administration costs are proportionally less than for small mills. The results suggest a more effective production and management of large production units. Furthermore, relative cost share of depreciation increases with size, this may imply that large mills in general are more modern and utilizing more capital-intensive technologies.

When evaluating average operating margins relative to company size, one could assume that larger companies also can realize higher margins since they are likely to apply more advanced technologies in production, and thus presumably with lower production costs. The results does not provide evidence for this.

The fact that depreciation as well as sales and administrative costs increase with operating margin can be interpreted as modern technology and intensive sales and marketing activities as success factors. The relative share of raw material and labor costs does, on the other hand, decerease with rising margins, suggesting that a larger share of resources is applied in processing the raw material.

The smallest production units (0-5 employees) should be treated with caution. Some of the small enterprises are not necessarily involved in sawmilling and production of round wood. This may affect the excessive operating margins reported in Figure 3. For the remaining production units, the data should represent the industry average.

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16. TIME consistency and time constancy in forest decision making

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Abstract
Traditional forest economics, as exemplified by Faustmann's formulation of forest value, assumed a constant economic environment, and an indefinitely repeated sequence of identical forest rotations. Unpredicted and predicted changes disrupt this constancy. A schedule of declining discount rates which is rolled forwards through time causes revision of perceived optimal rotation, even if circumstances do not change, bringing inconsistency of decision as time perspective alters. Not only may optimal rotation change: also, decisions about what is and is not profitable may change, leading sometimes to perpetually postponed investment, or adoption of investments that are modified through change in time perspective, and so no longer appear profitable. Other management decisions may also be revised as time moves on. Although many decisions may suffer from time inconsistency, mostly the ensuing loss of profitability is small. But it is important that forest economists give formal treatment to the problem.

Introduction
When Martin Faustmann wrote his famous paper of 1849, the forestry world must have looked a time-consistent place. Supply, demand, prices, costs may have fluctuated, but were not perceived to exhibit a steady, predictable trend. The interest or discount rate *was* 4% and was implicitly projected to remain so for ever. Thus it was reasonable to base analysis of forest rotation and forest value on an indefinitely repeated sequence of equal forest rotations having identical cash flow and duration. Since his time many variations have been added to the problem (Newman, 2002): but often these elaborate on the theme of a world in which the optimal management regime remains the same from rotation to rotation.

Some things *have* changed. Different commentators project different trends in revenues and costs: Barnett and Morse (1963) identified forestry prices on an upward trend – uniquely among major natural resources; on the other hand, Hultkrantz et al. (2014) found no upward trend in Swedish stumpage prices. Environmental values have been introduced to the rotation length discussion, theoretically by Hartman (1976), more practically by Calish, Fight and Teeguarden (1978). Fisher and Krutilla (1975) have argued that increasing value for environmental consumption justified using a lower discount rate for them, with consequences for forest rotation that we shall mention later.

And, crucially, arguments are increasingly heard, and heeded by a widening group of governments, that discount rates not only *do* change through time and across products, but should be *expected* to change through time according to a declining protocol.

Yet forest economists continue to use land expectation value (LEV) – net present value of an infinite series of rotations – as though things had *not* changed. The pages of *Journal of Forest Economics* continue to be much occupied with such papers.

Unexpected changes

Unexpected changes of course alter the forest management decision seen as optimal. The recognition of the value of forests' carbon-fixing ability is a pre-eminent example. Cultural forest investments become worthwhile (Hoen and Solberg, 1994). Social profitability is greatly increased by including carbon values, and rotations may be dramatically prolonged. Results for Japanese larch (*Larix kaempferi*) of productivity 12 m^3/ha/year in the UK are shown in table 1.

Table 1: Effect of carbon pricing on profit and rotation

	No carbon price	NEA (Tol, 2013) carbon prices	Stern (2006) carbon price	DECC (2013) carbon prices
Optimal rotation (years)	50	55	60	140
DCF (no carbon price)	£2764	£2719	£2620	£1399
NPV (with carbon)	£2764	£5003	£8819	£43,013

Source: Price (2014).

Perceptions may also change unexpectedly. The introduction of REDD was initially seen as an effective and efficient way to replace handouts to poor forest-dependent populations, by market trading for such things as carbon-fixing services. Now, however, it has been termed "a narrative of disappointment", with problematic political structures and insufficiently developed methods of monitoring carbon levels (Hofstad, 2016). An expedient switch from output-based to input-based measures will change forest economics as perceived by both implementing agencies and funders. If inputs are subsidised, profit-maximising will entail more inputs, but possibly not more outputs.

Changes that are consistent with prediction

The literature on optimal forest rotation (e.g. Johansson and Löfgren, 1985) provides many general proofs of how the rotation would change with specified, predicted changes. For example, an upward price trend lengthens rotations, whereas a single jump in price shortens them (because of the increased opportunity cost of land for successor rotations). Usually, the proofs give no indication of how strong the effect is.

To be specific, taking a Norway spruce crop of productivity 12 m^3/ha/year, with unchanged UK prices and a 3% discount rate, the optimal rotation is 66 years; with an upward price trend of 1% it is 75 years; with a one-off doubling of price it is 64 years.

Now that trends in prices other than that of timber are being projected, an ensuing change in optimal investment and rotation are also being projected. In a general sense, Price (2015) shows the effect by modifying the effective discount rate for specific forest outputs. Depending on whether it is an end-of-rotation value or a value attributed to the ongoing existence of the forest that is discounted at a lower effective rate, future rotations may be projected as shorter or longer.

More specifically, Sjølie et al. (2013) show that as time proceeds and carbon becomes more dominant in decisions, there is less investment in CO_2 mitigation in the short term, but more in the long term.

Ekholm (2016) demonstrates that a rising carbon price increases the first rotation's length, except where taxes are to be paid on harvesting near-mature plantations. While prices continue to rise, subsequent rotations will be further lengthened.

Changes that are predicted, and do materialise, do not cause a revised decision when they occur: the form of forest management changes from rotation to rotation and thus is inconstant, but decisions should not be considered time inconsistent.

The test of genuine time inconsistency – also known as dynamic inconsistency – is that decisions which seem optimal at one time, at a later time will be revised. This is so, even though no changes occur, of the kinds discussed above. The cause of such revision is change of time perspective.

The sources of genuine time inconsistency

In classical economics, the discount function is a negative exponential, and it is almost invariably so presented in traditional forest economics. The consequence is, that from whatever time perspective a decision is viewed, relative values remain the same. For example, with a 4% discount rate, if the reference point in time moves onwards by 10 years, the discounted value of each cost or benefit is increased by a factor of 1.480. What seemed profitable before will seem profitable after; the *most* profitable in a group of investments will remain so.

Increasingly, however, arguments are made that discount rates should decline through time. The governments of the UK, France, Norway and Denmark have all mandated specific (though different) schedules of declining rate.

Two kinds of non-exponential time discounting may be distinguished. The more extreme form might be termed "now" or "immediacy" preference. Shackle (1958) expresses it thus: "There is for us a moment-in-being which is the locus of every actual sense-experience, every thought, feeling, decision and action." The intuitive decision, which delivers maximum net benefit in the instant, is taken with little consideration of future consequences, and little regard given to *how far* in the future they occur. Time passes, a different moment becomes "now", and the decision may be seen very differently, inducing regret and remorse (Price, 1993, chapter 7)

Clearly, in forest economics, immediacy preference cannot be the generally underlying model, else no forest investment would ever happen, and saleable trees would all be immediately felled. This is an "at the limit" model of individual human psychology, and cannot and should not be allowed to affect any template for social decision making. In the real-world private context, it is evidently not a descriptor of existing forest owners' decisions. Instead, their felling decisions seem consistent with other models: conventional investment appraisal; sustaining a succession of stand age classes; or felling to meet special needs as and only as they become immediate, as in the "Volvo effect" (Brazee, 2003).

Perhaps a certain amount of "now" preference is evident in knee-jerk responses to unfamiliar situations – particularly unforeseen threats – as when in the 1960s the problem of catastrophic wind damage to plantations became evident in the UK. Where no formal guidance exists, there is attraction in following instinct, and many stands were felled prematurely "to be on the safe side": in part this was an attempt to rid the decision maker of an immediate sense "that it would be irresponsible to be seen to ignore the risk". Subsequent economic analysis often showed that it would have been better to grow the crop further towards its planned rotation (Price, 2011a). No doubt some knee-jerk managers subsequently regretted their hasty decisions.

The less extreme form of declining discount rate is often called "hyperbolic discounting", although not strictly related to mathematical hyperbolas. Kula (1981), Bellinger (1991) and Bayer (2003) see discounting as the prerogative of those alive at the time of the decision, but only for the portion of project benefits accruing to themselves: benefits to later generations are discounted only over those generations' lifetimes. This causes the discount rate to fall towards a positive asymptote. A declining overall rate is often justified by combination of negative exponentials having different exponents; Li and Löfgren (2000) make provision for combining the different time perspectives of diverse groups (utilitarians, conservationists); Weitzman (1998, 2001) similarly combines the views on discounting of many economists; Price and Nair (1985) show that a "national discount rate" ought to move through time towards the discount rate of the group whose income is growing the slowest (though they prefer to discount the income of different groups separately). If different world scenarios produce different rates of diminishing marginal utility, that too would reduce the discount rate through time (Price, 1997). Additionally, Price (1993, chapter 18) combines the discount rates due on goods with high and low income elasticities of demand.

The most widely advocated sets of declining discount rates appear to be based on variability of future returns on investment (Newell and Pizer, 2004). The associated rate of diminution of marginal utility with income growth will also tend to decline through time. Other interpretations include that time preference rates will adjust in line with rates of return (Newell and Pizer, 2001), and that the mean investment required to pay compensation for future damages will come to decline at less than the initial rate (Price, 2004). All of these can be argued to justify declining discount rates, though alternative treatments, such as separate discounting of different entities, have also been recommended (Price, 2005).

Whatever the source, declining discount rates bring dynamic inconsistency (Strotz, 1956). A decision seen as optimal from the initial time perspective may be seen as not-optimal from a later time perspective. Sometimes this leads to useless regrets that a different decision was not made – particularly when psychological "now-preference" causes short-term gratification to engender subsequent disutility, as with over-eating, alcoholic hangovers or imprudent sexual transactions (Price, 1993, chapter 7). Learning from experience may help to avoid repetition of the worst-made decisions, as does "anticipated retrospect" – an ability to internalise how the decision of the moment might be seen in the cold light of tomorrow's morning.

For other cases, a provisional decision is made for future action, which may be revised as the future comes nearer and the time perspective is re-assessed. Into this category, most forest decisions fall. Present decision makers may consider that revision of decisions is not appropriate (from their own time perspective) and may attempt to "lock in" the optimal decision as they see it (see Elster (1984) for a general treatment). One further provision is needed, for a formal set of declining discount rates to cause time inconsistency: the set is not tied to historical dates ("the discount rate between 2017 and 2016 is 4%"), but rolls forwards as the present time moves on ("the discount rate between next year and now is 4%, as it will be when 'next year' has become 'now'"). This appears to describe the UK Treasury's schedule, which remained the same over the 10 years since its introduction, the rate dropping from 3.5% to 3% at 30 years into the future, whatever the base year of the appraisal; what in 2003 was the discount factor for 2053 is now, in 2016, the discount factor for 2066. French, Norwegian and Danish agencies may also adopt a "mobile" schedule.
The Norwegian Finance Department (Det Kongelige Finansdepartment, 2014) seems to suggest that the mandated rates are to be used in assessing the profitability of present government investments (Hoen, pers,comm.). HM Treasury (2011) states that "The NPV is the primary criterion for deciding whether government action can be justified." Neither gives clear guidance on revisiting assessments, for example near a forest rotation's end. But it would be reasonable to assume that any such reassessment would use the schedule of rates prevailing at the time, of which, *ceteris paribus*, presently advocated rates may be the best estimate.

Time (in)consistency with crop age

It is a consistent result, that a Faustmann rotation remains the same, no matter what point in the rotation it is viewed from. Consider a thinned crop of Scots pine (*Pinus sylvestris*) of mean annual productivity 8 m^3/ha/year, growing in UK conditions and with UK prices. Using a constant 3% discount rate, the optimal rotation is 77 years at whatever stage in the crop's life the appraisal is made. A constant and consistent management regime may be applied throughout the present rotation and all succeeding rotations, except as unpredicted change in physical or economic conditions may determine.

But now introduce Norway's discount schedule: that is 4% for 0-40 years, 3% for 40-75 years, 2% thereafter. For the moment constrain all future rotations to be the same as the present one (this enables a “normal” age class structure to be maintained). The profit-maximising rotation is now extended to 83 years, as a result of the 2% discount rate prevailing after 75 years. This is shown in figure 1, with NPV/ha over 500 years the criterion of profitability.

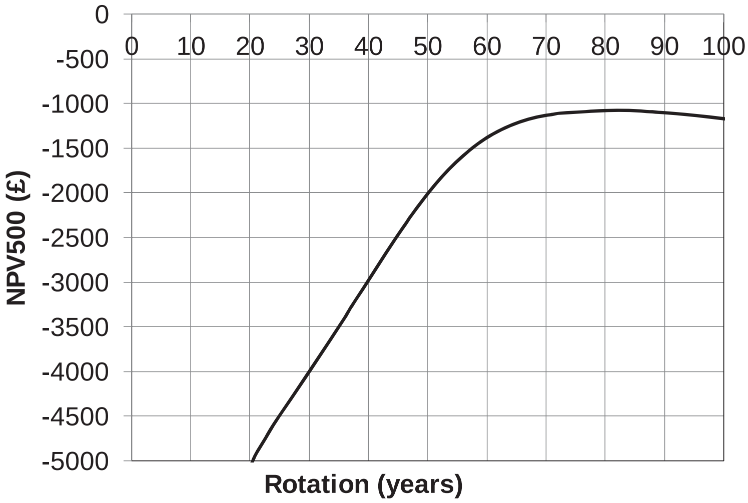

Figure 1: Profile of profit with rotation, Norway’s discount schedule

But in table 1 are shown the optima, seen from the perspective of various crop ages, with the discount schedule rolled forwards, so that higher discount rates prevail as the end of the rotation approaches; but also as the value of the second rotation becomes a greater influence.

Table 2: Optimal rotation determined at different crop ages

Crop age (years)	0	5	10	20	30	40	50	60	70	80	83
Optimal rotation (years)	83	75	77	77	77	72	74	74	75	82	83

Perhaps by good fortune, at no age is the optimum shorter than the present age, and at the end the optimum is the one originally determined. The inconstancy of perceived optimal rotation is nonetheless disconcerting.

The succession of rotations as time passes ...

Now let each succeeding rotation be optimised separately, as discussed in Price (2011b). The example is Norway spruce having productivity of 16 m^3/ha/year, with UK cash flows but under Norwegian discount rates.

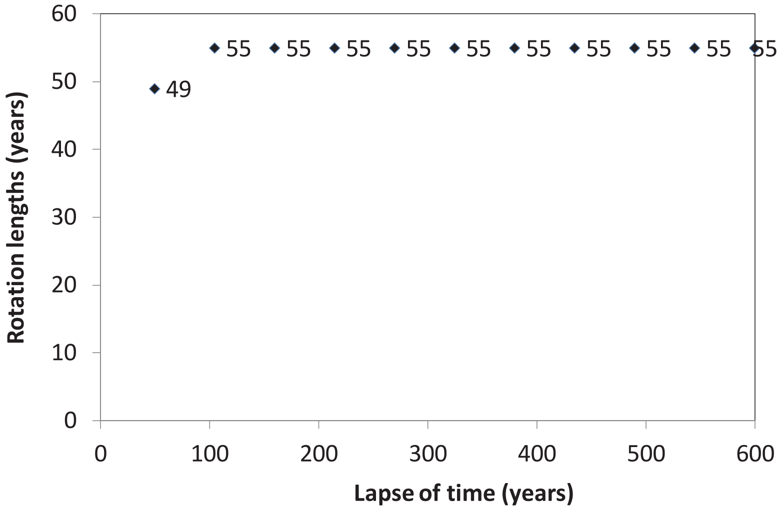

Figure 2a: Time perspective from the beginning of the rotation

As might be expected, the rotation lengthens in successor rotations as the applicable discount rate drops: the result is *inconstant*. This poses problems both for age-structure of forests (ideally, with equal areas in each age-class), and for timber supply. However, if the discount schedule is rolled forwards 45 years, the change of time perspective means that the optimal first rotation is shortened to 46 years. The optimal second rotation now becomes the same as the original first rotation, and so on until the rotation stabilises at 55 years when the discount rate has also stabilised. But as time moves on, successive generations would make the same revisions of perceived optima, and all rotations would in the event be curtailed at 46 years. (This turns out also to be almost exactly the Faustmann rotation calculated at the initial 4% discount rate.) Thus the smart expectation (considering how future generations will act) is that the rotation length will be *constant*, but that it will be *inconsistent* with what is identified in the initial optimisation.

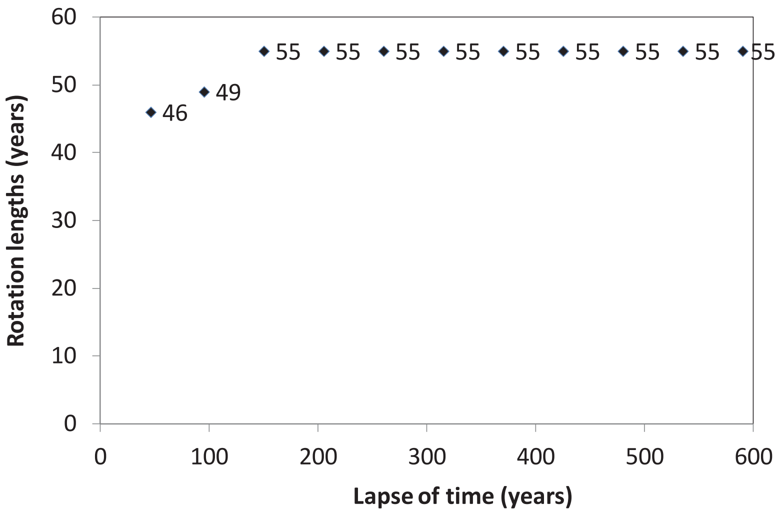

Figure 2b: Time perspective from 45 years into the first rotation

Does it matter? In terms of LEV, not very much. The LEV (using the declining schedule of rates) for the optimised sequence of rotations is £5255, that of a repeated 46-year rotation £5151. This 2% loss might well be compensated by the convenience of maintaining a constant rotation, and hence an undisturbed age-class structure. Taking an overall optimising view, the best constant rotation to adopt is 51 years, with LEV of £5236, trivially less than that of the optimised sequence.

The mystery of the perpetually delayed investment

Consider now an hypothetical case, on productive land. The investment cost for forming a stand is NOK 7500, and the revenue is in the very long term asymptotic to NOK 300,000 (but does not reach that level during the intended rotation). For convenience of management, a uniform 60-year rotation is projected. Applying a Norwegian discount schedule, the LEV is a marginal NOK 426. Table 3 shows how this is made up from the NPVs of successive rotations.

Table 3: Contribution of succeeding rotations to LEV

Rotation number	1	2	3	4	5	6	7	8	9	10
NPV (NOK)	–799	812	287	87	27	8	2	1	<1	<<1

The first rotation, to which discount rates of 4% then 3% apply, is loss-making, but all subsequent rotations are profitable, more than outweighing the first-rotation loss. Thus the profit-maximising decision should be to postpone investment for 60 years, and to "start with the second rotation". But time passes, and as the discount schedule rolls forwards, the decision for foresters in 2076 looks exactly like that in 2016: the first rotation is unprofitable, and investment should be delayed a further 60 years. Thus "... all generations agree that forestry is the profitable long-term use for the land area, and all agree that conversion to forestry should be postponed" (Price, 2011b). There is a kind of consistency here, but not very interesting forestry!

If the first generation could lock their successors into a planting covenant, they would, but they can't.

Similarly, let there be a development project, requiring investment of NOK 2,500,000 per year for 4 years, in order to increase CO_2-fixing benefits by NOK 350,000 per year (net of project maintenance costs). This benefit will continue for 120 years. Made in 2016, the investment yields a typical forestry IRR of 3.6%. Using Norway's discount schedule, the project's NPV is NOK 90,000. But it would be *more* beneficial if postponed until 2046, then yielding NPV of NOK 792,000. The ideal postponement period is 29 years, the bulk of investment cost being postponed through the period of highest discount rate, and NPV reaching NOK 797,000. Revisited in 2045, however, the new time perspective would favour postponement for a further 29 years. This project too is postponed indefinitely.

The optimal rotation that should never have started

As already seen, the perceived optimal rotation may vary, according to the crop's current age. This carries strange possible consequences. I have previously used the example, based on the discount schedule proposed by Kula (1981), of a stand felled earlier than planned (Price, 1984). In the following parallel case, Norway's discount schedule is applied to a crop of oak (*Quercus petraea*) with productivity 4 m^3/ha/year according to a UK yield model. The price for the largest size of (high-quality) material is £100/m^3. To broaden the spectrum of benefits, carbon fluxes are included too, with a price of £20 per tCO_2e.

On the optimal rotation of 121 years, the crop is just profitable, when carbon values are included. However, once the crop's age passes 75 years (when the 2% discount rate was originally in force), the optimal rotation drops to 108 years. On this rotation the overall project makes a small loss, seen from the time of initial investment, and would not have been undertaken by a rational agency. (Realising this, those who fell the crop at 108 years do not replace it: because the loss on the next rotation is small, this does not affect the optimal rotation significantly.)

Kula (pers.comm.) proposed the rule that future generations must comply with the decisions of the present one (in which case, the project would have been worthwhile). This does not accord with the way of the real world, in which each generation views decisions from its own perspective, and usually is unable to lock in its own preference for the future.

Other investments as the time frame moves on

The examples above concern optimal rotation, and whether forestry should be undertaken at all. Rolling forward the discount schedule also affects the profitability of investments that may be undertaken during a crop's life.

For example Scots pine tends to produce large knots, so pruning may be needed to achieve a high-quality premium price. Take a crop of productivity 3.5 m^3/ha/year. Suppose selective pruning can be done at age 50 at a cost of NOK 2000/ha, and that a price premium of NOK 500/m^3 is expected on the large sawlog material at a felling age of 140 years (when there will be much material of this size). Seen from the beginning of the rotation, the premium revenue is mostly discounted at 2% relative to the pruning cost, according to the Norwegian schedule: a marginal profit of NOK 76/ha is achieved. Some early cultural thinning might also be done to improve crop quality.

But when pruning age is reached, the discount schedule has rolled forwards, and a 4% discount rate is in force for 40 years of the interval between pruning and receipt of premium. The operation would now make a loss of NOK 1001/ha, and will be abandoned. If any early expenditure had been incurred to support a pruning regime, it would have been wasted.

Road network planning provides examples of both inconstancy and inconsistency. Up to the 1960s, horse-powered extraction was the norm in the UK, with high cost per m^3-km, and a road spacing norm of about 200 m. The advent of tractor-powered extraction, coupled with discounting of cost-savings through close spacing, brought dramatically increased optimal spacing. Further changes followed oscillations of government-prescribed discount rate. These changes exemplify inconstancy rather than inconsistency.

However, inconsistency does arise from shifting time perspective. To show the extreme effect, a stylised afforestation project is devised, using the most productive crop found in the UK, grand fir of productivity 30 m^3/ha/year, to represent a high-yielding crop. Its first thinning is at age 19. A heavier discount regime than Norway's is applied: 8% between years 0 and 15; 6% between years 15 and 35; 4% thereafter. Felling is at age 50, which is optimal according to the discount schedule. Technical data for roading and harvesting are "normal", and the network optimisation process is as described in Price (1989).

If the road network is constructed at year 0, the optimal density is 0.816 km/km^2; if it is planned for construction in the year before first thinning, it is 1.322 km/km^2. But from the time perspective of year 18, it is 1.230 km/km^2, because a heavier discount now applies to the years between road construction and the greatest part of harvesting. It is apparent that the time of actual road construction, rather than the *time perspective* taken on it, is the more important timing factor. The losses from "incorrect" density – however defined – are not very great.

Conclusions

Time inconstancy is a problem for stable planning e.g. of normal forests. Whether it is predictable or not, it requires adaptive forest management, whenever the hand of a traditional past does not obstruct meeting the needs of present and future. In so far as the inconstancy is predictable, future indicated changes, e.g. in timber supply, should be incorporated in present decisions. Some forest management conditions, particularly distribution of age-classes, are to say the least inconveniently affected by inconstancy. But these problems have long been part of the discourse of forest economics.

Time inconsistency is a newer consideration. Under consistently varying discount rates, change of time perspective would be expected, such that decisions made for future periods are revised as time moves on. It is quite easy to devise circumstances in which decisions made now, would be reversed in a later context. In general, however, the loss of net benefit by making the "wrong" decision seems surprisingly small. What matters more is that decision processes should conform with reality, even when that reality changes from time to time, and that forest economics should engage visibly with the problems created by declining discount schedules.

The case for declining discount rates might also be more vigorously challenged, but on grounds of questionable theoretical justification, rather than just because of its practical inconvenience.

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17. To believe or not to believe: Statements from forestry literature

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Abstract

Specialist literature is read for learning facts, but facts may be mixed with myths despite that the work was written with honest intentions. I investigated three cases of questionable statements in forestry literature: two from Norwegian textbooks of silviculture and one from a conference paper on forestry history. I observed that the statements were based on secondary sources and had been transferred from author to author over several decades. During that process the original statements in the primary sources were sharpened while they were loosing much of the context and limitations they once had been put forward with. It has been experimentally shown by others that peer-reviewing does not rule out all weaknesses in a paper for an international audience, hence it is likely that my results are not limited to forestry literature in a national language.

Utdrag

Vi leser faglitteratur for å lære fakta, men fakta kan være blandet med myter til tross for at arbeidet ble skrevet med ærlige hensikter. Jeg etterforsket tre tilfeller av tvilsomme utsagn i skogbrukslitteraturen: to fra norske lærebøker i skogskjøtsel og ett fra en norskspråklig konferanserapport om skogbrukshistorie. Jeg observerte at utsagnene bygget på sekundære kilder og at de var blitt overført fra forfatter til forfatter gjennom flere tiår. De opprinnelige utsagnene i primærkildene var blitt spisset gjennom denne prosessen og mistet mye av sammenhengen og begrensningene de i sin tid var blitt framsatt under. Andre forskere har vist eksperimentelt at fagfellevurdering slett ikke fjerner alle svakheter i en vitenskapelig artikkel beregnet på en internasjonal leserkrets. Det sannsynliggjør at mine resultater ikke er begrenset til skogbrukslitteratur på nasjonalspråk.

Introduction

Anyone who has authored a textbook or other teaching material, written a thesis, or contributed to the introduction of a scientific article, has experienced that valuable time is saved when using secondary sources from trustworthy authors rather than searching for the primary sources behind all the statements that ought to be included. This is particularly true if the statement in question is marginal to your own specific research expertise, but still worth sharing for the purpose of educating your readers, putting your scientific report into a proper context, or to simply show off your knowledge. The time thus saved can be used for going into depth of the core matter of what you want to communicate.

If you allow yourself to spend some days on investigating an apparently valid statement from a secondary source, you might end up in the dusty basement of your institutions's library leafing through a long forgotten paper that proves to be the primary source of the statement. Who wrote it, in which context, and based on what? These are important questions in source criticism.

The aim of the present article is to show how results from a primary source can be influenced by the process of being cited from author to author.

Material and Methods

I selected three cases of questionable statements that I have encountered over the years when dealing with forestry literature; two from textbooks (Skinnemoen, 1969; Børset, 1985) and one from a conference paper (Frivold, 2012). First, I tracked the statements backwards source by source in order to identify the primary source. If an author had asserted a statement and left the reference out, I made a qualified guess of the source. If I found the same statement in it, I assumed that my guess was right. Then, with the primary sources as points of departure, I described the development of the statements author by author until they had reached the textbooks and the conference paper where I first found them.

Results

The Mysterious Case of Dispersal Capacity

Dispersal capacity (Norwegian and Danish: *spredningsevne*) is nowadays a concept used by ecologists in the sense of the capacity of an organism to redistribute spatially from one generation to the other (e.g. Edenhamn et al., 1999; Rolstad & Gjerde, 2003; Dullinger et al., 2015). When I studied forestry in 1967–72, we encountered the concept in another sense, namely as the capacity of individuals in an even-aged forest stand to disperse into different tree sizes with time. This is vital in the natural development of a stand. If the dispersal capacity is low, each tree will get too little room for developing large dimensions, while if the dispersal capacity is high, some trees gain at the cost of their neighbours and thus may attain large, commercially attractive dimensions. Our textbook in silviculture (Skinnemoen, 1969) told us that dispersal capacity in this sense primarily is species-dependent, and that the dispersal capacity of Norway spruce (*Picea abies*) is poor. However, site quality also plays an important part: the better the site, the larger the dispersal capacity for a given species. Provenance may also have some influence (Skinnemoen, op.cit.: 332–333).

My first research project as a young assistant dealt with development and yield in non-thinned plantations of Norway spruce in West Norway (Frivold, 1976). Contrary to the textbook, most of the plots in my material showed a high dispersal capacity despite being pure stands of Norway spruce. I found no significant correlation between site quality and dispersal on tree sizes. How come that our textbook apparently was wrong?

Skinnemoen's passages about dispersal capacity are very similar to those in an older Norwegian textbook (Opsahl, 1945: 88–89), but both authors omitted references for them. However, we can find the same statements in the two editions of a textbook by Barth (1905: 7–8; 1912: 7–8), albeit in an older style of language. Barth suggests the reader to compare with Hauch (1905). In another Norwegian forestry textbook of the early 20th century, Myhrwold (1928: 510) defines the concept without elaborating it, referring to Hauch & Oppermann (1902) and Hauch (1918). Thus, Hauch emerges as a hot name in our search for the primary source.

LUDVIG ALFRED HAUCH (1845–1938) was a chief forest manager in South Zealand in Denmark where he was employed at the private estate of Bregentved, an estate famous for its oak and beech forests. Hauch was particularly engaged in regeneration issues. He was a colourful personality and a zealous author of professional papers. In 1926, the King awarded him the titular mark of *hofjægermester* [Hunting Master of the Court]. With the austere economic conditions of Danish forestry after WW1, Hauch's ardent argumentation for very dense regenerations of oak and beech became at odds with mainstream trends in silviculture. When Hauch had passed away at the age of almost 93, Professor Carl Mar: Møller introduced the obituary with the words *Saa døde endelig den gamle Hofjægermester* [So, finally the old Hunting Master of the Court died] (Møller, 1938; see also Jagd, 1961: 234–239).

Together with ADOLF OPPERMANN (1861–1931), a professor of forestry at the Royal Veterinary and Agricultural College in Copenhagen, Hauch authored a serialised textbook of forestry that was completed in 1902 (Hauch & Oppermann, 1902). Here, the concept of *Spredningsevne*, dispersal capacity, is introduced as the capacity of a tree species to make some of the individuals in a [pure] stand grow more vigorously than others, leading to a dispersal over a greater number of size classes. Based on visual observations of dense seedling crops, the authors state that birch (*Betula* sp.) and beech (*Fagus sylvatica*) have a large dispersal capacity and Norway spruce a poor one, with oak (*Quercus* sp.) somewhere in between. Data from measurements of 150 four-year old beech seedlings in a sample plot of 0.39 m^2 serve as the only numeric example. It is observed that for each species, the dispersal capacity is larger on rich than on meager soils (Hauch & Oppermann, 1902: 101–102).

Hauch later elaborates on the subject in several papers in Danish, Swedish and German periodicals (Hauch, 1904, 1905, 1910, 1912, 1918). In the paper from 1905, which is a shorter version in German of the 1904 paper, he admits that his term dispersal capacity

(Danish: *Spredningsevne*, German: *Ausbreitungsvermögen*) is somewhat unfortunate because botanists use it in another sense; however, he cannot think of any better word. From further observations at Bregentved, Hauch claims that beech, oak and pine possess a very large dispersal capacity in the seedling stage, while it is very low in spruce and ash, hence the forester should make cultures of the former species much more dense than cultures of the latter. In spruce, he had noticed an abandoned seedbed with a density corresponding to 360,000 seedlings per hectare in which all individuals were competing so strongly that they virtually stopped growing. While a density of 8,000 plants per hectare should be sufficient in a culture of spruce, beech, according to Hauch, requires an initial density of 2 – 3 millions of seedlings per hectare if the aim of the management is future stands of top quality timber. He suggests that differences in the root structure of the species at the seedling stage is a reason for the specific differences in dispersal capacity. In oak, provenance might possibly have some influence.

This 1905 paper by Hauch is the source of Barth, who immediately introduced the concept to Norwegian forestry literature. AGNAR BARTH (1871–1948) was a professor of silviculture at the Agricultural University of Norway from 1921 to 1942. He was a strong personality with a keen interest in biology, and a prolific spokesman for uneven-aged forestry (Skinnemoen, 1948; Norsk Forstmannsforening, 1954: 39). His numerous publications include a textbook of forestry, which he prepared in two volumes while serving as a state forest manager in Middle Norway and head of the local forestry school. The set of books appeared in two editions. In the first volume, Barth, (1905, 1912) presents Hauch's term and some of his assertions. However, he puts them in the context of the pole stage (i.e. the stem exclusion phase) in regard to thinning, rather than in Hauch's context of the early seedling stage in regard to appropriate seeding density. From here, the inherent poor dispersal capacity of spruce spread to Opsahl (1945) and Skinnemoen (1969), together with the statement that the better the site, the larger the spreading capacity. It may be noted that when Barth wrote a new textbook of silviculture as a professor a few decades later (Barth, 1938), he omitted the concept completely.

In conclusion, the statement in the textbook I had as a student, describing Norway spruce with generally poor dispersal capacity over size classes, is a clear example of a claim that lost its original context on its way from author to author. However, the concept itself might still be practical when discussing the need for thinning.

The Contradictory Case of Norway Maple

In the early 1990s I wrote a book about silvics and silviculture of forest tree species, mainly in the context of forestation of abandoned agricultural landscapes in Norway (Frivold, 1994). I decided to include some information about the influence of tree species on soil properties in spite of not being a soil expert. The chapters include one about maple, primarily Norway maple (*Acer platanoides*) that is native to South East

Norway, South and Middle Sweden, South Finland, and much of Central Europe. Arriving at the question of the possible influence of Norway maple on soil development, I consulted the latest standard Norwegian textbook on silviculture (Børset, 1985) and a Swedish textbook on the ecology and silviculture of so-called noble or temperate broadleaved species (Almgren et al., 1986).

Børset (1985: 394) reports that *maple strongly improves the soil properties through its leaf litter*. Almgren et al. (1986: 87) reports that *leaf litter of maple decomposes easier than that of beech and oak, but still does not belong to the very best species in this context.* Given the modest importance of maple in Scandinavian forestry, this discrepancy is hardly crucial for practical forest management. But it did trigger my curiosity. Why should the properties of Norway maple leaf litter suddenly change from one side of the state border to the other?

Børset (1985) does not provide references in text. The publisher of the textbook had turned that option down for the sake of readability. Anyway, we find exactly the same wording about maple two decades earlier, in a contribution to a five-volume presentation for the public about Norwegian forestry (Børset, 1962: 95), likewise without references. Børset was my old professor of silviculture at the Agricultural University of Norway (now: Norwegian University of Life Sciences). I know that he was well acquainted with German forest literature. The statement about maple and soil is in perfect accordance with a textbook of silviculture by Köstler (1955) and a monograph of maple by Hoffmann (1960); both available in the reference library of the Department of Silviculture at Børset's time. Hoffmann refers to Köstler, who does not provide a reference in this matter, and to Ebermayer regarding nitrogen content of leaves of the related species sycamore maple (*Acer pseudoplatanus*). It is possible that Børset (1962: 95) contented himself with the assertions of Köstler. Anyway, let us follow Hoffmann's track back to Ebermayer and see where it brings us. Ebermayer (1882: 58–59) refers to Stöckhardt (1866a).

JULIUS ADOLPH STÖCKHARDT (1806–1886) was a distinguished German chemist and educationalist who was appointed as a professor of agricultural chemistry and technology at the Royal Saxonian Academy of Forestry and Agriculture at Tharandt near Dresden in 1847. Among his main interests was mineral fertilization, in which, as opposed to his inspirer Justus Liebig, he included the use of nitrogen (Wienhaus, 1999).

On Friday, 29th July 1864 Stöckhardt and his team collected leaves from twelve different broadleaved species including sycamore maple in an old coppice at Tharandt to investigate their value as fodder for livestock. One year later leaves from four more species were collected and added to the investigations. Results from the lab analyses, presented with two decimals, show that the dry matter of leaves and green shoots of sycamore maple has a high content of protein matter, only beaten by grey alder (*Alnus incana*) (Stöckhardt, 1866a, 1866b: 133–134). Stöckhardt (1866b: 123) was well aware that the chemical content of leaves changes during the growing season, so if the aim of the experiment was to investigate soil improvement he would clearly have collected the leaves in the fall.

ERNST EBERMAYER (1829–1908), another German chemist, worked as a professor of agricultural chemistry and pedology at the University of Munich where he made numerous publications about chemical balances in soils (Fabricius, 1909). In a treatise on the scientific basis of forestry and agriculture, he notes that as a mean, 16% of the protein content of dry matter of plant components is nitrogen. With this factor he converts the protein values from Stöckhardt (1866a, 1866b: 133–134) into nitrogen content in per cent of dry matter, also with an accuracy of two decimals (Ebermayer 1882: 55, 58–59).

Ebermayer converted Stöckhardt's data with honest intentions, but the accuracy of the results is delusory. The standard factor he used for the conversion has later proved to be quite inexact (see e.g. Jones, 1931; Yeoh & Wee, 1994; Mariotti et al, 2008).

A sixty-something years later, VIKTOR TOIVO AALTONEN (1889–1955), a professor of pedology at the Finnish Forest Research Institute, wrote a treatise in German about soil and forest with special reference to northern European silviculture. Here, he repeats Ebermayer's table with all its decimals, including its value for sycamore maple (Aaltonen, 1948: 141). This table is however only one element in a large number of European and North American surveys reviewed in the more than 150 pages long chapter about the influences of forest on soil. Aaltonen (1948: 174) concludes that the scientific basis for ranging soil improvement by tree species is still incomplete, and when it comes to easy decomposition of leaves he is not willing to put up more than a tentative species list, mainly focused on Nordic conditions. Here, ash (*Fraxinus exelsior*) and elm (*Ulmus glabra*) are ranked as the best; maple (*Acer* sp.) and linden (*Tilia cordata*) as the second best; birch (*Betula* sp.), aspen (*Populus tremula*) and alder (*Alnus* sp.) as the third best; beech (*Fagus sylvatica*) and oak (*Quercus* sp.) constitute the fourth group; coniferous species form the fifth and poorest group.

JOSEF N. KÖSTLER (1902–1982), who in this matter is one of the sources of Hoffmann (1960) and most likely also the source of Børset (1962, 1985), ought to have been well acquainted with Aaltonen's work. Not only had he urged Aaltonen to publish the soil and forest treatise in German; he even wrote a foreword to it. Köstler made a career as a professor of forest policy in Hannoversch Münden 1934–1938 and became General Director of the *Centre International de Sylviculture* in Berlin 1939–1944. In 1940, the Government of Germany granted the office and the staff of the latter organisation extraterritorial status, thus placing them above German law. The staff built up what was probably the world's largest forestry library at the time (Ball & Kollert, 2013). After WW2, Köstler worked as a professor of silviculture at Munich 1946–1972. Allegedly, he favoured practical experience over an experimental approach. He wrote an influential textbook of silviculture which was published in 1950 and reprinted in 1955 (Mosandl, 2007: 16–17). The 1955 reprint was included as a textbook for Norwegian forestry students at the master level of silviculture in the late 1960s. Köstler (1955: 139) claims without references that *sycamore maple is desirable as a mixed-in species not only for its valuable wood, but also because of the easily decomposable leaves that, in many mountain areas, for ages have been highly appreciated as litter material in husbandry sheds*. He adds that *Norway maple,* a species more confined to lowland areas, *is still more praised for its soil-improving qualities*.

EGON HOFFMANN lived on the other side of the post-war Iron Courtain as a chief forest manager in the German Democratic Republic. His monograph on maple from 1960 is probably the first ever in Europe about this genus. Regarding influences on soil, he quotes the two passages of Köstler word by word except for the comment on litter material in sheds. Hoffmann adds that because decomposing organisms need nitrogen for their development, the nitrogen content of leaves is an important factor for the rate of decomposition. By use of Ebermayer's values for nitrogen content, reduced to an accuracy of one decimal, Hoffmann shows that leaves of sycamore maple are only surpassed by those of grey alder in this respect. Other factors also play a part, like root depth, bedrock, soil structure, and acidity. Because of the rather easy leaf decomposition and the deep and powerful root system, *both* sycamore maple and Norway maple have very valuable qualities for influencing humus conditions and thus for improving soil and yield according to Hoffmann (1960: 67–69).

What about the Swedish colleagues Almgren et al. (1986: 87), who plainly report that leaf litter of maple decomposes easier than that of beech and oak, but still does not belong to the very best species in this context? They make this claim without referring to anyone, but it is very likely that it has found its way from the tentative species list of Aaltonen (1948: 174). Birch, aspen, alder, and conifers are all outside the scope of Almgren et al. (1986). If we subtract these species from Aaltonen's list, we end up with the following ranking with regard to easy litter decomposition: ash and elm; maple and linden; beech and oak.

In conclusion, the enthusiastic Norwegian textbook statement that Norway maple strongly improves soil properties is very likely based on secondary sources that prove much less scientifically reliable than they might appear. Børset (1985: 483) does include Aaltonen (1948) as an important source for preparing the textbook, but has not used it in the passage about maple. The passionless Swedish textbook statement is in perfect agreement with the species ranking that Aaltonen (1948: 174) made from a substantial review of scientific results up to that time. Aaltonen's reservations, however, are no longer included.

The Case of Liberalism and Forestry Restrictions

It would be cowardly not to include one of my own slips of the pen over the years I have been dealing with forest sciences. In 2012 I was an invited speaker at a Nordic seminar of forestry history in Denmark and gave a presentation about Norwegian outdoor life and forestry in the 20th century. My original manuscript with its footnotes and references was rather long and I planned to elaborate it further for final publication. Therefore I made an shortened version as a conference paper for the Danish Forestry and Hunting Museum to be published on its webpage, including pictures but omitting notes and references (Frivold, 2012). In a brief introductory paragraph (p. 2), I stated that *all royal restrictions on private forest management in Norway had been sacrificed on the altar of market liberalism between 1795 and 1836*. When finishing my presentation, some Danish colleagues in the audience objected that on the contrary, the Dano-Norwegian monarchy had imposed more *strict* regulations on forestry in Denmark during the last decades of the union (as Scandinavian readers will know, the Monarchy lost Norway in 1814). Why should the ideals of market liberalism form the forest policy of the monarchy for Norway and not for Denmark, when the Government in Copenhagen was worrying about future supply of accessible and useful forest products in all parts of the Monarchy?

I had based my somewhat catchy statement on an outline of the history of the forest administration in Norway from the report of the Forestry Commission of 1849 (Indberetning … , 1850: 111–112), which was the closest I could find to the time period in question, and a book about Norwegian forestry history by professor of forest technology, forest policy and forestry history at the Agricultural University of Norway, JULIUS K. SANDMO (Sandmo, 1951: 143). Both sources put the 1795 repeal of most restrictions to forestry in Norway in the context of the trend towards market economy, which, according to Sandmo (l.c.), led to a repeal of provisions to forestry in all of Europe – except Denmark.

It is likely that the answer lies in the Danish National Archives. Regrettably, time and travel costs do not permit me to search there myself within the scope of the present article. However, OVE FELDBÆK (1936–2015), a professor of economic history in Copenhagen, studied documents that lead to the repeal of 1795 and concludes that a major reason for it was persistent pressure from stakeholders of the forestry industry in Norway (Feldbæk, 1998: 87, 224). The official reason was that the restrictions had not worked according to their purpose (Timme, 1842: 249–250).

According to Sandmo (1951: 144–145) and Fryjordet (1994: 493, 532), the Norwegian Parliament repealed the last surviving restrictions on forest management in 1836 in line with the view that property rights should be inviolable. By this vote, private owners were granted a complete freedom to manage their forests at their own discretion. It is easy to put this in the context of market liberalism.

In 2013, the Norwegian Parliament made all its proceedings back to 1814 available on the Internet in scanned versions. As I read the proceedings in question (Fig. 1), a major underlying reason for the 1836 repeal of remaining laws regarding forestry was the lack of a professional, trustworthy forest supervision. The laws included the Royal Ordinances of 5th December 1685 and 21st September 1750; the former forbidding forest owners to exploit their forests excessively, and the latter, renewed in 1812, banning the lease of forests to others for a period of more than one year (see Schou, 1795a: 523–524, 1795b: 191–192; Timme, 1842: 542).

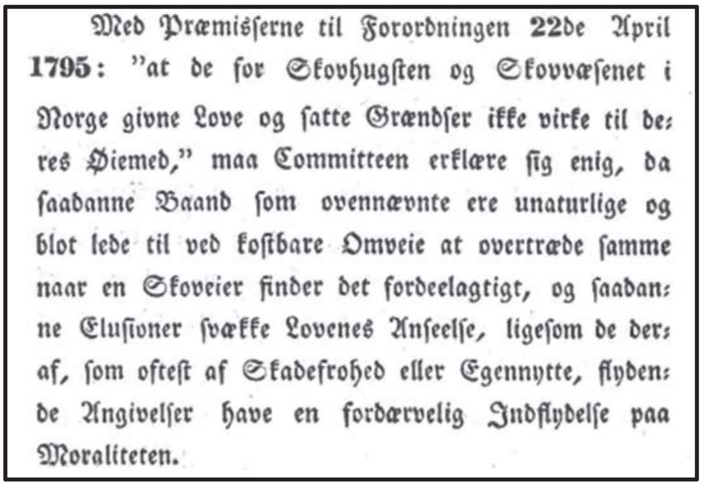
Med Præmisserne til Forordningen **22**de April **1795**: "at de for Skovhugsten og Skovvæsenet i Norge givne Love og satte Grændser ikke virke til deres Øiemed," maa Committeen erklære sig enig, da saadanne Baand som ovennævnte ere unaturlige og blot lede til ved kostbare Omveie at overtræde samme naar en Skoveier finder det fordeelagtigt, og saadanne Elusioner svække Lovenes Anseelse, ligesom de deraf, som oftest af Skadefrohed eller Egennytte, flydende Angivelser have en fordærvelig Indflydelse paa Moraliteten.

Fig. 1. Primary sources are not always particularly easy reading. This passage from the proceedings of the Norwegian Parliament from 1836 reads, in my translation: The [Parliament] Committee must declare that it agrees with the premises for the Ordinance 22nd April 1795 'that the provided laws and prescribed limits for forest exploitation and forest management in Norway do not work according to their purpose', because such restraints as the above-mentioned are unnatural and only lead to their own infringement by way of costly circuits when a forest owner finds it advantageous, and such elusions weaken the esteem of the laws, like the denunciations, usually from malice or self-interest, emerging from them have a pernicious influence on morality. (Stortingsforhandlinger (1836-37), 4. del, O. 4.5.1836, pp. 420–421)

The Parliament Committee in charge of the matter concluded that with some economical effort, a forest owner could elude these laws. Dependent on the kind of offence, violations were subject to a fine, half of it paid to the informer, or punishable by royal confiscation of timber and land. Thus, those informing on forest owners were usually motivated by self-interest or malice rather than by concern about future forest resources for the nation (Stortingsforhandlinger, 1830, 1836–37).

In conclusion, the transition from mercantilism to market liberalism formed only a part of the reasons for repealing royal regulations on private forest management in Norway between 1795 and 1836. My catchy statement was based on two secondary sources, and the fact that the oldest source was written no more than 55 years after the 1795 event does not make it less secondary. I was proud of the statement because I thought it was well written, but I will exclude it in the final version of the paper (Frivold, *in prep.*).

It is not without reason that historians tend to spend time in archives, like many forest scientists tend to spend time and money on experiments in the field or in the lab.

Discussion

The Limitations of Language

All three cases have their starting point in publications in Norwegian intended for a Norwegian or Scandinavian audience. The two textbooks of silviculture were authorized by the Ministry of Agriculture for use in forestry schools and were also used at the university level. Common practice was that authors asked friends and colleagues to read the manuscripts before they were submitted to a publisher. A serious publisher will also give comments to the text. The conference paper had not been edited.

English as a universal language of science is a fairly recent phenomenon. Up to the 1980s, it was common to publish papers and treatises in many fields of forest sciences in the national language, possibly with an English summary or abstract. And it is still common to do so in forestry history, where hardly any of the primary sources are in English anyway unless you are dealing with English-speaking countries. Consequently, most of the references in the present paper are in Norwegian, Danish, Swedish or German. A reviewer who wants to test if my conclusions are reproducible must be able to read these languages, even if the text should happen to be printed in a Fraktur typeface (as in Fig. 1).

The Effect of Peer Reviewing

None of my cases included statements from peer-reviewed journals, the most creditable publishing channel for scientific papers in recent times. Peer review is often performed with double blinding, that is, the identity of authors is removed from the manuscript and the identity of the reviewers is hidden for the authors; all done to avoid personal biases. However, in narrow research fields confined to specific local settings, blindings can be illusory.

Godlee, Gale & Martyn (1998) made an experiment to examine the effect of the quality of peer review of blinding reviewers to the authors' identities, and of requiring reviewers to sign their reports. With the authors' permission, a paper already peer-reviewed and accepted for publication by the *British Medical Journal* was altered to introduce 8 weaknesses in design, analysis, or interpretation. All reviewers whose speciality seemed broadly relevant to the subject of the paper were selected from the database of the journal; 420 reviewers were invited to comment on the manuscript and 221 (53%) returned a report. The mean number of weaknesses commented on was 2. Only ten per cent of the reviewers identified four or more of the eight implanted areas of weakness. Neither blinding reviewers to the authors's identities nor requiring them to sign their reports had any significant effect on the rate of detected errors.

Peer reviewing increases the chance for detecting doubtful statements before a manuscript is published, but is no guarantee for a perfect product. As Benos et al. (2007: 151) put it: *While peer review is often viewed as the gatekeeper to the realm of truth, a staff of editors and reviewers cannot make that distinction in a few months*.

Moral

Do not take everything you read in the specialist literature for granted. We do our best within our time limits, but no one is perfect.
A statement supplied with a reference needs not be more reliable than the source the author referred to.

The context and limitations of experiments and observations are easily lost on the way from the primary source to secondary and subsequent sources, for the sake of brevity and clarity.

Authors of professional papers should use references in text whenever feasible. If the author-year system might disturb your target audience, use footnotes or endnotes – provided that your publisher or supervisor permits it. When citing statements from large works, state the appropriate page number(s).

With repeated revisions, the number of errors in a manuscript asymptotically approaches zero.

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18. The European forest research family - resilient and ready for the future?

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Abstract
In this paper, the future success of the European forest research family is considered in the light of three factors: research capacities, collaboration and links of research to policy and practice. European forest research capacity is assessed based on surveys on staff, funding and publications. Collaboration is reflected by frameworks for networking and the results of collaboration in form of joint publications. Finally, needs for improving interaction between science, policy and practice are addressed.

Keywords: forest research capacity, research networking, science-policy-practice interaction.

1. European Forest Research Family

1.1. Staff and funding

The core of the European forest research family consists of the staff conducting forest research in the National Forest Research Institutes (NFRIs). According to the survey conducted by EFI (Pelli 2008), these institutes have academic staff altogether 3,600 labour years (Fig. 1). It was also estimated that the same amount of researchers exist outside NFRIs, mainly in the Universities. Respectively, the total number is 7,200 academic forest researchers in Europe.

According to the EFI survey, the total funding of NFRIs in Europe was 310 Million Euros in 2007, giving an estimate of 620 Mill. for all organisations. There are no reliable numbers for Europe from recent years, but Foresterra ERA-Net survey in 8 Mediterranean countries (Scarascia et al., 2014) indicates that the research capacity outside NFRIs may be higher than assessed in EFI survey. Respectively, the total funding for forest research in Europe may then be higher than 620 Million Euros per year. It also should be kept in mind that Euros and person years are always approximates for the reason that the concept of "forest research" varies between respondents of the questionnaires.

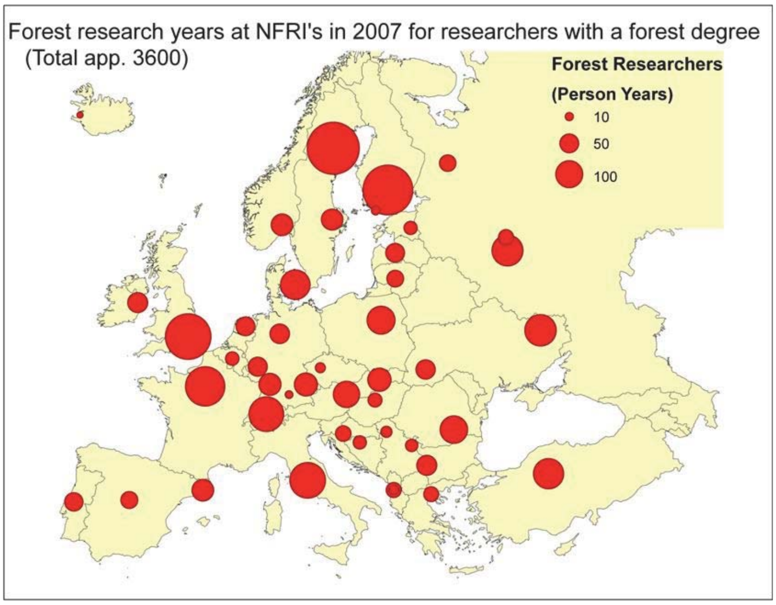

Fig. 1. Forest research capacities of NFRIs (Pelli, 2008).

The Sumforest ERA-Net survey found that 9% of funding in participating institutions was coming from international sources (Svensson and Perhans, 2015), while in the earlier EFI survey (Pelli 2008) that number was 8%. Even if the development of total forest research funding remains uncertain, it is encouraging that the share of international funding has been slightly increasing.

1.2. Volume of research publications

Another approach to assess research capacities has been taken by INRA by carrying out a global bibliometric analysis of forest research (Tatry and Leiser, 2012). Results were later declined at European countries scale (Amm, 2014, Paivinen et al. 2014) consisting finally of 55,700 publications from 2002 to 2011. The search was realized in the Web of Knowledge WoK® (Thomson Reuters, 2016), based on the Scientific Citation Index Bibliographic databases. Forest research in the study was defined by 'modular thematic equation', including more than 100 forest related keywords defining which publications belong to the category "forest research". Number of publications per country or per institute included all papers having one author from respective country or institute. Note that this is corresponding the way institutes or countries express their publication statistics, but adding up the country numbers would result some doublecounting.

The most active publishers come from Germany, UK and France, altogether 900 p.a., 780 p.a. and 690 p.a. publications, respectively, during the 10-year period (Table 1). Of the countries where number of publications is higher than 200 p.a., the average annual growth rate for Spain, Italy, Switzerland and Poland was highest, more than 10%. This indicates that the investment in forest research of these countries has increased during the period 2002-2011. Other countries, such as Croatia, Romania, Serbia, Lithuania and

Latvia also have high growth rate, which can be partly explained by the low number of publications in the beginning of the period.

According to the bibliometric survey, the most active institutions are the Swedish University of Agricultural Sciences (221 publications p.a.), INRA (181), University of Helsinki (163), the Finnish Forest Research Institute (148) and Russian Academy of Sciences (148). It also can be noted that the 30 most active institutions in Europe publish 30% of all papers.

According to the INRA study, the absolute number of forest research publications in Europe has almost doubled during the 10-year period, being 7600 p.a. in 2012. In addition, the share of forest publications of all indexed scientific publications has slightly increased.

However, in the interpretation of the figures describing the volume of publications by countries and by institutions, it must be kept in mind that the results reflect the original set of keywords used in datamining.

Table 1. Number of forest research publications during the period 2002-2011 where at least one author is from respective country. AAGR= Average annual growth rate. (Amm, 2014).

Countries	Number of publications	% of publications	AAGR scientific output
Germany	8979	13,05 %	5,67
United Kingdom	7779	11,31 %	6,07
France	6902	10,03 %	7,65
Spain	5992	8,71 %	12,93
Sweden	5015	7,29 %	3,36
Finland	4709	6,85 %	3,51
Italy	3986	5,79 %	12,14
Switzerland	2714	3,95 %	11,48
Netherlands	2560	3,72 %	8,26
Poland	2492	3,62 %	13,02
Russia	2094	3,04 %	4,59
Belgium	2092	3,04 %	9,40
Austria	1879	2,73 %	6,26
Portugal	1632	2,37 %	15,44
Norway	1537	2,23 %	8,06
Denmark	1396	2,03 %	4,86
Czech Republic	1345	1,96 %	10,75
Greece	811	1,18 %	7,60
Slovakia	673	0,98 %	0,82
Estonia	588	0,85 %	10,49
Hungary	572	0,83 %	12,68
Croatia	538	0,78 %	27,31
Slovenia	487	0,71 %	17,29
Ireland	375	0,55 %	8,01
Romania	364	0,53 %	26,28
Serbia	288	0,42 %	32,59
Lithuania	273	0,40 %	22,31
Bulgaria	226	0,33 %	9,74
Ukraine	173	0,25 %	11,20
Latvia	107	0,16 %	22,03
Luxembourg	67	0,10 %	Undefined
Belarus	62	0,09 %	Undefined
Bosnia	60	0,09 %	Undefined
Macedonia	22	0,03 %	Undefined
Albania	0	0,00 %	Undefined
Motenegro	0	0,00 %	Undefined
Moldavia	0	0,00 %	Undefined

2. Networking

2.1 Infrastructures for networking

Resilience of forest research is depending on ability of the research community to cooperate and share experiences with other researchers, institutes and countries. The forest research family has long tradition, since 1892, in cooperation and networking through International Union of Forest Research Organisations (IUFRO). With 700 member organisations in more than 100 countries it is the only global level network of its kind. In Europe, COST is the longest running framework, since 1971, supporting trans-national cooperation among researchers and scholars. COST actions are networks centered around nationally funded research projects in fields of common interest. Today, COST has 20 ongoing actions within forest sector.

The European Forest Institute (EFI) was established in 1993 to promote research cooperation and networking. With its 25 members countries and 115 member institutions, five regional offices and three project centres cross Europe, it is today in excellent position to offer services of cooperation to researchers, institutes and European countries. The Forest –Based Technology Platform (FTP) was established in 2005 when forest owners, woodworking industries and pulp&paper industries came together to share a common goal: to advance the competitiveness of the European forest sector. Thanks to FTP and its Strategic Research Agenda, the EU contribution to the forest sector research has increased 100%, totalling 450 Million Euros from the EU during the past 5 years. There are also regional networks for collaboration, such as SNS (Nordic Forest Research Co-operation Committee), financed by Nordic Council of Ministers.

These examples demonstrate that for forming research consortiums and carrying out joint projects, infrastructures exist for researchers and institutes willing and able to utilize them.

2.2 *Joint publications*

The INRA bibliographic study also provides a tool to assess collaboration through joint publications. Collaboration is measured by number of publications with authors from more than one institute. The first observation is that the most active collaborations are domestic. SLU in Sweden has strongest links to the Universities of Umeå and Lund, INRA in France to University of Lorraine, Cirad and CNRS, Metla in Finland to the Universities of Helsinki and Eastern Finland. In Switzerland, ETH Zurich and WSL have formed closest collaboration.

When looking at international collaboration, and excluding the numbers from small research countries, highest collaboration rate is in Netherlands, where 72% of publications has an author also from outside Netherlands. Countries like Switzerland, UK, Denmark and Austria have more than 60%. Germany and France have 58%, Norway 57%, Sweden 46% and Finland 37%. The lowest rate is in Poland (26%). The collaboration at the country level is depicted in Figure 2.

The most voluminous institutional and international collaborations in Europe are as follows: Swedish University of Agricultural Sciences (Se) mostly collaborates with the University of Helsinki (Fi), Metla (Fi) and INRA (Fr). INRA collaborates especially with the Wageningen University and Research Centre (Nl) and CNR (It). Wageningen strongly collaborates also with the Max Planck Society (De).

The bibliometric analysis by INRA presents an interesting tool to measure international collaboration in forest research. This creates additional value to the other indicators describing international collaboration, such as international funding, participation to the international projects and to staff mobility programmes.

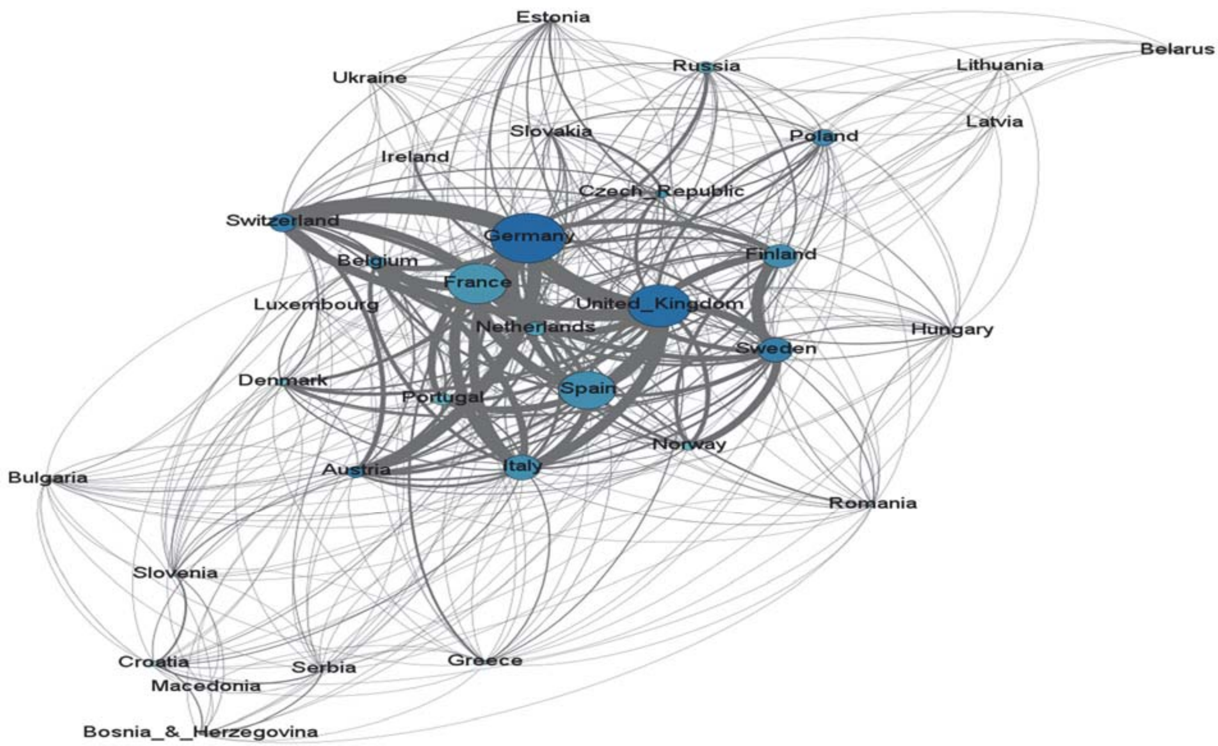

Figure 2: International collaborations network. Node size depends on the number of collaborations per country. Link size depends on the intensity of collaboration between the countries. Note that, for a better graphical visualization, only links between countries that collaborate at least 4 times are drawn. (Amm, 2014)

3. From science to policy and practice

3.1. Policy statements

The utilization of scientific information and knowledge as a basis for policy making has been generally acknowledged. In the main international forest policy process in Europe, the Ministerial Conference on the Protection of Forests in Europe (MCPFE), already the first resolutions in the 1990 Strasbourg conference highlighted the importance of research. In 2007, the Warsaw declaration demanded “effective measures to improve understanding between policy makers, practitioners and the scientific community in order to better use scientific knowledge and research results relevant to forests and the forest sector as a sound basis for decision making.” (Forest Europe, 2015).
The EU forest strategy gives to the Commission a role to “assist Member States and stakeholders in transferring technological and scientific knowledge to forest practice and the market.” (European Commission, 2013). At the national level, both the National Forest Strategy for Finland (Ministry of Agriculture and Forestry, 2015) and the

Bioeconomy Strategy for Finland (Ministry of Employment and Economy, 2014) underline the need to boost the socio-economic impact of forest research by developing decision support and utilizing the new information and knowledge to create novel products and services.

It can be concluded that there are several initiatives both at the European and national levels in the fields of governance of forests and the environment, signalling the need to further improve the science-policy-practice interface. However, the implementation of these principles varies very much.

3.2. Examples of science-policy-practice interfaces

A well known process of science-policy interaction is the International Panel on Climate Change (IPCC), which was established in 1988 under the United Nations. It aims at synthesizing scientific information on climate change and presenting it to decision makers in a digestible format. Other examples include The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES 2015) and the Science for EU Environment Policy Interface (SEPI 2015).

The Global Forest Expert Panels (GFEP 2015) initiative was launched in April 2007 to provide objective and independent scientific assessments of key issues to support more informed decision making at the global level. Under the coordination of IUFRO, thematic reports on the Adaptation of Forests and People to Climate Change, the International Forest Governance, Biodiversity, Forest Management and REDD+ and Forests and Food Security have been published.

In the Forest Europe (formerly MCPFE) process, the scientific community has been one of the participants in the Multi-stakeholder Dialogue and in the work of Expert Level Meetings (ELM). However, Mayer (2015) concludes that in Forest Europe, "there is no science mechanism for systematic knowledge input," and recommends that one be established. The Forest Based Technology Platform, which is an industry driven EU initiative, has taken the role of identifying the most relevant research topics contributing to the EU political goals towards a sustainable and competitive forest sector in Europe.

In Finnish science policy, a question of the utilization of research as a basis for strategic national decisions in various fields has been recently raised. In the report on the state of Finnish forest research, Seppälä (2014) argues that the main problem in national research is not scarcity of resources, but the slow and low implementation of the results. In order to address these needs, Tapio Ltd. has launched a project to develop a pilot version of a science-policy-practice interaction for the forest sector in Finland (Päivinen and Toivonen, 2015). The aim is to create a flexible arrangement for bringing the research results faster and more efficiently for the use of decision makers. It is based

on the concept of topic-wise, ad-hoc panels as meeting fora for science, practice and policy experts of the topic in question. The selection of relevant topics for the panel is based on scenarios on expected future and timing of the national and international political processes regarding the topics.
The multidisciplinary scientific panel will formulate the synthesis reports, which may include a comprehensive review and/or a short policy brief. The dissemination and feedback to science will be via events, seminars and meetings organized by the actors and stakeholders in the field. The first pilot concentrated on availability of timber from private forests in Finland (Päivinen et al. 2016)

In formulating instruments for science-policy-practice interactions, the most important elements as seen in the Future Forests-project in Sweden are as follows (Nordin, 2014):

- Actors must engage in defining the question that needs to be answered,
- Interaction must be formalized – to some extent – to assure transparency, and
- Interface processes may be owned by interface organizations if these can be seen as trustworthy by all actors.

4. Future of forest research

According to the UN estimates on global population growth, by 2030 we need 50% more energy and food and 30% more fresh water. Their sustainable production are threatened by climate change and shifts in socio-economic conditions.

The needs for producing and using raw materials more efficiently are addressed in today's policy discourse. At the national and EU levels circular economy and bioeconomy are regarded as solutions to these demands. Forests are especially in Northern Europe important sources for raw material for traditional and new products of bioeconomy. In tackling these challenges, forest research, including its political and socio-economical dimensions, will be of uttermost importance.

The Forest research family - in collaboration with scientists of other fields - will have a demanding job to find solutions to the problems which occur at the global, regional and local levels. In order to maintain the ability of responding to the needs for better scientific information for decision-making, forest research capacities should be guaranteed, and if necessary, directed to the fields of most importance. In order to increase the impact of forest research findings, interaction with policy makers and practitioners should become part of everyday work of researchers and scientific institutions.

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