Scandinavian Forest Economics
No. 48, 2018

Proceedings of the Biennial Meeting of the
Scandinavian Society of Forest Economics
Helsingør, Denmark, May, 2018

Jette Bredahl Jacobsen, Astrid Hagelund, Bo
Jellesmark Thorsen (eds.)
Proceedings of the Biennial Meeting of the Scandinavian Society of Forest Economics Helsingør, Denmark, 22 – 25 May, 2018

Scandinavian Society of Forest Economics

ISSN xxx-xxxx
SCANDINAVIAN SOCIETY OF FOREST ECONOMICS

SSFE BOARD:

Denmark
Member: Bo Jellesmark Thorsen (chair) - bjt@ifro.ku.dk
Deputy: Tove Enggrob Boon - tb@science.ku.dk

Finland
Member: Teppo Hujala - teppo.hujala@luke.fi
Deputy: Katja Lähtinen - katja.lahtinen@uva.fi

Norway
Member: Hans Fredrik Hoen - hans.hoen@nmbu.no
Deputy: Even Bergseng - even.bergseng@nobio.no

Sweden
Member: Camilla Widmark - camilla.widmark@slu.se
Deputy: Peichen Gong - peichen.gong@slu.se
Preface

The Biennial Meeting of the Scandinavian Society of Forest Economics (SSFE) for 2018 took place in Helsingør during the days 22nd-25th of May 2018. Some 70 researchers from around the world gathered to celebrate the 60th anniversary of the SSFE. They enjoyed four wonderful, sunny and warm days together in beautiful surroundings, presenting and discussing ongoing research, and engaging in numerous discussions in breaks and during the field trip. It is a sign of its quality that it remains vigorous and is able to attract also a large number of young researchers in the field. This will keep the SSFE alive for many decades to come.

On behalf of the SSFE, I thank our four keynote speakers who were all selected to highlight the science-policy interface: Associate Professor Laura Bouriaud, University Stefan cel Mare Suceava, Romania; Professor Sven Wunder, Centre for International Forest Research/European Forest Institute, Spain; Professor Eirik Amundsen, University of Bergen, Norway; Professor Carsten Rahbek, Centre for Macroecology and Climate Change, University of Copenhagen, Denmark.

In full compliance with tradition, the programme also included a within-programme excursion. The theme was the science and policy processes underlying current efforts to enhance biodiversity protection in forest and nature areas in Denmark. The SSFE is grateful to Professors Niels Strange and Carsten Rahbek and WWF expert Thor Hjarsen, for setting up the programme and giving the participants an interesting insight into links from scientific analyses to practical in-the-field implementation.

This Biennial Meeting followed up on the tradition of appointing worthy Honorary Fellows, which was established in Lom, Norway in 2008. This year four new Honorary Fellows joined the ranks: Professor Ole Hofstad and Professor Birger Solberg, both at Norwegian University of Life Science; Professor Olli Sastaamoinen, University of Eastern Finland and Professor Richard J. Brazee, University of Illinois at Urbana-Champaign. Furthermore, as a first, the SSFE also awarded a price for the best PhD presentation during the conference. This was awarded to Ms. Noora Miilumäki. A Diploma and a small gift followed the appointment.
The organisers and the participants wish to express their gratitude to SamNordisk Skogforskning (SNS) under the Nordic Council of Ministers for its indispensable financial support to the Biennial Meeting. We also wish to thank Ms. Charlotte Bukdahl Jacobsen for her great effort in making all practical and organisational matters work so smoothly. We appreciate that Ms. Charlotte Bukdahl Jacobsen, Ms. Astrid Hagelund and Professor Jette Bredahl Jacobsen, have edited this volume of the Proceedings series of the SSFE.

Frederiksberg, November 2018,

Bo Jellesmark Thorsen
## Contents

Preface ........................................................................................................................................ 1

Honorary Fellows .......................................................................................................................... 9
  Olli Saastamoinen ....................................................................................................................... 10
  Ole Hofstad ................................................................................................................................ 14
  Birger Solberg ............................................................................................................................ 18
  Richard J Brazee ......................................................................................................................... 25

SSFE 2018 PhD Presentation Prize .............................................................................................. 28
  Noora Miilumäki ....................................................................................................................... 28

WG 1: Business Economics of Forestry and Forest Management and Planning...................... 29

Full length papers .......................................................................................................................... 29

  1. Optimal rotations with declining discount rate: searching for a search algorithm .................. 30
  2. Assessing the sensitivity to forest owner rationality of a Swedish forest partial equilibrium model ........................................................................................................ 43

Abstracts ...................................................................................................................................... 47

  3. Determinants of Nonindustrial Private Forest owners’ Willingness to Harvest Timber in Norway ......................................................................................................................... 48
  4. Optimal harvest strategy for even-aged stands with price uncertainty and risk of natural disturbances ......................................................................................................................... 49
  5. The effects of altered survival probabilities on economically optimal species compositions – an example from Germany using a pan-European dataset ........................................................................ 50
  6. The economics of dedicated hybrid poplar biomass plantations in the western U.S. ................................................................................................................................. 52
  7. Economic impacts of increased forest conservation and utilization of woody biomass for energy in Europe: an analysis with a new forest sector model – EUFORIA ........................................................................................................ 53
  8. Regulation of Moose Hunting in Scandinavia ......................................................................... 55

The Implications of Age-Structured Models .............................................................................. 55
10. IDENTIFYING ISSUES RELATED TO ADDITIONALITY AND LEAKAGE IN VOLUNTARY FOREST CARBON OFFSET PROGRAMS ............................................. 57
11. EVALUATING FOREST CARBON PROJECTION BIAS RELATED TO SPATIAL DETAIL .................................................................................................................. 58
12. Empirical analysis of forest tree species composition on financial risk and economic return based on the results of a forest accountancy network ........... 60
13. Competitive harvest in age-structured forests ............................................................ 62
14. Optimal rotation sequence of Norway spruce in a changing climate .................. 63
15. Digital services and forest information offered via Metsään.fi portal as forest owners’ decision support ............................................................. 65
17. Economic evaluation of growth effects in mixed forest stands: A simulation study for Norway spruce and European beech in Southern Germany ............................................ 69

WG 2: Forest Policy ........................................................................................................... 71

Full length papers ............................................................................................................. 71
18. Societal costs of urban tree diseases ...................................................................... 72
19. Caveats about CAVAT what does its “tree amenity value” actually measure? .................................................................................................................. 87
20. Influencing economic policy: Experiences from the Danish Economic Councils ........................................................................................................... 103
21. Estimating the Benefits of the Interrelationship between Climate Change Adaptation and Mitigation – A Case Study of Replanting Mangrove Forests in Cambodia ................................................................. 115

Abstracts .......................................................................................................................... 162
22. Economic and environmental impacts of the EU forest conservation and wood for energy policies .................................................................................. 163
23. “Being one of the boys” - perspectives from female forest industry leaders on gender diversity and the future of Nordic forest-based bioeconomy ................................................................. 164
24. Not so biocentric – An evaluation of benefits and harm associated with acceptance of forest management objectives among future environmental professionals in Finland. ............................................................... 166
25. Time to evaluate forest owner typologies? ........................................ 168
   Insights from Sweden........................................................................... 168
26. How do forest owners develop trust in their timber procurement organization? ................................................................. 169
27. Forest owners’ attitudes to climate change and climate change adaptation in Norway and Sweden........................................... 171
28. Environmental vs forestry views on and stakeholders’ satisfaction with recent Estonian forest policy processes: .................................................. 173
   Estonian ‘Forest war’ 2016 - 2018 ......................................................... 173
29. Growing relevance of open foresight by forest industry companies in transformation to the circular bioeconomy ................................. 175
30. Future of forest bioeconomy in the eyes of Finnish young forest owners: a research agenda................................................................. 177

WG 3: Forest Industry and Forest Products Markets.................................. 179

Full length papers.................................................................................. 179


Abstracts .............................................................................................. 186

32. Perspective on Sustainable Development by Non-Industrial Private Forest Owners and Sawn Wood Customers .......................... 187
33. Sustainable urban development ....................................................... 189
   Market development for wood construction ..................................... 189
34. Perceptions of wood usage acceptability among consumers –........ 191
   Results on systematic literature review ............................................ 191
35. Diversification of the forest industries: ........................................... 192
   Role of new wood-based products .................................................... 192
36. Structural change of forest industries and its impact on forestry carbon balance in Finland ................................................................. 193
37. Consumer choices and bio-based products .......................................................... 195
38. Wooden Multistory Construction in Finland: Perceptions from municipal civil-servants on the benefits of wood and barriers to project implementation .............................................................................................................. 197
39. The use of networks in international opportunity recognition: A multiple case study on Finnish wood products industry SMEs ................................................................. 199
40. Future scenarios and pathways for utilization of wood product industries by-products in Finland ........................................................................................................... 200
41. Sustainable forest-based bioeconomy: A case of biorefinery ...................... 202
42. Do institutions in the housing markets cause delays in detached house building processes? – Views of Finnish homebuilders ........................................................... 204
43. A network analysis of Finland’s forest bioeconomy .................................. 206
44. End-user expectations and perceptions of living in a wooden multi-story construction - A case study ................................................................. 208
45. Services and evolving production of wood-based solutions – higher value added, new normal or business as usual? .......................................................... 210
46. Business Model Dynamics in Swedish Wood Construction & Manufacturing Industry .............................................................................................................. 212

WG 4: International Forestry .................................................................................. 215

Full Length papers ................................................................................................. 215
47. Carbon sequestration payments in Miombo woodlands when transaction and inventory costs are included ........................................................................ 216
48. Management practices of selected exclosures in the Tigray, Ethiopia... 231

Abstracts .............................................................................................................. 240
49. Charcoal Production, Trade and Consumption in Tanzania: Analytical Review of Previous Studies .......................................................... 241

50. Spatial and seasonal patterns in incomes from environmental products extracted in community-managed forests in Nepal ........................................ 243
51. A typology of environmental product periodic markets in the Himalayas ............................................................... 245

Poem ..................................................................................................................... 246
List of participants .............................................................................................. 254
Honorary Fellows
Olli Saastamoinen began his studies in forestry in 1965 in the Faculty of Agriculture and Forestry at the University of Helsinki (UH) and got Forester’s title in autumn 1968. Olli has said that the short graduation time was not due to his diligence but rather due to the forestry program: ’Social economics of forestry’ students had less obligatory field courses than silviculture or forest technology students.

Interest in Russian language brought him a scholarship to Leningrad Forest Technical Academy in 1968–1969. This was the root for the later cooperation with Russian forestry universities and research institutes, yielding several joint symposium proceedings and articles related to forestry, forest policies and economics during the transition period. The cooperation influenced the SSFE meetings, broadening the geography of the participants from outside the Scandinavia. The major single outcome was ”Forestry of the Republic of Karelia” (Myllynen and Saastamoinen 1995) followed by important scientific articles in collaboration with Tatu Torniainen and e.g. EFI well-known professor A.P.Petrov (Torniainen et al. 2006).

The scholarship organized by professors Päiviö Riihinen and Matti Keltikangas (UH forest economics) made Olli to investigate forest recreation in Saariselkä forest and fell area in Lapland. The major method was interviewing tourists, hikers and skiers in the wilderness huts, where tired visitors having arrived to rest were in this way made even more tired.
The licentiate thesis on "The Recreational use of Saariselkä-Itäkaira area" (Saastamoinen 1972) was finalized at the Department of Forest Economics of the Finnish Forest Research Institute (Metla). Olli was nominated as the first researcher of multiple use forestry at Metla in 1973, to work in the Rovaniemi research station in Lapland. New topics such as the interactions between reindeer husbandry and forestry (Saastamoinen 1978), and the economic valuation of forest uses in Finnish Lapland (Saastamoinen 1977) postponed the dissertation "Economics of Multiple Use of Forestry in Saariselkä Forest and Fell Area" (Saastamoinen 1982). It included an attempt to conceptualize multiple use forestry from the angle of production theory of R. Frisch. A possibility for post-doctoral studies was granted by Kellogg’s Foundation at the University of British Columbia.

"Multiple Use Forestry in the Scandinavian Countries" (Saastamoinen et al. 1984) was the first State-of-the-art compilation of research in this field only, based on the SSFE-seminar at Saariselkä. It was followed many other similar meetings and publications showing that multiple use forestry research and practice was not any more a sidetrack of forest research although not yet a boulevard for all.

In 1986 Olli left the position of the head of the Rovaniemi research station to become an associate professor of forest economics at the later Faculty of Forestry, University of Joensuu. Teaching included also forest policy and gave possibilities to enlarge the research and teaching fields into areas such as social sustainability, the weak roles of multiple use in forest policy and forest legislation, and tropical forestry. At that time, Olli also participated to an early development of the new area of forest ethics, in which he contributed on later decades on European and IUFRO arenas.

When SSFE had in 1996 its biennial meeting in Mekrijärvi, the research and field station of the University of Joensuu, Olli introduced his matrix framework for the evaluation of total valuation of forests in Finland (Saastamoinen 1995). In 1998 Olli was promoted to become a full Professor, and in 2004 he was invited to become the member of the Finnish Academy of Science and Letters. He acted the Dean of the Faculty of Forestry in 2003–2007.

When Olli Saastamoinen started his multiple use forestry research some 50 years ago, his interests were focused on the topics and themes that have for
a long time been a part of common, often everyday activities of people visiting forests and adjacent areas for walking, hiking, and skiing, for collecting berries and mushrooms, or travelling further away to do more or less the same in the more attractive landscapes close to touristic services. What was new within forest sciences and forestry was not the contents of activities as such but the new concepts - multiple use of forests, multifunctional forestry - which were needed to make forestry people to observe, understand, manage and protect the larger complexity of values and possibilities, which forests are able to produce or maintain for the human welfare and common good.

In the turn of century, a new paradigm – ecosystem services (ES) – entered the arena of all living nature, and not least to that of forests. Olli Saastamoinen was again among the first to see the potential of the concept (Matero et al. 2003) to see the possibilities the ES concept may provide. In 2012–2014 he led a research group funded by The Maj and Tor Nessling foundation to make, among other things, the first attempts for systematic identification and classification of the forest, agro-, water and peatland ecosystem goods and services of Finland based on the Common International Classification of Ecosystem Services (CICES); see Kosenius et al. (2013).

Selected publications


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 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 scientific works is as follows:

Ole Hofstad - Selected publications

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: Leader of Scandinavian Society of Forest Economics (1988-1990), 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 active in research 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 publications) 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 40 of his scientific works is as follows:


Richard J. Brazee, or Dick as he calls himself and is we know him in the SSFE, obtained a BA in Economics and Mathematics from the University of Michigan in 1979. He spend 1979-1980 as a Fulbright-Hayes Fellow at University of Sydney, Australia, studying econometrics and operations research. He returned to complete and obtain a master degree in Mathematics in 1983 at University of Michigan. Dick has always had an interest for the way we use natural resources. To pursue this interest he enrolled as a PhD student to pursue this interest, and in 1987 graduated with a PhD in Natural Resource Economics from University of Michigan.

Since then, Dick Brazee has made a significant mark in the field of forest economics. For those of us who have studied the optimal management of forest stands when prices are uncertainty, one paper stands out. In 1988, he and Bob Mendelsohn published a paper, “Timber harvesting with fluctuating prices”, in Forest Science introduced the concept of reservation prices and showed how forest owners facing stochastic prices would choose a set of optimal reservation prices, prescribing at what prices to harvest each age class, for given information about future price distributions. This paper paved the way for numerous studies implementing various extensions and debating the wider market equilibrium implications of these dynamics. Dick contributed to this expansion of the forest economics literature too, with important contributions like Brazee and Mendelsohn (1990), Forboseh, Brazee and Pickens (1996), Brazee et al. (1999) and Brazee and Bulte (2000).
Perhaps little known to forest economists, Dick has also made important contribution to marine economics, contributing e.g. a seminal paper on marine reserves (Holland and Brazee 1996) and he has contributed to economic studies of several other aspects of our use of natural resources. Dicks impressive academic contributions are reason enough to have him on a permanent invitation list for conferences and workshops on forest economics.

Dick, however, is a Honorary Fellow of the SSFE equally much for his long commitment to the SSFE and to his tireless effort to enhance cooperation among forest economist in Europe, the USA and around the world. He has been an engaged and committed force in numerous SSFE meetings, active also in the Faustmann 150 years symposium and several follow-up events, and finally also a longtime associate editor of the Journal of Forest Economics. Dick has also served on numerous PhD assessment committees around Europe, and we are many that have benefitted from his sharp analytic mind and warm personality. We are honored to count him among our friends.

BJT

Selected publications


SSFE 2018 PhD Presentation Prize

Noora Miilumäki

Ms. Noora Miilumäki holds an MSc in Environmental Engineering from University of Oulu and is currently a doctoral student with the University of Helsinki. In Helsingør, she presented her work on “End-user expectations and perceptions of living in a wooden multi-story construction – A case study”. Her thorough and engaged presentation won her the SSFE Prize for Best PhD Presentation, awarded for the first time ever.

Her research aim is to use case wood-frame multi-story construction projects to study and understand how the business ecosystems around such projects work. In her research, she will emphasize the relationship between the ecosystem and the end-user, the latter providing indispensable information through their perceptions and needs. She will collect this information using both interviews and surveys, and analyze them using a mixed method approach.
WG 1: Business Economics of Forestry and Forest Management and Planning

Full length papers
1. Optimal rotations with declining discount rate: searching for a search algorithm

Colin Price (corresponding author) 90 Farrar Road, Bangor, Gwynedd LL57 2DU, UK; c.price@bangor.ac.uk

Hanne Kathrine Sjølie, Department of Applied Ecology and Agricultural Sciences, Inland Norway University of Applied Sciences

Sylvain Caurla, Université de Lorraine, Université de Strasbourg, AgroParisTech, CNRS, INRA, BETA, 54000, Nancy, France

Rasoul Yousefpour, Freiburg University, Germany

Abstract
Previously, several ways have been explored for determining the optimal sequence of forest rotations under declining discount rates. The first-used algorithm optimised each of ten successive rotations, adding the benefit of advancing later crops to the value of shortening earlier rotations. Iterating gave sensible early crop rotations, but later ones were unreasonably long, changing chaotically. A backwards-recursive algorithm, applied to as many rotations as fitted into 1000 years, used a first-order condition to optimise the sequence, giving reasonable, stable solutions. These attempts used a generalised formula for final felling revenue, and excluded intermediate thinning revenues. Including real-world cash flows from four European countries produced some explicable results, but also variation and instability, particularly with thinnings included. Even with all revenues aggregated at the rotation end, some unreasonable and chaotic results occurred. Hence an algorithm was used that identified the maximum NPV occurring throughout each crop cycle, successor crops’ provisional values being included. This avoided local optima being identified as global optima. Change of earlier rotations reschedules later crops, so iteration is always needed. Results were sensible and stable, rotations lengthening until discount rate stabilised. Anomalies and oscillations were resolved by expedients like a discount rate declining continuously, not stepwise.

Keywords: declining discount, optimal rotation
Background

Many academic arguments have been made, that discount rates should decline over time (e.g. Kula (1981); Wietzman (1998); Gollier (2002); Newell and Pizer, (2004)). Now several European governments (Denmark (Finansministeriet, 2013), France (Lebègue et al., 2005), Norway (Det Kongelige Finansdepartment, 2014) and UK (UK Treasury, undated)) have mandated use of such rates, as shown in table 1, for public sector appraisal.

A case can be made against this theoretical approach to valuing the future (Price, 2004, 2005), and other means do exist to tackle the underlying problems (Price 2017). However, if such rates are deployed, they undermine the foundations of classical forest economics (Price, 2012).

### Table 1: UK, French, Danish and Norwegian discount schedules

<table>
<thead>
<tr>
<th>Period (years from present)</th>
<th>UK</th>
<th>France</th>
<th>Denmark</th>
<th>Norway</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td>3.5%</td>
<td>4%</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>30-35</td>
<td>3%</td>
<td>2%</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>35-40</td>
<td>3%</td>
<td>2%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>40-70</td>
<td>3%</td>
<td>2%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>70-75</td>
<td>3%</td>
<td>2%</td>
<td>2%</td>
<td>3%</td>
</tr>
<tr>
<td>75-120</td>
<td>2.5%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>120-200</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>200-300</td>
<td>1.5%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>300-∞</td>
<td>1%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Classical approaches don’t work

In particular, a central problem in forest economics, determining optimal forest rotation, can no longer be solved by applying the Faustmann formula,

\[
\text{[Net present value (NPV) of a perpetual series of rotations]} = \frac{\text{NPV of first rotation}}{1 - e^{-\rho T}}
\]

either in iterative numerical mode, or algebraically. This is because:

- the discount rate, \( \rho \), changes from rotation to rotation, so that
- the optimal rotation, \( T \), changes, lengthening as discount rate declines.

Hence

- the multiplier \( 1/(1-e^{-\rho T}) \) from the NPV of the first rotation to the NPV of a perpetual series can contain no unique discount rate, and
the first rotation’s value is not representative of the following ones, and
the time lapse, \(T\), between one rotation and the next also varies.

Instead of a unique rotation that is optimal for each succeeding forest crop, there is an optimal sequence of lengthening rotations. This is unlikely to be determinable algebraically, particularly when the discount rate changes discontinuously – which it does in the schedules shown in table 1.

Brazee (2018) has derived algebraically the conditions for optimal harvest ages within a sequence under declining discount rates, but that approach has not so far treated numerical changes for specific cases.

To avoid confusion in the following discussion, the term “rotation” will be used strictly to denote the length of time between crop initiation and crop termination. “Crop” will be used to denote one individual cycle of crop growth within the sequence of cycles.

Because the length and value of each crop affects the position in chronological time of succeeding crops – hence the crops’ values and rotations’ lengths – rotations cannot be optimised individually. Even when the possibilities are limited to ten crops, each with rotation up to 200 years, evaluating all possible permutations of rotation length serially would take tens of thousands of years. Hence an intelligent search algorithm is needed.

**A preliminary search procedure**

As presented at SSFE’s 2008 meeting in Lom (Price, 2009), the first attempt to determine the optimal sequence of rotations took a succession of ten crops, each having maximum allowable duration of 1000 years. To these, the UK’s schedule of discount rates was applied. Each was optimised by identifying the first age at which shortening the rotation by a year would reduce overall NPV: subsequent crops were included by adding the effect of bringing their own NPVs one year earlier in time. The crops were arranged in sequence, such that the discount factor applied to each cash flow was one that combined the several discount rates applying over the whole period, from the time of the cash flow back to time zero. Provisional optimisation of early crops’ rotations affected the timing and thus discount rates applying to later crops, which therefore affected the value of bringing later crops forwards, which in turn affected earlier crops’ provisional optimal rotation. It was expected that iterative calculation would generate a stable sequence.
Earlier rotations, as determined under this protocol, were often reasonable and consistent, lengthening as the discount rate declined. Compare figure 1 with figure 2.

![Graph](image)

**Figure 1**: A typical result of the protocol described in Price (2009)

However, later rotations were often unreasonably long, and changed chaotically with further iteration. The chaos periodically infected earlier rotations too. By contrast, single rotations of maximum NPV had stabilised quickly at reasonable values. It may be surmised that the iterative process of including successor crops was what caused the problem. A fixed *number of crops* irrespective of their *rotation length* is also a theoretical problem with possible practical consequences: a different algorithm was clearly needed.

**A backwards recursive solution, using a first-order condition**

The fixed number of crops problem was solved by defining a standard 1000-year period over which rotation sequences would be compared. Within this period as many rotations were included as would fit into it. Thus shorter rotations entailed a greater number of crops. The period was sufficiently long, that whatever happened beyond it would have little signification.

 provisionally, starting rotations were 200 years. A backwards-recursive algorithm (Price, 2011), was applied, with successive and sequential shortening of each of the crops’ rotations. The process continued until reduction of NPV from shortening, by one year, the currently considered crop’s rotation was no longer outweighed by increase of NPV from bringing forwards, by one year, the profit from each of the successor crops. This is the optimisation perspective of first-order conditions (e.g. Price, 1989,
chap.13; Chang, 1998). As the overall sequence of crop rotations shortened, additional crops were added, to fill up the 1000-year reference period. Reasonable and stable solutions were derived (figure 2).

![Figure 2: Lengthening optimal rotations under the UK’s discount schedule](image)

Successive optimal rotations were longer, until the discount rate stabilised after 300 years. For given parameters, the solution was unaffected by starting conditions, provided only that starting rotations all exceeded the final optimal ones. Variation of parameters such as crop productivity had the expected effects. When a uniform discount rate was used in the protocol, all rotations were the same, and identical to the Faustmann rotation. All these results suggest a reliable algorithm. However, unreasonable solutions occurred when large crop formation costs were included.

This approach was presented at the 3rd Faustmann Conference, and published in *Journal of Forest Economics* (Price, 2011).

**Including real-world data with intermediate cash flows**

These two early attempted solutions had used a generalised formula for final felling revenue. They excluded intermediate cash flows, as from thinning.

Hence the algorithm was adapted, so as to take in real-world cash flows for felling, thinning and crop formation, as supplied from four European countries: UK, Norway, France and Germany. Norway spruce was chosen, as a widely distributed commercial species, with a wide range of productivities. The discount schedules for these countries were also used. For this algorithm, and for the next one, a single country’s discount rate might be combined with another country’s cash flows, where this makes a
point more strongly than using only within-country data. The results were presented at SSFE’s meeting in Oscarsborg (Price et al., 2016).

A particular problem arose from thinnings. Under the first-order condition search, spikes of thinning revenue might produce local optima that abort further search, and are thus identified as global optima. The potential existence of multiple optima is discussed by Brazee (2018). In order that thinnings were not altogether excluded, their revenues were aggregated with final felling revenues. However, in a discounting context, where timing is important, this is unsatisfactory, and some other solution ought to be found.

While results were generally explicable and consistent, sometimes the solution depended on starting conditions. With a discount rate falling below 2% (as in the UK’s schedule) unreasonable and chaotic results arose, as exemplified by figure 3. Irregularity of cash flow – compared with that under the previously used, well-behaved function – may have caused this. Smoothing cash flow profile sometimes, but not always, solved the problem.

Figure 3: Norway spruce productivity 7.5 m³/ha/year; smoothed German cash flows; UK discount rates

A “global search” approach

These problems were eventually circumvented through a radically different algorithm, less elegant than the first-order solutions adopted above, but effective. As previously, provisional rotations of 200 years were set: in practice, no rotation as long as this was identified in any solution.
• Crop formation costs and thinnings were included at their prescribed time within the rotation.
• Arbitrarily, a sequence of seven crops was taken. No methodological problem would be created by increasing this number, but it was not necessary, because …
• … for the seventh and successor crops, the rotation could be optimised according to the usual Faustmann formula. This was because the seventh crop always began after – sometimes long after – the chronological time when the discount rate became constant.
• For the sixth crop, the NPV of each possible rotation length, at its provisional location in chronological time, was calculated. For each possible rotation length, the seventh crop was initiated immediately after this rotation’s end, and the NPV of the seventh crop and its successors was included. The rotation of maximum overall NPV was the provisionally optimal one.
• The same procedure was adopted for successively earlier crops, always including the value of initiating the following succession of crops at the end of each current crop rotation. In each case the discount factors used were those for the provisional location in time.
• This process was repeated backwards to the first crop.
• The provisional optimal rotation for each crop affected the position in chronological time of all its successors. This altered the profile of discount factors applicable over those crops’ own rotations. Hence the whole provisional optimisation process needed to be iterated using the newly applicable discount factors.
• A stable solution normally arose within 20 iterations (Price et al., 2017) – much more quickly than with previous algorithms.
• The algorithm was applied to whatever combination of inputs was of interest.
• A discount rate that declined continuously rather than in steps was also introduced. Its profile approximated that for the UK’s discount rates. Note that the Faustmann formulation for the optimal final rotation is not strictly correct for this continuously declining rate. However, in practice even the rotation without any discounting is not much longer than that resulting from the lowest applied rate within this profile.
Table 2 shows the evolution of results through a few iterations

Table 2: Results of a few iterations, for UK data, with continuously declining discount rate, and an imposed minimum 50-year rotation

<table>
<thead>
<tr>
<th>Crop</th>
<th>Iteration</th>
<th>Initial</th>
<th>1&lt;sup&gt;st&lt;/sup&gt;</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt;</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt;</th>
<th>4&lt;sup&gt;th&lt;/sup&gt;</th>
<th>5&lt;sup&gt;th&lt;/sup&gt;</th>
<th>6&lt;sup&gt;th&lt;/sup&gt;</th>
<th>7&lt;sup&gt;th&lt;/sup&gt;</th>
<th>…</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>200</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>51</td>
<td>51</td>
<td>55</td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>200</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>58</td>
<td>60</td>
<td>60</td>
<td></td>
<td>59</td>
</tr>
<tr>
<td>III</td>
<td>200</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>58</td>
<td>64</td>
<td>64</td>
<td></td>
<td>62</td>
</tr>
<tr>
<td>IV</td>
<td>200</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>55</td>
<td>65</td>
<td>69</td>
<td>69</td>
<td></td>
<td>65</td>
</tr>
<tr>
<td>V</td>
<td>200</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>69</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td></td>
<td>69</td>
</tr>
<tr>
<td>VI</td>
<td>200</td>
<td>200</td>
<td>50</td>
<td>69</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td></td>
<td>72</td>
</tr>
<tr>
<td>VIIff.</td>
<td>200</td>
<td>145</td>
<td>73</td>
<td>74</td>
<td>74</td>
<td>74</td>
<td>73</td>
<td>73</td>
<td></td>
<td>73</td>
<td></td>
</tr>
</tbody>
</table>

Results were generally sensible and stable, with rotations lengthening up to the time when the discount rate stabilised. No outcomes resembling figures 1 and 3 were obtained, for any combination of inputs. Figures 4 and 5 give more examples.
Figure 4: Norway spruce productivity 12 m³/ha/year; French cash flows; Danish discount rates

Figure 5: Norway spruce productivity 3.5 m³/ha/year; Norwegian revenues; zero crop formation costs (natural regeneration); stepwise UK discount rates

One reservation should be noted about the protocol described: at the identified optimum for a given crop, the discount rate profile over this crop’s own rotation is precisely correct, for all possible crop ages. If the present rotation is shortened or lengthened, however, for subsequent crops the crop age is commensurately displaced relative to the discount rate profile, slightly affecting calculated NPV. Despite this potential problem, both theoretical analysis and numerical experiment showed that the peak of
NPV at the identified optimum is actually sharpened when adjustment is made for this imprecision: the optimal rotation is correctly identified by the protocol, and its NPV correctly calculated.

Among the results were the following.

- Whenever this was tested, the optimal sequence was independent of provisional starting conditions.
- With a constant discount rate (e.g. Germany’s 4%), the optimal rotation for all crops was equal, and the same as that derived by the Faustmann formula.
- A schedule of high discount rates gave shorter rotations than one of lower rates.
- For a given schedule, throughout the period when the discount rate declined, succeeding rotations lengthened. Figure 5 shows an 85-year rotation persisting through a period of discount rate decline: this result was traced to a local maximum of revenue occurring at that age.
- In accordance with results using a constant discount rate, higher (financial) productivity crops had shorter rotations for a given discount schedule. Using the UK schedule, the Norwegian crop with productivity 3.5 m$^3$/ha/year had rotations ranging from 85 to 120 years (figure 5). With the same discount schedule, the French crop with productivity 12 m$^3$/ha/year, high prices and free crop formation had rotations ranging from 53 to 69 years.
- Lower crop formation costs shortened rotations: for example “free” crop formation cost by natural regeneration decreased the French rotations shown in figure 4 to from 56 to 51 years, and 65 to 61 years.
- Allocating thinning revenues to the time when the thinnings actually occurred had lengthened rotations: for French data, rotations were about 10 years longer than those where all revenues had been aggregated at the end of the crop cycle.

With the UK’s schedule, which declines stepwise to a minimum of 1% over a 300-year period, anomalies sometimes arose, with one crop having a shorter rotation than either the previous crop or the successor crop. The anomaly invariably occurred at the rotation end preceding a change in discount rate. When the stepwise decline was replaced by a continuous decline over a similar range of rates, the anomaly disappeared in every case.
where it had occurred, so it may be attributed to the stepwise discount schedule.

Sometimes, large and indefinitely repeating oscillations occurred over a cycle of iterations, again, notably with the UK discount schedule. For example, in the third crop of the sequence for Norway’s cash flows (see figure 5) the rotation actually oscillated between 110 and 85 years. In such cases, the “best optimum” can be identified by inspection, but the NPVs of the two states are very similar. Again, when such oscillations occurred, they often disappeared if the continuously declining schedule was used instead, or if irregularly changing cash flows were smoothed.

**Conclusions**

After several attempts to find an algorithm for determining the optimal sequence of rotations, the last-described algorithm:

- used global search within each rotation rather than a first-order condition, so avoided stopping at local optima;
- gave results which were independent of starting conditions;
- included thinning revenues and crop formation costs, at the time in the crop cycle when they actually occur;
- allowed a perpetual sequence of crops to be included – not of much practical significance, but making the solution tidy; and
- delivered results from changing inputs that paralleled those found in conventional Faustmann optimisations.

The results may be considered reliable for the conditions described. Anomalous or oscillating results were attributable to stepwise discount or irregular revenue functions: they usually disappeared when smoothed functions were used. These results are in any case of small practical significance, as NPVs were very little affected by the found anomalies or oscillations.

The spreadsheet is still under development, to make it easier to use.
References


Det Kongelige Finansdepartment. [The Royal Finance Department] (2014). Prinsipper og krav ved utarbeidelse av samfunnsøkonomiske analyser mv. [Principles and Requirements for the Preparation of Economic Analyses, etc.].

https://www.fm.dk/nyheder/pressemeddelelser/2013/05/ny-og-lavere-samfundsoekonomisk-diskonteringsrente (accessed 08.07.16).


2. Assessing the sensitivity to forest owner rationality of a Swedish forest partial equilibrium model

Ljusk Ola Eriksson(*) and Lars Sängstuvall

Swedish University of Agricultural Sciences (SLU)
Department of Forest Resource Management

E-mail(*): Ola.Eriksson@slu.se

Introduction

The forest sector is expected to face major challenges due to the need to mitigate climate change and contribute to the bioeconomy. Thus, strain is put on the supply side of the sector, i.e. to deliver enough fiber to be harvested and distributed on forest sector branches. To navigate into the future it is vital to get an idea how adaptations of forest management could promote the transition towards a bioeconomy. Partial equilibrium models (PEMs) have been shown to be powerful tools to analyze the forest sector in terms of the interaction between branches and forest management. Still, whatever clever schemes to enhance the provision of ecosystem services a PEM may come up with it is the forest owners that finally makes the decisions. It is well established that, for a number of different reasons, forest owners do not always act according to the standard economic rationality. Thus, to claim validity of the analyses with a PEM it becomes essential to replicate the behavior of forest owners.

One feature of forest owner behavior is the existence of significant amounts of old forest that from a strictly financial point of view should not be there. Without any explanatory provisions in an economically driven model this forest will be the first one to harvest unless transport costs are prohibitive. The study that is briefly presented here aims at testing a few approaches to deal with this anomaly. The study uses a PEM designed for Sweden, termed SweFor.
SweFor model overview

The supply of saw timber, pulpwood and forest fuel emanates from the projection of national forest inventory (NFI) plots. Harvested volumes from a plot are transported to facilities (sawmills, pulp mills, and heating plants) that are within range. To make it possible to reflect transport cost variability the capacity and the location are specified for each facility. The decision to transport feedstock to a particular facility is made at road side. Forest fuel can only be transported to a heating plant, whereas logs can be used by any branch. The demand side of the sector is represented by three branches – mechanical wood, pulp and paper and district heating – each described by a demand function with constant elasticity.

The problem is to maximize the present net social value, i.e. the discounted surplus under the demand functions deducted with the discounted costs associated with forest management and transport (industry costs are embedded in the demand function).

The model is constructed following the Model I concept with a 100-year planning horizon divided into 5-year periods. The number of NFI plots is 5,553, and the number of sawmills, pulp mills, and heating plants are 41, 35, and 63, respectively.

Behavioral models

Forest owners are assumed essentially to be profit maximizers. However, the age class structure of Swedish productive forest indicate that for some reason part of the mature forest does not get harvested. Three different approaches are here tested in order to see what method might make sense as a way of replicating forest owner management. Institutional owners, controlling almost half the productive forest area of Sweden, are assumed to be economically rational.

The three approaches consist of attaching an amenity value to old forest (Amenity), constraint regulation of the amounts of old forest through restrictions (AgeCtrl), and a random assignment of management program (Random). The results from the model without any provisions for maintaining old forest is termed Basic.
Amenity values are implemented by assuming that the value is associated with old trees rather than areas with old trees. To avoid a particular cut-off age the value is given by a logistic function with 50% of the maximum value assigned by age 100 and 98% by age 140. The amenity value is set to 20 SEK m$^{-3}$, representing forgone rent of 0.6 SEK m$^{-3}$ and year at an interest rate of 3%.

Random is implemented by randomly selecting a certain portion (20 %) of the management programs before solving the PEM.

For approach AgeCtrl it is required that the forest area in the age intervals (80,120] and (120, ∞] years should not be less than currently available. As a method of replicating behavior of individual forest owner it is not valid, however may function as a check of the results of the other methods.

**Results and discussion**

The results with respect to old forest (Figure 1) show that a random assignment of management does not cater for maintaining this forest. It may be interpreted to mean that forest owners do not leave forest just out of ignorance. In contrast, the amenity value approach is quite successful in maintaining old forest, at least if compared to the strict volume control exercised by method AgeCtrl.

Studying the impact on prices (Figure 2), the results indicate, compared to the standard PEM assumption Basic, that for the random assumption there is a drop in harvests at the end of the horizon, implicated by the price increase. The random management is compensated for by adapting management over time except at the end of the horizon when it appears not to be possible. The amenity value approach follows very closely the Basic model. If Basic is assumed to show the maximum net social surplus solution it could be argued that the amenity value of private forest owners has little impact for the affected branches on national level.
Figure 1. The total amount (private and institutional owners) of old forest area in the age interval \((120, \infty]\) over the 100 year horizon.

Figure 2. Saw timber prices over the 100 year horizon.
Abstracts
3. Determinants of Nonindustrial Private Forest owners’ Willingness to Harvest Timber in Norway

Altamash Bashir and Hanne K Sjølie

Faculty of Applied Ecology, Department of Forestry and Wildlife (Campus Evenstad), Inland Norway University of Applied Sciences,

N-2480, Norway

Corresponding Author: altamash.bashir@inn.no, hanne.sjolie@inn.no

Abstract: Non-industrial private forest (NIPF) owners own 79% of the productive forest area in Norway. NIFP owners form a very heterogeneous group with regard to property size, forest state and owner characteristics, which affects the supply of wood and other ecosystem services. Thus insight into landowners’ management objectives and their reasons for owning forest are central for better understanding of the determinants of management decisions which is crucial for efficient policymaking. Contrasted to comparable countries, where several studies of forest owners have been carried out, few analyses exist of NIPF owners’ management objectives in Norway. In this study we aim to fill part of this void by exploring variables which might influence timber harvest and ownership attitudes and objectives among NIPF owners in Norway. Two populations were created, one with private owners who had harvested timber for sale at least once during the last fifteen years and the second of owners had not harvested any timber for sale during this period. The population of owners having harvested timber for sale consists of almost 56 000 owners, and the second population of more than 72 000 owners. The gross samples were made up totally 3150 owners, with adjusted response rates of 56% and 49%, respectively. Preliminary results from logistic regression and decision tree analysis suggest that forest area, tax incentives, conservation measures and distance from property were important factors influencing NIPF landowners’ decision to harvesting timber. In the next step, analyses of timber harvest volume will be carried out alongside investigation of owners who do not harvest timber for sale at all.

Key words: NIPF, Ecosystem services, Harvesting, Questionnaire, Forest management objectives
4. Optimal harvest strategy for even-aged stands with price uncertainty and risk of natural disturbances

Andres Susaeta, School of Forest Resources and Conservation, University of Florida

Peichen Gong, Department of Forest Economics, Swedish University of Agricultural Sciences

Abstract: Forestry decisions are typically made under conditions of uncertainty from multiple sources. This paper presents a reservation price model to examine the joint impacts of natural disturbances and stumpage price uncertainty on the optimal harvesting decision for even-aged forest stands. We consider a landowner who manages a loblolly pine stand to produce timber and amenities, under age-dependent risk of wildfires and uncertainty in future timber prices. We show that the incorporation of risk of wildfires decreases the optimal reservation prices. The inclusion of risk of wildfires leads to lower land values, and reduces the mean harvest age compared to the case of no-risk of wildfires. Higher economic gains are obtained with the reservation price strategy compared to the deterministic rotation age model.

Keywords: adaptive harvest strategy, reservation price, optimal harvest age, natural disturbances, forest fire.
5. The effects of altered survival probabilities on economically optimal species compositions – an example from Germany using a pan-European dataset

Carola Paul\textsuperscript{1,2,*}, Susanne Brandl\textsuperscript{3}, Stefan Friedrich\textsuperscript{1}, Wolfgang Falk\textsuperscript{3} and Thomas Knoke\textsuperscript{1}

\textsuperscript{1}Institute of Forest Management, TUM School of Life Sciences Weihenstephan, Technische Universität München. Hans-Carl-von-Carlowitz-Platz 2, 85354 Freising, Germany

\textsuperscript{2}Department of Forest Economics and Sustainable Land Use Planning, University of Göttingen, Büsgenweg 1, 37077 Göttingen

\textsuperscript{3}Bavarian State Institute of Forestry (LWF), Hans-Carl-von-Carlowitz-Platz 2, 85354 Freising, Germany

\*carola.paul@uni-goettingen.de

\textbf{Abstract:} Increasing natural hazards in Central Europe complicate long-term forest management decisions. Survival probabilities have been used in bio-economic models to account for risks in species selection. Yet, our understanding of the effects of climate change on these survival probabilities and the potential economic consequences is still weak. This study therefore aims at analysing the effect of altered survival probabilities on the economically optimal selection of tree species and type of mixture (mixed stands vs. block mixture). Our objective was to identify species portfolios which are economically robust against different climate change scenarios.

We developed a statistical model to derive empiric survival probabilities using a European dataset (ICP Forest Level I and II data). These were then included in a bio-economic model based on Monte Carlo Simulation and Modern Portfolio Theory. This approach is used to analyse ideal shares of spruce and beech for two types of mixtures (block mixtures excluding biophysical interactions and mixed stands, including biophysical interactions) in an example forest enterprise in South-East Germany.

The simulated climate change effects led to a decrease in the objective function of a risk-averse forest owner; this was despite applying the
economically optimal management. Mixed stands outperformed block mixtures for all climate scenarios. We found that climate change effects only moderately altered the optimal species compositions. These effects were in a similar magnitude compared to classic drivers of investment decisions. Based on sensitivity analysis we estimated that spruce would be very unlikely to lose its dominant position in the economically optimal species composition, despite its low survival probabilities. We also find that mixed stands were generally more robust against both types of perturbations.

We conclude that directly addressing the uncertainty in climate change effects will improve understanding of potential economic consequences and help to design purposeful adaptation strategies.

**Keywords:** Climate Change; Value at Risk; Survival probability; Accelerated Failure Time Model; Portfolio Theory
6. The economics of dedicated hybrid poplar biomass plantations in the western U.S.
Authors: Chudy RP\textsuperscript{1,2}, Busby GM\textsuperscript{3}, Binkley CS\textsuperscript{2}, Stanton BJ\textsuperscript{2}

1- Forest Business Analytics, Lodz, Poland, 90-154, Poland
2- GreenWood Resources, Portland, Oregon, 97201, United States of America

Abstract: Promising growing conditions and developed renewable energy policy environment make the western U.S. a potentially suitable region for dedicated woody biomass (DWB) plantations for energy generation. To support the regional development of biomass and biofuels markets, the USDA awarded an AFRI grant to the Advanced Hardwood Biofuels (AHB) Northwest project. As part of the AHB project, GreenWood Resources—a timberland investment and forest management company—manages hybrid poplar plantations for biomass production at four demonstration sites: Clarksburg, Hayden, Jefferson, and Pilchuck. Drawing on AHB data and plantation management experience across this range of growing and market conditions, we report here on the economics of dedicated hybrid poplar biomass plantation investment. We use data from study sites in a discounted cash flow investment model to estimate financial returns and to test the sensitivity of returns to key variables. Results indicate that, even with above-market assumptions for biomass prices (USD 110/BDMT), plantation investment returns average just 4% in real, inflation-adjusted terms across all sites. Financial returns are most sensitive to changes in price, yield, and land cost assumptions. We find that current market pricing for forest biomass in the western U.S.—approximately USD 46/BDMT—produces negative financial returns from DWB plantation investment on all four sites. As a result, such investments are unlikely to attract private-sector capital. Given current economic conditions and plantation technology, the development of a large-scale DWB plantation base in the western U.S. would require either a material increase in the biomass price, policy support, or a dramatic improvement in plantation yields.

Keywords: dedicated woody biomass, short-rotation plantation forestry, short rotation coppice, AFRI, renewable energy, U.S.
7. Economic impacts of increased forest conservation and utilization of woody biomass for energy in Europe: an analysis with a new forest sector model – EUFORIA

Chudy RP¹, G.S. Latta², H.K. Sjølie³, B. Solberg¹.

1- Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, P.O. Box 5003, 1432 Ås, Norway
2- Department of Natural Resources and Society, University of Idaho, Moscow, ID 83844, USA
3- Avdeling for Anvendt økologi og landbruksfag, Høgskolen i Innlandet, Postboks 400 2418 Elverum

Abstract: Recently, European Union countries have agreed on a new 2030 Framework for climate and energy, including EU-wide targets and policy objectives for the period between 2020 and 2030. The new strategy aims to send a strong signal to the market, encouraging private investment, low-carbon technology and electricity networks. This continuation of previous policy still recognizes wood biomass as an important component among renewable energy sources. Current forest management practices, which by many, have favoured industrial roundwood production while not adequately considering biodiversity protection and diminishing areas of old growth forests, have been considered as main challenges in Europe nowadays. Therefore, a traditional and new forest-based sector, renewable wood-based energy policy and forest biodiversity conservation are, all together, important components in the upcoming sustainable bioeconomy era. Talking about the sustainable bioeconomy, there is a need to recognize possible impacts of increased pressure on forest resources, together with their consequences on forest markets. These consequences are still not well known today.

The main aim of our research is to assess how various policies, like increased forest biodiversity conservation or policies for increased bioenergy, might affect the forest sector in Europe, considering specifically the international trade in roundwood and the competition for wood between bioenergy production and the forest industries. To reach our objectives, we developed a new partial equilibrium dynamic forest sector model -
EUFORIA (EUropean FORest and Industry Assesment model), which combines detailed forest resource information on stand ages, forest types and growth rates, with data regarding wood demand coming from forest industrial production, consumption of products and trade. During Scandinavian Society of Forest Economics (SSFE) 2018 Seminar, we present the EUFORIA model, its structure, assumptions and data requirements, and some preliminary results.
8. Regulation of Moose Hunting in Scandinavia.

The Implications of Age-Structured Models

Frank Jensen\textsuperscript{1}, Anders Skonhoft\textsuperscript{2} and Jette Bredahl Jacobsen\textsuperscript{1}

\textsuperscript{1} Department of Food and Resource Economics, University of Copenhagen, Rolighedsvej 23, 1958 Frederiksberg C, Denmark.

\textsuperscript{2} Department of Economics, Norwegian University of Science and Technology, Dragvali, 7491 Trondheim, Norway

\textbf{Paper presenter:} Frank Jensen.

\textbf{JEL codes:} C61; D62; H21.

\textbf{Keywords:} Moose hunting; Age-structured models; Predation by wolves; Meat value; Browsing damage; Traffic accidents; Differentiated subsidy.

\textbf{Abstract:} In this paper, we discuss optimal regulation of moose hunting in Scandinavia based on an age-structured model, which include calves, yearlings and adults. We set-up models with and without including a predator and in both models a private landowner is assumed to maximize the sum of the meat value and the browsing damage costs on trees on his own property. Contrary, a social planner maximizes the sum of the meat value, the browsing damage cost on all landowner’s property and the costs of traffic accidents. In the model without predation, we find that a subsidy to increase the harvest and reduce the population size is optimal for calves and adults. The marginal subsidy shall be differentiated between the two population stages and must include: a. the difference in the marginal browsing damage cost between the landowner and the social planner; b. the marginal cost of traffic accidents; c. the difference in shadow prices on the population restrictions between the landowner and social planner. The marginal subsidy to the harvest of yearlings needs to be zero because it is beneficial for both the landowner and social planner to let these grow and become adults. In the model with predation, the marginal subsidy to increase the harvest of calves and adult must be adjusted by the survival rates.

Frank Jensen\textsuperscript{a}, Jens Abildtrup\textsuperscript{b}, Anne Stenger\textsuperscript{bc}, Jette Bredahl Jacobsen\textsuperscript{a}, and Bo Jellesmark Thorsen\textsuperscript{a}

\textsuperscript{a} University of Copenhagen, Department of Food and Resource Economics
\textsuperscript{b} National Institute of Agricultural Research
\textsuperscript{c} University of Strasburg,

Paper presenter: Frank Jensen

Keywords: Principal-Agent Models; Optimal Rotation Periods; Amenity Values; Forest Owner Objectives

JEL codes: Q23; H23; D82

Abstract: In this paper we construct a general principal-agent model to discuss voluntary subsidies to a forest owner to increase the rotation period in a situation with asymmetric information about the owner’s cost type. It is shown that for the forest owner with low cost the voluntary subsidy shall be based on differences in the objective functions between the principal and the agent. However, for an owner with high costs the subsidy shall also include an incentive cost to secure correct revelation of the owner’s cost type. The general model is used to study various forest owner objectives such as maximization of the value of timber, maximization of the social welfare and maximization of a mix between the timber value and the social welfare. With welfare maximization there is no difference in the objective functions between the regulator and the forest owner so no contract is necessary. We also investigate the implications of regulator uncertainty about the forest owner payoff. Both when the regulator perceives a wrong objective function for the forest owner and when regulator is uncertain about the objective function of the owner, uncertainty may imply a lower welfare compared to a situation with full certainty about the forest owners goal.
10. IDENTIFYING ISSUES RELATED TO ADDITIONALITY AND LEAKAGE IN VOLUNTARY FOREST CARBON OFFSET PROGRAMS

Gregory Latta

1 Department of Natural Resources and Society, University of Idaho, Moscow, ID USA

Abstract: Market models have been widely used to simulate U.S. climate policy impacts on the forest and agricultural sectors. A consideration rarely addressed is the voluntary nature of landowner participation in either the existing or proposed markets for carbon emissions reductions. This study modifies an intertemporal partial equilibrium model of the U.S. forest sector to assess the market, land use, and greenhouse gas (GHG) implications of a voluntary carbon offset program for improved forest management. Results over a range of carbon prices and offset program rules are evaluated for market participants as well as non-participants. In this modeling exercise additionality is demonstrated by landowners who enroll at low carbon prices with no management change while leakage is calculated as the ratio of the carbon change on non-participating lands divided by the carbon change on participating land over the full range of prices. The implications of restricting offset allocations to carbon fluxes in forests with greater than average carbon stocking levels is explored as well as including payments on project initiation to participants with initial stocks greater than average stocking. In addition to quantifying additionality and leakage impacts to the U.S. forest sector, the results highlight the complexity of accounting for those interactions in methodologies aimed at quantifying improved forest management emissions reductions.

Contact Information: Gregory Latta, Department of Natural Resources and Society, University of Idaho, 875 Perimeter Drive, MS 1139, Moscow, ID 83844 USA, Phone: 541-734-6264, Email: glatta@uidaho.edu
11. EVALUATING FOREST CARBON PROJECTION BIAS RELATED TO SPATIAL DETAIL

Gregory Latta¹ and Justin Baker²

¹Department of Natural Resources and Society, University of Idaho, Moscow, ID USA
²Research Triangle International, Research Triangle Park, NC, USA

Abstract: Regardless of the uncertainty surrounding national policy, states and regions of the United States are moving forward with greenhouse gas (GHG) reducing policies to mitigate anthropogenic climate change. These mitigation efforts typically assume that land use, land use change and forestry will continue sequestering carbon at recent levels or even grow in the near-term. Recent studies evaluating the potential contribution of U.S. Forests to national GHG accounts have ranged widely with and in many cases show forests as a reducing sink and even in many cases becoming a net GHG emissions source. Direct comparisons between the various models utilized is difficult as they vary widely in geographic range, spatial scale, temporal focus, and forest products detail. We use the recently developed Land Use and Resource Allocation (LURA) modelling system to investigate potential forest carbon projection bias associated with the level of spatial detail of the U.S. forest resource base and forest products manufacturing. LURA is well suited for such an analysis as the supply side of the model includes over 150,000 USDA Forest Service Forest Inventory and Analysis (FIA) forestland plots over the conterminous United States. Demand data is based on a spatial database of over 3,000 forest product manufacturing facilities representing 11 intermediate and 13 final solid and pulpwood products. We construct a set of scenarios which include keeping each forest plot and manufacturing facility as its actual location. A second scenario places plots and mills at their county-level average location. A third scenario averages the spatial detail of forests and mills at the state-level average location and a final scenario averages the location detail over eleven regions. Future supply is based on empirical yield functions for log volume, biomass and carbon and transportation costs are derived from fuel prices and the scenario-specific locations of FIA plot from which a log is harvested.
and mill or port destination. Trade between mills in intermediate products such as sawmill residues or planer shavings is also captured within the model formulation. Results depicting historic and scenario-specific forest GHG accounting are generated. Maps of the spatial allocation of both forest harvesting and related GHG fluxes are presented at the National level and regional detail is given highlighting changes in the US North, West and Southeast.

Contact Information: Gregory Latta, Department of Natural Resources and Society, University of Idaho, 875 Perimeter Drive, MS 1139, Moscow, ID 83844 USA, Phone: 541-734-6264, Email: glatta@uidaho.edu
12. Empirical analysis of forest tree species composition on financial risk and economic return based on the results of a forest accountancy network

Johannes Wildberg

Georg-August-Universität Göttingen, Department of Forest Economics
Büsgenweg 3, 37073 Göttingen, Germany

Abstract: Decisions about tree species and their respective coverage in forest enterprises is one of the most relevant and challenging tasks in forest production planning as choices usually have long-lasting ecological and economic consequences concerning entire rotation periods. The selection of tree species for the establishment of forest stands can be regarded as a financial investment. Just as for every investment, the expected economic success of a forest enterprise depends on the expected returns and volatility thereof. In finance theory the so-called diversification effect will allow to lower the risk of volatile return. This study is an attempt to combine finance theory with empirical accounting data to support the hypothesis of reducing the risk of volatile economic returns in forest enterprises through tree species diversification.

Based on the data of a forest accountancy network in Germany, the effect of tree species diversity on economic success was analyzed. We used economic parameters of 35 private forest enterprises in Western Germany documented over a time span of more than 45 years to calculate historic economic returns and volatility. The data revolves around the most relevant tree species in Germany including Norway spruce (Picea abies L.), Common beech (Fagus sylvatica L.), Common oak (Quercus robur L.) and Scots pine (Pinus sylvestris L.).

The data demonstrated a negative correlation between species diversity of a forest enterprise and volatility of the economic return. Furthermore, the spruce-dominated forest enterprises generated the highest economic return joined with the highest absolute volatility. The pine enterprises showed the lowest economic return and absolute volatility, while the broadleaf enterprises performed in the middle. The data revealed an opposite trend in species diversity as compared to the volatility and amount of economic
return. Decision makers in forestry have to balance this tradeoff to make successful investment choices.

**Keywords:** forest accountancy network, tree species diversity, forest economics
13. Competitive harvest in age-structured forests

Lintunen, J.

Natural Resources Institute Finland (Luke), jussi.lintunen@luke.fi

Abstract: I examine timber supply in a market-level setting, in which competitive harvests from individual forest stands satisfy a randomly varying timber demand. The risk-neutral and rational forest owners follow even-AGED management and choose optimal harvest ages. I show that the forest owners follow a reservation price strategy, where harvests are triggered by price realizations that are above a critical price threshold. I construct rational expectation equilibrium, in which the forest owners optimize the reservation prices for each age-class and the timber price follows an endogenous random process. In equilibrium, the reservation prices depend on the current age-class distribution of the forest and the current state of timber demand.

In previous models, in which timber price follows an exogenous stochastic process, the forest owners who use a reservation price strategy harvest only when prices are high. In market equilibrium the current and expected future timber prices are affected by forest owners’ decisions. The quantitative results suggest that in market equilibrium, competition between forest owners restricts their reservation price decisions. Consequently, the forest owners cannot reap excess rents from random price fluctuations. Due to the same reasons, highly volatile demand, implying highly volatile timber prices, does not automatically lead to longer rotations. Both of these endogenous price results challenge previous results obtained from models with an exogenous stochastic timber price process.

Keywords: Competitive equilibrium, rational expectations, timber market, stochastic demand, optimal rotation, on-going rotations
14. Optimal rotation sequence of Norway spruce in a changing climate

Lintunen, J., Rautiainen, A., Uusivuori, J.

Natural Resources Institute Finland (Luke), jussi.lintunen@luke.fi

Abstract: The changing climate is likely to alter environmental and economic conditions in the coming decades and even centuries. Given the long planning horizon of forestry, these changes affect the optimal management decisions of the current forest stands. The notable changes in growing conditions, economic growth, and climate regulation, make the usual static Faustmann framework unwarranted.

We optimize the even-aged management of a Norway spruce stand for timber and climate benefits in a changing climate. We assume that the climate forcing caused by both atmospheric carbon and surface albedo, is regulated by a climate policy that becomes more stringent over time, until climate change has been globally brought under control. We derive a consistent scenario for the global climate and the climate policy using the DICE-2013R integrated assessment model and synchronize the local growth conditions (Kuusamo, Finland) with the global climate scenario. Thus, the scenario includes a decreasing interest rate, changing growth conditions, and changing prices of carbon and albedo forcing. The resulting optimal forest management is different for each present-day and future tree cohort and the optimal solution is a rotation sequence – rather than a single rotation.

In line with previous studies, we find that carbon regulation lengthens rotations, whereas albedo regulation shortens them. Carbon regulation has a stronger impact than albedo regulation. Therefore, the outcome of regulating both forcing mechanisms is relatively similar to that of regulating carbon only. A relatively stringent climate policy encourages longer rotations despite the rotation shortening impact of improving growth conditions. After the climate change issue has been solved, and the global mean temperature is brought to its preindustrial level, the growing conditions in Northern Finland become worse than they are today. Thus, rotations become very long. The impact is further magnified by the low interest rates projected for the distant future by the DICE model. Potential timber price
increases, caused by carbon pricing, soften the policy’s impacts on forest management.

**Keywords:** Optimal rotation, Norway spruce, carbon, albedo, climate change, declining interest rate
15. Digital services and forest information offered via Metsään.fi portal as forest owners’ decision support

Sari Pynnönen¹, Emmi Haltia², Teppo Hujala³

¹ Department of Forest Sciences, University of Helsinki, P.O. Box 27, 00014 University of Helsinki, Finland; sari.pynnonen@helsinki.fi

² Pellervo Economic Research PTT, Eerikinkatu 28, 00180 Helsinki, Finland

³ University of Eastern Finland (UEF), School of Forest Sciences, P.O. Box 101, FI-80101 Joensuu, Finland

Abstract: Today’s societies often evidence conflicting expectations on how to use forests. With the scarcity of resource, the privately owned forests are an important source for provision of multiple ecosystem services such as timber, biodiversity and recreational assets. Decision making in the presence of many alternative forest uses requires lot of information and hence challenges forest owners. Digitalisation offers many possibilities to enhance the delivery of forest resource information and to develop new approaches for forest owner advisory services. In addition, the availability of diverse forest data that take into account ecological, economic and social aspects could be a key to enhance the sustainability of the forest uses.

We aim to explore the strengths and weaknesses of the Finnish Metsään.fi e-service portal as a decision support tool for forest owners. Digital, state-funded Metsään.fi e-service portal offers forest inventory data and recommendations on possible forest management and felling activities to family forest owners free of charge. The service also offers the possibility for being in touch with forest service providers and authorities via internet, i.e. to notice about future logging or leave a call for bids to timber buyers. The portal makes use of the forest inventory data from a national forest resource database. We utilize the viewpoints of theories of diffusion of innovations, e-service quality and e-satisfaction.

This study uses web-based survey data about forest owners’ views on “Metsään.fi” -service. The data were collected in August 2016 and it consisted of 5742 responses, response rate being approximately 17. The survey included statement sets answered on Likert-scale, questions about respondent’s experience with the service and their socio-demographic
background information as well as open-ended questions where the respondents were asked to comment on the properties they think are particularly good in the service, and on the other hand what needs to be developed. We will use a logit model to identify factors that explain the respondents’ activity in using the service. The analysis will be deepened with the qualitative analysis of open questions.

According to the preliminary results, forest owners would like to have for example means to compare the outcomes of different forest management decisions. The easiness and simplicity of the use were praised in responses. By identifying factors that either encourage or discourage forest owners to continue using the service portal, the study produces knowledge for further development of the platform and its services.

**Key words:** digital service; e-satisfaction, decision support; family forest owner; web-based survey

Shashi Kant, Faculty of Forestry, University of Toronto
(shashi.kant@utoronto.ca)

and

Ilan Vertinsky, Sauder School of Management, University of British Columbia
(Ilan.vertinsky@ubc.ca)

Abstract: The main foundation of neo-classical economics, including Faustmann’s economics, is based on assumptions including the assumptions of rational economic agent and absence of externalities. This foundation makes the claim of economists that economics being positive and not normative questionable. Behavioral economists, for the last two decades, have collected evidence through economics games, such as Dictator and Ultimatum Games, against the assumption of rational economic agent and the assumption of externalities has no standing in view of climate change.

The evidence from economic games against rational economic agent is strong but behavioral economists have not been able to provide a new foundation based on evidence and heterogeneity of preferences and not on assumptions. One very good example of assumptions in behavioral economics is that consistently observed higher offers in UG as compared to DG are interpreted as strategic behavior (conventional rational behavior) while positive allocations in DG as evidence of Other Regarding behavior. The rational behavior based interpretation is counter-intuitive with respect to OR behavior.

To test the validity of strategic behavior in UG, a series of DG and UG was conducted in an Oje-Cri First Nation in Canada. Elicitation of motives for allocation and partial information, where a participant received a clue about the other participant’s age or gender, were added to the design of games. Fifty eight members split evenly between two genders participated. There are many key findings of these games. First, in the case of no information, the average UG allocation is significantly higher than the average DG allocation for the aggregate group of all players. Second, in the case of some information about the second player, when the second player is either a
woman or an elder, the average UG allocations are statistically not different than the average DG allocations for all five sub-groups as well as the whole group. Third, mature and elder people, as first players, do not make statistically significant higher allocations in UG compared to DG either in the case of no information or in any of the five cases of some information. Fourth, males and young people, as first players make significantly higher allocations in UG compared to DG in the cases of males, young, and mature people being the second players. Finally, analysis of motives indicates that higher allocations in UG as compared to DG may not be due to strategic motives.

The results indicate the need to develop economic theories based on real preferences of people and not based on different types of assumptions of human preferences used by behavioral economists. Only evidence based economic models will make economics as positive economics.
17. Economic evaluation of growth effects in mixed forest stands: A simulation study for Norway spruce and European beech in Southern Germany

Stefan Friedrich¹, Carola Paul², Susanne Brandl³ and Thomas Knoke¹

1. Institute of Forest Management, Technical University of Munich, Germany, st.friedrich@tum.de
2. Department of Forest Economics and Sustainable Land-use Planning, Georg-August-Universität, Göttingen, Germany
3. Dept.of Soil and Climate, Bavarian State Institute of Forestry, Germany

Recent findings from the observation of experimental forest sites show that mixed forest stands have a higher productivity than monocultures (over-yielding). The objective of our study was to determine whether these changes in the biodiversity-productivity relationship (BPR) would result in different portfolios than without these mixing effects.

To answer this question, we set up a model for a simulation study with Norway spruce and European beech. We used growth data for pure stands of N. spruce and E. beech generated with SILVA 2.2 for 15 different regions in Southern Germany also representing a climate gradient. Overyielding was included via two scenarios representing the minimum and maximum level of over-yielding found in studies on the growth of N. spruce and E. beech in mixed and pure stands.

We included price fluctuations and different survival rates for the two species to represent risks. Survival rates were calculated from a pan-European dataset of the forest damage survey (Level-I and II plots) allowing a mixture and climate sensitive parametrization.

With Monte-Carlo-Simulations we calculated the distribution of returns (annuities) for the different scenarios and our objective function, the Value-at-Risk (VaR).

The results show that in block mixture (mixing pure stands on forest enterprise level) stands of pure spruce are economically favourable despite a high susceptibility towards natural hazards. When mixing on a small scale
(single tree to group-wise mixture), effects of over-yielding and higher stand resistance suggest that an admixture of beech to the pure spruce stands is economically favourable.

Keywords: Modern Portfolio Theory, Survival Analysis, Mixed Forests, Value at Risk, Over-yielding
WG 2: Forest Policy

Full length papers
18. Societal costs of urban tree diseases

Colin Price
90 Farrar Road, Bangor, Gwynedd LL57 2DU, UK
c.price@bangor.ac.uk

Abstract: Diseases of tree species commonly planted in urban areas are spreading rapidly. Rather than effects on wood production, which still dominate the economics of forests, those on ecosystem services dominate evaluation of urban tree resources. A model for assessing carbon transactions by forest crops was adapted for single trees, and showed that disease could be beneficial through abbreviating rotations, under government prices. A major valuation of London’s tree resource has made an “as-is” assessment, not referring to any changes. Its data were reworked, considering the changed flow of costs and benefits if disease led to trees’ being replaced earlier. Physical impacts on air pollution were significant: those on temperature, flood and noise abatement less so. Several approaches to valuing aesthetic effects, and many variants of them, have been applied: the CTLA system, the CAVAT system, the Helliwell system, and mainstream valuation methods such as contingent valuation and hedonic pricing. Their application to typical urban tree situations in the UK shows results similar but in some disagreement. Ecosystem disservices may also be abated, though evaluations are rarely undertaken. Taking the most realistic methods and results, effects on replacement cost, aesthetics and pollutants seem the most serious results of urban tree diseases.

Keywords: Tree disease, urban trees, ecosystem services

Introduction

The recent rapid spread of tree disease has economic causes: increase in timber and horticultural trade; international movement of human beings; the acceleration of climate change, leading to extended range for insects and pathogens and lowered resistance and resilience in trees suffering more environmental stress. This spread affects trees commonly found in urban settings.
There are also economic consequences. In evaluating them, the key question (as arguably in all economic evaluation) is, what changes if trees become infected? what difference does it make, in an economic sense?

**What changes?**

Among the consequences of urban tree disease are:

- diseased trees look unattractive;
- dead trees hold infection potential;
- public safety is compromised;
- officials fear liability;
- ecosystem services are lost;
- so, tidy-mindedness and custom lead to …
- treatment, which may be expensive and/or ineffective.
- Hence, often, felling, disposal and replacement costs are incurred.

However, the last-named eventuality may entail complex future changes. A replacement tree will not live for ever, so will itself need periodic replacement, according to its functional life span. For example, if aging of a tree causes it to become less beautiful, or to constitute a public hazard, replacement may come at 150-year intervals. And, by the same token, if the tree were not lost to disease, it would be replaced anyway in due course; then, again, at 150-year intervals. Suppose the tree is presently 100 years old, and that a 1% discount rate applies in ecosystem service decisions. The possible profiles of discounted costs are shown in figure 1. With a realistic £2000 cost of felling and replacing a tree in an urban setting, the difference of summed discounted cost streams is £1000 per tree.
Figure 1: Alternative profiles of replacement cost

The lost value of ecosystem services: the case of CO₂

But in the meantime, and especially if the tree is not replaced, the following (and other) ecosystem services will be lost.

- Provisioning services, by contrast with a forest context, are likely to be insignificant in an urban – and especially a street – setting because of:
  - the dispersed spatial scale of the resource;
  - public safety considerations, leading to the tree’s being dismantled in non-commercial pieces;
  - infrastructure damage that would arise from felling a whole tree;
  - the likely shortness of utilisable bole and irregularity of its profile;
  - (perceived) issues about timber quality;
  - biosanitary requirements for disposal of felled material.

- Regulating services such as CO₂ sequestration will be disrupted, as will...

- supporting services e.g. nutrient recycling.
Cultural services, particularly landscape effects, will temporarily vanish.

There may also be effects on ecosystem disservices.

As an example of the effect on regulating services, take a collection of 100-year-old ash trees, *Fraxinus excelsior*, stricken fatally by *Hymenoscyphus fraxineus*. The planned replacement, with ash, was to be at 150 years, and this gives the “no disease” baseline. After infection, however, the trees will be felled immediately. There is no guaranteed disease-free replacement but trees of genera *Acer*, *Platanus* and *Tilia*, having the same productivity, will replace the ash, one-for-one. The effect on carbon fluxes is evaluated using the spreadsheet CARBBROD.xls (Price & Willis, 2015), on a per hectare basis. DECC’s carbon price schedule (DECC, 2013) and the Treasury discount schedule (HM Treasury, undated) are adopted. Table 1 presents the results. In the first comparison, no utilisation of the biomass is undertaken: it is just burnt. Alternatively, the material is sorted, cleaned and chipped, and 50% is used as biofuel, displacing an equivalent calorific value of fossil fuel.

Table 1: Net present values per hectare for carbon transactions

<table>
<thead>
<tr>
<th></th>
<th>DECC CO₂ prices, Treasury discount</th>
<th>Constant £75/tCO₂ 1% discount rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No fossil fuel displace d</td>
<td>50% fossil fuel displace d</td>
</tr>
<tr>
<td>Disease</td>
<td>£–1,208 15,332</td>
<td>£17,394 20,013</td>
</tr>
<tr>
<td>No disease</td>
<td>£–1,208 15,332</td>
<td>£17,394 20,013</td>
</tr>
<tr>
<td>Net cost of disease</td>
<td>£–1,208 15,332</td>
<td>£17,394 20,013</td>
</tr>
</tbody>
</table>

The results in the left-hand body of table 1 are wholly unexpected, disease appearing beneficial. Yet they are explicable: disease brings early volatilisation of carbon, when DECC’s discounted carbon prices are low, and medium-term sequestration by the replacement trees, when those prices are high. Contrarywise, replacement in 50 years would bring volatilisation at a time of high prices, and sequestration at a time of falling discounted prices. Disease seems beneficial to the carbon account, using prices mandated by the UK government. Partial utilisation of biomass does not reverse this result. It can be seen that the profile of carbon prices is the cause: a constant carbon price brings the expected result, that disease is costly (central body of table 2). Using a 1% discount rate brings a further surprising result, with disease seeming beneficial to the carbon account, in the case that fossil fuel is displaced (right-hand body). Nothing should be taken as being obvious. The results resemble those of Price & Willis (2015).

This treatment of CO₂ effects, as a difference of flux values, contrasts markedly with that undertaken by a significant assessment of London’s trees (Rogers et al., 2015), which valued the stock of carbon in trees and carbon sequestration, with no reference to the effect of any specific change. The following sections further reinterpret the London results, in a context of the particular change occurring when trees die or are removed through disease.

Other ecosystem services

The London i-tree study (Rogers et al., 2015) was a major survey of the city’s tree resource. Across this resource, it aimed to value all significant ecosystem services (but of course did not do so perfectly). It produced some big numbers, valuing tree-based ecosystem services at £133 million/year. But it did not answer that key question: what changes? Is the £133 million/year just to be used politically to defend existing trees against all that might harm them, or to make people feel good about them?

The effect of tree diseases evidently needs a more specific valuation, focusing on the results of trees’ being lost along with their ecosystem services – and possibly replaced. The i-tree study was used to provide some figures as a base. The unit on which valuation was focused was a 10 m × 10 m plot of land on which a representative tree might be growing. For
purposes of scaling, 100 such trees would occupy one hectare. This plot size
is adopted illustratively: it does not actually affect results.

According to the i-tree study, trees’ greatest physical ecosystem service
is the removal of pollutants, particularly nitrogen dioxide and particulates.
This service is valued at £126 million per year. I am not in a position to
question this value, nor to ask what happens to these pollutants following
removal from the atmosphere (i-tree London mentions the ensuing water
pollution, but does not cost it). Table 2 interprets these figures at plot level.

Table 2: Annual value of pollution reduction per plot

<table>
<thead>
<tr>
<th>Pollution cost reduction/year</th>
<th>£126,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of London</td>
<td>158,481 ha</td>
</tr>
<tr>
<td>% tree cover</td>
<td>× 14 %</td>
</tr>
<tr>
<td>Tree cover</td>
<td>22,189 ha</td>
</tr>
<tr>
<td></td>
<td>= 221,887,000 m² ÷ 221,887,000 m²</td>
</tr>
<tr>
<td>Pollution reduction per m² per year</td>
<td>= £0.568</td>
</tr>
<tr>
<td>Pollution reduction per 10 m × 10 m plot per year</td>
<td>× 100</td>
</tr>
<tr>
<td></td>
<td>= £56.8</td>
</tr>
</tbody>
</table>

In figure 2, the effect of disease’s removing a tree from a plot is shown. The
assumptions are that a tree’s efficacy in removing pollutants is related to its
leaf surface area, and that leaf surface area approaches the value for the
mature tree according to:

\[ \text{[Current area]} = \text{[Mature area]} \times (1 - e^{-0.025\times\text{[Age]}}) \].

This formulation is speculative, based on no precise evidence from the
literature. Disease defoliates trees and would compromise their pollutant
removal function even if they were not felled. Once again a 1% discount
rate is used, and it is assumed that replacement, now, or at a counterfactual
age 150, would be with a tree of similar ecosystem functionality.
Noise abatement is discussed by Davies et al. (2017): but, given the absence of monetary valuations in the literature, and the likely lack of effect of individual trees, this service is not further considered.

Trees affect urban air temperature variously. In summer, direct shading and the greater reflectivity of vegetation compared with hard surfaces create a more comfortable ambience. Leaf transpiration and interception and re-evaporation of rainfall have an air conditioning effect. For deciduous trees, this effect is suspended in winter, so is appropriate to season.

The effects can be significant. Bowler et al. (2010) found temperature was reduced by about 1°C in an urban park, compared with its surroundings.

Defoliation or felling largely terminates such effects.

Table 3 offers an evaluation based on and modified from a US study (McPherson et al., 1999), which considers savings in air conditioning cost as a result of trees’ presence. “Several speculative adjustments are made: for the spatial arrangement of Britain’s urban trees as groups more than as street trees; for the less extreme climate (although Britain’s is getting closer to California’s); for a less extravagant culture of energy use; for efficiency gains” (Price, 2010).

Figure 2: Effect of tree loss on pollutant removal value

Source: Price (2017a)
Table 3: Illustrative valuation of air conditioning

<table>
<thead>
<tr>
<th>kWh saving per tree per year</th>
<th>122</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial configuration factor × 0.5</td>
<td></td>
</tr>
<tr>
<td>Climate factor × 0.5</td>
<td></td>
</tr>
<tr>
<td>Cultural factor × 0.5</td>
<td></td>
</tr>
<tr>
<td>Energy efficiency gain ÷ 2</td>
<td></td>
</tr>
<tr>
<td>Price per kWh × 0.13</td>
<td></td>
</tr>
<tr>
<td>Annual value = £0.99</td>
<td></td>
</tr>
</tbody>
</table>

Although relatively small, this is greater than the £0.14 per tree derived from London i-tree’s valuation. Following the process used above for pollutant removal, the overall annual cost of losing trees to disease is only £1.76 per plot (i-tree) or £12.43 (own calculations).

A more significant effect of temperature amelioration may be reduced mortality attributable to heat stress. Table 4 shows illustrative calculations using figures derived from several sets of mortality statistics, and based on the consequences of the 2003 European heat wave. Speculative assumptions, especially that excess death rate is proportional to excess temperature, have been used in the absence of fully researched information.
Table 4: A speculative valuation of reduced mortality through heat stress

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess deaths in England &amp; Wales</td>
<td>2139</td>
</tr>
<tr>
<td>Population of England &amp; Wales ÷ 58,000,000</td>
<td></td>
</tr>
<tr>
<td>Population of London × 8,500,000</td>
<td></td>
</tr>
<tr>
<td>Excess death rate in England and Wales ÷ 16%</td>
<td></td>
</tr>
<tr>
<td>Excess death rate in London × 42%</td>
<td></td>
</tr>
<tr>
<td>Pro rata deaths:</td>
<td>823</td>
</tr>
<tr>
<td>London excess temperature ÷ 15°C</td>
<td></td>
</tr>
<tr>
<td>Excess deaths per excess °C</td>
<td>55</td>
</tr>
<tr>
<td>(Reducing) recurrence period ÷ 10 years</td>
<td></td>
</tr>
<tr>
<td>Mean lives saved per year</td>
<td>5.5</td>
</tr>
<tr>
<td>Value of statistical life (elderly) × £1,000,000</td>
<td></td>
</tr>
<tr>
<td>Number of 10 m × 10 m plots ÷ 2,218,870</td>
<td></td>
</tr>
<tr>
<td>Value per plot per year</td>
<td>£2.47</td>
</tr>
</tbody>
</table>

Again, using the procedure adopted for pollution, the cost per plot through losing a 100-year-old tree to disease is £32.81.

Hydrological effects result largely from better infiltration of water into the ground with consequent flood mitigation. London i-tree used the city’s sewage treatment cost of £0.807 per m³ as a basis – one supposes, on the grounds that this was a cash number, related to water. But ecosystem services have quality, time and space utilities, none of which are addressed by this basis. For what it is worth, converting £0.807/m³, as performed for pollutants, resulted in a cost per plot of £15.85, as a result of losing, then replacing a 100-year-old tree. Speculative damage costing based on Environment Agency figures for flood damage gave a lower value, though admittedly for a rural area (EKOS et al., 2009).
Cultural services

Perhaps surprisingly, evaluation of aesthetic services of urban trees is much more advanced than that for physical services. “Expert methods” include CTLA’s (1983) and CAVAT (Doick et al., 2018). Both, controversially, use replacement cost as their amenity value basis: like-for-like replacement is not the immediate result of loss to disease or pests (Price, this volume); nor should replacement cost be assigned only to aesthetic gain. Replacement cost is best treated as it has been above, as an item in its own right. For the record, London i-tree adopted CAVAT, which yielded a value for the stock (not an annual value) of £43,300,000,000.

Helliwell’s (1967) method, like CTLA and CAVAT, relies on expert judgement of aesthetic factors, though it is open to wider input. Its monetary basis is expert consensus on “reasonable” value – more subjective than replacement cost, but also more relevant to aesthetic valuation.

Consumer-based approaches include contingent valuation and allied stated preference methods (Areal & Macleod, 2006), and hedonic pricing (Payne & Strom, 1975). Contingent valuation of aesthetic matters encounters numerous biases, particularly problematic in the context of disease (Price, 2018). Hedonic house pricing of aesthetic quality depends, complexly and perhaps intractably, on how scenic elements aggregate into actual views (Price, 2017b, chapter 12). Again, the impact of tree disease is problematic to extract statistically.

Table 5 gathers some results for comparison’s sake.

Table 5: Some tree-based aesthetic evaluations, mostly stock based

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>* CAVAT London value</td>
<td>£43,300,000,000</td>
</tr>
<tr>
<td>Number of tree plots</td>
<td>÷ 2,218,868</td>
</tr>
<tr>
<td>Value per tree (London average)</td>
<td>= £19,515</td>
</tr>
<tr>
<td>† Helliwell per tree values (Bangor average)</td>
<td>= £6,850</td>
</tr>
<tr>
<td>Hedonic pricing: UK mean house price</td>
<td>= £220,000</td>
</tr>
<tr>
<td>Tree premium</td>
<td>× 3%</td>
</tr>
</tbody>
</table>
Number of trees per house? ÷ 3 = £2,200

Tree premium × 6%

Number of trees per house? ÷ 2 = £6,600

‡ HPM + expert judgement of quality, per point = £1,100

Annual equivalent per point × 5% = £55

* Rogers et al. (2015)

† Price (2013)

‡ Price (2017, p.378). Quality points are judged on an aesthetic scale.

The £55 annual equivalent was converted to an aesthetic value of £691 per point per benefited household. Further manipulation would have been needed to bring the £55 figure to an equivalent figure for the projected aesthetic change resulting from disease, and scaling to the number of trees in the assessment. In one case study, the result was an annual equivalent of £750 per tree-sized plot. Applying the protocol used for pollutants, this produced a net loss through disease of £9420. It is unsurprising that this should be less than the CAVAT figure, which was an absolute value rather than one relevant to changing circumstances.

It is noteworthy that, despite the different approaches and circumstances, all results agree on an aesthetic value for an urban tree of a few thousand pounds.

Other cultural services include the benefits of trees to health (Nilsson et al, 2011; Sarkar et al., 2015) and to education. I do not know of any chain of consequence followed through to a monetary equivalent value.

Education advantages too have been widely promoted. But it is possible that tree disease itself provides educational opportunities, if only to emphasise that humanity does not absolutely control ecosystems.

Whether supporting ecosystem services should be separately valued has been contested. Macdonald (2010) argues that these services merely allow
the ecosystem to function sustainably, and so deliver services that have already been valued. Double counting is therefore a danger.

Trees also generate ecosystem disservices: fallen trees cause damage and obstruction; roots cause lifting of pavements; limes (Tilia spp.) in particular deposit sticky exudates onto structures and vehicles. No published monetary valuations have come to light. But as an example my estimate can be recorded, that a small Buddleia on my chimney would have reduced solar electricity generation by about £50sworth per year, had I not had it removed. Sometimes, disservices can be valued easily, and sometimes they can be eliminated easily.

**Conclusions**

The estimated costs of urban tree disease are collected in table 6. Carbon figures are converted from a hectare to a tree plot size by dividing by 100.

Table 6: Some costs for loss of an urban tree, aged 100 years

<table>
<thead>
<tr>
<th>Service</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement cost</td>
<td>£1000</td>
</tr>
<tr>
<td>Provisioning services</td>
<td>?</td>
</tr>
<tr>
<td>Carbon</td>
<td>£–198 to £+186</td>
</tr>
<tr>
<td>Pollution abatement</td>
<td>£713</td>
</tr>
<tr>
<td>Noise abatement</td>
<td>?</td>
</tr>
<tr>
<td>Microclimate amelioration</td>
<td>£33</td>
</tr>
<tr>
<td>Hydrological effects</td>
<td>£16</td>
</tr>
<tr>
<td>Aesthetic services</td>
<td>£691 to £19,515</td>
</tr>
<tr>
<td>Other cultural services</td>
<td>?</td>
</tr>
<tr>
<td>Environmental disservices</td>
<td>–?</td>
</tr>
</tbody>
</table>
While all the figures are subject to doubts and variations, it is evident that replacement cost, pollution abatement and aesthetic values are the major components, and are likely to remain so under reasonable assumptions.

Results will differ according to the life-span of the affected species, and the age at infection. Figure 3 shows, however, that the loss of services at age 100 is reasonably representative of the whole possible spread of ages.

Figure 3: Net discounted loss of ecosystem services at different ages of tree death: illustrative value of services given as £1 per year for a mature tree

Scaling the result for the effect of disease also requires an estimate of how many trees, and which ones, will be affected, over what time scale. This is not a job for economists, but for pathologists and epidemiologists.

Acknowledgements
Thanks are due to Simon Cox, Kieron Doick and Glyn Jones for supply of information.

References


Price, C. (this volume). Caveats about CAVAT: what does its “tree amenity value” actually measure?


19. Caveats about CAVAT
what does its “tree amenity value” actually measure?

Colin Price
90 Farrar Road, Bangor, Gwynedd LL57 2DU, UK
c.price@bangor.ac.uk

Abstract: The CAVAT system for amenity tree evaluation is based on tree replacement cost, modified by several aesthetic factors. It does not in fact represent actual replacement cost. There are many contentious elements in its adaptation as an aesthetic value, including its cash value base, arguable subjective judgements and questionable quantifications. It is unclear which basket of services it values. It does provide a starting point in negotiating compensation claims, but not “a market price” for amenity trees. While these problems are endemic to such valuations, a wider set of changes ought to be assessed.

Introduction

Valuation of urban amenity trees has a history dating back to the early days of environmental economics (Helliwell, 1967; Payne and Strom, 1975; CTLA, 1983). From time to time new or variant methods are proposed (see Price, 2003), and comparative studies are made (Watson, 2002; Price, 2007a; Ponce-Donoso et al., 2017).

CAVAT (Capital Asset Valuation of Amenity Trees) is a relative newcomer (Neilan, 2010). It says of itself that it was developed because local authority tree officers ought to regard trees as assets, not liabilities. “… it expresses [tree] value in monetary terms, … directly related to the quantum of public benefits that each particular tree provides” (Neilan, 2017a, p.3, 2017b, p.3). These are the benefits nowadays often termed ecosystem services, such as: carbon sequestration, microclimate and hydrological mitigations, and noise abatement. But CAVAT’s focus is on aesthetic improvement or amelioration.

Intended uses are in assisting development control, assessing compensation claims, and rationalising tree stock management. Its valuation is based on the following.
The so-called unit value factor is the price of “representative” amenity trees from the nursery, per unit basal area, augmented by a multiplier to allow for the cost of planting.

This is scaled up by the actual basal area of the tree being evaluated (the target tree).

The value is further modified for several aesthetic adjustment factors:

- population density “score”;
- public accessibility “percentage”;
- crown condition and completeness “percentage”;
- special amenity or appropriateness factors, some of which are treated later, each contributing a 10% value augmentation;
- a life expectancy “parameter”.

All these are multiplied together.

**Claimed advantages**

CAVAT has been enthusiastically adopted by urban tree officers and planners. It is frequently presented and lauded at professional conferences. However, it has been treated with doubt and scepticism by environmental economists (including me). Its proponents have only cursorily acknowledged written criticisms of the sceptics (including mine). There is only brief reference to publications which cast doubt on its compatibility with mainstream environmental economics (Natural England, 2013).

Unlike, for example, the Helliwell system, but like the CTLA system, CAVAT is based on real cash (cost) transactions. Hence, supposedly, it should appeal to accountants and their allies.

It is said to be transparent (anyone could follow its calculations) and consistent (applied in similar circumstances, it will produce a similar answer). It yields a number – some number, any number – in a field where qualitative discourse has been the norm. And it does so in monetary terms, which allows comparison with other arguments such as costs of management and forgone development values. The aesthetic adjustment
factors have, almost unarguably, a positive ordinal relationship with expected tree value. But what is it a monetary measure of?

Is it really the like-for-like replacement cost?

It is claimed that “the purpose of CAVAT is to provide a compensation replacement value for single trees, on a like-for-like basis” (Doick et al., 2018, p.86). That, as I interpret it, means that anyone (developers, vandals) who destroys a tree should pay sufficient compensation to the public authority to enable its value to be restored.

However, like-for-like replacement mostly isn’t possible. Mature trees, such as those which are the usual target of compensation claims, are physically challenging to uproot and move into place, and their biological survival after such a move is uncertain. Specimens grown as “instant trees”, designed for transport to site, may be as tall as 12 m, but rarely taller. Hence CAVAT’s cost basis is that of much smaller plants, as commonly available from nurseries, scaled up in proportion to the basal area of the target tree. But such mathematical scaling up does not reproduce on the ground the visual effect of losing the target tree.

It might be that many small trees would be planted, having the same total basal area as the lost target tree. But this too, while potentially creating a considerable visual impact at the site or elsewhere, still would not reproduce the effect of losing one mature tree of equivalent basal area.

In due course a replacement tree may be expected to grow sufficiently to match the size and visual effect of the lost tree. But if a “replacement cost” were to be based on this line of thought, it might be more appropriate to scale up the actual cost of installing a replacement, by adding compound interest until the time when the target tree’s size had been reached (Detzel et al., 1998; Price, 2007b). But even this is an accounting fiction.

Rather than providing a like-for-like replacement, any of these expedients in practice shifts the time profile of replacement costs. Take a species with life expectancy in an urban setting of 150 years. If the target tree has to be replaced now, the cost will also be incurred for its replacement in 150 years’ time, and then in 300, 450 … years. But suppose the tree
survives to live out its natural span, until its physical disintegration poses aesthetic deterioration or physical danger. Then replacement costs will also be incurred, but at 50, 200, 350 … years. The cost of immediate loss is the difference in the discounted value of these cash flow streams. This failure to consider the differential of consequences (what changes?) if the tree is lost now, or at the end of its natural span, undermines many aspects of urban tree valuation (Price, this volume).

Aesthetic adjustment factors are included in CAVAT’s valuation. Yet they are irrelevant to actual replacement cost. Why should it cost more to replace a tree (bearing in mind that the cost of maintenance is not included) in an area of high population density and high visibility than in a remote location? Why should it cost more to replace a tree because it has some association with a famous person?

Why in any case should replacement cost be entirely attributed to retaining aesthetic values, given that there may be many other deemed benefits constituting reasons for replacing the tree?

Is it really the estimated amenity value of the tree?

A multiplicative relationship in deriving an amenity valuation is reasonable: as in everyday economics, the magnitude of individual benefit should be multiplied by the number of beneficiaries and a variable (such as a discount factor) representing duration of benefit.

What is more at issue is this: the scales on which individual elements in the product are assessed, and how individual benefit might map onto these.

For a start, is a tree which has a high calculated replacement cost necessarily more beautiful? The use by CAVAT of a constant “unit value factor” seems to avoid the difficulty: but this makes any claim to represent replacement cost very tenuous, as trees may cost quite different amounts to replace, depending on species and variety, and on the difficulties of the site, in addition to the already-included basal area measure.

Which brings us to that basal area measure. A tree’s visual impact depends on its crown’s visible area, an element included in Helliwell’s method. This in turn is correlated in a general way with basal area.
In a general, ordinal sense also, it is likely that the bigger – the more visible – a tree is, the more valuable it will be. But there will be diminishing marginal returns to size, as measured by basal area. And eventually a tree may become oppressively large, especially in intimate urban spaces, or block out views, or crowd out other aesthetic features, so the marginal value could become negative (Schroeder, 1986; Jianga et al., 2015).

A feature of CAVAT’s so-named quick method (Neilan, 2017b) is its banding of tree sizes (Doick et al., 2018, p.82), as presented in table 1.
Table 1: Translation of actual tree size into size bands, with value indicated

<table>
<thead>
<tr>
<th>Size band no.</th>
<th>Trunk diameter at breast height, cm</th>
<th>Value (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt;6</td>
<td>280</td>
</tr>
<tr>
<td>2</td>
<td>6–&lt;9</td>
<td>700</td>
</tr>
<tr>
<td>3</td>
<td>9–&lt;12</td>
<td>1,380</td>
</tr>
<tr>
<td>4</td>
<td>12–&lt;15</td>
<td>2,270</td>
</tr>
<tr>
<td>5</td>
<td>15–&lt;20</td>
<td>3,820</td>
</tr>
<tr>
<td>6</td>
<td>20–&lt;25</td>
<td>6,310</td>
</tr>
<tr>
<td>7</td>
<td>25–&lt;30</td>
<td>9,430</td>
</tr>
<tr>
<td>8</td>
<td>30–&lt;40</td>
<td>15,300</td>
</tr>
<tr>
<td>9</td>
<td>40–&lt;50</td>
<td>25,300</td>
</tr>
<tr>
<td>10</td>
<td>50–&lt;60</td>
<td>37,700</td>
</tr>
<tr>
<td>11</td>
<td>60–&lt;70</td>
<td>52,700</td>
</tr>
<tr>
<td>12</td>
<td>70–&lt;85</td>
<td>70,200</td>
</tr>
<tr>
<td>13</td>
<td>85–&lt;100</td>
<td>101,000</td>
</tr>
<tr>
<td>14</td>
<td>100–&lt;115</td>
<td>138,000</td>
</tr>
<tr>
<td>15</td>
<td>115–&lt;130</td>
<td>180,000</td>
</tr>
<tr>
<td>16</td>
<td>&gt;130</td>
<td>227,000</td>
</tr>
</tbody>
</table>

As intended, value rises about in proportion to the square of tree diameter. But why, even in a quick method, are actual values assigned to bands, rather than being used as they stand? One answer given is that “As generally in CAVAT, the banding approach is used, for robustness” (Neilan, 2017b, p.9) or “A banding approach helps provide robustness to an assessment” (Doick et al., 2018, p.80). That is to say, the answer obtained will not be sensitive to small errors in measurement (unless they occur at a band boundary). But by the same token, banding embodies unnecessary approximation: it is of some
concern that a tree of 40.0 cm diameter has 65% more ascribed value than one of 39.9 cm diameter. Might it not be better to use an approximate real value than a precise but inaccurate band?

For a given basal area, visual impact normally increases with a crown’s condition and completeness. On the other hand, a “surprising” condition, such that the crown is fragmented, may have more visual impact. And – what is not the same thing – visual appeal of a given tree crown may vary with aesthetic fashion and subjective taste. Consider the dialogue attached to the tree illustrated in figure 1. It is *crown incompleteness* that gives Scots pine (*Pinus sylvestris* L.) the visual qualities that appealed to the Romantic movement, for example as sometimes expressed in trees painted by Caspar David Friedrich. Such influence of shifting aesthetic judgement undermines CAVAT’s claim of consistency.

Figure 1: Scots pine with idiosyncratic appeal

“I’d say, crown about 40% complete.

But hey, it’s so picturesque. Like, seriously Gothic, man!

No % augmentation for Gothic. Sorry.

“Special factor adjustment” gives further scope for subjectivity. “[It] should be used sparingly; there may be up to a maximum of 4 special
factors and a maximum adjustment of 40%” (Neilan, 2017a). One can see why the author is cautious. These factors include that the tree is:

- an integral part of a designed landscape;
- by a school entrance;
- known to be planted by a notable person;
- rare or unusual species.

No argument is given or even attempted for the 10% adjustment figure, nor why being by a school entrance has the same importance as being planted by a notable person. Nor is there objective means of saying “how integral”, “how near” or “how rare” a tree would have to be to count, nor “how notable” a person had been, to be deemed worthy of such an accolade. In practice norms and designations might be referred to, but these themselves will have been the result of some past aesthetic judgement.

No-one should believe that attaching a number to a concept removes its subjectivity.

The quantity of human experiences is represented by a population density measure. Table 2 reproduces table 1 from Doick et al. (2018, p.75). Again, however, the raw numbers are condensed into density bands. It is notable that the band factor %, which is used in the actual calculations, does not rise nearly in proportion to actual densities – and does not rise at all beyond 119 persons per hectare. This implies people in very densely populated areas count for much less per head. And, for example, that those living at population density 5 persons per hectare count for $\frac{100}{5} = 20\%$ per head, compared with $\frac{125}{35} = 3.6\%$ per head for those living at 35 per hectare. The band numbers are labels, with no arithmetic significance.
Most economists would ask: “why isn’t benefit just proportional to the number of beneficiaries?” And the given answer has been: “a conservative approach was considered by the ... Executive ... to be more acceptable to ... stake-holders likely to use CAVAT and was, therefore, favoured” (Doick et al., 2018, p.75). Blind prejudice 1: economic rationality 0. If, as may plausibly be supposed, there is a correlation between population density and population poverty, this dispensation takes a more sinister turn, with “Conservative” having a political connotation.

The population density variable is modified by descriptors of visibility, each assigned to a band of value reduction, as compiled from figures in Doick et al (2018, p.75).

Table 2: Community tree index (CTI) factors

<table>
<thead>
<tr>
<th>Population Density / Ha</th>
<th>CTI Factor %</th>
<th>CTI Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>20 – 39</td>
<td>125</td>
<td>2</td>
</tr>
<tr>
<td>40 – 59</td>
<td>150</td>
<td>3</td>
</tr>
<tr>
<td>60 – 79</td>
<td>175</td>
<td>4</td>
</tr>
<tr>
<td>80 – 99</td>
<td>200</td>
<td>5</td>
</tr>
<tr>
<td>100 – 119</td>
<td>225</td>
<td>6</td>
</tr>
<tr>
<td>&lt;119</td>
<td>250</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 3: Visibility adjustment

<table>
<thead>
<tr>
<th>Visibility descriptor</th>
<th>Value reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully visible in or from a public place</td>
<td>0%</td>
</tr>
<tr>
<td>Wholly visible though in a public area not widely accessible</td>
<td>25%</td>
</tr>
<tr>
<td>Less accessible while still being in a publicly owned area</td>
<td>50%</td>
</tr>
<tr>
<td>Not accessible or wholly invisible to the public</td>
<td>75%</td>
</tr>
</tbody>
</table>
The numbers seem to be derived impressionistically. An insight into the thinking on valuation is unwittingly offered: “a tree that is not publicly visible still makes a range of contributions to public amenity …” (Doick et al., 2018, p.75). This threatens to move into contentious passive use value territory, where a tree has aesthetic value, just because the public knows about it. Or, suppose the tree is not only unseen, but unknown? This moves into even more contentious intrinsic value territory, where a tree’s right to exist (as an object of beauty) is asserted to constitute a public benefit. An alternative, equally contentious interpretation of “contributions to public amenity” is offered later.

The duration of benefit is embodied in life expectancy adjustment, reproduced in table 4.

Table 4: Life expectancy adjustment factors

<table>
<thead>
<tr>
<th>Life expectancy (years)</th>
<th>% value retained</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;80</td>
<td>100</td>
</tr>
<tr>
<td>40–80</td>
<td>95</td>
</tr>
<tr>
<td>20–40</td>
<td>80</td>
</tr>
<tr>
<td>10–20</td>
<td>55</td>
</tr>
<tr>
<td>5–10</td>
<td>30</td>
</tr>
<tr>
<td>&lt;5</td>
<td>10</td>
</tr>
</tbody>
</table>

Source: Neilan (2017a, p.13; 2017b, p.12)

These numbers are plotted in figure 2. They will be seen to lie close to a line showing capitalised value for a period (as a percentage of capitalised value in perpetuity) at a 5% discount rate. Value capitalised at the Treasury’s advised discount rate for public project assessment (HM Treasury, undated) is also shown. Given that discounting aesthetic values is a contentious matter (Price, 1993; 2017, chapter 16), a further curve shows the effect of discounting at a notional rate of 0.5% to reflect the risk of a target tree’s being destroyed by unknown forces, before its expected life is complete.
Figure 2: Tree life expectancy and value adjustment

The time horizon CAVAT adopts for tree benefits is 80 years, on the grounds that “eighty years is chosen as representing in round figures the current length of human life expectancy in the UK.” (Neilan, 2017a, p.12). But human life expectancy is irrelevant in this context: what is valued is public benefit, and this may continue far beyond any individual’s life span.

Despite the adjustment made for initial size of the target tree, the tree is implicitly deemed to have constant visual effect through its remaining life. This contrasts with the discounting of visual effect employed in Price (2017, p. 379).

In all these ways, the components of assessed amenity value are suspect: sometimes because judgements, often unsubstantiated, are made; but sometimes also, because the process departs from common economic convention and logic.

So is it really the capital asset value (as implied by the name)?

Capital value, although its meaning is much debated, is not other than the [capitalised] stream of future cost and benefit. In this sense, all that has been said above about CAVAT’s disputable valuation of amenity costs and benefits also undermines it as a capital asset valuation.

One could present CAVAT value as though a financial instrument: “[Some as yet unidentified person] promises to pay the bearer on demand
the sum of £X if this tree is damaged or lost sometime in the future” (so again values need discounting, but the time frame of doing so is different).

Which person or agency would own this instrument is doubtful, given that the values embodied are non-market ones; it is also doubtful whether such an instrument could meaningfully be traded.

I do not see that this conception adds usefully to the interpretations of value already discussed, though it might cloud the waters effectively.

**Is it really a political lever to gain appropriate compensation?**

CAVAT has been successful in extracting more money, usually from developers, than had been achieved before formal monetisation of tree value was employed. But this does not say that the extracted compensation is at the appropriate level. Unless, that is, there is some kind of underlying market equilibrium concept, as has been claimed. “[CAVAT]…attributes a value to an urban tree that two parties mutually agree on … [so is…] market driven … providing an indication of a ‘market’ price” (Doick et al., 2018, p.69).

Let us suppose the parties to be the developers and the public authority. For the developers, the upper bound of willingness to pay for the right to remove trees would be the development value forgone if the tree could not be removed. For the public authority, the lower bound of willingness to accept compensation would be the conceived replacement cost or the amenity value forgone, whichever CAVAT is supposed to represent. In the probably broad band between these values, the “market price” is in fact no such thing, as the requisite “many buyers and sellers” are absent. Instead, the figure resolved on would depend on negotiating skills and political leverage. CAVAT gives a starting point for negotiation; but no-one should confuse that with a proper basis for valuation.

Alternatively, consider a quasi-market as might be conceived by the public authority itself, in which a kind of equilibrium between replacement cost and amenity value is envisaged. In relation to planting cost, the argument could be “We wouldn’t have planted such a tree, if it hadn’t been worth (at least) the cost.” But of course, rationality would still be evinced, if the tree had been worth much more than the cost. Only in a general equilibrium setting, in which the whole spectrum of tree planting activities
and expenditures was examined, could a marginal tree value, resembling a market price, be identified. Besides, how did the authority know how much the tree was worth? To say it had been so valued by CAVAT is merely to mount a circular argument. Such equating of public worth and financial cost has been idly made since the time of Gregory (1955), and denounced in a tree context by Price (2007a; 2017 chapter 2). It has been implied that tree-based professionals are somehow imbued with the capacity to give an unbiased and representative account of aesthetic value: “CAVAT’s strength therefore is that it uses experts to give a valuation where only experts can” (Doick et al., 2018, p.89) (and implicitly the public can not). By contrast: “… cultural values are actually the ones on which the [public] have legitimate expertise, based on their own perception …; they are the ones on which scientific experts have no other information” (Price, 2018b, p.248).

Finally, and crucially, what basket of deemed benefits was balanced by experts against replacement cost? This question meets viewpoints, as expressed by proponents, which are at the least inconsistent, if not downright contradictory.

Some imply that CAVAT offers principally or exclusively a valuation of aesthetic matters.

- “CAVAT complements other forms of assessment of trees’ amenity.” (Neilan, 2017a, p.3, 2017b, p.3) [my italics]. That is, it doesn’t include the whole spread of values.
- “Indeed, many i-Tree Eco studies conducted in the UK … have augmented their i-Tree Eco survey with the CAVAT methodology in order to address Eco’s short fall in cultural ecosystem service considerations” (Doick et al., 2018, p.70) [my italics].
- “CAVAT has not been designed like i-Tree to value ecosystem services” (Doick et al., 2018, p.69); (services, presumably, other than cultural ones).

Contrastingly, other statements imply that a wider range of benefits is included, as must logically be the case, if judgements have been made that a tree, with its full range of ecosystem services, is worth replacing – one cannot replace a tree’s aesthetic services, without in some way activating its other services.
… [other amenity] benefits-based approaches (e.g. Helliwell system and i-Tree …) … reflect only a subset of … amenity tree benefits (and values). Consequently, a tool that provides a compensation value for … loss of an amenity tree is required. CAVAT has been designed to fill this void" (Doick et al., 2018, p.69) [my italics]. The meaning here is confusing, as the Helliwell system (2018) values only aesthetic benefits, while i-Tree may not include aesthetic benefits at all. Where the void lies is therefore uncertain.

[If a tree is] “not accessible or wholly invisible to the public … CTI adjusted score is reduced by 75% … recognising that a tree that is not publicly visible still makes a range of contributions to public amenity and well-being, including in respect of health, climate change and biodiversity” (Doick et al., 2018, p.75). So, it seems that CAVAT does take some account of ecosystem services other than cultural ones. Moreover, this remaining 25% double-counts the listed public benefits, which should have been assessed otherwise, e.g. in i-tree ECO. Notably, values such as CO₂ mitigation are experienced globally, so local population density is therefore wholly irrelevant to this segment of the implied calculation.

If it is not known which benefits have been balanced against costs, which ones are deemed to be in equilibrium with costs (however those are defined)? Of what do we have a market price?

Conclusions

In advocacy of the method, it is stated that CAVAT is widely used. The same could be said of nicotine, heroine and alcohol, but this does not prove that they are of public benefit.

In the face of all these criticisms, the creators of CAVAT might well ask: “So, what could be done that was any better?” Admittedly, many of the difficulties CAVAT faces, such as subjective judgement and banding, have been encountered by other systems. But, despite the problems, valuing the following changes, consequent on the loss of a tree, ought to be attempted.

The tree has to be disposed of, often no easy task in an urban setting.

It may be replaced, like for like or otherwise.

The cost of replacing it at the end of its “natural” life is avoided.
There is a change in the far future profile of replacement costs.

Aesthetic and other ecosystem services are curtailed – something to be valued independently of cost.

In future, those ecosystem services re-emerge, with a different time profile, and possibly at a different level.

These may not be easy effects to value, but it is necessary that the valuation should be attempted, if the capital value of a target tree is to be established.

References


Price, C. (1993). *Time, Discounting and Value*. Blackwell, Oxford; also available electronically from the author c.price@bangor.ac.uk


Price, C. (this volume). Societal costs of urban tree diseases


102
20. Influencing economic policy: Experiences from the Danish Economic Councils

Eirik S. Amundsen, University of Bergen and University of Copenhagen

Abstract: In general, research should benefit society, and there are many avenues one may follow to achieve that. In this paper, we consider the use of up to date applied research for economic policy recommendations conveyed through a Danish think tank, called The Danish Economic Councils. First, a description of The Danish Economic Councils is given, then some historical impacts of this institution is considered, before some more recent contributions of the Environmental Economic Council (which is a part of The Danish Economic Councils) is discussed. These encompass analyses of recreational values in Denmark, of targeted nitrogen regulation and of Danish energy and climate policy.

Keywords: Danish Economic Councils, applied research, policy recommendations

Introduction

Research is a public good that to a large extent is funded by governmental direct subsidies and support schemes partially intended to stimulate innovations (organizational and technological) and benefits from spillover effects that would otherwise not come about if left to private funding alone. Hence, the expectation is that research eventually should benefit society. Research, however, goes on at different levels and are at different stages, and not all obtained results are directly applicable to society. Basic research for instance may take years before it is put into use, if ever, whereas applied research has a more direct way to benefitting society.

Considering the social sciences (e.g. economics), up to date and well established results may find their way to policy makers through different channels. One goes through individual outreach activities of researchers that publish reports, participate in public commissions, write columns in
newspapers, take part in debates, and so on. Another goes through specific obligations of servicing governmental bodies. Under this arrangement (“myndighedsbetjening”) independent research institutions (e.g. university departments) enter into a contract with a governmental body to be on call to service on specific research/consultation work decided by the governmental body. This is quite extensively used in Denmark. Yet another way is through the activities of so-called “think tanks” that may be more or less independent from various kinds of interests. In Denmark, a specific “think tank” of economics was established some 50 years ago: The Danish Economic Councils.

The Danish Economic Councils is an independent economic advisory body. The primary objective of the institution is to provide independent analysis and policy advice to Danish policy makers. Similar institutions exist around the world. They are all national institutions and financed by the governments, but they may differ with respect to how independent they are from the Parliaments and the decision makers. Examples of such institutions are the Council of Economic Advisers that was established in USA in 1946, The Social and Economic Council of the Netherlands (SER), established in 1950, and The German Council of Economic Experts (1963). In the other Nordic countries, we have “Konjunkturinstitutet” which is a part of the Swedish Ministry of Finance, established in 1937 and The Economic Council of Finland (1966) that has the prime minister as the chairman.

**The Danish Economic Councils**

The Danish Economic Councils consist of two councils with one joint, independent Chairmanship. The Economic Council was established by law in 1962. The Council has 25 members representing unions, employers, the Danish Central Bank and the Danish Government. The members of the Economic Council meet twice a year to discuss a report prepared by the Chairmanship. The Environmental Economic Council was established by law in 2007. This Council has 24 members representing unions, employers, NGO's and the Danish Government. The members of the Environmental

---

1 See description at [https://dors.dk/](https://dors.dk/)
Economic Council meet once a year to discuss a report prepared by the Chairmanship.

The Chairmanship consists of four university professors of economics, and are publicly often referred to as the "economic wise men". The Chairmanship is independent, and is responsible for the analyses and conclusions provided in the three main reports: “Dansk Økonomi” (“Danish Economy”, published twice a year) and “Økonomi og Miljø” (“Economy and Environment”, published once a year). In addition to presiding over the councils, the Chairmanship has two tasks: To oversee the sustainability and soundness of the public finances, thus acting as an independent fiscal institution, (i.e. fiscal watchdog) and to analyze productivity and competitiveness of the Danish economy, thus acting as a National Productivity Board.

The Chairmanship is self-recruiting in the sense that it chooses new candidates among university professors of economics trained in general economic theory and with relevant specialties (e.g. within labor market, macroeconomics, environmental and resource economics, etc.). However, the candidates have to be approved by the Ministry for Economic Affairs and Interior. The Chairmen alone decide on the themes to be investigated, and otherwise follow a policy of independence from governmental bodies and other interest groups. The Chairmen are supported by a secretariat of 30+ persons engaging in specific analyses, writing drafts and helping out administratively. Many recently educated master and PhD.-candidates of economics are engaged. At the day of the council meeting, all council members sit in the same room and discuss the report that has (under confidentiality) been distributed a couple of weeks earlier. After the council meeting there is a press-meeting with interviews of chairmen and council members. Later on, typically on the same day, the report is presented before the relevant Parliamentary committee (e.g. the committee of Finance or the Energy and Environment committee). In the period after the council meeting each member of the council may write a commentary to the report. These are printed as addendums to the report, and subsequently the report with the addendums are openly published. The main report is not altered.
Historic impacts of the councils

Historically many ideas from the Danish Economic Councils have been adopted but the recommendations were not always popular. Recommendations regarding labor market policies have often been accepted, e.g. increasing the age of withdrawal from the labor market (reforming the early retirement program) and shortening the support period of unemployment. Furthermore, the idea of calculating and analyzing the effects of budgetary policies were developed by the Chairmen in the 1970’ies and are now generally adopted by the Ministry of Finance and elsewhere. On the other hand, repeated recommendations for increasing housing taxes have not been followed up by politicians. Other recommendations and conclusions of the Chairmanship have been outright unpopular. For instance, the EMU-chapter of “Danish Economy - 2000” was heavily criticized by many political parties when the Chairmanship concluded that “The benefits of joining the EMU (Euro) are small and uncertain”. Another example is the chapter on biodiversity published in “Danish Economy – 1998. This chapter came as a surprise to the council members that were not used to read about environmental matters in the reports. The chapter was also partly ridiculed by the media expressing that the Chairmanship tried to measure “the value of lark song”. Since then, however, the attitudes towards environmental matters among council members and the press have changed quite a lot. To some extent, this has been due to the foundation of the Environmental Economic Council.

Since the establishment of the Environmental Economic Council in 2007, many and varied topics have been dealt with in the reports. These comprise discussion of major questions such as economic growth and the environment, and, energy use and climate policy. Along with this, also questions related to so called genuine saving (i.e. taking account of resource use at large) has been dealt with. Otherwise, multiple chapters on pollution have been written, including pollution of air and groundwater, as well as pollution of lakes, rivers and coastal water. Also, several chapters on measures and instruments (e.g. green taxes) to internalize the negative effects of pollution have been published.
Examples of analyses in Economy and Environment

In order to illustrate the kind of analyses executed in the environmental reports, three examples will be presented: The study on recreational values in Denmark (2014), the study on regulation of agricultural nitrogen emissions (2017), and several studies on Danish energy and climate policy. To some extent, these analyses also illustrate the span of topics investigated and of methods applied in the reports.

Recreational values

The objective of this study was to assess the recreational values derived from natural areas and city parks across Denmark and to recommend policies for the management of such areas. Recreational values are among the most important of the various eco system services (e.g. sequestration, biodiversity, protection of groundwater) generated by nature (Bateman et al., 2013). In this study several questions were addressed: How important is the recreational value of the Danish natural environment? How important is localization for the size of recreational values and where is the recreational value highest? Does public afforestation and subsidies to private afforestation result in an efficient localization from the point of view of recreation? How large is the recreational value of a forest as compared with other use values of a forest (sequestration, biodiversity, protection of groundwater)? These questions were addressed using both “revealed preference methods” and “stated preference methods”.

The assessment, that was performed in cooperation with the Department of Environmental Science, Aarhus University, is based on a two multiple-site travel cost model combining spatial data on recreational trips and socioeconomic observations for the Danish population and the location of and characteristics of Danish recreational areas. In the analysis, a data set comprising some 2500 areas were compiled. The areas include both larger natural areas (forests, open natural areas, moors) and city parks in the five largest cities. Hence, the analysis does not include agricultural areas and small natural areas.

The analysis shows that recreational values may be quite large, but also that there is a considerable variation. Hence, while the average annual recreational value calculated was approximately DKK 8,000 per ha, the
values ranged from less than DKK 1,000 up to over DKK 700,000 per ha. City parks in the major cities turned out to have even higher values.

As shown in Fig. 1. The areas with the highest recreational values are typically located close to urban areas with a high density of potential users of the natural areas. One conclusion to be drawn from this is that new recreational areas should be placed on the outskirts of cities. An interesting other result from the analysis is that a natural area located close to a major city still has a very high recreational value when controlling for access to other outdoor recreation in such densely populated areas.

Fig. 1. Recreational values vs. concentration of population. Source: Økonomi og Miljø - 2014

Even though location is important, the recreational value also depends on the quality of the site. In particular, people seem to prefer sites with a combination of forests, lakes and streams and with a close proximity to the sea. Furthermore, the study showed that state-owned forests were preferred to privately owned forests. This is probably due to different management schemes and the less restrictive access rules of state-owned forests.

Regarding the importance of forests - and in particular state-owned forests - the report points to the large potential generation of high recreational values of choosing good locations for new forests. Assessment of new state-owned forests shows an annual average recreational value of a
approximately DKK 37,000, which is higher than the average for all recreational areas. However, the report also shows that some of the new forests could have been located even more favorably in terms of generating high recreational values.

The study also discusses the afforestation policy in Denmark where plans exist to double the forest cover. This is promoted both by creating new state-owned forests and by giving subsidies to new privately owned forests. By investigating the actual location of new privately owned forests, the report concludes that they are considerably less well located in terms of generating recreational values than the state-owned forests.

The report recognizes the importance of other ecosystem services of forests such as carbon storage, protection of ground water, and biodiversity preservation. However, the analysis shows that these are not as high as the potential recreational values. A main conclusion and recommendation of the study is that the creation of new forests should be governed by where the forests can generate high recreational values, and that the government should implement a more systematic approach when choosing where to locate the new forests.

*Regulation of nitrogen emissions*

As in many other countries, Denmark faces a problem of nitrogen use in agricultural production in that leaching of nitrogen rich fertilizers affects the ecological status of water bodies negatively (unclear water, oxygen depletion and deteriorated living conditions for flora and fauna). The negative effect of nitrogen use depends on several factors such as the amount of fertilizers used, the type of crops grown and the retention of soil (in addition to other factors e.g. rainfall and steepness of ground). The last two main factors are generally observable, while the first is not directly observable. Observability is important because lack of observability may lead to moral hazard problems, i.e. actions on the part of the farmers that are not in line with the intention of regulation. For instance, farmers may purchase fertilizers abroad, engage in second hand trade with farmers that are not subject to equally harsh regulation, and report less use of fertilizers than actually used.

---

2 It should be noted that not all ecosystem services were assessed e.g. such as the benefits generated by avoiding pesticide contamination of drinking water.
The study investigates how the existing nitrogen regulation may be improved by introducing some kind of a targeted regulation scheme. The existing regulation system in Denmark is a nitrogen allowance system, where the allowance granted to each farmer is based on the economically optimal amount of nitrogen for a given crop on a given field, less a certain percentage that is the same for all farmers. The percentage is neither dependent on the crop grown nor on the retention of the soil.

The problem with the allowance regulation is that it does not give any particular incentive to reduce nitrogen use on sensitive fields with low retention i.e. the fields that cause most harm to the coastal waters. This cannot, however, be solved by simply making the reduction percentages sensitive to each farmer’s retention characteristics or crop choice.\(^3\) The problem is that differentiation of nitrogen allowances would give rise to private economic benefits from circumventing the regulations. Hence, it would be profitable to transfer nitrogen from fields with a large allowance to fields with a low allowance. Therefore, the regulation would be very difficult to control and enforce.

Hence, a targeted regulation scheme that can substitute for the allowance system is called for. This is not an easy task, since a first best regulation system should confront the individual farmer with the harm inflicted on the receptors (e.g. lakes or coastal waters). As observed, the way from nitrogen use at the field to the cost inflicted on the receptor depends on many factors that are not all observable. Therefore, a second best regulation system is the best one can hope for.

In 2015 the government announced a new policy of targeted regulation to be gradually implemented and developed from 2019 on\(^4\). A part of this policy change involves a new specific regulation of nitrogen use based on so-called leaching rights. Basically, for each farmer there is decided a right in terms of a maximal amount of nitrogen leaching per ha land. This right is the same for all farmers in the same water catchment area, but the right differs between water catchment areas according to how harmful the nitrogen leaching is.

---

\(^3\) Such a change was discussed by the government in relation to the new water protection plans for 2015-21, but was never adopted.

\(^4\) Fødevare- og landbrugspakken (2015)
The 2017 report of Economy and Environment investigated an alternative to such a system, by considering a targeted crop tax i.e. a tax paid by the individual farmer that depends on the size of the cultivated area, the farmer’s choice of crops and the retention of the soil. In addition, a tax per live stock unit were proposed (i.e. to take account of nitrogen emissions from livestock manure). The report considered various version of the leaching right system and compared the cost to society of reaching the targets by the two systems. A firm conclusion of the analysis was that a crop tax would function better than the leaching right systems considered, and, therefore, the Chairmanship recommended that a crop tax should be adopted rather than the leaching rights system. It should be noted, however, that the final design of the leaching right system has not yet been decided on by the authorities.

_Energy and climate policy_

The Chairmen of the Environmental Economic Council have discussed the Danish energy and climate policy in several reports. In general, it is fair to say that the Chairmen have been rather critical to the policy adopted in Denmark. There are several aspects of this criticisms including; one concerning the targets of the energy policy, one concerning the energy policy related to the quota market and one concerning the efficiency of the PSO system.

The targets of the Danish energy policy are somewhat unexplained. In particular, one may point to the missing analyses of why Denmark should need to expand the electricity generation capacity by constructing large and costly new wind power plants when there is an easy access to the Nordic electricity market (that also includes the Baltic countries and that is well connected to the German electricity system.). As long as the new wind power plants can survive without subsidies this could, of course, indicate a sound investment for society. However, if subsidies are needed this may no longer be true.

Also, it is not obvious why Denmark (and the EU) have a general target of reducing energy use. Energy is a necessary factor of production like capital and labor, and just as it does not make sense to have targets on reducing the use of capital or labor, it does not make sense to have a target
on reducing the use of energy as such. Only fossil energy should be reduced, not general energy use.

A very important criticism from the Chairmen concerns the targets relating to carbon reduction of activities (e.g. electricity generation) that are included in the quota sector (EU ETS). Traditionally, carbon reductions in the quota sector have been redundant as they had no direct effect on global carbon emissions. The released amount of emission permits that would follow from the reduced emissions of carbon within the quota sector would simply be available to other members of the quota sector, without affecting the total emissions within the EU. With the newly adopted rules of the EU ETS (e.g. the reserve mechanism), this has now changed somewhat. Nevertheless, the main recommendation of the Chairmen still seems valid i.e. that Denmark should focus on carbon reductions in the non-quota sector such as transport, and heating and in particular involve the agricultural sector. In part, Denmark should also cover some of the reduction obligations by purchasing and cancelling out emission quotas.

A particular concern relates to the so-called PSO system for financing new wind power plants. The system is such that new offshore wind power plants are granted guaranteed electricity prices and these guaranteed prices are made up of the variable wholesale price of electricity and a residual PSO grant on top to reach the guaranteed price. Generally, falling wholesale prices of the common Nordic electricity market implied an increased subsidy in terms of a higher PSO that, thus, became increasingly burdensome for the society.

The new Danish offshore wind power plants come, to a large extent, in addition to existing capacity for electricity generation and thus have a negative effect on the Nordic wholesale prices. As the PSO is paid over the electricity bill, this implies increasing electricity prices of end users of electricity in Denmark. Hence, Danish consumers get higher end user prices of electricity while the rest of the Nordic market benefit from the induced lower wholesale prices. Recently, however, the criticism of the system (also complaints by the EU) has led to an abandonment of the system. Future subsidies will now be financed by the general state budget.
Concluding remarks

It is of course difficult to measure the influence of an institution such as the Danish Economic Councils. One cannot simply attribute a policy change that was recommended by the Danish Economic Councils as a proof of impact. There, may be so many other explanations as to why the policy change is made.

However, there is no doubt that the Danish Economic Councils have an influence with respect to generating debates on important economic issues. The fact that all Council members, representing the top leaders of the most important institutions in Denmark, sit in the same room and openly discuss the issues raised by the Chairmen, is an indication of influence, even though the members may not agree with the Chairmen’s recommendations. Also, the following press-meeting with national television and other media present, as well as the subsequent presentations before the Parliamentary committees guarantee that information of the various opinions on the issues raised are spread to a broader audience, and possibly, also generate further debate.

In conclusion, it seems fair to say that a think tank such as The Danish Economic Councils represents an important link between Academia and policy making, when it comes to using up to date applied research on reaching firm policy recommendations. Integrity is, however, important for a well-functioning think tank. Just as for public consulting work made by researchers at the universities, independence and arm’s length principles are imperative, and should be held dearly.

Literature


De Økonomiske Råd, “Dansk valutapolitik ved en skillevej” i “Dansk Økonomi,- Forår 2000”

De Økonomiske Råd, “Rekreative værdier” i “Economy and Environment - 2014”
De Økonomiske Råd, “Omkostninger ved VE-støtte” i “Economy and Environment - 2014”

De Økonomiske Råd, “Regulering af landbrugets kvælstofudledning” i “Economy and Environment - 2017”


A Case Study of Replanting Mangrove Forests in Cambodia

Lea Ravnkilde Møller

PhD candidate at UNEP DTU Partnership, DTU Management Engineering, Technical University of Denmark, Marmorvej 51, DK-2100 Copenhagen, Denmark

Jette Bredahl Jacobsen

Professor at the Department of Food and Resource Economics and Centre for Macroecology, Evolution and Climate, University of Copenhagen, Rolighedsvej 23, DK-1958 Frederiksberg C, Denmark

Keywords: Synergies; Adaptation, Mitigation; Expected Damage Costs; Climate Change

Abstract

The paper demonstrates welfare benefits of climate change adaptation leading to mitigation in a case study of mangrove forest replanting in part of the coastal wetland areas of the Peam Krasaop Wildlife Sanctuary in Cambodia. The community is suffering from storm damage which is expected to be increased by climate change. Replanting mangrove forests is a means to adapt to climate change, which protects the local community. Based on information on income, climate change and expected changes in the mangrove area, we simulate development in the mangrove forest area and the associated welfare economic consequences in terms of income loss and mitigation benefits. We estimate the adaptation benefit based on an expected damage cost approach and the mitigation benefit based on the amount of carbon sequestered in the replanted area as well as a carbon price.

---

5 This paper was presented in the previous SSFE conference, but by mistake not included in the proceedings. Therefore included here
For a wide range of scenarios and assumptions, the paper concludes that the welfare benefit of replanting is positive if one looks at adaptation alone and even more so if mitigation is included. Consequently, considering adaptation and mitigation benefits jointly leads to higher replanting intensities than considering adaptation alone. Payment for mitigation needs to be implemented if it is to attract private decision makers.

**Introduction**

Climate change adaptation and mitigation are two different approaches to handle climate change; mitigation is mostly seen as a global public good, reducing the cost of adaptation, and adaptation is mostly seen as a local and also often private good (Ingham et al. 2013; Kane & Shogren 2000), that reduce the need for (and thereby the marginal cost of) mitigation. As they are interrelated, if we want to maximise welfare, we need to look at both – assuming that climate change stays below a threshold where a mix of adaptation and mitigation is possible. (Watkins et al. 2015).

Technologies for adaptation and mitigation have largely been advanced individually due to the large variation of the spatial and temporal characteristics and different stakeholders and implementation approaches (Watkins et al. 2015). Consequently, also much of the literature focuses on only one of them (Canadell & Raupach 2008; McGlade et al. 2007; IPCC 2007) as does the United Nations Framework Convention on Climate Change (UNFCCC) and policy-oriented programmes in this framework such as the clean development mechanism (CDM), Nationally Appropriate Mitigation Action (NAMA), National Adaptation programmes of Action (NAPA), and Reduced emissions from deforestation and forest degradation in developing countries (REDD+). IPCC (2014b) finds that research into interrelationships between climate change mitigation and adaptation is fragmented, and examples from real life (Matocha et al. 2012; Verchot et al. 2007; Laukkonen et al. 2009) question the findings in the theoretical approaches (Felgenhauer & Webster 2013) highlighting a need for research regarding interrelationships between climate change adaptation and mitigation (Klein et al. 2007; Locatelli et al. 2011; Ingham et al. 2013; Kane & Shogren 2000; Watkins et al. 2015; Locatelli et al. 2015).
Therefore, the area is still in need of in-depth, empirical and local knowledge to understand the interrelationships and complexity of climate change adaptation and mitigation and for methodologic development and tools for implementation. This requires case specific information, which in many cases is not available. In this paper we illustrate how far we can get with establishing such a model, based on empirical data when available, and otherwise reasonable assumptions. We do so by looking at a local case study of adaptation by replanting mangrove (*Rhizophora apiculata* Bl.) forest in Cambodia. We quantify the possible welfare economic benefits of replanting and address unintended side-effects of interrelationship between climate change adaptation and mitigation (Locatelli et al. 2015). We do so by looking at two different replanting strategies – a fast and a slow – and three different climate change scenarios and estimate the avoided expected damage cost by replanting.

The underlying assumption is that adaptation is the main objective of local decision makers. However adaptation in the form of replanting may also contribute to mitigation as unintended benefits. This can ideally promote investment in adaptation through carbon funding and ecosystems services, which thereby potentially increases welfare. This is a situation in which the two measures complement each other. If a drop in the cost of adaptation or mitigation occurs, the ideal reaction will be to increase both (Ingham et al. 2013). This definition comes from Klein et al. (2007). Whether adaptation and mitigation are substitutes or complements is a much discussed area (Ingham et al. 2013; Kane & Shogren 2000; Felgenhauer & Webster 2013). Economic models have found that a mixture of adaptation and mitigation tends to be optimal from a substitution perspective (Ingham et al. 2013) while the policy literature reports that adaptation and mitigation tend to be complements (Locatelli et al. 2015).

Approaching adaptation and mitigation as complements allows us to assess whether a combination of climate change adaptation and mitigation at a local case level can contribute to greater welfare compared to initiatives in which adaptation and mitigation are addressed separately in response to climate change. If this is the case, there may be situations in which adaptation is not worth pursuing itself, but it may be worth pursuing if mitigation is also considered.
**Literature on the quantification and valuation of adaptation and mitigation**

One of the great barriers to understanding the interrelationships between adaptation and mitigation is the lack of quantitative indicators for adaptation (Lecocq & Shalizi 2007; Warren et al. 2012). One approach is the ‘expected damage cost’ (EDC) approach (Hanley & Barbier 2009; Barbier 2007), which looks at values directly. The EDC approach values storm protection in terms of the avoidance of future damage from storms (Barbier 2007) and falls in the category of ecosystem services valuation. Fisher et al. (2009) conclude that the number of papers addressing ecosystem service valuation is increasing exponentially. However, a search of the literature has shown that there are relatively few case studies based on the EDC approach even though some of the integrated assessment models (IAM) (Warren et al. 2012), such as the Dynamic Integrated Climate-Economy model (DICE) and the Regional Integrated model of Climate and the Economy (RICE) (Nordhaus 2014; Nordhaus 2011), are based on it. A number of studies refer to the ability of mangrove forests to protect communities and inland areas from storms and surges (Brauman et al. 2007; Das & Vincent 2009; Quisthoudt et al. 2012; Quisthoudt et al. 2013; Khan & Amelie 2015; Brisson et al. 2014; Sanford 2009) or they refer to the production function as an option for ecosystem service valuation (Fenichel et al. 2013; Liu et al. 2010; Sauer & Wossink 2013; Brauman et al. 2007; Jenkins et al. 2010). Barbier (2007) also mentions that the method have been used regularly in risk assessment and health economics - looking at how changes in assets affect the probability of a damaging event occurring. This method requires us to use the ecosystem as an input, developing a "production function" (Dupont 1991) for the mangrove’s ability to protect the community against storms. EDC is generally considered a valid approach for estimating the lower boundary of the value of avoided damages cost by mitigation of damages (Boutwell & Westra 2015), as it captures the full value of an ecosystem providing a service. It is not dependent on consumer preferences like other ecosystem service valuation methods (Brauman et al. 2007). Errors may appear with this method if the case is not well-defined or the quality of the data is poor (Boutwell & Westra 2015). In the current paper, we will use the EDC approach; and, because we focus on a very narrow case (as opposed to the larger climate models), the method of our study allows us to evaluate carefully the assumptions behind it and thereby point out
knowledge gaps. This is of particular importance in a developing country context where data is often limited, but where decisions area, of course, made. Consequently, judging the reasonability of the assumptions is crucial. We will return to this in section 6.

In this paper, the replanting of mangrove forests as a mitigation of climate change activity will be addressed through an estimation of the carbon sequestered and emitted in the replanted area, based on the IPCC (2014b) guidelines for calculating carbon sequestration in coastal wetlands. To estimate a value hereof, the social cost of carbon (SCC)\(^6\) is appropriate. The SCC is the net present value of one more or one less tonne of CO\(_2\)e emitted (van den Bergh & Botzen 2015). SCC can be found from IAM (Warren et al. 2012). Hope (2013) suggests an SCC of USD 106 per tonne of CO\(_2\)e for 2010, which is a mean estimate of an integrated assessment model (IAM) and considerably higher than the USD 81, which is used by the Stern review (Stern 2007). As Hope (2013) highlights, one has to be aware of the assumptions behind, e.g., discount rates, equity weight assumptions, socioeconomic scenarios, and climate sensitivity. Nordhaus (2011) estimates a cost of USD 12 per tonne of CO\(_2\)e at 2015 prices, including uncertainty, equity weighting, and risk aversion, based on the IAM RICE-2011 model, and the DICE-2013R model suggests USD 18.6 per tonne of CO\(_2\)e at 2005 prices (Nordhaus 2014). Tol (2008) did a meta-study based on 200 estimates of SCC with a mean of USD 25 per tC or USD 6.8 per tCO\(_2\)e, followed by other studies (Tol 2013; van den Bergh & Botzen 2014; van den Bergh & Botzen 2015). Van den Bergh and Botzen (2014) conclude that a cost of USD 125 per tonne of CO\(_2\)e represents the lower bound if one gives weight to the potential impact of climate change. As see, there is wide variation among these authors of the cost level – based among other things on disagreements of how to handle data (see, e.g., the editorial note in the vol. 29, no. 1 of the Journal of Economic Perspective (Anonymous 2015)).

An alternative to using SCC is to use the price of carbon traded on one of the existing markets. In an ideal world, where politicians take future generations fully into account and can agree on a social optimal amount of credits, this marketed price should reflect SCC. Though this is highly

---

\(^6\) Sometimes, a price per unit is used; sometimes, per unit CO\(_2\)e. One can be obtained from the other by recalculating the price based on the molecular weight of CO\(_2\) compared to a carbon molecule.
unlikely, it can be argued that it is the value current politicians can agree on assigning to it. Furthermore, such a market price is closer to potential compensation paid to local communities for the global public good of carbon sequestration, and may thereby better reflect potential local complements of adaptation. Consequently, we will use a range of such market prices from related markets, thereby obtaining a conservative estimate of the value of carbon mitigation – from a welfare economic point of view.

**Mangrove forests and climate change**

The mangrove forest is a forest type with the ability to survive in salty and brackish waters under influence of tidal water and an ability to colonize in a large range of habitats along ocean coastlines and estuaries throughout the tropics with a rather monoculture and inaccessible nature (Tomlinson 1986; Donato et al. 2011; Alongi 2008).

Mangrove forests play a key role for the livelihood of people living there, as a supplier of food, timber, fuel, and medicine (Alongi 2008). Mangrove forests also contribute to global biodiversity as a breeding and nursing ground for marine organisms (Gilman et al. 2008). The mangrove forest is one of the major carbon pools in the tropics, four to six times higher than boreal and tropical upland forests (Donato et al. 2011).

Climate change that impacts the mangrove forest may be such things as rising sea-level, increase in temperature, change in precipitation pattern, increase in storm frequency and intensity, and increased atmospheric CO$_2$ concentration (Gilman et al. 2008). The impact on the mangrove ecosystem is diverse: an increase in storm intensity and frequency can lead to increased damage to and mortalities of the forest (Alongi 2008), and other impacts may increase productivity and dynamics in the stand (Gilman et al. 2008; Alongi 2008). Mangrove forest ecosystems can be vulnerable to rising sea levels (Gilman et al. 2008). If the system cannot keep pace with the changing sea level compared to the change in elevation of the mangrove sediment, it can cause increased mortality among the trees (Gilman et al. 2008). Donato et al. (2011) state that it is unclear whether mangroves manage to keep pace with the sea-level rise, and Alongi (2008) argues that the mangrove can cope with rising sea levels by moving inland and that deforestation is more likely to exterminate mangrove forest. To know the
scale of the devastation from a rise in sea level, site-specific knowledge is necessary (Gilman et al. 2008). The mangrove forest’s response to climate change is very much dependent on the landscape dynamics and other ecosystem factors such as salinity and the level of nutrients; and, in many cases, it will respond positively (Alongi 2008).

In this paper we use the increased frequency of storms as a measure of the impact of climate change on the mangrove forest. Damage will be determined as hectares (ha) of destroyed mangrove forest. We do not consider the rise in sea level since data at the local level were not available.

The argument for considering the replanting of mangrove forests as adaptation is that it is very likely that increasing the area of mangrove forests will strengthen the resilience of the local community by protecting them from storm surges and natural hazards. Replanting will also contribute with a global mitigation benefit by carbon sequestration.

The case

The case study for this paper is the Peam Krasaop community located on the coast of Cambodia in the Koh Kong province, close to the border of Thailand. The Peam Krasaop community contains a mangrove forest (2,324.4 ha) and open water (2,300 ha). In addition, there are 5 ha of villages on the mainland, 16 ha of floating villages, and 15 ha of open land, which is being managed by 5 households, which support themselves on agriculture. The Peam Krasaop community is located inside the Peam Krasaop Wildlife Sanctuary, which is an area of approximately 26,000 ha. We focus on two townships within the Peam Krasaop community, the floating village and the new village. Both villages belong to the Peam Krasaop community.

Peam Krasaop has a population of 1,318 people distributed among 277 households (CCCA 2012). Their main occupations are based on ecosystem services from the mangrove forest such as coastal fishing, selling souvenirs, and providing tour guides.

The community in Peam Krasaop is very vulnerable to storms, and by climate change the storm frequency is expected to increase. Salt water is
intruding on the freshwater supply in the villages, damaging their livelihoods and threatening human safety. Another threat is flooding of the floating villages that are built on stilts near preferred fishing areas - on the edge of the mangrove forest and close to the open sea but, at the same time, close to the mainland. (CCCA 2012). Both types of villages will benefit from storm protection. The threats from storms have forced many to move from the floating village to the new village on the mainland. Many fishermen prefer to stay in the floating villages when they go fishing - to save money on fuel, but in periods with less fishing intensity they stay in the village on the mainland. The local fishermen are dependent on their boats for access to fishing grounds and to transport tourists. Not all the fishermen own their own boat. Some rent boats from others (Nielsen 2014).

The communities in Peam Krasaop are already exposed to the effects of storms and floods because of the vulnerability of their bad housing and fragile boats (CCCA 2012), and they have limited coping strategies with respect to storms. The community's vulnerability to storm is increased by the poor infrastructure in the area (CCCA 2012). An indication of the size of the problem can be seen from data from 2011 where there were 11 incidents of winds above 12m/sec. 38 houses, two fishing boats, and 1.4 ha of mangrove forest were destroyed as a consequence hereof.

The ecosystem services for the Peam Krasaop community are very sensitive to climate change since the sea grass beds and coral reefs in relation to the mangrove forest serves as breeding grounds for fish, mussels, crabs and other marine wildlife found in the area, which are vulnerable to increased sedimentation as a result of rising sea levels, storms, surges, and other natural hazards or changes in the ocean current. This leaves the entire local community extremely exposed if it does not adapt to climate change.

In October 2013, 15 ha of mangrove forest were replanted just outside the boundary of Peam Krasaop as a climate change adaptation initiative to protect and increase the community’s resilience to climate change. The project was financed by the European Union, national development aid programmes from Sweden and Denmark (SIDA & DANIDA) and, United Nation Environmental Programme (UNEP), and United nation Development Programme (UNDP) as a part of a larger project of vulnerability assessment and adaptation programmes in the coastal zone of Cambodia. The initiative is to replant 60 ha, which will not only strengthen the community's
resilience to climate change but also improve the conditions for the ecosystems services on which the community is so dependent. The initiative was implemented by hiring local people to gather mangrove seeds and plant them in the designated area. Only the replanting activities and damage from storms are considered in the case study.

In the following we will describe an estimation of the expected damage costs to assess the adaptation and mitigation benefits. We do so by considering two different scenarios of replanting – one where a certain area is replanted at once (corresponding to a project approach), and one where replanting occurs (to a smaller amount) every year over 100 years (corresponding to a situation where the problem is tried solved by small inputs available from daily management). For each situation, we calculate social welfare as the discounted sum of the avoided damage cost and the mitigation benefit, subtracted by the replanting cost – considering a range of replanting intensities. As there is large uncertainty about the impact of climate change on storm risk, we analyse the replanting scenarios for three different climate scenarios.

Modelling the welfare benefits of interrelationships

General model and model assumptions

To answer the research question of whether a combination of adaptation and mitigation can lead to higher welfare, we focus on a marginal valuation approach. How marginal valuation approach relates to EDC. So, we look at the benefit of replanting one extra hectare of mangrove forest. This allows us to identify the optimal area to replant (given the assumptions of the model). We assume that a social planner has a utility function \( U_i(A,M,H) \) from the mangrove forest under the impact of climate change in scenario \( i \). \( U_i \) is a function of \( A, M \) and \( H \), where \( A \) is the benefit of climate change adaptation, i.e., the ability of the mangrove forest to protect the local community from economic damage; \( M \) is the benefit of the climate change mitigation, i.e., the value of carbon storage in the replanted mangrove forest; and \( H \) is the possible co-benefit of adaptation and mitigation, such as increased welfare. Furthermore, there is a cost of replanting, \( Z \). Each differs depending on when they occur. As mitigation primarily is a global good and adaptation is a local, it makes sense to assume additivity and linearity in input, we can express the utility of a given mangrove forest over a finite
period $T$, discounted by $r$ representing the preference for the present over the future at time $t$:

$$U_t(A, M, H) = \int_{t=0}^{T} (A_t + M_t + H_t - Zs_t) e^{-rt} dt, \quad (1)$$

Where $A$, $M$, and $H$ depend on the area of mangrove forest; whereas $Z$ depending solely on the replanted area ($s_t$ = the replanted area of mangrove forest at time $t$). Replanting can have positive effects on both mitigation and adaptation. Thus, potential interrelationships between mitigation and adaptation may occur and only in the form of positive interrelationships, i.e. the two measures are complements to each other. Let $S_t$ be the area of mangrove at a given point in time, $l_t$ the area lost at time $t$, and $s_t$ the replanted area of mangrove forest at time $t$. The timeframe of $t$ is one year. Under climate change scenario $i$ at time $t$, the mangrove forest area (ha) may be written as:

$$S_{t,i} = S_t + s_t - l_t \quad (2)$$

$l_t$ is a function ($g$) of the current overall area of the mangrove forest ($S_t$) impacted by the climate change ($C_{it}$) in the current climate change scenarios ($i$) at time $t$:

$$l_t = g(S_t, C_{it}), \quad l_t \geq 0 \quad (3)$$

Notice that this implies that we assume that a replanted and an existing hectare of mangrove have the same value. Without a spatially-specific model, this is a reasonable assumption at the margin.

In the following section, we shall look at how $A$, $M$, $H$, and $Z$ are estimated.

**The benefit of adaptation (A)**

We estimate the increases of welfare benefit by replanting ($s_t$). This activity can increase the overall area of mangrove forest ($S_t$).
To estimate the ability of the mangrove forest to protect the local community, we use an ‘expected damage function’ (EDF), which will give us the option of calculating the marginal EDC, taking our point of departure in Barbier (2007) and Hanley and Barbier (2009). The EDF is derived from the ‘production function’ (PF) by which the environment is valued as an input in the creation of assets that increase the utility for the local community. In our case, the EDF describes the relationship between damage caused by storm and the loss of the mangrove forest and, thereby, production. Whereas Barbier (2007) and Hanley and Barbier (2009) deal with a static model, we have a dynamic model because this better captures the key attributes of climate change – the continuous change in conditions.

We use the aggregated households from this study site to represent the entire community and, thereby, the preferences of the social planner. The aggregated households’ expenditure function is expressed as \( m(P, C_i, U_i) \). \( U_i \) is the utility level for a given climate scenario \( i \), and \( U_i^0 \) indicates that no replanting is done in climate scenario \( i \). Notice that, with climate change, the utility may vary over time and, thus, will not reflect today’s consumption possibilities. \( P \) is a price vector for acquired goods consumed by the householdss. \( C_i \) represents the impact of climate change under the climate scenario \( i \).

The EDC, \( E[D(C)] \), is the welfare loss caused by changes in the number of acquired goods in the expenditure function, i.e., the minimum income needed to offset the change. This is a result of the expected damage to the households due to the shift of C. If we let \( C^0 \) denote the consequences of a ‘no change’ scenario and \( K(C) \) the minimum income for a household to maintain the initial utility level, then we can say:

\[
E[D(C)] = m(P^x, C^0, U^0) - m(P^x, C_i, U^0) = K(C) \quad (4)
\]

This will provide a measure of compensating surplus. We are assuming that the total area of mangrove forest may have a direct effect, i.e., a reduction in the impact of storms and other natural hazards in terms of damage to the local community, and this positive effect will also be strengthened by
replanting the mangrove forest. Thus, the PF for the damage caused by storm may be represented as (see equation 5):

\[ C = C(S), C' < 0, C'' > 0' \]  

(5)

By this, we are assuming that the damage caused by storm in relation to climate change increases with the decrease of the remaining mangroves, which is reasonable.

We can define the marginal willingness to pay \( W(S) \) for protection services of the mangrove forest in relation to the marginal impact of mangrove forest changed based on expected damage caused by storms and other natural hazards (Barbier 2007):

\[
W(S) = -\frac{\partial E[D(C(S))]}{\partial S} = -E\left[\frac{\partial D}{\partial C} C'\right], W' < 0
\]  

(6)

This is analogous to the Hicksian compensated demand function for market goods (Freeman III et al. 2014).

Because the risk of damage depends on the total area \( S \) at a given point in time, any mangrove loss (or increase) influences future potential damage. Thus, the aggregated value of an adaptation measure such as replanting an area of \( s_t \) can be calculated as the integral of the reduced damage at all points in time – discounted:

\[
V(A) = -\int_{t}^{T} \int_{S_{cor}}^{S_{cor+qr}} (W(S_{\tau}) dS_{\tau}) e^{-rt} \]  

(7)

We want to estimate the marginal value (in present value terms) of the last replanted hectare of mangrove forest in the context of climate change adaptation \( MV^{V(A)} \). We can express this as the marginal EDC:
The benefit of mitigation (M)

The benefit of mitigation is calculated as the monetary value of the carbon sequestration in the replanted mangrove forest at time \( t \), as the trees sequestrate CO\(_2\) from the air and capture it as carbon in the wood. From a social planner perspective, the monetary value could be seen as the SCC.

The benefit of mitigation at time \( M_t \) can be expressed as a function of \( \dot{S}_t \) over the time period we are considering:

\[
M_t = L(\dot{S}_t),
\]

where \( L \) is the function for captured CO\(_2\)e in the mangrove forest.

This can be rewritten as equation 10; \( S_t \) is reduced out of the function, since we are assuming that the existing mangrove forest is a closed system that does not contribute any additional carbon sequestration or emission. The mitigation benefit will be calculated on basis of the area of mangrove forest lost at time \( t \) (\( l_t \)) and the replanted area at time \( t \) (\( s_t \)):

\[
M_t = -l_t + s_t
\]

Aggregating and discounting over time, we have the contribution to equation 1, and the marginal value of mitigation can be obtained in a manner similar to equation 8 for adaptation.

Co-benefits in relation to replanting the mangrove forest (H)

The benefits that are achieved in addition to the benefits of climate change adaptation and mitigation are referred to as the co-benefits of replanting the mangrove forest (see equation 1). These co-benefits are related to the increased welfare that may be a result of an improvement of the breeding
conditions and the natural habitat for fish, dolphins, coral, etc., for this specific case study. It is a welfare gain because of the enhanced economic activities that are dependent on the mangrove forest for the local community/fishery and tourism. The case we are considering is coastal fishery and open access fishery. Therefore, the fishery in the area is not optimally managed and also suffers from unsustainable fishing. The consequence of open access is that, if any profit is apparent, it will draw the attention of new fishermen, who will then establish themselves in the community, which will equalise any producer surplus. However, it will still affect the welfare through its influence on consumer surplus (Barbier 2007). We are assuming that the co-benefits are positive and increasing with $s$. However, the data required to estimate the influence of co-benefits is limited in our case. Therefore, they are assumed to be zero ($H_i=0$) in our case study, but the model could easily be expanded.

**Replanting costs (Z)**

The cost of replanting the mangrove area, $Z$, is assumed to be constant per hectare. We assume that the cost of replanting the mangrove forest as an adaptation initiative is equal to the cost of replanting mangrove forest as a mitigation initiative. Thus, if the cost has been accounted for in estimating the benefit of adaptation, it will not be necessary to account for the cost again in estimating the benefit of mitigation.

**Simulation**

With the utility function described above and specification of the components, we can now describe the simulations performed. To analyse the welfare consequences under different scenarios and strategies for adaptation to and mitigation of climate change, we are operating with three damage scenarios and two replanting strategies. We carried out the simulations in the MATLAB2013 environment.
**Damage scenarios as a consequence of climate change**

When the wind speed reaches 12 m/sec, damage occurs (CCCA 2012). Therefore, in the following, we shall refer to this as a storm even if it is not defined so in technical terms. From 1979 to 2012, wind speeds over 12 m/sec were measured at two points outside Cambodia's coast. These historical data have provided us with an opportunity to calculate the daily probability of storms for each month of each year (Nielsen 2013). It is sometimes argued that storm frequencies and strength in some locations will increase. However, according to IPCC 5th assessment report (Hijioken et al. 2014), there is currently no indication that the frequency of storms will increase or decrease off the coast of Cambodia; however, coastal and marine systems will suffer from climatic and non-climatic drivers, as strength and impacts of storms. Therefore, we base our simulation on the historical data, simulating day-specific risk of wind speeds higher than 12 m/sec for a 100 year period. Developing three damage scenarios illustrating how the PF for a damaged mangrove forest will develop under the influence of the storms. The PF for the damage scenarios, equation (5), is partly based on the assessment of the destroyed mangrove area in Peam Krasaop from 2011 (CCCA 2012), assuming that ecosystem services do not respond linearly to changes in habitat size (Barbier et al. 2008).

To comply with the uncertainty regarding the expected climate change for the study area, and that no detailed data exist, consequently we set up three scenarios that can demonstrate a range of possible changes. The first is a baseline scenario, reflecting the climate of today; the second contemplates greater destruction; whereas the third has stronger storm occurrences once in a while, damaging the resilience of the system. The three damage scenarios are described by equation 11:

\[ C_t(S) = b \cdot e^{-as}, \]  

(11)

**Damage Scenario 1:** Is based on our knowledge of storm occurrences in 2011, and we simulate the start of the first storm by removing 0.08 ha of mangrove forest, based on equation 11, where \( a = -0.001770 \) and \( b=5 \). This reflects an almost ‘no change’ scenario (as compared to today). However,
the amount of mangrove forest removed per storm increases slowly but exponentially because of the assumption made in equation 5.

**Damage Scenario 2:** Is based on that 1 hectare of mangrove forest will be removed each time a storm occurs to start with, and then it develops exponentially. Equation 11 was fitted based on this assumption: $a = 0.00099$ and $b=10$. The destruction of the mangroves develops exponentially.

**Damage Scenario 3:** Is based on damage scenario 1 and an obstruction of, for each 30 storms, one typhoon will occur. The typhoon is assumed to destroy 50 ha of mangrove forest each time. The typhoon's destruction of 50 ha is not influenced by the replanting strategies of mangrove forest under the simulation, as damage scenarios 1 and 2 are. The simulated typhoon’s destruction reflect a severe incident but without causing complete destruction.

Figure 1 shows how the three damage scenarios will destroy the existing 2,324.4 ha of mangrove forest over time, assuming there is no replanting to delay the destruction. Under damage scenario 1, the destruction is minimal compared to damage scenario 2 in which everything will be destroyed by year 60 and damage scenario 3 in which everything will be destroyed by year 63. The reason the two curves cross is that the obstruction in damage scenario 3 over time delays the total destruction compared to damage scenario 2. From around year 50, damage scenario 2 start to go beyond 50 ha of destruction. It is assumed that no regeneration of the storm-damaged areas will occur.
Figure 1 the destruction of the mangrove forest from year 1 to 100 in the three damage scenarios without any replanting of the mangrove forest.

Replanting strategies

We operate with two replanting strategies for adaptation that differ in terms of the time when the replanting occurs. The replanting strategies are meant to reflect two extreme approaches. While early replanting is, ceteris paribus, favoured compared to later because of the increasing destruction rate, it may not always be feasible due to limitations in the availability or access to knowledge, capital, and labour. The two replanting strategies for simulations are defined as follows:

**Replanting Strategy A:** One-shot replanting of mangrove forest at intervals of 1 ha from 0 to 500 ha, where replanting is only carried out in year 1 of the 100 year period of the simulations. This reflects the fastest possible action.

**Replanting Strategy B:** Continuous replanting of mangrove forest at intervals of 0.25 ha from 0 to 15 ha, where replanting is carried out each year in the 100-year simulation period. This reflects a situation in which, e.g., labour availability is limited and, therefore, constrains the magnitude per year.

**Data and functional forms**

In this section, we describe the data and various assumptions for the concrete simulation. The Cambodia Climate Change Alliance (CCCA)
carried out a vulnerability assessment of the community's risks from climate change in 2012. The CCCA obtained data through informal questionnaires and facilitated group discussions with the communities concerned. In January 2014, we visited the 15-hectare replanting site and the community of the fishermen just outside the city of Koh Kong in the Peam Krasaop Wildlife Sanctuary. Exploratory interviews with fishermen and other member of the community were conducted in which the information obtained through the CCCA (2012) was confirmed. For the simulations, the replanted mangrove area is assumed to be located inside the Peam Krasaop community border. Areas in which climate change is having an impact on the mangrove forest were also visited along with two park rangers and an interpreter. Information about cost and expenses in relation to the replanting site was also obtained through the project coordinator (VAAP LDCF 2013) along with additional information about the fishermen's use of equipment, commodities, and belongings (Nielsen 2014).

**Replanting cost**

The cost of replanting was obtained through the CCCA, which was responsible for replanting the 15 ha of mangrove, costs include gathering seeds for new plants, renting boats, hiring people from the community for seed-gathering and planting mangrove seedlings, monitoring, and later replanting, if necessary. The cost also include an event to raise awareness of the project in the community (CCC 2012). The cost does not include soil preparation. The total cost of replanting 15 ha was USD 16,441 (or USD 1,096 per hectare). The cost of replanting the mangrove forest used in the simulation, excluding the awareness event, is estimated to be USD 896 per hectare.

**EDC**

The annual EDC is calculated based on the income lost. Thus, apart from the information on the area of damaged mangrove depending on the remaining area, we also need information of household income and assets. The 277 households in the community can be divided into three different
categories of poverty, where 51% belongs to the two poorest groups. The community’s aggregated income as USD 445,416 per year (CCCA 2012).

To assess the annual damage costs as a function of remaining mangrove, data from tree situations were considered. The first one is an estimated cost of USD 49,400 of storm damage in 2011 where 2023 ha mangrove was left (CCCA 2012). The second one is an estimation of the loss of a total destruction of the community, which we assume will occur when 2/3 of the mangrove is destroyed (770 ha is left). Here the fishing options present around the mangrove forest are no longer assumed sufficient to sustain livelihood. The average household earns 1608 USD/year (CCCA 2012), so the aggregated income for the 277 households is USD 445416. Adding the value of their assets (taken from Nielsen 2014), results in a loss of USD 1.2 million. Finally, we use a lower bound estimate of damage of USD 1,800 as it is unlikely that storm damage can be completely avoided because of the poor quality of houses and boats. Based on these three points, an exponential function of the EDC depending the area (ha) of mangrove forest remaining each year is estimated as:

\[ D(S) = c \times e^{gS} \quad (12) \]

where \( c = 14,726,276.0915 \) and \( g = -0.00291 \). To avoid extraordinary large damage costs when little mangrove is left, we set an upper boundary of USD 1.6 million.

The expected damage cost is calculated on an annual basis. When no mangrove is left, livelihood options corresponding to the annual income are lost – every year, forever. This is of course only true to the extent that people cannot move away and find other ways to sustain themselves. In the other extreme, we can assume that they just find another living, and thereby there is no income loss present once people move away. Given the limited

---

7 the two lowest income groups are characterized by not having their own home, living on land illegally, having their own house but very far from the main road or having a very low income but living close to the main road (CCCA 2012). Other indicators of these groups are that they have lost family income, faced food shortages, have sold properties, or borrowed money from people within the last 12 months (CCCA 2012).

8 This is an aggregated value for the whole community. It is biased towards the poorer income groups due to their low-quality houses and boats.

9 This is not equally distributed. But as we work with aggregated values, the distributional aspect does not matter for the estimation.
livelihood options in the area, and the importance of the mangrove not only in this village but for larger areas, this may also be unrealistic. Consequently, we use the one extreme – calculating the annual loss as present every year after destruction. The other extreme, zero cost once the mangrove is destroyed was also calculated but results are not shown. But we will refer briefly to these results in the result section.

Calculating carbon sequestration under the influence of the damage scenarios and replanting strategies

The IPCC tier 1 guidelines have been used (IPCC 2014a; IPCC 2006) to estimate the possible carbon sequestration and emission in the mangrove forest, with respect to the remaining, replanted and damaged mangrove forest.

The area of mangrove forest destroyed under the three damage scenarios will count for the full destruction in the year it occurs, creating an emission of 129 tonnes of carbon per ha/year (IPCC 2014a).

The time span for calculating the carbon sequestration in the replanted mangrove forest is based on Alongi (2008). Alongi (2008) uses long-term data from French Guinea, which indicates that a mangrove forest stand follows a series of successive stages: rapid early development, a maturity stage, and, finally, a stage of senescence in which the stand breaks down and a new stand is regenerated and colonised. In the calculation of the possible carbon sequestration, we limit the influence of gap dynamics only to consider how much of the mangrove forest is left in each scenario of the simulations.

At first, the replanted mangrove forest will create carbon emissions of 1.62 tonnes ha/year (IPCC 2014a), this stage of rapid early development will lasts five years (Alongi 2008; Fromard et al. 1998). After that, the replanted mangroves will reach the maturity stage and create sequestration in the amount of 6.65 tons carbon ha/year (IPCC 2014a), which we estimate will last approximately 65 years in the replanted area (Alongi 2008).

Replanting strategy B in which replanting is done every year will contribute consistently to carbon sequestration from year 6 until 0 ha is left, but the act
of replanting will only be done until the threshold of 770 ha left mangrove forest is reached. However, even if the threshold of 770 ha is reached, CO\textsubscript{2} emission will continue from mangrove destruction until 0 ha mangrove is left none is left.

Human collection of fuel wood and other wood removal leading to deforestation should also be included in the estimation of the carbon sequestrated for the area. Data availability on this subject is very poor for the Peam Krasaop community. Therefore, the net emissions from fuel wood and wood removal have not been included in the calculation.

The benefit of climate change mitigation is estimated on the basis of the amount of carbon sequestrated and converted to tons CO\textsubscript{2}-equivalent (tCO\textsubscript{2}e) under the constraints and assumptions mentioned above for the calculation of the amount of tCO\textsubscript{2}e, which we then assign a monetary value. We are using three different CPs to give the carbon sequestration a monetary value; we use prices from existing markets, to reflect what local decision-makers will take in to account. The first CP (CP1) represents the price for the ‘certified emission reductions’ (CERs) under the ‘clean development mechanism’ (CDM), under the Kyoto protocol. The price for trading CERs on 10 February 2014 was USD 0.54\textsuperscript{10} per tCO\textsubscript{2}e (Fenhann 2014). The second carbon price (CP2) refers to the social cost of tCO\textsubscript{2}e. We apply the very low SCC price of USD 6.8 per tCO\textsubscript{2}e, referring to Tol (2008)\textsuperscript{11}, who bases this estimate on over 200 estimates of the SCC. The third CP (CP3) is the average price of CERs traded between 21 May 2007 and 10 February 2014 (Fenhann 2014), which is EUR 9.66 or USD 13.18 (XE 2014). The CPs are multiplied by the amount of tCO\textsubscript{2}e sequestrated or emitted for the specific year and in the specific replanting stage for each of the replanting strategies and damage scenarios. Therefore, they will have a negative monetary value if more CO\textsubscript{2}e is emitted than sequestrated.

\textsuperscript{10} The CP for CERs on February 10 2014 was EUR 0.40 (for exchange rates, see XE (2014)).
\textsuperscript{11} Converted to tCO\textsubscript{2}e from his reporting of USD 25 per tC
Calculation of the marginal value of climate change adaptation, mitigation and replanting cost

If we know the annual EDC for the three different damage scenarios combined with the two replanting strategies, including the cost of replanting for each adaptation initiative, and the monetary value of the mitigation initiative (carbon sequestered and emitted in the mangrove forest), it is possible to calculate the present value of each adaptation and mitigation initiative under each of the replanting strategies. In this way, we can calculate the expected marginal EDC for each replanting and damage scenario and, thereby, evaluate the different strategies. To reflect the preference for the present over the future, we made the simulations with four different discount rates: 4% and 12% is presented in the paper. This reflects the choice that the decision-makers have to take, and what priorities they have (Arrow et al. 1996). The four discounts rates contribute to a sensitivity test of the expected marginal EDC for each replanting and damage scenario. Discount rates at 4% or lower reflect a private planner or an alternative investment in a developed country, whereas 12% or higher reflect the private actor in a developed country. Specific for Cambodia can the discount rates for micro-loans reach 2-3.5% per month, cumulative equivalent to close to 50% per annum (CCCA 2012). Therefore, the discount rate most commonly used in developing countries is applied.

For each damage scenario and replanting strategy (and discount rate), we first calculate the present value of the cash flow of the EDC. Then, we summarise the present values over the 100-year period in each of the different stages of the replanting strategies. This is used to calculate the marginal value as given by equation 8. Because storms are random, the exponential development of the strengths and destructive power of the storms in the three damage scenarios, the estimated expected damage, is not smooth. So, to calculate the slope, different approaches were used, depending on what fitted best. The model fitted for the adaptation under the replanting strategy A was a two-term exponential function by which the derivative function gives the marginal value of one extra ha mangrove forest

---

12 The marginal EDC and mitigation values in relation to the replanting cost under influence of 2% and 20% discount rates is available in Appendix B.
replanted. This fitted poorly for adaptation, mitigation and replanting costs\textsuperscript{13} under replanting strategy B and mitigation under replanting strategy A. So, here, we used a moving average of 5 adjacent points of the present value, where the marginal value is found as the difference between two adjacent points of the moving average.

**Results**

**Annual values for adaptation and mitigation**

In this section, we will first present the annual EDC, $A_t$, for the adaptation strategy for replanting strategies A and B, and the corresponding annual mitigation benefit (figures available in appendix A), $M_t$, for the 100 year period that we run the simulations over. These form the basis for the marginal curves for EDC and CP1, CP2, and CP3, which may be compared with the marginal replanting cost.

Figure 2 below shows the annual EDC, $A_t$, over time for replanting strategy A at three different levels of replanting - 0 ha, 250 ha, and 500 ha - and for the three different damage scenarios. It is seen that $A_t$ increases over time as fewer mangroves remain but also that replanting delays destruction and, thereby, increases $A_t$. When the forest is total destroyed, $A_t$ will be equal to USD 1.6 million, corresponding to the opportunity cost of the mangrove forest and the communities complete destruction. Under damage scenario 1, $A_t$ is low compared to the two other damage scenarios. In fact, it is close to zero, and total damage will not occur. If replanting is done, $A_t$ decreases from an average of USD 21,015 at 0 ha to USD 9,847 at 250 ha and USD 4,997 at 500ha – a change that is not visible in figure2. In damage scenario 2, total destruction will occur in year 52 if no replanting is done, and replanting 250 and 500 ha, respectively, may postpone this for 17 and 37 years, respectively. For scenario 3, total destruction will occur in year 51, and replanting 250 or 500 ha may postpone this for 10 and 18 years, respectively. Thus, the more severe the damage, the smaller is the effect of major replanting now.

\textsuperscript{13} Notice that, because replanting in scenario B occurs over time, the marginal cost of one extra hectare is not constant – e.g., replanting stops in the scenarios when the mangroves are completely destroyed.
Figure 2. Simulated annual expected damage cost, \( A_t \) (x-axis), over the 100-year period (y-axis) for replanting strategy A and three different levels of replanting (0 ha, 250 ha, and 500 ha) influenced in the three damage scenarios.

Figure 3 shows a similar picture as figure 2, just for replanting strategy B. For replanting strategy B, the replanting cost is incurred each year as the mangroves are replanted until only 770 ha of mangrove forest are left. The no-replanting strategies are identical to Figure 2, and we also find that replanting under damage scenario 1 has a small effect, though larger than under replanting strategy A. In damage scenario 2, replanting 15 ha per year may delay the increase in annual damage cost, so that total destruction is not reached. For damage scenario 3, replanting 15 ha a year will result in total destruction in year 89. The overall picture for figure 3 is that replanting delays the increase in \( A_t \) and that replanting of 15 ha a year makes a significant difference in this regard, especially in damage scenario 2 in which the mangrove forest is not destroyed within the 100-year simulation period.
Figure 3. Simulated annual expected damage costs, $A_t$ (x-axis), over the 100-year period (y-axis) for replanting strategy B and three different levels of replanting (0 ha, 5 ha and 15 ha) influenced in the three damage scenarios.

The results for the annual mitigation values show that, for replanting strategy A for all three CPs, damage scenario 1 has a positive mitigation value from year 6 to 76. After year 76, the mitigation value becomes slightly negative, which is caused by the limited destruction of mangrove forest in damage scenario 1 and further slowed down due to the termination of replanting. For the damage scenarios 2 and 3, it is clear that the destruction of the mangrove forest has a negative impact on the annual carbon sequestration (see figure A1, A3 and A5 available in appendix A).

Mitigation values for replanting strategy B, damage scenario 1, is the one less influenced by destruction, whereas damage scenarios 2 and 3 are both heavily influenced by the destruction of the mangrove forest, which creates a large amount of emissions that influence the monetary value of mitigation negatively. Similar to the annual damage costs ($A_t$)(figures 2 and 3), it is possible to see that replanting has a significant influence on the mitigation in damage scenarios 2 and 3, as it delays the point of complete destruction. When no forest is left, no carbon is sequestrated or emitted (see figure A2, A4 and A6 available in appendix A).
Marginal Values

Figure 4 shows the aggregated present value of damage costs as the marginal EDC (i.e., the damage costs avoided by replanting one more hectare) at a discount rate of 4% for replanting strategies A and B along with the present value of the marginal mitigation value and the marginal replanting costs at the three CPs. We see that, for both replanting strategies, the marginal EDC in damage scenario 1 is around the same size as the marginal replanting cost – they intersect at 68 ha for replanting strategy A and 2.25 ha for replanting strategy B. However, if mitigation is included, it will be worth doing the replanting. If the price is high (CP2 or 3), the curves never intersect; but, if the price is low, we see that looking at mitigation and adaptation jointly will lead to an optimal replanting of 209 ha in replanting strategy A and 5 ha per year in replanting strategy B. For damage scenarios 2 and 3, the EDC is well above the marginal replanting cost. So, replanting is beneficial. If mitigation were considered as a single product, it would only be worthwhile to do replanting if prices were above the low price scenario (CP1). A similar pictures may be seen if we apply a discount rate of 2% (see appendix B, figure B1).
Figure 4. The marginal avoided EDC for the two replanting strategies A and B (adaptation initiatives) in each of the three damage scenarios (the black solid lines with dots), together with marginal mitigation values for the three CPs: CP1 = USD 0.54 per tCO\textsubscript{2}e, CP2 = USD 6.8 per tCO\textsubscript{2}e, CP3 = USD 13.18 per tCO\textsubscript{2}e (the dashed lines). The thin black line shows the marginal replanting costs. All assume a discount rate of 4%.

These results assume a 4% discount rate – reflecting the discount rate of a social planner. A higher discount rate might reflect the decisions of a private actor – if incentives are provided for public good mitigation. Figure 7 shows the results for a 12% discount rate. Here, we see that, in damage scenario 1, the marginal EDC is considerably below the marginal replanting costs, and only CP2 and CP3 are high enough to justify replanting. In damage scenarios 2 and 3, however, we see that the EDC and the replanting cost intersect, so that, looking at adaptation alone in damage scenario 2, optimal replanting intensities are 243 ha under replanting strategy A and 10 under
replanting strategy B. In damage scenario 3, we see that, for replanting strategy B, replanting more than 15 ha/year is optimal; whereas, for replanting strategy A, the optimal replanting is 132, i.e., below the optimal for damage scenario 2. This is because the benefit of replanting is higher in damage scenario 2. This can also be seen from Figure 2, where the integral of the difference between replanting 250 ha and 500 ha is larger in damage scenario 2 than damage scenario 3.

Figure 5. The marginal avoided EDC for the two replanting strategies A and B (adaptation initiatives) in each of the three damage scenarios (the black solid lines with dots), together with marginal mitigation values for the three CPs: CP1 = USD 0.54 per tCO₂e, CP2 = USD 6.8 per tCO₂e, CP3 = USD 13.18 per tCO₂e (the dashed lines). The thin black line shows the marginal replanting costs. All assume a discount rate of 12%.
Looking at mitigation, we see that, for the lower discount rate, price scenarios CP2 and CP3 pay off the replanting costs fully – it is more pronounced than for lower discount rates. If the discount rate is increased to 20%, the replanting costs exceed the mitigation values (see appendix B, figure B2).

Two assumptions are crucial for the above shown results, namely the choice of assuming continued loss once the mangrove is left, and the choice of using relatively low carbon prices compared to many of the SCC estimates which should be used in welfare economic analyses. Assuming that people just find other livelihood options if the mangrove is destroyed would reduce the expected damage cost. In the case of a 4% discount rate this would still result in the expected damage cost being larger than the replanting costs for damage scenario 2 and 3. For a discount rate of 12%, damage scenario 2 and replanting strategy A, the EDC and the replanting costs, would intersect each other at 220 ha, i.e. around 100 ha less than in the scenarios shown. For the corresponding replanting strategy B, the benefits from around 8 ha of replanting will offset the costs. This pattern is repeated for the other scenarios. Consequently, while the area optimal to replant is reduced, an effort is still beneficial. And if mitigation benefits are included it is even more so. This leads to the second sensitivity – namely, what is a high SCC of carbon was used: in that case, it would be beneficial from a welfare economic point of view to replant the maximum area analysed for all scenarios.

Discussion

Main findings

The aim of this paper was to analyse the interrelationships of the benefits of climate change adaptation and mitigation. We do so by looking at the marginal value of replanting in a small case study in which causes and effects are visible and, thereby, possible to interpret in a broader context.

The overall assumption is that there is a joint benefit from climate change adaptation and mitigation; thus, they complement each other. From a social planner’s point of view, adaptation alone makes replanting mangroves beneficial as the adaptation benefits are larger than EDC. Mitigation
emphasises this. Our results show that even for the highest replanting intensities we have analysed (500 ha from the beginning or 15 ha per year over 100 years), replanting is worth the effort. If the discount rate is high, 12%, we find that adaptation by replanting is only beneficial to some extent – in damage scenario 2, replanting 250 ha from the beginning or 10 ha per year over the next 100 years is optimal, and in damage scenario 3, replanting 140 ha from the beginning or 15 ha per year over the next 100 years. So, in conclusion, the study shows that, looking at adaptation alone only makes replanting the mangroves worth the effort if increases in storm frequency occur. If mitigation is included, prices as low as in CP2 (6.8 USD per tCO\textsubscript{2}e) makes the highest replanting intensity worth the effort. Consequently, looking at both adaptation and mitigation, makes replanting worth the effort even if there is no increase in storm frequency. Notice that this cost estimate is well below most estimates of SCC. van den Bergh and Botzen (2014) indicate that an SCC should not go below USD 125 per tonne CO\textsubscript{2}e. Applying such high values would just make the emphasis on including mitigation in adaptation more pronounced, as the marginal mitigation benefits in Figures 4 and 5 would be very much above the marginal replanting cost. If we are thinking of paying for carbon sequestration through a market price in a carbon emission trading scheme, it is much more likely that we lie in the lower end of CPs – unless there is political will to have the amount of quotas to reflect the SCC.

From a private decision maker’s point of view, only adaptation is relevant – unless mitigation is paid for. And a higher discount rate would very likely also apply. In the study here, we operated with a 12% (real) discount rate; and, in that case, the area it would be optimal to replant would be smaller than in the social planner case for all damage scenarios. However, if payment for mitigation is implemented to reflect an increase in public good provisions together with the adaptation component, replanting would still be optimal – also from a private decision maker’s point of view. An increase to 20% makes the whole thing a bit more impervious for investors, since the replanting cost exceeds the marginal benefits of mitigation and the EDC.

Comparing the two replanting strategies, we see that, if we assume that storms always destroys mangroves, a continuous replanting (replanting strategy B) may, in many instances, be beneficial – as it can halt ongoing destruction. Replanting strategy A delays destruction of the mangrove. But,
will still lead to total destruction. Consequently, a mixture of the two strategies is probably best – a large replanting initially to reduce the risk level and, then, continued replanting of what is destroyed to make sure that the high risk levels are not reached again.

Boutweel and Westra (2015) argue that the values revealed by the EDC method are at the lower boundary compared to other ecosystem valuation methods. Consequently, the adaptation estimates in this study may be considered conservative, even though we do not consider alternative livelihood options.

Policy implications

The complexity of climate change will also need a complex response; a benefit from implementing both adaptation and mitigation is shown, and a mix of the two replanting strategies is suggested.

A mixture of the two replanting strategies is suggested as the optimum for interlinkages between adaptation and mitigation from a social planner perspective, thereby reducing risk by replanting a large area to start with and then continuously replanting to maintain the acquired level of reduced risk. If payment for mitigation were included, this might motivate private investors to pledge money to replant in a manner similar to replanting strategy A. The investment should avoid being a "one-time wonder" in which the level of risk reduction from adaptation is seen long before the impact of climate change. By creating a mixture of the replanting strategies, it is possible to see long-term results from the investment, enforced by including stakeholder involvement and awareness of the mangrove forest and climate change. This could create the motivation for the community to continue replanting the mangrove forest (similar to replanting strategy B) and strengthen their resilience to climate change by learning to recognise the importance of natural resources to sustain their livelihoods, an aspect already reflected in the high replanting costs from the CCCA project. This is an investor opportunity to signal social responsibility that would be beneficial both locally and globally and, from a long-term perspective reduce risk.
The arguments for pursuing both climate change adaptation and mitigation for maximising welfare, is reinforced by that there is a limit for climate change adaptation, therefore a threshold for the mix of adaptation and mitigation (Watkiss et al. 2015). If climate change exceed this threshold, the cost of adaptation will only be a burden to future generations (Laukkonen et al. 2009). This enhances the arguments for the mixture of replanting strategies suggested, since the benefits of both adaptation and mitigation will have the large impact now but secure future risk reduction on a local scale.

Laukkonen et al. (2009) argue that local stakeholders should be persuaded to enhance their response to climate change. To do this, not only academic information but also the empirical knowledge - such as fishermen's knowledge about tidal water and the mangrove forest - is needed. From the exploratory interviews of fishermen in Peam Krasaop, it was easy to track awareness of the mangrove forest, since the forest sustains their livelihoods. However, there is a large gap between this awareness and the knowledge of how they could participate in protecting the mangrove forest and the co-benefits they derive from it. For example, when the tide is high, fishing is possible in the replanted area, so boats propellers destroy new seedlings, which delays the developing of the newly planted seedlings. Laukkonen et al. (2009) underline that stakeholder involvement should not be a top-down process but a process that strengthens the feeling of collective responsibility. Through this process, it will also be possible to address other factors that cause damage and degradation to the mangrove forest. For example, the community has recognised the income opportunities from tourists visiting the mangrove forest. This is an important issue to address since the fight against climate change is not always the first priority among local communities (Warren et al. 2012; McGray et al. 2007). Therefore, it is also important to support sustainable development, which is necessary since climate change will continuously provide challenges (Laukkonen et al. 2009). The use of local initiatives may, in the long run, strengthen and reinforce regional or national strategies (Laukkonen et al. 2009).

This strengthens the argument to pursue climate change adaptation and mitigation simultaneously from a social planner perspective. For this specific case, one could argue that adaptation and mitigation are complementary but with a known contradictory example (Matocha et al.
2012; Laukkonen et al. 2009): it is easy to imagine situations with a free-rider effect - fishermen who do not participate in the replanting or who damage newly planted seedlings. Once again, this underlines the need to make awareness and sustainable development a part of the adaptation and mitigation project.

Caveats

This paper is based on a case study in Cambodia in which data have been collected from locally-available knowledge. The quality of such an approach lies in its connection to decisions actually being taken. It can also be seen as a starting point for stakeholder involvement. However, there are some obviously caveats to the estimation. The economic data are based on the best available knowledge, and it is not considered whether, e.g., replanting costs could be lower. Another element it would be relevant to include is other threats from climate change - especially, rising sea levels but also temperature increases and changes in precipitation. Adapting to an increased number of storms may be worthless if the mangrove forest is flooded by rising sea levels. However, for the current study, this data was not available. Therefore, we leave it to future research.

The EDC approach is also applied in large climate change models and IAM (Warren et al. 2012) such as the RICE and DICE models (Nordhaus 2014; Nordhaus 2011). An advantage of using it on a local scale, such as here, is that its limitations become quite clear: results are not better than the data and assumptions behind them. Nevertheless, using it at a local level, where processes are clear, makes it possible to identify drivers affecting the trade-offs between costs occurring now and damage avoided in the future. In the current case, it has been demonstrated to be highly sensitive to the intensity of storm risks. Another consequence of the assumption is that replanting strategies that are not continuous will, in the long run, lead to destruction. While this may be correct in the near future, one could hope that, as the ecosystem becomes resilient, it will no longer be the case.
Conclusion

Methodological developments for handling the interrelationships between climate change adaptation and mitigation demand innovative thinking. The paper combines general economic theory with case-specific knowledge obtained from stakeholders, contributing with empirical knowledge. This paper is a step on the way towards developing a methodology to estimate the interrelationships between climate change adaptation and mitigation. Thus, it illustrates how we can evaluate different strategies for adaptation and mitigation.

This case from Cambodia shows that, from a social planner perspective, there are positive benefits from replanting mangroves taking only adaptation into consideration but even more when mitigation is included. Consequently, looking at adaptation and mitigation jointly leads to higher replanting intensities than looking at adaptation alone. For this to motivate for private decision makers to pledge money for investment, payment for mitigation needs to be implemented. But the price levels do not need to be very high for replanting to be beneficial. To avoid private investment from becoming "one-time wonders", it is argued that private investments should include a learning element and involve stakeholders from the local community if we are to see a long-term effect through sustainable development, since the preference is to mix the two replanting strategies in order to reduce risk and secure the level of risk obtained.

Acknowledgements

We would like to thank the people of Peam Krasaop, who allowed us to conduct field work in their community, the project team behind the Cambodia Climate Change Alliance programme, Mr. Jens Erik Lyngby at DHI, Mr. Tue Kjell Niels for supportive information, and Anne Olhoff and colleagues for comments and fruitful discussions. A special thanks to Mr. Chea Leng and Mr. Sun Try, who made the field work possible.
References


CCCA, 2012. *Assessment of Community Vulnerability and Risks from Climate Change in the Coastal Zone of Cambodia*, Phnom Penh, Cambodia. Available at: http://www.czmcam.org/.


Fenhann, J. V., 2014. Excel sheet with historical carbon prices, gathered from Point carbon’s homepage from November 30th, 2006 until February 10th, 2014 (e-mail: jqfe@dtu.dk).


Klein, R. J., Huq, S., Denton, F., Downing, T. E., Richels, R. G., Robinson,


Available at: http://www.mdpi.com/1999-4907/2/1/431/.


Nielsen, T.K., 2014. personal communication; e-mail: tuekellnielsen@gmail.com [Accessed April 25, 2014].

Nielsen, T.K., 2013. *The Vulnerability Assessment and Adaptation*
Programme for Climate Change within the Coastal Zone of Cambodia; Wind Speeds off the Coast of Cambodia, Phon Phen.


VAAP LDCF, 2013. Commune project proposal 2013; Mangrove
Restoration, Peam Krasaob, Cambodia.


Warren, R. et al., 2012. Scoping Study: Modelling the interaction between mitigation and adaptation for decision making. Available at: http://www.nature.com/doifinder/10.1038/nature08823.


Appendix A:

Mitigation values for carbon sequestration and emissions over a 100-year period, for replanting strategy A and B.

Figure A1 Shows the simulated annual mitigation values, $M_t$ (x-axis), for carbon sequestration and emissions over the 100-year period (y-axis) for replanting strategy A and three different levels of replanting (0, 250, and 500 ha) influence on the three damage scenarios. $M_t$ is based on CP1= USD 0.54 per tCO$_2$e.
Figure A2 shows the simulated annual mitigation values, $M_t$ (x-axis), for carbon sequestration and emissions over the 100-year period (y-axis) for replanting strategy B and three different levels of replanting (0, 5, and 15 ha a year) influence on the three damage scenarios. $M_t$ is based on CP1= USD 0.54 per tCO$_2$e.
Figure A3 Shows the simulated annual mitigation values, $M_i$ (x-axis), for carbon sequestration and emissions over the 100-year period (y-axis) for replanting strategy A and three different levels of replanting (0, 250, and 500 ha) influence on the three damage scenarios. $M_i$ is based on CP2= USD 6.8 per tCO$_2$e.

Figure A4 Shows the simulated annual mitigation values, $M_i$ (x-axis), for carbon sequestration and emissions over the 100-year period (y-axis) for replanting strategy B and three different levels of replanting (0, 5, and 15 ha a year) influence on the three damage scenarios. $M_i$ is based on CP2= USD 6.8 per tCO$_2$e.
Figure A5 Shows the simulated annual mitigation values, $M_t$ (x-axis), for carbon sequestration and emissions over the 100-year period (y-axis) for replanting strategy A and three different levels of replanting (0, 250, and 500 ha) influence on the three damage scenarios. $M_t$ is based on CP3= USD 13.18 per tCO$_2$e.
Figure A6  Shows the simulated annual mitigation values, $M_t$ (x-axis), for carbon sequestration and emissions over the 100-year period (y-axis) for replanting strategy B and three different levels of replanting (0, 5, and 15 ha a year) influence on the three damage scenarios. $M_t$ is based on CP3= USD 13.18 per tCO$_2$e.

Appendix B:

Marginal EDC and mitigation values for different interest rates

Figure B1 Present values for marginal EDC in replanting strategies A and B (adaptation initiatives) for each of the three damage scenarios, together with marginal mitigation values for the three CPs (CP1 = USD 0.54 per tCO$_2$e,
CP2 = USD 6.8 per tCO₂e, CP3 = USD 13.18 per tCO₂e) and the replanting costs, assuming an interest rate of 2%.

Figure B2 Present values for marginal EDC in replanting strategies A and B (adaptation initiatives) for each of the three damage scenarios, together with marginal mitigation values for the three CPs (CP1 = USD 0.54 per tCO₂e, CP2 = USD 6.8 per tCO₂e, CP3 = USD 13.18 per tCO₂e) at an interest rate of 20%.
Abstracts
22. Economic and environmental impacts of the EU forest conservation and wood for energy policies.

Alexander Moiseyev (moiseyev17@gmail.com) and Birger Solberg (birger.solberg@nmbu.no), Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, Norway

Abstract: Forest conservation and use of wood for energy can be alternative policies to mitigate climate change. However, the design of these policies can lead to both desirable and unwanted economic consequences. The global partial equilibrium forest sector model and the FORMIT forest simulation model has been applied together to study the market impacts of the Business as Usual (BAU) and two alternative scenarios – Maximum Bioenergy and Biodiversity scenarios. The Biodiversity scenario is similar to BAU on the demand side, but differs on the biomass supply side as it assumes 20% of the EU forest growing stock set aside in 2010, longer rotation periods and no logging residues removals in the EU region. The Bioenergy scenario differs by higher energy wood demand in Europe and globally, and on the wood supply side by shorter rotation periods, selection of the faster growing species and high share of residues removals.

Bioenergy scenario will substantially increase EU forest owner’s gross income from selling wood, forest industries gross sales and value added, while employment will be marginally lower than in the BAU scenario. Biodiversity scenario will negatively affect EU forest owner’s gross income from timber sales and forest industries gross sales, value added and employment. In addition, harvest leakage can be very significant CO2 emission source. When taking into account reduced growing stock in forests under Bioenergy scenario and increased wood imports under Biodiversity scenario none of these policies demonstrate clear benefits for mitigating climate change. Changes in forest growing stock is the largest carbon emission source, however, energy substitution effect can be very significant making wood for energy carbon neutral. The latter may change after 2050 due to declining GHG displacement factor.

Key-words: climate mitigation, partial equilibrium modeling, scenario analysis, biodiversity, energy wood.
23. “Being one of the boys” - perspectives from female forest industry leaders on gender diversity and the future of Nordic forest-based bioeconomy

Baublyte, G., Korhonen, J. & D’Amato, D. & Toppinen, A.*

University of Helsinki, Department of Forest Sciences, Latokartanonkaari 7, FI-00014, Helsinki, Finland,* Corresponding author anne.toppinen@helsinki.fi

Abstract: In the face of ageing workforce and rising sustainability challenges (Päätäri et al., 2016), skilled future leaders are needed to enable renewal of the forest sector. According to previous literature, diversity in top management positions tends to have positive effects on firm performance (Adams et al., 2015; Hansen et al. 2016; Perrault, 2015). Nonetheless, women are still underrepresented in the top leadership positions in the Nordic forest sector, despite increasing female share in the higher education programs.

In this study, we assess perceptions of female leaders on the state of gender diversity in Nordic forest industry. We also inquire about female’s perspectives on the future of forest sector in the bioeconomy, and about the potential contribution by the Nordic forest industry to fulfilling the goals of the Global Agenda 2030. Elite interviewing strategy (Berry, 2002) was used to engage top management team members in seven Finnish and Swedish forest companies. Among the identified total sample of 32 female leaders, 10 were available to be interviewed in person or over the phone. Thematisation was used to analyse collected qualitative interview data.

Based on the results, adjusting own professional image and behaviour to match the standards set by the male colleagues is still expected for women leaders (Hoyt and Murphy, 2016). Culture-specific issues are posing an additional challenge to female career development, including practices promoting exclusion, such as sauna and hunting traditions. Adapting to “being one of the boys” appears to persist as a norm for female leaders in the forest industry. Some interviewees saw female gender also as an advantage in certain circumstances, for instance in terms of better being remembered among the male dominated groups.
Perceived gender-related challenges in leadership positions provide further insights to strategic business development. The critical role of forest-based bioeconomy for a sustainable global future was recognised by all study participants. However, the interviewed female leaders stated that their influence on the industry sustainability agenda comes from being in a senior position and is not a gender-related aspect. Nonetheless, the ability of Nordic forest companies to adapt to strategic renewal into bioeconomy will require a more diverse company culture, not just gender-based, and to be fostered at all organisational levels.

**Keywords:** forest sector, bioeconomy, gender diversity, career roles, sustainability

References:


Hoyt, C., Murphy, S. 2016. Managing to clear the air: Stereotype threat, women, and leadership. The Leadership Quarterly, 27, 387–399


24. Not so biocentric – An evaluation of benefits and harm associated with acceptance of forest management objectives among future environmental professionals in Finland.

Brent Matthies\textsuperscript{12}, Annukka Vainio\textsuperscript{3}, Dalia D'Amato\textsuperscript{45}

1 Faculty of Agriculture and Forestry (Dept. of Forest Sciences), University of Helsinki, Latokartanonkaari 7, P.O. Box 27, FI 00014 Helsinki, Finland

2 Dasos Capital, Itämerentori 2, FI 00180 Helsinki, Finland

3 Natural Resources Institute Finland (Luke), Bioeconomy and Environment, Latokartanonkaari 9, FI 00790 Helsinki, Finland

4 Helsinki Institute of Sustainability Science

5 Faculty of Agriculture and Forestry (Dept. of Forest Sciences), University of Helsinki, Latokartanonkaari 7, P.O. Box 27, FI 00014 Helsinki, Finland

Abstract: It is not yet completely clear how individuals weigh positive and negative consequences of specific environmental actions to the self, others and nature, and how these evaluations are associated with the acceptance of such environmental actions. We explored how the acceptance of ecosystem service-related forest management objectives were associated with perceived positive and negative consequences, perceived knowledge of these objectives, and gender among future professionals. We analysed a survey collected among Finnish university students majoring in agriculture and forestry, and biological and environmental sciences (N=159). We found that environmental concerns followed a two-factor structure: concerns for humans and concerns for the environment. Perceived harm to nature and humans reduced the acceptance of timber and bioenergy objectives, but only the effect of perceived harm to humans remained when they were considered together with perceived benefits. Perceived knowledge of the objectives had little effect on acceptance of the objectives. Females endorsed the biodiversity and climate objectives more than males, whereas males endorsed timber objectives more than females. These results show that in the context of ecosystem service management, positive consequences
are more important than negative in evaluating bioeconomy objectives, and that consequences to humans are more important than consequences to the environment.

**Highlights**

- Environmental concerns were clustered by two factors: anthropocentric and biospheric.
- Positive consequences were more important than negative in determining acceptance.
- Consequences to humans were more important than to the environment.
- Gender influenced the endorsement of forest management objectives.
25. Time to evaluate forest owner typologies?

Insights from Sweden

Brian Danley

PhD student, Department of Forest Economics, Swedish University of Agricultural Sciences (SLU), Centre for Environmental and Resource Economics (CERE)

Abstract: The large literature on non-industrial private forest (NIPF) owner typologies typically assumes that different kinds of owner groups will respond to different policy instruments according to shared attitudinal characteristics. By implication, multiple policy instruments are often recommended to engage different kinds of forest owners. Although forest owner typologies using principle component analysis and subsequent K-means clustering techniques are now prolific, surprisingly little empirical work has been done to link forest owner attitudes with forest owner opinions or experiences of different policy instruments. This study uses the standard tools of analysis for NIPF owner attitudes on a survey of Swedish forest owner opinions concerning forest conservation policy. Results show significant but weak relationships between attitudes and Sweden’s command and control green tree retention measures, participation in voluntary FSC or PEFC certification, and overall interest in taking more environmentally beneficial forest management measures. Interestingly, responses to hypothetical financial incentives to conserve productive forest have little or no relationship to owner attitudes. Taken together, results suggest the need for typology studies to empirically test how forest owner attitudes relate to actual or potential policy instruments.
26. How do forest owners develop trust in their timber procurement organization?

Dianne Staal Wästerlund¹, Anna Henckel¹, Agnes Källman¹, Erika Nylander¹, Elias Andersson¹, Elin Olofsson²

¹ Swedish University of Agricultural Sciences (SLU), Dept. of Forest Resource Management, Umeå, Sweden
² SCA Skog, Umeå, Sweden

Abstract: The strong competition to buy timber from private forest owners caused timber procuring organizations in Sweden to focus on longterm relationships with forest owners. A prerequisite for such relationships is trust. Trust in a business relations’ context can develop through different cognitive processes. The purpose of this study was to determine which processes forest owners use to develop trust in their timber procuring organization and to what extent age, gender and residence affected this development. Interviews among 29 forest owners revealed that forest owners reflected primarily on the perceived credibility of the company when asked to define trust. Benevolence to adapt to the forest owners’ wishes is important but not included in their own definition of trust. Non-resident owners have a tendency to judge if the timber procurer can be trusted rather than the company. Most forest owners also judge the timber procurement organization’s capability to deliver what they promise when making the timber deal. Forest owners that lack experience in selling timber try to assess and interpret the companies’ motives and if found matching their own, the forest owners also express high levels of trust. Otherwise these new forest owners rely primarily on recommendations from a third party they find trustworthy. The judged competence of the timber procurer was an important factor in the development of trust. Forest owners with experience or with a strong believe in their own knowledge, also relied on their own prediction of the outcome when judging if the timber procurer can be trusted. Female forest owners had lower levels of trust in their timber procurement organization than male forest owners. Problems in communication caused some female forest owners to express distrust but
general gender differences in trust may also contribute to the gender differences found.
27. Forest owners’ attitudes to climate change and climate change adaptation in Norway and Sweden

Authors: Kaja Heltorp, Oskar Ness and Hans Fredrik Hoen.

Abstract: Based on data collected from an online questionnaire distributed to 10000 randomly sampled members of the forest owners associations in Norway and Sweden, we analyse beliefs and perceived vulnerability to climate change, and the willingness and perceived feasibility of suggested adaptive practices in the two neighbouring countries. Each forest owner association (7 in Norway, 4 in Sweden) distributed invitations to participate in the survey to a representative number of randomly selected members. The response rate was 20%. The topic has been surveyed quantitatively in Sweden before, while our work is the first large-scale study based on a random sample of forest owners in Norway.

The questionnaire was composed of 32 questions, of which 10 were follow-ups dependent on previous replies. The majority of questions were statements, with answer alternatives as a balanced likert-scale of seven points described with words, including a neutral alternative.

The questionnaire design followed current state of the art knowledge in the survey literature and built on findings from studies of forestry decision makers’ attitudes and perceptions on climate change and previously identified barriers towards adaptation from across Europe. The literature suggests that believing in climate change, perceiving high risk and vulnerability, and possessing knowledge on how to adapt, facilitates adaptation. On the other side, lacking knowledge on climate change and adaptation, not believing in climate change and not perceiving forests to be vulnerable have been identified as potential barrier to behavioural change. We test whether this (still) applies to the Swedish and Norwegian owners. We furthermore asked respondents about the perceived need for advice on climate change adaptive management, and the owners’ perceptions regarding their own knowledge on the subject. The survey follows up findings from a qualitative study, based on focus-group interviews, in Norway conducted in 2016. These findings included belief in an overall positive effect of climate change for forestry as the result of increased growth due to longer growing season and increased demand for forest-based
products, and low willingness to implement adaptive actions not in line with the current management paradigm in Norway such as increased promotion of diversity in species.
28. Environmental vs forestry views on and stakeholders’ satisfaction with recent Estonian forest policy processes:

Estonian ‘Forest war’ 2016 - 2018

Meelis Teder* & Paavo Kaimre

Estonian University of Life Sciences

*Corresponding author meelis.teder@emu.ee

The presentation will be based on the article ‘The participation of stakeholders in the policy processes and their satisfaction with results: a case of Estonian forestry policy, (Forest Policy and Economics 89 (2018) 54-62, https://doi.org/10.1016/j.forpol.2017.05.007)

mailto:meelis.tdr@gmail.com

Abstract: The article explains the stakeholders’ interactions and satisfaction with their participation in the forest policy processes in Estonia until 2015. The interactions during the policy formulation and decision-making stages are observed with special attention to the role of scientists. Representatives of three target groups were interviewed: forestry officials, stakeholders and forestry scientists. To evaluate scientists’ participation in policy processes, we use the idealised role models of Pielke (2007). The stakeholders tend to believe their main form of participation in policy processes is decision-making, not realising that the final decisions are made by forestry officials or by politicians: the minister, government or Parliament. Consensual proposals or decisions are important because these usually form the basis for final formulations in policy documents. The policy processes are mostly facilitated by forestry officials whose mediation skills need improvement. There is a major conflict between stakeholders representing timber production and environmental protection. In policy discussions, the environmentalists should provide more analysis, otherwise their viewpoints are ignored. Forestry scientists fall short in their most important role as honest brokers; they must learn how to integrate themselves into policy processes. Very often scientists act as observers, but other participants expect them to actively bring scientific information and knowledge into
discussions. In addition to the face-to-face meetings, new communication tools (e-consultation and e-participation) are available, but they are underused in the policy formulation processes.

Since 2016 Environmental NGO-s are not satisfied with recent forest policy developments, it led to active protests and establishment of new forest related civic movement. Within last two years, the forest policy related problems have been very actively discussed in Estonia. Recently forestry scientists were forced to be more active in news media and in public debates, but a lot of additional work has to be done.

In March 2018 was launched the formulation of new national forestry programme, compared with previous processes, the representation of different stakeholder groups is enlarged.

**Keywords**: forest policy, decision-making, participation, advocacy, stakeholder, forestry scientist.
29. Growing relevance of open foresight by forest industry companies in transformation to the circular bioeconomy

Teppo Hujala¹*, Eric Hansen², Jyrki Kangas¹

1 University of Eastern Finland, School of Forest Sciences, P.O. Box 111, FI-80101 Joensuu, Finland

2 Eric Hansen, Oregon State University, Wood Science and Engineering, 119 Richardson Hall, Corvallis, OR 97331, USA

* Correspondence: teppo.hujala@uef.fi

Abstract: The circular bioeconomy represents a societal paradigm shift and transition challenge that inevitably influences how companies act in their evolving operational environment. The disruptive features may be particularly difficult to foresee and tackle strategically in companies operating in mature industrial sectors, such as the forest industry. This presentation considers large forest industry companies in a circular bioeconomy sphere and scrutinizes their opportunities to hasten their socio-technical transition pathway with a combination of open foresight and open innovation activities. Examples from three large Finland-based forest industry companies representing different levels of corporate foresight and innovation management are used to illustrate how those companies are approaching their future competitiveness. Further, the presentation will discuss what are the general assets of and recommended focal points for mature industry companies in their pursuit towards business success with futures-oriented innovation in a circular bioeconomy transition. The classified evidence from annual reports and sustainability reports indicates that the explored companies appear as more advanced with their open innovation than open foresight processes. This may be partly due to open foresight not yet having been recognized and institutionalized as an activity worth carefully communicating to stakeholders. However, there are signs in research literature that open foresight is becoming a more important success factor and communication item in the corporate world. Enhancing cross-sectoral collaboration and nurturing a futures-oriented organizational culture appear pivotal when pursuing future competitiveness in a circular bioeconomy. The conclusions further highlight top management
commitment, employee and stakeholder participation, and a mix of inside and outside perspectives in companies’ exploration of future opportunities and challenges.

Keywords: corporate transition; open foresight; open innovation; Future-Fitness-Portfolio
30. Future of forest bioeconomy in the eyes of Finnish young forest owners: a research agenda

Teppo Hujala¹, Antti Erkkilä², Irmeli Mustalahti²

¹ University of Eastern Finland, School of Forest Sciences, POB 101, FI-80101 Joensuu, Finland
² University of Eastern Finland, Department of History and Geography, Joensuu, Finland

* Correspondence: teppo.hujala@uef.fi

Abstract: Vision of sustainable European forest-based bioeconomy (Winkel et al. 2017) calls for a new policy narrative, which among other relevant things stresses inclusiveness. An important actor group to incorporate in co-creation of future bioeconomy is young forest owners, whose values and decisions will shape the forests of coming decades. In Finland, where some 15 million hectares of forest land is family-owned, young people may have a say in forest management and policy either as forest owners directly or via their extended families. However, the values, capabilities, and involvement of young forest owners are poorly known. Our research group is part of a research consortium called “All youth want to rule their world (ALL-YOUTH)” funded by the Strategic Research Council at the Academy of Finland. ALL-YOUTH involves young people 16-25 years of age in co-creating solutions together with scholars, policy makers and other actors. Bioeconomy is one of the themes of interest in the empirical research with the youth, and practice partners include, for example, the Finnish Forest Centre, the Ministry of Agriculture and Forestry, and the Finnish 4H Organisation. This presentation will first introduce our theoretical framework to study young forest owners, comprising responsive governance, capability theory, and translocality. Thereafter we will present a research agenda of research questions and sequential future steps, followed by preliminary results of our first inquiries. The overall objectives are: i) understanding young forest owners’, or future owners, intrinsic views on forests, bioeconomy, and the environment; ii) increasing interaction of knowledge and views between forest owner generations; and iii) incorporation of young forest owners’ perspectives in forest policy processes, especially relating to the update of the National Forest Strategy.
2025. Empirical research is being organized to include: 1) Stock-taking of young forest owners in Finland and its sub-regions in terms of number and age distribution, gender, and forest area; 2) interviews of a sample of young forest owners to learn their orientation towards bioeconomy; 3) a national survey targeted to young forest owners between 16 and 25 years and owning more than 1 ha forest land (population: 6786, of whom 61% are male and 39% female); 4) participatory action research (PAR) with selected young forest owner collaborators, to learn more about their reasoning and capabilities to participate forest bioeconomy with policy and practical action and via innovative digital platforms developed in the ALL-YOUTH project.

**Keywords:** generational change, knowledge exchange, capability approach, inclusiveness, youth

WG 3: Forest Industry and Forest Products Markets

*Full length papers*
31. Sustainable Development – International Framework – Overview and Analysis in the Context of Forests and Forest Products – Green Business opportunities – A literature review on competitiveness and resources

Hyytiä, Annika¹

¹University of Helsinki, Finland, annika.hyytia(at)helsinki.fi

Abstract: Nordic countries have many resemblances and collaboration in the way towards sustainable development. There are new promising opportunities for the forest sector in the sustainable development and green policies. In the green policies, sustainable development has an important significance. Policy with quality management aspects including certification and standards have a remarkable role in the value chain from forests. The value chain and innovations in the sustainable development of the forest sector provides opportunities for competitiveness and business. Markets are linked to the sustainable development framework. In Finland and in the European Union, the framework of value added products, markets and competitiveness in the sustainable development framework is highlighted. The Corporate Social Responsibility, the CSR, provides a significant framework with the sustainable development.

This is a qualitative research based on research articles and literature including academic sources, for example Proquest, Academic Search Complete (EBSCO), Agris, CAB Abstracts, SCOPUS (Elsevier), Web of Science (ISI) and Google Scholar and Internet sites.

Introduction

The global forest sector is nowadays diverse and interlinked with other sectors (Hurmekoski, E. and Hetemäki, L. 2013). In the worldwide forest industry development, there is a competition for resources and challenges in social and environmental aspects and strengths in management of raw material supply (State of World’s Forests 2011). Climate change, consumer demands and values, increasing competition for raw materials, bioeconomy,
energy policies, and ecosystem services evaluation are among topical drivers in the forest sector. Legislation can provide opportunities for competition. (Mattila, Osmo 2015).

The European Union Commission’s Corporate Social Responsibility Strategy is built on international organizations’ guidelines and principles as the United Nations, the ISO, and the OECD (Corporate Social Responsibility (CSR) 2017).

**Theoretical background**

Market orientation and stakeholder orientation have an obvious position in the field of corporate responsibility strategy. Market orientation and stakeholder orientation are business theories that have notable parallels in sustainability suppositions and how the role of a corporation is observed in the quest of sustainable development. Sustainable development orientation is needed if corporations will contribute to sustainable development. (Heikkurinen, Pasi 2011)

The Corporate Social Responsibility, the CSR, is an integral part of a business concept, and a proactive and strategic business approach (Cohen, David, Mathey, Anne-Hélène, Biggs, Jeffrey and Boyland, Mark 2014).

The stakeholder theory is a useful instrument for evaluating the Corporate Social Responsibility (Wang, Lei and Juslin, Heikki 2011). The Corporate Social Responsibility, the CSR, research results support the development of a responsible management approach in the future. It includes effective allocation of resources and ethical business practices. (Mikkilä, Mirja 2006)

**Quality and sustainable development**

Forest certification has an important role in promoting the sustainable forest management, the SFM (Rametsteiner, Ewald and Simula, Markku 2003).
Product quality is important internationally. Tools for quality include chain-of-custody standards. (Toivonen, Ritva 2011) Forest certification can be viewed as quality management (Rouvala, Annika 2005).

**CSR in the markets**

Policy in the climate change provides a framework for agreements comprehending legal, non-legal, governmental and non-governmental agreements. Market mechanisms include certification. Certification systems with standards may act as incentives in the markets and for market access. (Bernstein, Steven and Cashore, Benjamin 2012).

Responsibility in the value chain is important (Heikkurinen, Pasi 2013). Global framework increases the number of corporations in the Corporate Social Responsibility, and an international framework can enhance the Corporate Social Responsibility (Lim, Alwyn and Tsutsui, Kiyoteru 2012).

**Conclusions**

Quality is part of competitiveness. It can provide a sustainable image to customers. The CSR framework with forest certification seems increasingly important in the sustainable development framework with the international and national policy and marketing opportunities. The Corporate Social Responsibility, the CSR, seems to be more and more significant in the international and national policy framework. International approaches, strategies, collaboration and agreements have a significant role in the sustainable development. Global framework is essential in the framework of the CSR.
References


Jagger, Pamela; Brockhaus, Maria; Duchelle, Amy E; Gebara, Maria Fernanda; Lawlor, Kathleen; et al. 2014. Multi-Level Policy Dialogues, Processes, and Actions: Challenges and Opportunities for National REDD+ Safeguards Measurement, Reporting, and Verification (MRV). Forests; Basel Vol. 5, Iss. 9, (2014): 2136-2162.


Rametsteiner, Ewald and Simula, Markku 2003. Forest certification — an instrument to promote sustainable forest management? Available at: https://www.researchgate.net/profile/Ewald_Rametsteiner/publication/1083


Abstracts
32. Perspective on Sustainable Development by Non-Industrial Private Forest Owners and Sawn Wood Customers

Anna Thorning, PhD-student

Department of Business, Economics and Law, Mid Sweden University

Abstract: The Swedish forest resource is central for development of a sustainable bio based economy. For a truly sustainable bio based economy it is important to include all relevant aspects of sustainability and for companies to incorporate responsible practice in their business e.g. through Corporate Responsibility (CR). In recent years CR has been implemented as an important strategic aspect in the forest industry to legitimize business and to create competitive advantage. Especially larger forest companies have responded to stakeholders and society’s expectations on how to conduct business and meeting market demands e.g. through forest certification. Forest certification as a way to actively work with sustainable development has not been effective among Non-Industrial Private Forest owners (NIPF); only 17 percent of NIPF in Sweden holds a forest certificate. In Sweden NIPF can be regarded as a backbone of Swedish forestry as they own 50 percent of forestland and are key to reaching several sustainable development goals set by the Swedish parliament. In Sweden many NIPF are organised through Forest Owners Association (FOA) who strive to generate benefits for their members while maintaining their own industry and meeting the needs of global customers. NIPF and FOA customers have therefore been identified as key stakeholders that strongly influence FOA strategic CR operations. Two stakeholder perspective, that of NIPF and customers, serve as starting points for explaining competitive FOA strategies. Previous research point to a research gap due to that many studies have investigated and categorised NIPF but none or few have studied drivers and barriers for sustainable development as a part of forest ownership or how the two groups perceive CR in the relationship to the wood procurement process and the FOA value chain. Assuming that sustainable development is framed in terms of the triple bottom line, the social dimension needs to be further investigated.
The purpose of the PhD-studies is to explore FOA potential for strategic CR to create competitive advantage. An overall aim is to develop tools and models for sustainable value chains specific for FOA. Therefore a case study to investigate and compare sustainability aspects regarded as important by key stakeholders will be conducted and drivers and barriers identified. Through a mixed method approach and theory framework based on system transition towards a service dominant logic for co-creation of value this study will contribute to the understanding of FOA specific prerequisites for implementing strategic CR.

*Keywords*: Corporate Responsibility, Forest Owners Association, Stakeholders, Non-Industrial Private Forest owners, co-creation of value
33. Sustainable urban development

Market development for wood construction

Cecilia Mark-Herbert, Fredrik Sjöström & Anders Roos

Cecilia.mark-herbert@slu.se, fkom0002@stud.slu.se, Anders.Roos@slu.se

Department of Forest Economics, Swedish University of Agricultural Sciences

Abstract: An increasing awareness of challenges for sustainable development in spatial planning calls for new ways meeting consumer needs in house construction (SDG 11). The rise of wooden multistory construction (WMC), new engineered and or modular wooden products are seen as opportunities in emerging bio-economies. Institutional changes, a change in building codes in particular in Sweden has opened up for a market development for wooden multistory construction. However, the market for WMC for residential use has not developed substantially in a national perspective. In spite of efforts to promote market development though various institutional efforts (a change in legislation, political promotional activities and multi-stakeholder dialogues) the WMC market appears stagnant. Locally, however, organized collaboration seems to a tremendous WMC development. The aim of this study is to explain conditions for collaborative efforts that may promote the development of a market.

The case study shows that collaboration in public private partnerships, (PPP) joint efforts between private actors, construction industry, and local societal actors, municipalities may indeed promote the development of a local market for MWC. Perceived conditions that promote the development of PPP in MWC in this case are related to an increased societal awareness of sustainable development, understandings of properties of wood as a construction material and political objectives that serves as institutional support for an industrial change process. Identified factors that may challenge the market development are related to perceived properties, shortcomings, of wooden materials, lacking industrial know-how and a limited number of actors on the market.
This case study contributes to our theoretical understanding of conditions for market development in the case study in terms of:

• perceptions, experiences as well as hearsay, of wood as a construction material,

• challenges to document sustainability effects – for example life cycle analysis,

• technological lock-in, where construction stakeholders may have vested interests in materials and techniques, and

• a market structure, where a limited number of WMC actors may have difficulties to be competitive in public procurement processes in large projects.

All of these conditions are met in successful PPPs; public private partnerships may offer long-term marketing relationships in which learning about wooden materials, ways to assess the environmental effects and learning about construction techniques are developed. Future research is needed to further investigate conditions for promoting PPP and how the learning outcomes from these PPP-WMC initiatives can be translated to a larger market scale.

**Key words:** marketing, promotion, SDGs, wooden multistory construction, WMC
34. Perceptions of wood usage acceptability among consumers –

Results on systematic literature review

Charlotta Kankaanpaa

Abstract: Societal objectives to increasing the usage of wood, e.g., in building sector and more generally in housing are related to the overall goals to support sustainable development through the management of environmental impacts and enhancement of social and economic benefits of the construction sector. The acceptability of wood as a material for building and housing among consumers strongly affect, e.g., the market diffusion potential of different types of engineered wood products used in housing. Despite this, holistic information on the existing scientific knowledge concerning consumer perceptions of the acceptability of different types of wood products and, e.g., the drivers behind different types of perceptions is lacking. The purpose of this study is to fill these gaps in the existing comprehension of consumers’ views on the pros and cons of the wooden products in the international markets with a special focus on the aspects of sustainable development. As a methodology of the study, a systematic literature review is implemented by scanning the peer reviewed articles published in international scientific journals during the 2000s. In all, combinations of 12 keywords are being used in scientific databases (e.g., ScienceDirect and Business Source Premier (EBSCO)) to gather the material to be analysed with qualitative thematisations.
35. Diversification of the forest industries:
Role of new wood-based products

Elias Hurmekoski*1,2, Ragnar Jonsson3, Jaana Korhonen2, Janne Jänis4, Marko Mäkinen4, Lauri Hetemäki1, Pekka Leskinen1

* Corresponding author

1 European Forest Institute, Yliopistokatu 6, 80100 Joensuu, Finland
2 University of Helsinki, Department of Forest Sciences, Latokartanonkaari 7, 00790 Helsinki, Finland
3 European Commission, Joint Research Centre (JRC), Via E. Fermi 2749, I-21027 Ispra, Italy
4 University of Eastern Finland, Department of Chemistry, Yliopistokatu 7, 80130 Joensuu

Abstract: This study identifies new wood-based products with considerable potential and attractive markets, including textiles, liquid biofuels, platform chemicals, plastics and packaging. We draw on the theory of value chain to examine how the position of forest industry in respective value chains determines the unit value of its production. Consequently, an assessment is provided as to the degree these emerging wood-based products could compensate for the projected decline of graphic paper markets in four major forest industry countries (USA, Canada, Sweden, and Finland). Assuming a 1–2% percent market share in selected global markets implies a potential increase of 18-75 billion euros per annum in the revenue stream in the four selected countries by 2030, ceteris paribus. This corresponds to 10–43% of the production value of forest industries in 2016. This range compares to a projected decline of graphic paper industry revenue of 5.5 billion euros by 2030. The respective impact on wood use are manifold, as many of the new products utilize byproducts as feedstock. The impact on primary wood use, almost entirely attributable to the construction and to some extent textile markets, would be 15-133 million m³, corresponding to 2-21 % of the current industrial roundwood use.

Keywords: bioeconomy; competitiveness; forest industry; new wood-based products; value chain
Structural change of forest industries and its impact on forestry carbon balance in Finland

Elias Hurmekoski*1,2, Tanja Myllyviita3, Jyri Seppälä3, Tero Heinonen4, Timo Pukkala4, Heli Peltola4, Antti Kilpeläinen5, Lauri Hetemäki1, Antti Asikainen5, Pekka Leskinen1

* Corresponding author

1 European Forest Institute, Yliopistokatu 6, 80100 Joensuu, Finland
2 University of Helsinki, Department of Forest Sciences, Latokartanonkaari 7, 00790 Helsinki, Finland
3 Finnish Environment Institute, Centre for Sustainable Consumption and Production, Mechelininkatu 34a, Helsinki, Finland
4 University of Eastern Finland, Department of Forestry, Yliopistokatu 7, 80130 Joensuu
5 Natural Resources Institute Finland, Yliopistokatu 6, 80100 Joensuu

Abstract: Substituting more carbon intensive products with wood-based alternatives may compensate for the reduction of forest carbon sink. The objectives of the study are to define a long-term outlook for forest product markets in Finland, to compute updated displacement factors for established and emerging wood-based products, and based on the above, to determine how an increasingly diversified market structure may influence the carbon balance in soil, standing forests and wood products. We mobilize these research questions by modelling the carbon balance of the Finnish forest sector to 2050 using a forest management optimization model (MONSU) and a separate product substitution model. Three scenarios are simulated:

1. Baseline scenario – constant annual harvest level of 70 million m$^3$, with around one half of the total wood use going to new products by 2050. The diffusion of emerging wood-based products is approximated based on overall market sizes and an assumed rate of substitution in construction, textile, chemical, and biofuel markets.

2. Same as 1., but log use increased by 10% and pulpwood use reduced by 10%. The relative share of pulp-based products (exports) is assumed to decline, while that of wood construction is assumed to increase.
3. Same as 2. but reversed (log 10% decrease, pulpwood 10% increase).

Compared to previous papers, our study emphasizes the long-term dynamics of the techno-system by producing estimates for i) long-term market development including selected emerging wood-based products, and ii) a range of displacement factors that match the projected market structure and consider the eventual decarbonisation of the energy system in the long-run. Besides the simulated overall carbon balance, the results will portray a range of substitution benefits attainable from using wood for products. Increasing the production of logs on the cost of reduced pulpwood production is expected to yield higher avoided carbon emissions through two mechanisms. Firstly, the amount of carbon bound to growing forest increases, as the tree diameter grows. Secondly, more wood is being directed to long-lived products in the construction sector.

**Keywords:** bioeconomy; carbon balance; displacement factor; forest industry; national forest inventory; structural change; substitution

Emmi Haltia¹ and Matleena Kniivilä²,¹

¹ Pellervo Economic Research PTT, Eerikinkatu 28, 00180 Helsinki, Finland, emmi.haltia@ptt.fi
² Natural Resources Institute Finland (Luke), Latokartanonkaari 9, 00790 Helsinki, Finland, matleena.kniivila@luke.fi

Abstract: The aim of this study was to identify consumer segments related to wood-based products in Finland, examine consumers’ attitudes towards bioeconomy, and determine factors that impact on the consumers’ willingness to buy wood-based products. The study used survey data of 3648 respondents that was collected as a part of a larger mail survey. In addition to the survey, the results of the study are based on literature review. The project was funded by the Prime Minister's Office of Finland and aimed at improving national bioeconomy policies in Finland.

As the concept bioeconomy is likely to be poorly known among consumers, instead of asking directly about bioeconomy, the survey questions focused on attitudes towards pro-environmental and domestic products. Furthermore, questions related to specific production, e.g. energy production and wood construction, were included.

Three different types of consumers were identified: 1) consumers emphasizing pro-environmental choices (39 %), 2) consumers emphasizing importance of domestic production and economic issues (39 %), and 3) price-conscious consumers opposing pro-environmental choices (22 %). In group 1 the share of women and persons having university degree were higher than in population on an average. In group 2 the share of senior citizens was higher than in the whole population. In group 3 typical respondent was middle-aged or young man. Interestingly, no major differences in income were found between the groups.

According to the results, a considerable share of Finnish consumers had positive attitudes towards pro-environmental and domestic products. These attitudes are, however, reflected only partly on actual consumer choices. For example, pro-environmental attitudes increased the probability of choosing an eco-friendly option for household electricity contract in logit model, but
the impact was rather small. The key factors for potential pro-environmental choices are prices of products and easy access to them. Existing behavioral patterns may hinder adopting new, environmentally friendly ways of action, even when attitudes and values would be pro-environmental.

Policy instruments used to advance bioeconomy should impact on the relative prices of products, improve product availability and create positive examples of the use of products in order to change existing behavioral patterns. Preferring bio-based products in public procurement could increase the familiarity of these products. In addition, consumer behavior can be modified with so called nudging methods which are based on behavioral economics.

**Keywords:** Bioeconomy, consumers, pro-environmental products, behaviour change, nudging
38. Wooden Multistory Construction in Finland: Perceptions from municipal civil-servants on the benefits of wood and barriers to project implementation

Florencia Franzini¹, Ritva Toivonen & Anne Toppinen

¹Department of Forest Sciences, University of Helsinki, P.O. Box 27, 00014 Helsingin Yliopisto, Finland,*corresponding author, florencia.franzini@helsinki.fi

Abstract: Despite several national level wood construction programmes since the mid 1990s, the share of wooden multistory construction (WMC) remains currently at about 5-6 % in Finland. Municipalities hold the legal authority and responsibility to zone land-use plans, and as the only entity capable of this, their key civil-servants are the gatekeepers of construction projects. This authority extends to enacting regulations, which force builders to comply with the use of dictated construction materials, like wood. But material compliance is rarely implemented.

This paper presents the analysis of perceptions and attitudes regarding WMC development in Finland as interpreted by civil-servants engaged in strategic municipal planning and development. The Theory of Planned Behavior was used as a framework for the questionnaire, in which the interviewees were asked to elicit their personal opinions on WMC, what they perceive the attitudes of other actors in Finland to be regarding WMC, and how they view the process of communication between different actors related to WMC. Semi-structured interviews were conducted between May 2017-January 2018 with 11 civil-servants who held high-level administrative roles in the planning and development of their city. Participants were required to be both influential to decision-making processes within the municipality, yet varied regarding their professional backgrounds.

Based on the qualitative content analysis of the data, interviewed civil-servants held various attitudes to WMC. Multiple benefits were perceived by participants including themes related to the industries economic value, the materials technical qualities, resident quality of life, and environmental
sustainability. On the other hand, limited support for WMC is largely perceived to be a result of market barriers which trigger a high cost of WMC erection. These barriers include: a slow developing and weak wood construction industry, limited regulatory support from local and national government, and poor topical communication and access to WMC information. Some views among civil-servants were contradictory to each other. Civil-servants also perceived that other actors held diverse views on WMC, and these perceptions were also contradictory. It is interesting to note that civil-servants seem to have very limited communication with the public and academia, and that communicating with the end-users was sometimes seen as burdensome.

**Keywords:** wooden multistory construction, Theory of Planned Behavior, Qualitative Content Analysis, Nordic region,
39. The use of networks in international opportunity recognition: A multiple case study on Finnish wood products industry SMEs

Hietala, J., Hänninen, R., Kniivilä, M. & Toppinen, A.

University of Helsinki, Department of Forest Sciences, Latokartanonkaari 7, Helsinki Finland

ABSTRACT: The transition to bio-economy will create new international opportunities for firms operating in the wood products industry. International opportunity recognition is emphasized as a key concept for entrepreneurial success in international business operations. Through 11 qualitative interviews from 7 wood product industry SMEs in Finland, this study examined how firms recognize international opportunities by utilizing a network perspective on internationalization. The results suggest that wood products industry SMEs recognize international opportunities reactively per se. Social networks formed for example at professional forums are an important information channel for identifying international opportunities. Through vertical business networks firms have been able to increase their international market presence and knowledge and free their resources to other activities. The role of sales agents is emphasized to have positive effects on information flow, whereas, excessive reliance on vertical networks raises concerns on international opportunity recognition. Horizontal dyadic business networks are formed mostly when needed, and facilitate new international opportunities through co-operation. Institutional networks represent a more systematic way of recognizing international opportunities in initial market entry.

Key words: Wood products, SME, opportunity recognition, networks, internationalisation
40. Future scenarios and pathways for utilization of wood product industries by-products in Finland

Janni Kunttu1,2*, Elias Hurmekoski1, Henrik Heräjärvi2, Teppo Hujala2, Pekka Leskinen1

1European Forest Institute, Yliopistokatu 6, 80100, Joensuu, Finland
2University of Eastern Finland, Yliopistokatu 7, 80100, Joensuu, Finland

*Corresponding author
email: janni.kunttu@efi.int

Keywords: by-products, wood product industries, preferable futures, scenario analysis

ABSTRACT: International policies and market forces, as well as regional circumstances such as structure of the industries render optimization of wood flows difficult. The aim of this study was to explore a variety of preferable futures of by-product allocations and determine the salient drivers affecting the future development. To this end, this study i) defined alternative by-product allocation scenarios in Finland until 2030, ii) evaluated their likelihood and advantages and possible disadvantages, and iii) analyzed the factors affecting the implementation of the scenarios. A Q2 scenario technique was used as a basis for this study to collect data from industries, research, interest group, and policy experts. This scenario analysis utilized both quantitative data using cluster analysis and qualitative data using qualitative content analysis and a futures table. Three scenarios were determined: I) Traditional production lines, which is dominated by pulp and energy production, but addresses versatile ways of utilizing sawdust, II) Versatile uses, which drives a great variety of uses, including new bioproducts, for all by-products, III) long-lifetime products, where by-products are only used for wood composites-, and particle- and fiberboards. The ‘pulp and bioenergy’ scenario reflects the current Finnish industry in Finland the most. In the ‘Versatile uses’ scenario, the main idea is to improve economic risk diversification, as well as fossil fuel and material substitution potential. The experts considered ‘Versatile uses’ slightly less probable than ‘Pulp- and bioenergy’ due to the intensive research and piloting needs. The idea of the ‘long-lifetime products’ scenario is to
maximize the long-term carbon storage in harvested wood products and minimize carbon release to the atmosphere. The experts considered the ‘long-lifetime products’ the most difficult to implement, as it would require global investments in renewable energy technologies to reduce the demand of wood based energy generation, and increased market share for wood panels. The main drivers affecting the implementation of the scenarios are non-restrictive international policies, which enable to invest equally on any industrial activity contributing fossil product and fuel substitution or carbon storage increment, and funding for multiple long-term research themes. Both of those drivers indirectly improve the competitiveness of wood based products and fuels. In addition, cross-sectoral co-operation is a crucial factor to foster material circulation, which again contributes the high added value production and resource efficiency in any scenario. This study states that each scenario can increase resource efficiency, but the sustainability impacts, whether they are negative or positive, are depending on development of the drivers.
41. Sustainable forest-based bioeconomy: A case of biorefinery

Jenni Miettinen* and Markku Ollikainen

Department of Economics and Management, University of Helsinki

*jenni.miettinen@helsinki.fi, P.O. Box 27, FI-00014 University of Helsinki, Finland

Abstract: The business environment of the forest sector has changed due to several grand societal challenges and related policy drivers affecting the market. New policies are called for to promote the shift from the current forest industry to a forest bioeconomy, which denotes producing a large set of new and high value-added products alongside old products and a consequential diversification of business.

Analytical studies on the functioning of forest biorefineries and the policies promoting bioeconomy are still lacking. This study develops an analytical framework of biorefinery consisting of a pulp company producing possibly electricity and supplying a variety of side streams to bioproduct companies that produce new forest-based products.

We examine how the possibility of selling side streams to bioproduct companies impacts the use of wood and production of energy within the pulp mill. We also focus on the economic interaction between the pulp mill and the bioproduct company. Thus, we ask whether the new market is competitive or imperfectly competitive and how it impacts the use of wood. Also we examine cases where material shortages may emerge for the bioproduct company. We compare these cases to the socially optimal solution obtained by maximizing the joint profits of the pulp and bioproduct company.

We demonstrate that in a perfectly competitive market, the possibility of bioenergy production in the pulp company increases use of wood. Furthermore, the revenue from selling the side streams increase the use of wood further. We also demonstrate that when the pulp mill is a monopoly seller, it sells less side streams and uses more wood in energy production relative to perfect competition. Then, the bioproduct company may not be able to buy enough raw material and cannot maximize its profits. These
results indicate that there is a need for new bioeconomy policies promoting the shift to a sustainable forest-based bioeconomy.

**Keywords:** bioeconomy, forest biorefinery, new forest products, pulp and paper industry
42. Do institutions in the housing markets cause delays in detached house building processes? – Views of Finnish homebuilders

Jaakko Jussila & Katja Lähtinen

Department of Marketing and Communications, University of Vaasa, Vaasa, Finland

Abstract: Buying a home is the biggest and most important purchasing decision for many consumers. The customers ending up to select a detached house have considerably more power to affect different characteristics (e.g., floorplan, materials) of their homes as a result of differences in business logics and building processes between companies producing houses for detached and multi-storey housing markets. From the perspective of wooden industries, effects on customer choices on the structural materials is not of a minor importance, as in Finland, for example, approximately 80% of the new detached houses are made of wood. Despite the higher level of customer-orientation in the detached housing markets compared to multi-storey housing markets, also the customer-orientation in the detached housing markets is still at low level. This is not only caused by companies’ strategic solutions, but also institutional factors such as local regulation and control of buildable land, which have been discouraging the development and initialization of innovative business solutions. The overall purpose of this study is to fill the existing gap in the research information on the role of institutions affecting the building processes of detached houses. The material of the study is composed of survey data (n=661, response rate 27.5%) gathered from builder-families by phone interviews in January 2015 analyzed with quantitative and qualitative methods. According to the results, regardless the type of detached house building process, institutional factors cause many challenges for the purchasers (e.g., bureaucracy on accessing building permit and financing the project). From the perspective of public authorities, this is an indication of the need for renewing some regulatory processes, while from the perspective of building companies it gives opportunities for enhancing the customer-orientation. Related to that, for mutual benefits of the companies and consumers, communication and information services related knowledge on building process abreast with entirely new types of business models should be developed in the future to
manage the risks among consumers related to different institutional factors in the housing markets and construction sector.
43. A network analysis of Finland’s forest bioeconomy

Jaana Korhonen, Alex Giurca, Maria Brockhaus, Anne Toppinen

Abstract: The forest sector is widely considered as “the foundation of the Finnish bioeconomy” (Biotalous, 2017). Finland’s bioeconomy strategy encourages collaboration between the forest sector and other sectors in the quest to develop knowledge, technologies and innovative products (MEE, 2014). However, scholars have noted that although there is a plethora of bio-based innovation projects and experiments in Finland, they often lack interconnectivity and coherence (Bosman and Rotmans, 2016). Yet inclusion of a broader range of actors and stakeholder from outside these established industries (e.g., entrepreneurs, brokers, resource providers, consumers, citizens etc.) will be crucial for the bioeconomy innovation network (van Lancker et al., 2016).

In Finland, focus has mainly been on incremental innovations that keep the overall structure of existing industries intact (Bosman and Rotmans, 2016). Current developments point to a direction where already established organizations are creating “business ecosystems” around themselves. Nonetheless, it is still unclear whether the bioeconomy network is truly diverse and open or rather protective and closed. As the social capital, openness and structure of a network are assumed to have implications for the future development of the bioeconomy, the forest-bioeconomy innovation network in Finland needs further empirical assessment.

The main objective of this study is to provide an understanding of actors, their interests and emerging policy coalitions in the Finland’s bioeconomy policy arena. Furthermore, we aim to analyze how conducive these structures are for innovation (expressed through inclusion of new actors and emergence of new products within these networks) in Finland’s bioeconomy development. Empirically, the current study builds on a nation-wide survey conducted with central organizations in the Finnish forest-based bioeconomy, and social network analysis.

• What type of organizations are involved in Finland’s forest bioeconomy network?
• What are actors’ and coalitions beliefs influencing the future of the bioeconomy?

• How is the network structured in regards to innovativeness and innovation at the organizational level within the forest-based bioeconomy value chains?

Cited literature:

Biotalous, 2017. Wood and forest [WWW Document]. URL

   doi:10.3390/su8101017


44. End-user expectations and perceptions of living in a wooden multi-story construction - A case study

Noora Miilumäki1*, Eliisa Kylkilähti2, Minna Autio3, Anne Toppinen1

1Department of Forest Sciences, 2Department of Economics and Management, 3Department of Education

University of Helsinki, P.O. Box 27, 00014 Helsingin Yliopisto, Finland

*Corresponding author noora.miilumaki@helsinki.fi

Abstract: Urbanization and sustainability are among the major drivers to induce changes in housing. Wooden multi-story construction (WMC) may deliver a solution towards these changes utilizing bio-based resources and providing multi-family solutions. In the end, however, housing is not empty apartments, but homes, where we as end-users spend most of our time and money. Could WMC be not only a sustainable solution, but also one that meets the needs and wants of the end-users?

This paper aims to find out what the expectations of Finnish homeowners towards WMC are and whether their perceptions about wooden living change after some experience from it. The study is conducted using semi-structured qualitative interviews in a case wooden multi-family building finalized in May 2017. The first round interviews included seven homebuyers about to move into the case building. Their views are then compared with the perceptions after one year of habitation.

The first interview round supported the notion that end-users can have prejudices towards wood as a construction material, mostly related to its durability, moisture sensitivity and fire safety. Still, due to its positive characteristics such as “clean”, “natural” and “quiet”, wood was considered as a pleasant bonus feature of the new home. Some of the end-users did express their willingness to pay more for wood as a construction material of their homes given that they were provided with neutral information about the superior qualities of wood compared to concrete. The second round of interviews will shed light to whether the above opinions of the end-users have changed over time, and in what ways. An interesting follow-up question is also how to better integrate end-user concerns already in the
WMC building phase, and which manner of collecting such information would be the most fruitful one.

Keywords: end-users; wooden construction; case study; interviews
45. Services and evolving production of wood-based solutions – higher value added, new normal or business as usual?

Päivi Pelli, University of Eastern Finland, School of Forest Sciences, paivi.pelli@uef.fi

Abstract: Servitization in manufacturing has been investigated in the engineering field studies since late 1980’s. This refers to the trend of the manufacturing companies adding services to their products and gradually moving downstream in the value chain to increasing service provisioning. Services have been a means to differentiate the company offering, sustain relationship with the customers to create more stable income, as well as keep in pace with the customer processes, to improve efficiency and seek means for product and process innovation. In Finland, the bioeconomy strategy sets the goal towards higher value-added products and services based on forest resources. It is tempting to make an analogy to servitization in manufacturing and seek for higher value added from services also for the traditional forest industry companies, but how justified are such analogies?

This paper takes the prefabrication of modular wooden elements as an empirical study context to elaborate the question. Prefabrication provides many benefits for introducing wood-based solutions for multistory construction. Yet, the role of services has been little investigated within these increasingly automated processes where wood products industries, including also the traditional forest industry companies, are involved.

Method includes three steps: 1) value-added analyses of three case product supply chains (prefabricated modules and elements): where value is created and how it is distributed across different production stages as well as geographically; 2) extended analysis of the production networks (whole supply chains, all materials), including product and company data and interviews of representatives of industry federations: what is the role of services and which trends and drivers are identifiable; 3) brief overview on the recent developments of the forest industry and wood products sector in Finland.

The three cases illustrate the evolving supply chains in prefabrication, but the analyses cannot be generalized to whole industry. Overall, few studies
have been carried at this level of detail about the role of services in production of construction materials. For the first, construction sector supply chains are to a large extent local / regional, not only for wood and wood products but also for other materials and products. Furthermore, regulations, norms and standards are local, and for example, the planning and engineering services that are necessary for designing the technical solution need to be acquired in the country where the wood products are used. Also, assembly and pre-fabrication or on-site services are domestically sourced. The three case analyses illustrate that prefabrication seeks for efficiency and cost competitiveness; supply chains are evolving and the different suppliers of materials, products and services seek for optimal position in the value network, and; digital processes open both opportunities and challenges for the suppliers. Services are embedded in the production processes and the texture of the supply chains in multiple ways. Noteworthy, the value networks analyzed provide also glimpses of possible sources for a higher value added in the future – the question raises whether it will be the established market players to take the necessary steps and/or which could be the means to support recognition and realization of these opportunities.

**Keywords**: prefabrication of wood, construction sector, services, servitization, bioeconomy
46. Business Model Dynamics in Swedish Wood Construction & Manufacturing Industry

Sarah Ebadzadeh Semnani & Tomas Nord

Abstract: The term “business model” has been frequently used amongst both academics and practitioners over the past two decades. However, despite its ubiquity, there are still no consensus on its exact definition and applicability (DaSilva & Trkmann 2014). To date, major scientific contributions of business model concept has been from fields of technology and information management, strategy and organization theory (Wirtz et al. 2016). It is however, not entirely possible to draw a clear line between these three fields. This study follows more of a strategic perspective and considers business models as conceptual (Al-Debei & Avison 2010), managerial (Magretta 2002) and analytical (Lambert & Davidson 2013) tools, used for abstract representation of company’s architecture or structure (Wirtz et al. 2016). Therefore, business model is described as “the logic of the firm, the way it operates and how it creates value for its stakeholders” (Casadesus-Masanell & Ricart 2010, p.197).

The abstract nature of business models facilitates a better understanding of changes in organizations. This is referred to as business model dynamics (Cavalcante et al. 2011; Wirtz et al. 2016). There are scholars who seek to make a clear distinction between incremental changes focusing on specific components of business models, and disruptive changes leading to a complete transformation of business models, or in other words, business model innovation (Cavalcante et al. 2011; Voelpel et al. 2004). The literature highlights the importance of studying business model changes within a specific industry or context (Doz & Kosonen 2010). A literature review of empirical research on business models from 1996 to 2010, revealed that the context-specific studies were mainly carried out in young and fast growing industries such as biotechnology; or in industries that faced disruptive technological changes; like telecommunication, information and media (Lambert & Davidson 2013). As a result, one of the areas left under-researched is mature industries with a slower rate, or, less sophisticated technological developments. One of these industries is wood construction & manufacturing (Hansen et al. 2007); which will be studied under the Swedish context in this work.
The Swedish wood construction & manufacturing industry is considered a mature branch. It consists of many Small & Medium Enterprises (SMEs) and very few giant actors (TMF 2017). 2

Up until recently, the innovations in this industry were mainly focused on process innovation (Hovgaard & Hansen 2004) and digitalization activities were mostly directed towards Computer-Aided-Manufacturing (CAM) and use of customized machineries for efficiency in wood utilization and production (Hovgaard & Hansen 2004). However, the industry is currently facing new trends. One, being solution providing and servitization, which puts a demand on higher involvement of customers in several stages before and after the product delivery (Tuli et al. 2007). Furthermore, the pervasiveness of e-commerce and digitalization has enabled some of the companies to reach the end-users directly. The other trend, is towards modularity or, as labelled by Kowalkowski et al. (2015), industrializing. This means mass-production of customized offerings, which has a direct focus on manufacturing and production efficiency.

These new industry trends can act as forces of change in the companies that are active in this branch. Nevertheless, not all companies react similarly to these forces. Some may completely transform/innovate their business models, whereas others may incrementally/gradually implement changes to different components of their business models. This research will therefore study business model dynamics in different companies undergoing varying degrees of change in their business models.

Reference List


WG 4: International Forestry

*Full Length papers*
47. Carbon sequestration payments in Miombo woodlands when transaction and inventory costs are included

Arezoo Soltani¹² (E-mail: arezoo.soltani@hvl.no), Ole Hofstad² (E-mail: ole.hofstad@nmbu.no)

¹ Faculty of Social Sciences, Western Norway University of Applied Sciences (HVL), P.O. Box 7030, NO-5020, Bergen, Norway.
² Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences, P.O. Box 5003, NO-1433, Ås, Norway.

Abstract: We considered a principal interested in reducing emission of CO₂ in Tanzanian Miombo woodland as efficiently as possible through REDD+ payments to a village agent who has maximum net present value of land use as his objective. We included payments for carbon sequestration, forest inventory, and other transaction costs. The objective was partly to relate the CO₂-price avoiding deforestation to agricultural rent and interest rate. Furthermore, we studied how the price of CO₂ depends on biological and socio-economic factors. We found that REDD+ funds required to avoid deforestation and forest degradation are at the high end of the currently accepted range for REDD+ payments.

Key words: Miombo, transaction cost, inventory cost, REDD+, payment interval

1. Introduction

Reduced Emissions from Deforestation and forest Degradation (REDD+) was conceived as a special case of Payment for Environmental Services (PES) (Wunder, 2007; Gómez-Baggethun et al., 2010). It was considered a relatively cheap way of reducing greenhouse gas emissions (Eliasch, 2012; Stern, 2007). REDD+ was also embraced because the results-based payment approach reframes the political relationship from a donor-recipient model to something closer to a partnership between equals (Hofstad, 2016).
The implementation of REDD in Tanzania started relatively early (Angelsen and Hofstad, 2008), but has come under criticism for continuing a traditional donor funded conservation pattern (Lund et al., 2017). Benjaminsen and Svarstad (2018) even called it climate colonialism. One of the most serious hindrances to fulfilment of the original promises has been the difficulty of setting up a market for reduced emissions at local level. A realistic system for contracts between sellers (farmers, villages, or districts) and buyers (agents, funds, or governments) of reduced emission of CO$_2$ has not been implemented.

The theoretical literature dealing with contracts on REDD+ is meagre (Harstad, 2016), but Salas and Roe (2011) is a most relevant example of game theory applied to REDD+, see also (Cordero Salas, 2013). One robust conclusion from that work is that optimal contracts have no upfront payment – all payments are conditional and provided at the end of the contracting period. Now there are quite a few studies of the costs of REDD+ in both Tanzania (Fisher et al., 2011; Merger et al., 2012; Araya and Hofstad, 2016) and elsewhere (Rakatama et al., 2017). The majority of these studies reported opportunity costs, but quite a few also estimated implementation costs.

In the following, we combine biological and economic information on land use in common woodland (Miombo) areas in Tanzania with contract design, implementation and transaction cost in order to assess the marginal cost of reducing CO$_2$ emissions from deforestation and forest degradation. We considered a principal interested in reducing emission of CO$_2$ as efficiently as possible through REDD+ payments to a village agent who has maximum net present value of land use as his objective. We included payments for carbon sequestration, forest inventory, and other transaction costs. The objective was partly to relate the CO$_2$-price avoiding deforestation to agricultural rent and interest rate. Furthermore, we studied how the optimal contract interval depends on biological and socio-economic factors. We used a dynamic bio-economic model to simulate the sensitivity of CO$_2$-price and cost of avoided deforestation. The cost was calculated as the net present value of all payments made by the principal over a 60-year period compared to the mass of CO$_2$ sequestered in forest biomass. The study addresses the following research questions: (1) Which price of CO$_2$ stops both
deforestation and forest degradation? (2) What is the total cost of saving Miombo woodland through REDD+ payment?

2. Method

We built a non-linear dynamic goal programming (GP) model and run it over a period of 60 years assuming the existence of one decision maker namely a principal (the buyer of reduced emission of CO₂). The principal aims for efficient payment to reduce emission of CO₂, and seems to be concerned about the agent’s (the seller of reduced emission of CO₂ or the village community) net present value of land use (NPV). It is important for the principal to find out the price of CO₂, $P_s$, in order to minimize the cost of reduced emission of CO₂ ($USDTN$). She also needs to know the optimal land use to maximize NPV. The agent owns forest that can be converted to cultivate maize, be harvested to produce charcoal or generate REDD+ payment. The GP model is defined as follows:

Goal objective: Min $\alpha=w_1(P_1/NPV_{\text{max}}) + w_2(B_2/USDTN_{\text{min}})$

(1)

subject to

$g_j(x) \leq 0$, $j=1,2,\ldots,n$

$NPV + P_1 - P_2 = NPV_{\text{max}}$

$USDTN + B_1 - B_2 = USDTN_{\text{min}}$

$x_k \geq 0$, $k=1,2,\ldots,n$

$B_1 \geq 0$, $B_2 \geq 0$, $P_1 \geq 0$, $P_2 \geq 0$

where

$\alpha$ is the magnitude of GP objective function sought to be minimized

$w_1$ and $w_2$ are weights or punishments for deviating from the two goals

USDTN is the sequestration cost per ton reduced emission of CO₂ measure in USD/MgCO₂e⁻¹
NPV is the village community’s net present value of land use

g_j(x) is the jth model constraint

x_k is the kth decision variable

B_1 and B_2 are non-negative auxiliary variables representing the amount of under and over achievement of the environmental goal, measured in MgCO2e

P_1 and P_2 are non-negative auxiliary variables corresponding to under and over achievement of the economic goal, measured in USD

The magnitudes of NPV_{max} and USDTN_{min} were obtained by optimization of individual single objective functions. Since no penalty points are incurred for over achievement of environmental goals (USDTN ≤ USDTN_{min}) or long-run income (NPV ≥ NPV_{max}), only B_1 and P_1 need to be included in the objective function. The auxiliary variables have different measurement units. B_1 and B_2 are measured in USD MgCO2e^{-1} and P_1 and P_2 in USD. Therefore, these were divided by USDTN_{min} and NPV_{max} to get unit free values that can be written in the same function.

The village community’s net present value of land use can be calculated by using Eq. 2.

\[
NPV = \sum_{t=0}^{60} [CR_t + SR_t + MA_t - (COST_t^{Deforest} \cdot L_t^{Crop})] \cdot (1 + r)^{-t}
\]

(2)

Where

CR_t is the income from charcoal production measured in USDha\(^{-1}\) can be calculated by using Eq.6

SR_t is the sequestration net revenues measured in USDha\(^{-1}\) (Eq.8)

MA_t is the income generated from maize production, measured in USDha\(^{-1}\) and can be calculated by using Eq.9

\[
COST_t^{Deforest}\]

is the cost of clearing forest for crop cultivation (112 USDha\(^{-1}\)),

r: the agents’ interest rate (5.3% (Hofstad and Araya, 2015))
$L_t^{Crop}$: Cropland area at time t, it is assumed that at the beginning of planning period ($t = 0$) $L_0^{Crop} = 0$

As shown by Eq. 3 to Eq.5, the forest can be converted to crop production.

$$L_t^{Total} = L_t^{Forest} + L_t^{Crop} \tag{3}$$

$L_t^{Forest}$: Forest area at time t, when $t = 0 \Rightarrow L_0^{Forest} = 1$

$$L_{t+1}^{Crop} = L_t^{Crop} + L_t^{Deforest} \tag{4}$$

$L_t^{Deforest}$: Area deforested during time t subject to $\sum_{t=0}^{T} L_t^{Deforest} \leq L_0^{Forest}$

$$L_{t+1}^{Forest} = L_t^{Forest} - L_t^{Deforest} \tag{5}$$

The income from charcoal production can be calculated as follows:

$$CR_t = \varepsilon \cdot P_c \cdot H_t \cdot L_t^{Forest} \tag{6}$$

$\varepsilon$ efficiency parameter, quantity of charcoal output per ton of biomass input (5 bagsMg$^{-1}$)

$P_c$ net price of charcoal (3 USDbag$^{-1}$).

The harvest level ($H_t$) can be obtained from Eq. 7, which is a is a growth model developed by Hofstad and Araya (2015):

$$S_{t+1} = [(1 + a) \cdot S_t - b \cdot S_t^2] - f \cdot S_t - H_t \tag{7}$$

where $a$ and $b$ are the model’s constants, $a = 0.09147$, $b = 0.00047$, while $f = 0.0185$ is the expected rate of biomass loss due to wildfire.
\( S_t \) biomass stock of trees in period \( t \) and the initial biomass was set at 40 Mg ha\(^{-1} \) (Hofstad and Araya, 2015).

\( H_t \) biomass harvested in period \( t \), subject to \( H_t \leq S_t \).

If the villagers decide not to deforest or harvest forest, they receive sequestration net revenues. The equation to calculate \( SR(t) \) is combined with if statement meaning that villagers will not be taxed if the convert the forest to maize cultivation. It is assumed that the villagers are payed annually.

\[
SR_t = (0.5 \cdot 3.67 \cdot P_s \cdot [S_t - B_t] \cdot L_t^{Forest})
\]

(8)

\( P_s \) farm-gate price of sequestered CO\(_2\) (in USD/Mg\(^{-1} \))

\( B_t \) reference line biomass at time \( t \). The quantity of \( B_t \) depends on the contract between the buyer and the seller. We assume \( B_t = 0 \)

The constants 0.5 and 3.67 in Eq.8 are carbon content in wood biomass and the weight of CO\(_2\) relative to carbon.

The income generated from maize production can be calculated by using Eq. 9.

\[
MA_t = x \cdot L_t^{Crop}
\]

(9)

\( x \): is the annual profit of cultivating one hectare of maize (64.5 USD/ha\(^{-1} \))

The sequestration cost per ton reduced emission of CO\(_2\) (USD/tn) can be calculated by using Eq. 10.

\[
USD/tn = \frac{CS}{SS}
\]

(10)

Where SS is quantity of CO\(_2\) equivalents stored in forest biomass over and above the reference level at the end of project measured (t=60) measured in MgCO\(_2\)e and CS is the cost of sequestration measured in USD.
\[ SS = (0.5 \cdot 3.67 \cdot [S_{60} - B_{60}]) \cdot L_T^{Forest} \]

(11)

\( B_{60} \) is the reference level at the end of planning period and assumed to be zero.

\[ CS = \sum_{t=0}^{60} SR_t (1 + rr)^{-t} + \sum_{t=0}^{60} (PI + IM) \cdot L_t^{Forest} (1 + rr)^{-t} \]

(12)

where \( PI \) is inventory cost (0.66 USDha\(^{-1}\) (Katani et al., 2016)), IM is the transaction cost [1.2 USDha\(^{-1}\) (Kessay et al., 2016)] and \( rr \) is the principal interest rate (\( rr = 2\% \)).

The GP model was solved as a non-linear optimization problem using the RMINLP solver of GAMS (Brooke et al. 1998). For sensitivity analysis, an adjusted scenario analysis approach focusing on one parameter at a time was used. It was done by varying the magnitude of the following parameters; the forest density, forest growth, the agent’s interest rate, the principal’s interest rate, price of charcoal, profitability of maize cultivation, transaction and inventory costs. Table 1 presents the list of parameters used in sensitivity analysis.

### 3 Results

Figure 1 illustrates the development of biomass over the planning period. Under BAU, the forest is converted to cropland at the beginning of planning period. While under REDD+ payment with no deforestation and forest degradation (NDF), the forest biomass increases considerably.
Figure 1. Development of forest biomass under BAU (business as usual) and NDF (no deforestation and forest degradation)

Table 1 shows the magnitude of NPV in BAU and sensitivity analysis. The highest NPV was observed when the productivity of maize cultivation and the price of charcoal increased. The lowest magnitudes of NPV is related to B20 and AHIR, while the principal interest rate and the magnitudes of transaction and inventory cost do not influence NPV.
Table 1. The magnitude of NPV under BAU and sensitivity analysis

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Parameters</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAU</td>
<td>Business as usual</td>
<td>2338</td>
</tr>
<tr>
<td>B60</td>
<td>Initial forest biomass increased to 60 Mg ha(^{-1})</td>
<td>2632</td>
</tr>
<tr>
<td>B20</td>
<td>Initial forest biomass decreased to 20 Mg ha(^{-1})</td>
<td>2138</td>
</tr>
<tr>
<td>HFG</td>
<td>Parameter (a) in growth model increased by 100%</td>
<td>2386</td>
</tr>
<tr>
<td>AHIR</td>
<td>Agent’s interest rate increased from 5.3% to 10%</td>
<td>1446</td>
</tr>
<tr>
<td>HTIC</td>
<td>The transaction and inventory cost increased by 100%</td>
<td>2338</td>
</tr>
<tr>
<td>HYM</td>
<td>The productivity of maize increased by 50%</td>
<td>4328</td>
</tr>
<tr>
<td>PHIR</td>
<td>Principal interest rate increased from 2% to 5%</td>
<td>2338</td>
</tr>
<tr>
<td>HPC</td>
<td>Price of charcoal increased from 3 to 10 USD bag(^{-1})</td>
<td>3714</td>
</tr>
</tbody>
</table>

NPV: net present value of land use (10\(^3\)USD)

As shown by Table 1, the price of CO\(_2\) is higher when the forest biomass at the initial stage is 20 Mg ha\(^{-1}\), and lowest when the forest is dense (initial biomass is 60 Mg ha\(^{-1}\)), or when it grows faster. The amount of inventory and transaction costs do not influence the price of CO\(_2\), while the principal has to offer a higher price of CO\(_2\) if the agent’s interest rate, or the price of charcoal or the maize yield is high. Table 2 illustrates how biological and economic factors influence the sequestration cost per Mg reduced emission of CO\(_2\). When forest is degraded (B20: initial forest biomass equals to 20 Mg ha\(^{-1}\)), the sequestration cost is largest. While the sequestration cost is lower than BAU when the forest is dense (B60: the initial biomass is 60 Mg ha\(^{-1}\)) or lowest when it grows fast (HFG). The sequestration cost is higher than BAU when the agent interest rate is 10% (HTIC), is higher than (HTIC) when the price of charcoal increases (HPC), and is the highest when the maize productivity increases (HYM). The cost of sequestration is lower than BAU when the principal interest rate increases to 5% (PHIR).
Table 2. Biological and economic influences on price per ton CO₂ and marginal cost of stopping deforestation and degradation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( P_s )</th>
<th>USDTN</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAU: business as usual</td>
<td>0.82</td>
<td>35.25</td>
</tr>
<tr>
<td>B60: initial forest biomass increased to 60 Mg ha(^{-1})</td>
<td>0.81</td>
<td>34.94</td>
</tr>
<tr>
<td>B20: initial forest biomass decreased to 20 Mg ha(^{-1})</td>
<td>1.14</td>
<td>37.67</td>
</tr>
<tr>
<td>HFG: parameter ( a ) in growth model increased by 100%</td>
<td>0.34</td>
<td>14.68</td>
</tr>
<tr>
<td>AHIR: agent interest rate increased from 5.3% to 10%</td>
<td>1.13</td>
<td>47.88</td>
</tr>
<tr>
<td>HTIC: inventory and transaction cost increased by 100%</td>
<td>0.83</td>
<td>41.98</td>
</tr>
<tr>
<td>HYM: yield of maize increased by 50%</td>
<td>1.56</td>
<td>65.89</td>
</tr>
<tr>
<td>HPC: price of charcoal has increased from 3 to 10 USD bag(^{-1})</td>
<td>1.25</td>
<td>52.91</td>
</tr>
<tr>
<td>PHIR: principal interest rate increased from 2% to 5%</td>
<td>0.83</td>
<td>16.51</td>
</tr>
</tbody>
</table>

\( P_s \): farm-gate price of sequestered CO₂ (USDMg\(^{-1}\))

USDTN: the sequestration cost per Mg reduced emission of CO₂ (USD)

4. Discussions and conclusion

The price per sequestered ton CO₂ that makes forest equally profitable to local farmers as traditional cropping systems commonly found in areas of Miombo woodland in Tanzania was below 1 USD if payment was made every year for as long as the woodland is kept intact.

Two factors contribute to more costly REDD contracts – 1) higher agricultural rent, here exemplified by higher maize yield, and 2) higher price of charcoal. The latter is explained by the fact that much charcoal is produced during deforestation. Both factors make deforestation more profitable to the agent – and REDD+ more expensive to the principal. In our simulations, we have chosen variable values that are well within the variation observed in much of the Miombo areas in Tanzania. In other words, we have estimated the marginal cost of REDD under average
Miombo conditions. However, deforestation tends to take place in marginal areas (Angelsen et al., 1999). Marginal areas are defined by low agricultural rent and often by low prices of charcoal. Low agricultural rent may be due to poor biological productivity, e.g., low maize yield, or because costly transport (long distance to market and/or poor rural roads) leads to low farm gate prices of crops. Expensive transport is also the main explanation of low charcoal price at kiln (Hofstad and Sankhayan, 1999). Therefore, if the principal is able to concentrate her efforts in marginal agricultural parts of the country where deforestation is rampant, the cost of REDD may be lower than the estimates presented here.

As observed earlier (Araya and Hofstad, 2016) the state of the woodland itself influenced the cost of REDD+. Preserving a degraded woodland of only 20 Mg ha\(^{-1}\) aboveground biomass was more expensive than the preservation of a woodland of high biomass density. However, we would have expected a more pronounced difference. Part of the explanation for the relatively small difference is that the CO\(_2\) price paid to the agent was 1.14 USD MgCO\(_2\)e\(^{-1}\) in the degraded case, and only 0.81 USD in case of the dense woodland. A more significant reduction in the cost of REDD was observed when we introduced faster growth rates in forest biomass. Miombo woodlands grow rather slowly due to nutrient-poor soils and limited availability of water (Frost, 1996). If the principal could choose a forest type with higher biological growth potential, she would find that the cost of REDD would be lower.

The economic feasibility of REDD+ depends on several factors, including the forest type (Olsen and Bishop, 2009; Venter et al., 2009; Araya and Hofstad, 2016; Pandit et al., 2017; Rakatama et al., 2017) and alternative land uses (Coomes et al., 2008; Olsen and Bishop, 2009; Wulan, 2012; Phan et al., 2014; Rakatama et al., 2017). The opportunity costs have been estimated to be low for moist tropical forests with high carbon densities (Osborne and Kiker, 2005; Bellassen and Gitz, 2008; Olsen and Bishop, 2009; Yamamoto and Takeuchi, 2012), and high for dry tropical forests (Merger et al., 2012; Borrego and Skutsch, 2014). The more profitable and more productive the alternative land use is, the more expensive the payment will be (Rakatama et al., 2017). Lin et al. (2014) have shown that much of Tanzania falls into the category of low or medium suitability for the implementation of REDD+ if the more suitable target is defined as areas
with high forest carbon contents, high deforestation risks, and low opportunity costs. If the sole objective of REDD+ agent is to reduce the largest amounts of emissions of CO₂ at the least cost, our results seem to indicate that it would not be rational to invest in Miombo woodlands, especially degraded Miombo woodlands. Ideally, the buyer would look for forest types with a higher biomass density and higher growth rates.

References:


Cordero Salas, P. 2013. Designing contracts for reducing emissions from deforestation and forest degradation (English). Policy Research


48. Management practices of selected exclosures in the Tigray, Ethiopia

Dawit Gebregziabher 1,2 Arezoo Soltani1,3 & Ole Hofstad1

1 Department of Ecology and Natural Resource Management, Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences, P.O. Box 5003, NO-1433, Ås, Norway.

2 Department of Agricultural and Resources Economics, College of Dryland Agriculture and Natural Resources, Mekelle University, P.O. Box 231, Mekelle, Ethiopia.

3 Faculty of Social Sciences, Western Norway University of Applied Sciences (HVL), P.O. Box 7030, 5020, Bergen, Norway.

Abstract: A comparative study of three exclosures, a system for management and rehabilitation of severely degraded common pool resources was conducted in Tigray region of Ethiopia. Tensuka, Abel Dega and Adi Gedaw exclosures were selected and group discussions using participatory rural appraisal were used for data collection. Significant differences were observed among the three exclosures in respect of the type of land assigned as exclosures and the way the outputs from each exclosures were distributed. The results indicated that from a social and institutional point of view, exclosures are managed and governed in significantly different ways that it is difficult to use the same term for all of them.

Keywords: Common pool resources, cut and carry, exclosure, Tigray.

1. Introduction

The Tigray Region of Northern Ethiopia is characterized by land degradation (Mekuria et al., 2007; Yayneshet et al., 2009), and exploitation beyond the carrying capacity of nature that threatens both ecosystem functions and economic production. In the 1970s, a number of soil and water conservation measures and efforts were started in order to rehabilitate degraded land in Tigray (Mekuria, 2013). However, the authorities realized
that it is less costly to address land degradation in Tigray by closing off the most badly degraded areas from agriculture and grazing, to form exclosures (Aerts et al., 2009). The primary purpose of the establishment of exclosures in Tigray was to enhance environmental regeneration in degraded areas (Gebremedhin et al., 2003; Balana, 2007), rather than to generate any economic gains. It is well documented that the establishment of exclosures in Tigray has been effective in enhancing ecosystem functions (e.g., Descheemaeker et al., 2006; Yayneshet et al., 2009; Tefera et al., 2005; Nyssen et al., 2009; Yami et al., 2006) and increasing the growth of grass and trees (Descheemaeker et al., 2006).

Although exclosures are described as areas that have been closed off to protect against interference from people and livestock, their history of establishment and social arrangement governing access are significantly different. However, only a few and limited research investigations were conducted to study the social and institutional aspect of exclosures (Yami et al., 2006; Yami et al., 2013; Yami et al., 2009). This study represents an effort in this direction by undertaking a few case studies illustrating various paths of establishment and management of exclosures. The study, therefore, aims at addressing the following main questions: (1) which type of land was demarcated as exclosures? (2) How are outputs from exclosures distributed? (3) What are the negative consequences of establishment of exclosures in the study sites?

2. Method

2.1. Description of study sites

For the purpose of this study, we selected three exclosures in Tigray region, namely Tensuka, Abel Dega and Adi Gedaw (Figure 1) that are adjacent to Koraro, Hayelom and Debre Genet villages, respectively. Croplands, grazing lands, exclosures and settlement are the four main land use types in these villages with mixed crop-livestock system as the main economic activity (Araya, 2014; Bekele et al., 2012). Table 1 presents some basic information about the selected exclosures.
Legend

- Atsbi district
- Hawzen district
- Naeder Adet district
- Location of villages in each district
Table 1. Salient features of the selected exclosures

<table>
<thead>
<tr>
<th></th>
<th>Tensuka</th>
<th>Abel Dega</th>
<th>Adi Gedaw</th>
</tr>
</thead>
<tbody>
<tr>
<td>District</td>
<td>Hawzen</td>
<td>Atsbi</td>
<td>Naeder Adet</td>
</tr>
<tr>
<td>Year of establishment</td>
<td>2005</td>
<td>1994</td>
<td>1999</td>
</tr>
<tr>
<td>Distance to Mekelle from the village (Km)</td>
<td>134</td>
<td>55</td>
<td>329</td>
</tr>
<tr>
<td>Adjacent village</td>
<td>Koraro</td>
<td>Hayelom</td>
<td>Debre Genet</td>
</tr>
<tr>
<td>Human population with access rights in 2014</td>
<td>1767</td>
<td>585</td>
<td>1210</td>
</tr>
<tr>
<td>Area of the exclosures (ha)</td>
<td>168</td>
<td>80</td>
<td>234</td>
</tr>
</tbody>
</table>

2.2. Data collection and analysis

Participatory rural appraisal (PRA, Chambers (1994)) was used to collect data. The information was gathered through group discussions. Two group discussions were conducted in each village. Key informants, individuals having first-hand information about exclosures, and guards of exclosures were invited to participate in the group discussions. The participation was voluntary. The development agents of the village office of the Bureau of Agriculture and Rural Development (BoARD) assisted the communication with the key informants. At the beginning of each group discussion, the first author explained the purpose of the study to participants and clarified that the information would be confidential. A list of relevant questions was made prior to the group discussions. The questions addressed specifically (i) which lands were chosen to be demarcated as exclosures, (ii) how outputs from exclosures were distributed, (iv) what are the negative consequences of establishment of exclosures. In order to capture much of the information, a standard voice recorder was used during the group discussions after the participants gave their consent. The recorded data was transcribed into written format and later on was presented to and discussed with researchers.
from Mekelle University and experts of BoARD. Finally, the written format was used to address the research questions of the study.

3. Results

The type of lands demarcated as exclosures: In Koraro village, the area assigned as Tensuka exclosure used to be a severely degraded grazing land with deep gullies, which were created by flood. Croplands near this grazing land suffered from wind damages and livestock grazing. It was mentioned during the group discussions that wind erosion was a severe problem in Hawzen district such that fertile soils were eroded. The Koraro village community perceived less crop damages after Tensuka exclosure was established. Similarly, Abel Dega exclosure was established on a severely degraded grazing land with almost no vegetation. However, croplands located on a steep hillside were demarcated as Adi Gedaw exclosure.

Distribution of outputs from exclosures: Grass was the main output from the exclosures. It was harvested through cut and carry system. The harvest of grass in exclosures was allowed mainly in September as announced by the development agents of BoARD. The distribution of grass from exclosures varied across exclosures. According to information received from the group discussions, villagers in Hayelom and Debre Genet divided the area of exclosures into several plots. The access right to harvest grass in each plot was given to a group of ten villagers. The area of each plot was further divided among the members of the group, and each member harvested grass only from the part given to him/her. The plots were approximately equal in size but not necessarily equal in producing grass. To solve the issue of inequality in grass production, the plot distribution was made each year such that groups did not receive the same plots every year. The participants of group discussions highlighted that dividing the exclosure among small groups has reduced the incident of free riders and thus has led to an efficient management. In contrast, villagers living near Tensuka exclosure harvested grass commonly without dividing the area of the exclosure among themselves. Furthermore, members of Koraro village community holding access right could collect grass in Tensuka exclosure without any restriction as far as they used their own and not hired labor. Local community in Koraro village was permitted to collect wild
Ziziphus fruits from the exclosure. This fruit is edible and could be sold in the district market at a price of 3.60 Ethiopian Birr /kg (1USD = 20 Ethiopian Birr, October 2015). There was no restriction on the quantity of fruits that each family could collect.

**Negative consequences of establishment of exclosures in study sites:**
Participants in the group discussions mentioned that the cut and carry fodder system was more labour demanding than livestock husbandry based on grazing system. Therefore, they were sceptical about the expansion of existing exclosures. While participants of group discussions in Debre Genet village mentioned a serious conflict regarding having access rights to Adi Gedaw exclosure since 2011. Some reported that only those whom their former croplands had been demarcated as Adi Gedaw exclosure had access right to harvest grass within the exclosure. While others did not confirm the existence of such agreement. The issue was specifically raised during the second group discussion in Debre Genet village. The participants mentioned that during the time of establishment of Adi Gedaw exclosure, there was no land valuation procedure that could have been used as a base for compensation. The owners of the croplands had received substitute lands within the village boundary, but they claimed that the lands were smaller and less fertile than their former lands. Therefore, they abandoned the given lands; instead, they demanded to be the only ones having access right to harvest grass in Adi Gedaw exclosure. They have forwarded their claims to the village and district administration offices. However, the other segment of the village believed that the access right to harvest grass belonged to all inhabitants of Debre Genet village, who reside adjacent to the exclosure. The group discussion concluded that the conflict has influenced the management of the exclosure negatively and should be resolved.

Local communities in the studied villages in general and those living adjacent to Tensuka exclosure in particular had experienced shortage of firewood. They mentioned during the group discussions that they had to travel long distances to find firewood, and pointed out the establishment of exclosure, increased human population and degradation of natural resources as the main reasons for such a shortage. Villagers had different strategies to cope with the shortage of firewood. For example in Debre Genet village, if someone needed firewood for a ceremony such as wedding or other religious gatherings, he/she could request to purchase firewood if there was
any deadwoods available in Adi Gedaw exclosure. A committee nominated by the villagers decided upon such an application and if accepted, the applicant could collect only specific amount of deadwoods within the exclosure. Money obtained from the sale of deadwood would be used for common purposes in the village.

Respondents also mentioned the conflict between the guards and villagers during the group discussions especially in Koraro village. The conflict arose because the guards also lived in the same village, and when they reported an illegal activity, it caused a discomfort or ostracism by the reported neighbor or the friend. The ‘respected old men’ usually resolved such conflicts. Participants of the group discussions in Hayelom village mentioned that the location of Abel Dega exclosure has troubled some of the villagers. The exclosure was located very close to the settlement and it was difficult for villagers to keep livestock from entering the exclosure. Therefore, those living near the exclosure have been charged when their animals were found grazing in the exclosure.

4. Discussion

Three exclosures in Tigray Region were studied based on the information gathered through PRA. The results indicated that there are significant differences among the studied exclosures based on the land demarcated as exclosures and the way outputs were distributed. Our results illustrated that the establishment of exclosure on cultivated lands had led to serious conflict among local communities living adjacent to the exclosure. While establishment of exclosures on communal grazing lands had less negative consequences. Such information might be useful when designing new exclosures. As defined by Aerts et al. (2009), the term exclosures refers to areas that have been closed off to protect against interference from people and livestock. From the biological point of view, this makes a perfect sense. From the social and institutional point of view, however, it was difficult to use the same term for all the exclosures in Tigray as they have been governed and managed in significantly different ways.
References


Araya, K. 2014. GIS and RS Based Assessment of Area Exclosure and Vegetation Cover Change in KoraroTabia, HawzenWoreda. Mekelle University.


Northern Ethiopia re-photographed after 140 years. Sci. Total. Environ. 407(8), 2749-2755.
Abstracts
49. Charcoal Production, Trade and Consumption in Tanzania: Analytical Review of Previous Studies

Greyson Zabron Nyamoga¹&² and Birger Solberg²

¹Sokoine University of Agriculture – SUA
College of Forestry, Wildlife and Tourism, Department of Forest and Environmental Economics
P.o Box 3011, Morogoro, Tanzania

²Norwegian University of Life Sciences, Faculty of Environmental Science and Nature Management (MINA), Department of Ecology and Natural Resources Management (INA), P.o Box 5003, Ås, Norway

Corresponding Author: gnyamoga@suanet.ac.tz or greyson.nyamoga@nmbu.no

Abstract: Production and consumption of forest products like charcoal play a significant role in enhancing the livelihoods of people but it may also lead to adverse environmental impacts. Different theories can be used to explain the high rate of charcoal consumption in Tanzania. Many studies exist on the supply of charcoal but most does not specify the theories explaining this high range of charcoal consumption. It is therefore important to review some theories relating the high consumption of charcoal in Tanzania and hence apply these theories together with the findings to develop appropriate policies which may help to reverse such adverse conditions in the country. In this paper, we review some literature on charcoal consumption and theories behind those studies. Based on the reviewed literature, it is evident that there is high demand and consumption of charcoal in Tanzania but few empirical studies have explained and linked the theories supporting these evidences. The high consumption of charcoal is influenced by increased urban population, emerging middle-income group, per-capita income, price and household size. However, studies to assess the effects of charcoal production and consumption to climate change, substitution rates and linkage to energy ladder theory in Tanzania are inevitable. Theories need to be researched, developed and linked to the high consumption of charcoal in order to develop mechanisms for eliminating the problem which is again linked to deforestation in Tanzania.
Key words: Charcoal consumption; Deforestation; Efficiency; Behaviour theory, Energy ladder, Per-capita income; Household size; Marketing systems; Urbanization; Ecosystems
50. Spatial and seasonal patterns in incomes from environmental products extracted in community-managed forests in Nepal

Henrik Meilby¹, Santosh Rayamajhi² and Gokul Gaudel²

¹ University of Copenhagen / Department of Food and Resource Economics

heme@ifro.ku.dk / Rolighedsvej 23, 1958 Frederiksberg C, Denmark

² Institute of Forestry, Pokhara Campus, P.O Box: 43, Hariyokharka, Pokhara, Nepal

Abstract: For many rural households in developing countries, environmental products collected from forests and other uncultivated areas are important sources of cash and subsistence income and a partial basis for their livelihoods. Over the last decade a number of studies, small and large, have examined the role of environmental incomes in different rural environments. However, information about harvesting patterns, distribution of incomes to different products and the sustainability of extraction is usually limited. Therefore, as a basis for estimating the quantity collected and income from different products and their spatial and seasonal distributions we conducted a one-year survey around four villages with access to community-managed forests in the lowlands, the middle hills and the high mountains of Nepal. Repeated household surveys had previously been carried out (2005-2012) and good local estimates of prices and total amounts collected were therefore already available for a wide range of products. Through group discussions, we identified main entry and exit points around each of the community managed forests. Subsequently we carried out measurements of products and interviews with collectors passing through the exit points over the course of a year (four cycles, 2012-2013). In each case, we asked the collector to identify the place of extraction among a set of previously mapped geographical units identified through a participatory mapping exercise. In this paper we provide an analysis of the collection and income patterns observed, including the type of products collected, the spatial, seasonal and demographic distribution of the collection activity, the effort involved in collection, the associated return to labour, and the degree to which collection was done, either as an independent activity, or jointly with other activities.
Keywords: community forestry, non-timber forest products, sustainability, livelihoods, exit point survey
51. A typology of environmental product periodic markets in the Himalayas

Sumitra Paudel and Carsten Smith-Hall

Abstract: There is limited information on periodic markets for environmental products. This paper uses the case of medicinal and aromatic plant periodic markets in Nepal to develop a typology of periodic markets for environmental products. Data were collected on the structure and function of 55 periodic markets in Morang District in Southern Nepal through medicinal plant retailer interviews, direct observations of market characteristics, and recording of daily transactions in individual medicinal plant stalls. The study identified three types of markets and two types of medicinal plant retailers which were further divided into four sub-types and eight specific types. Each market type is characterized according to nine factors: location, accessibility, physical layout, size, varieties of products traded, market control, market infrastructure, retailers, and movement range of retailers. The periodic market typology is applicable to the rest of the Nepal. Periodic market trade included 58 medicinal plant species with an annual trade estimated at 30 tonnes, equivalent to 10% of the total district medicinal plant trade. The annual value of USD PPP 0.48 million was 1.26 times higher than the district level harvester value and equivalent to 84% of the district level wholesale medicinal plant trade value. Retail trade of medicinal plants is hence of substantial economic importance and should not be ignored in trade studies. Traditional spiritual belief is a key driver behind medicinal plants trade and the demand is likely to remain buoyant in the future. The study highlights the need to recognise the role of local markets and the domestic medicinal plant trade to the local and national economy and to focus future governmental interventions on making appropriate market development and medicinal plant trade policies.

Key words: medicinal plants; retail trade; market types; economic importance; Nepal
Poem

The scope of forest economics

Remembering how well things were
within the recent past,
we come to Hamlet’s Helsingør
to find the truths that last.

We young economists have risen to
the challenges we see:
now forest economics isn’t
quite the work it used to be –
just maximising NPV.

This is not to decry our teachers,
those who made our pathways straight
through cash flow practicals, with each assigned a different discount rate,
(so classes could interpolate
the IRRs, both small and great).

But nowadays we seek the means
to bring in social issues,
with politicians, geeks and greens,
as well as toilet tissues.
The problems we must treat will range
from world-wide cash flow crisis
to microfactors that may change
all reservation prices.

The tradition

And yet, we still respect the past
and build on what our forebears did.

So, when we later raise a glass
to them, we set our work amid
the works they made, and keep the embers
of the fires they lit alive.

Those now-departed former members,
still we celebrate, and strive
to harvest benefits that stem
from willingness to learn
their insights, so become, like them,
respected in our turn.
Old problems

The questions that those old guys raised on optimal rotations still occupy our thoughts – rephrased with many complications.

The future that we face displays disturbing variations; and rationality is fazed by untrue revelations.

Of course, some cash flows will occur. But other aims may oust man-managed forests as they were conceived to be by Faustmann.

Policy

First, plenaries distilled in essence trade-offs in our daily task. Should we highlight useful lessons, or time-frames politicians ask? So, is “today or, if not, sooner” part of present thinking’s quirks?

Can shift of paradigm fine-tune a policy that almost works?
Where forest regulation once

was just a forest matter,

does polycentric governance

mean foresters lose influence –

and bureaucrats grow fatter?

The field trip

Next, the field excursion day

to Jaegersborg Dyrehave,

where wildlife themes did not outweigh

political palaver.

Should deer have come within the fence,

and peasants been evicted,

with homes forgone, and large expense,

and common rights restricted?
Then, cutting through the wildlife hype,
why should we save stag beetles that
are not of Danish genotype,
and lack sufficient habitat?
Should income be no more received,
because of efforts to restore
the state that beetles had achieved,
unaided, many years before,
when humans wielded axe and saw?

Most questions take a rear seat
for our return, but memories prompt
*this* question: is our trip complete
without a visit to a swamp?
there to meet its fierce mosquit-
o-dominated fauna.
Sprayed with bug-repellent DEET
we soon, with itching skin, retreat
to soothing shower or sauna.

Then, still ongoing, parallel
and oft-conflicting sessions
– I couldn’t go to all, and tell
my overall impressions:
except, these also are a trip
in which we navigate
the swamps of sweated scholarship
and bottomless debate.

**Ecosystems**
But not to know, is no excuse
in wildlife calculations.
In models, should we try out loose
and first approximations?
Should we value passive use
in framing regulations?
or take the viewpoint of a *moose*
on balanced populations?

**Bioproducts**
The bioproduct groups compiled
debates, of which the crux is:
how to increase markets, while
decreasing carbon fluxes?
Should the pine and spruce and birch
be utilised the same?

or should we launch, through deep research,

the value-added game?

**International**

And, knowing forests are for all,

should we be glad to see a
growth of markets in Nepal?

but conversely should fear
the forest loss in Tanzania
when charcoal use increases,
miombo degrades every year
(with CO$_2$ releases).

**Concluding comments**

We must move on, or else incur
dramatic wrath of certain
ghosts in Hamlet’s Helsingør,
behind tradition’s curtain:
to be or not to be a boon
to those who read our papers?
to be or not to be in tune
with policy re-shapers?
to be or not to be a force

to change how people think,

of wildlife, beauty, and of course

the forest carbon sink?

What? and how? those are the questions

offered here in rhyme.

But any further good suggestions –

please, bring in two years’ time.
## List of participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Surname</th>
<th>organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexander</td>
<td>Moiseyev</td>
<td>Norwegian University of Life Sciences</td>
</tr>
<tr>
<td>Altamash</td>
<td>Bashir</td>
<td>Inland norway University of Applied Sciences</td>
</tr>
<tr>
<td>Anna</td>
<td>Thorning</td>
<td>Mittuniversitetet /Mid Sweden University</td>
</tr>
<tr>
<td>Anne</td>
<td>Toppinen</td>
<td>University of Helsinki</td>
</tr>
<tr>
<td>Anni</td>
<td>Tuppura</td>
<td>Lappeenranta University of Technology</td>
</tr>
<tr>
<td>Annika</td>
<td>Hyytiä</td>
<td>University of Helsinki</td>
</tr>
<tr>
<td>Arezoo</td>
<td>Soltani</td>
<td>Faculty of Social Sciences, Western Norway University of Applied Sciences</td>
</tr>
<tr>
<td>Birger</td>
<td>Solberg</td>
<td>NMBU</td>
</tr>
<tr>
<td>Bo Jellesmark</td>
<td>Thorsten</td>
<td>University of Copenhagen</td>
</tr>
<tr>
<td>Brent</td>
<td>Matthies</td>
<td>University of Helsinki</td>
</tr>
<tr>
<td>Brent</td>
<td>Matthies</td>
<td>University of Helsinki</td>
</tr>
<tr>
<td>Brian</td>
<td>Danley</td>
<td>Swedish University of Agricultural Sciences</td>
</tr>
<tr>
<td>Carola</td>
<td>Paul</td>
<td>University of Göttingen</td>
</tr>
<tr>
<td>Carsten</td>
<td>Rahbek</td>
<td>University of Copenhagen</td>
</tr>
<tr>
<td>Carsten</td>
<td>Smith-Hall</td>
<td>University of Copenhagen</td>
</tr>
<tr>
<td>Cecilia</td>
<td>Mark-Herbert</td>
<td>SLU, Swedish University of Agricultural Sciences</td>
</tr>
<tr>
<td>Charlotta</td>
<td>Kankaanpää</td>
<td>University of Vaasa</td>
</tr>
<tr>
<td>Name</td>
<td>Surname</td>
<td>Institution</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Charlotte</td>
<td>Jacobsen</td>
<td>University of Copenhagen</td>
</tr>
<tr>
<td>Colin</td>
<td>Price</td>
<td>Colin Price Free-lance Academic Services</td>
</tr>
<tr>
<td>Dawit</td>
<td>Mekonen</td>
<td>Norwegian University of Life Sciences (NMBU)</td>
</tr>
<tr>
<td>Dianne</td>
<td>Staal Wästerlund</td>
<td>SLU</td>
</tr>
<tr>
<td>Dick</td>
<td>Brazee</td>
<td>University of Illinois at Urbana-Champaign</td>
</tr>
<tr>
<td>Eirik Schröder</td>
<td>Amundsen</td>
<td>University of Bergen</td>
</tr>
<tr>
<td>Elias</td>
<td>Hurmekoski</td>
<td>European Forest Institute</td>
</tr>
<tr>
<td>Florencia</td>
<td>Franzini</td>
<td>University of Helsinki</td>
</tr>
<tr>
<td>Frank</td>
<td>Jensen</td>
<td>University of Copenhagen</td>
</tr>
<tr>
<td>Gregory</td>
<td>Latta</td>
<td>University of Idaho</td>
</tr>
<tr>
<td>Greyson</td>
<td>Nyamoga</td>
<td>Norwegian University of Life Sciences</td>
</tr>
<tr>
<td>Hans Fredrik</td>
<td>Hoen</td>
<td>NMBU</td>
</tr>
<tr>
<td>Heikki</td>
<td>Pajuoa</td>
<td>Metsäteho Oy</td>
</tr>
<tr>
<td>Henrik</td>
<td>Meilby</td>
<td>University of Copenhagen</td>
</tr>
<tr>
<td>Janni</td>
<td>Kunttu</td>
<td>European Forest Institute</td>
</tr>
<tr>
<td>Jenni</td>
<td>Miettinen</td>
<td>University of Helsinki</td>
</tr>
<tr>
<td>Jette Bredahl</td>
<td>Jacobsen</td>
<td>University of Copenhagen</td>
</tr>
<tr>
<td>Johannes</td>
<td>Wildberg</td>
<td>Georg-August-Universität Göttingen, Abteilung Forstökonomie und Forsteinrichtung</td>
</tr>
<tr>
<td>Name</td>
<td>First Name</td>
<td>Affiliation</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Jussi</td>
<td>Lintunen</td>
<td>Natural Resources Institute Finland (Luke)</td>
</tr>
<tr>
<td>Jyri</td>
<td>Hietala</td>
<td>Helsinki University</td>
</tr>
<tr>
<td>Jaana</td>
<td>Korhonen</td>
<td>University of Helsinki</td>
</tr>
<tr>
<td>Kaja</td>
<td>Heltorp</td>
<td>Norges miljø- og biovitenskapelige universitet</td>
</tr>
<tr>
<td>Katja</td>
<td>Lähtinen</td>
<td>University of Vaasa</td>
</tr>
<tr>
<td>Laura</td>
<td>Bouriaud</td>
<td>University Stefan cel Mare Suceava</td>
</tr>
<tr>
<td>Matleena</td>
<td>Knivilä</td>
<td>Natural Resources Institute Finland</td>
</tr>
<tr>
<td>Maurizio</td>
<td>Sajeva</td>
<td>Pellervo Economic Research</td>
</tr>
<tr>
<td>Meelis</td>
<td>Teder</td>
<td>Estonian University of Life Sciences</td>
</tr>
<tr>
<td>Niels</td>
<td>Strange</td>
<td>University of Copenhagen</td>
</tr>
<tr>
<td>Noora</td>
<td>Miilumäki</td>
<td>University of Helsinki</td>
</tr>
<tr>
<td>Ola</td>
<td>Eriksson</td>
<td>SLU</td>
</tr>
<tr>
<td>Ole</td>
<td>Hofstad</td>
<td>NMBU</td>
</tr>
<tr>
<td>Olli</td>
<td>Saastamoinen</td>
<td>University of Eastern Finland</td>
</tr>
<tr>
<td>Peichen</td>
<td>Gong</td>
<td>Swedish University of Agricultural Sciences</td>
</tr>
<tr>
<td>Päivi</td>
<td>Pelli</td>
<td>University of Eastern Finland</td>
</tr>
<tr>
<td>Pär</td>
<td>Wilhelmsson</td>
<td>Swedish University of Agricultural Sciences</td>
</tr>
<tr>
<td>Rafal</td>
<td>Chudy</td>
<td>Norwegian University of Life Sciences</td>
</tr>
<tr>
<td>Sarah</td>
<td>Ebadzadeh Semnani</td>
<td>Linköping University</td>
</tr>
<tr>
<td>Name</td>
<td>University</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td>Sari</td>
<td>Pynnönen, University of Helsinki</td>
<td></td>
</tr>
<tr>
<td>Sjur</td>
<td>Baardsen, Norwegian University of Life Sciences</td>
<td></td>
</tr>
<tr>
<td>Stefan</td>
<td>Friedrich, Technical University of Munich - Institute of Forest Management</td>
<td></td>
</tr>
<tr>
<td>Sven</td>
<td>Wunder, Center for International Forestry Research, CIFOR</td>
<td></td>
</tr>
<tr>
<td>Teppo</td>
<td>Hujala, University of Eastern Finland</td>
<td></td>
</tr>
<tr>
<td>Tomas</td>
<td>Nord, Linkoping University</td>
<td></td>
</tr>
</tbody>
</table>