Sustainable forest management and bioenergy expansion

- A multi-scale approach from global to local -

（持続可能な森林管理とバイオマスエネルギーの拡大

－全球から地域までの多規模アプローチ－）

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LIST OF ACRONYMS AND ABBREVIATIONS

AD	Avoiding deforestation
AR5	Assessment Report 5
ASMGHG	US Agricultural Sector and Mitigation of Greenhouse Gas (model)
ATFS	American Tree Farm System
BAU	Business as usual (scenario)
B/C	Benefit/cost ratio
BECCS	Bioenergy with Carbon Capture and Storage
BioCCS	Bioenergy with Carbon Capture and Storage
CCS	Carbon capture and storage
CFP	Certified forest product
CGER	Center for Global Environmental Research
CH_4	Methane
CHP	Coupled Heat and Power
CIS	Commonwealth of independent states
CO_2	Carbon dioxide
CoC	Chain of custody
CS	Carbon storage
CSA	Canadian Standards Association
DH	District heating
DIMA	Dynamic Integrated Model of Forestry and Alternative Land Use / former name of G4M
EEE	European Center for Renewable Energy
EJ	Exajoule
EOR	Enhanced oil recovery
EPIC	Environmental Policy Integrated Climate (model)
ESM	Ecosystems Services and Management Program
EU	European Union
EU27	European Union of 27 countries
FAME	Fatty acid methyl ester / biodiesel
FAO	United Nations Food and Agriculture Organization
FC	Forest certification
FMC	Forest Management Certification
FSC	Forest Steward Council
G4M	Global Forest Model
GCP	Global Carbon Project
GDP	Gross domestic product
GHG	Greenhouse gas
GLOBIOM	Global Biosphere Management Model
Gt	Gigaton
GTAP	Global Trade Analysis Project (model)
GW	Gigawatt
ha	hectare
IAM	Integrated Assessment Model
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
iLUC	Indirect land use change
IMAGE	Integrated Model to Assess the Global Environment
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change

IUCN	International Union for Nature Conservation
JRC	European Commission Joint Research Center
km	kilometer
kW	Kilowatt
m	meter
m^3	cubic meter
MESSAGE	Model for Energy Supply Strategy Alternatives and their General Environmental Impact
MTCS	Malaysian Timber Certification System
MW	Megawatt
MWth	Megawatt thermal
N_2O	Nitrous oxide
NGO	Non-government organization
NIES	National Institute for Environmental Studies
NPP	Net primary productivity
PEFC	Programme for the Endorsement of Forest Certification
PJ	Petajoule
PM10/PM2.5	Particulate matter 10/2.5 micrometers or less in diameter
POLES	Prospective Outlook for the Long-term Energy System
ppm	Parts per million
PRIMES	General purpose model for energy supply and demand
PSI	Policy and Science Interface Research Group
RED	Reducing emissions from deforestation
REDD	Reduced emissions from deforestation and degradation
REDD+	Reducing Emissions from Deforestation and Forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries
RUE	Radiation use efficiency
SCI	Science citation index
SCP	Sawmill co-products
SDG	Sustainable development goal
SE4All	Sustainable energy for all
SFI	Sustainable Forestry Initiative
SFM	Sustainable forest management
SPSS	Statistical Package for the Social Sciences
SRES A2r	Revised IPCC scenario (IIASA)
tdm	Tons dry matter
UNECE	United Nations Economic Commission for Europe
UNEP-WCMC	United Nations Environment Program – World Conservation Monitoring Center
UNFCCC	United Nations Framework Convention on Climate Change
USD	US Dollar
USGS	US Geological Survey
WG	Working group
WREC	World Renewable Energy Conference
WTP	Willingness to pay
WWF	Worldwide Fund for Nature
ZNDD	Zero net Deforestation and forest degradation
€	Euro
¥	Japanese Yen
χ^2	chi square (test)
/year	per year
y^{-1}	per year
°C	Degree centigrade
°	Degree geographical resolution

ABSTRACT

Integrated assessment modeling scenarios in which global warming is limited to 2°C above pre-industrial level by the end of this century expect bioenergy to contribute between 15-245 Exajoules per year to the global energy portfolio by 2050 excluding traditional bioenergy. Such scenarios often include large-scale deployment of bioenergy combined with carbon capture and storage (BECCS) as a possibility to remove carbon from the atmosphere. Substantial impact on direct and indirect land use change is to be expected. This thesis examines biomass feedstock potentials and assess bioenergy expansion at global, regional and local scales. For the global level it is argued that only the integration of multi-level assessments using top-down and bottom up approaches will help identifying realistic bioenergy potentials at high geographic resolutions. While the demand for bioenergy from Integrated Assessment Models can serve as a target, the combination of biophysical and economic land use models can help breaking this down into realizable and sustainable potentials on the ground. This thesis goes all the way from global bioenergy feedstock assessment under different protection and conservation scenarios to a conservative and environmentally sound assessment of bioenergy potentials on regional levels. The regional analyis concentrates on Korea and Japan. Finally, at the local level, the public opinion of rural town citizens in Japan with respect to sustainable forest management, forest certification and forest-based bioenergy are investigated. The motivation behind this is to examine to which extent success strategies from Austria can be replicated in Japan, which is similar to Austria in terms of forest and geographical situation. At the global level, this thesis finds that 160 million hectares of forest might be lost by 2050 for increased energy production if no sustainability safeguards like REDD policies will be applied. For the local level, the thesis states that there is a large bioenergy potential for Korea and Japan, even though the BECCS potentials seem to be limited under the presented methodologies. For the local level, the thesis concludes that sustainable forest management can also be an entry point for a bioenergy-driven rural revitalization strategy. Forest owners in rural Japanese towns show good knowledge on forest certification. Sustainable forest management based on forest certification ensures that economic and environmental goals can be achieved in unison. Especially, investment in forest infrastructure is among the main elements to ensure competitive harvesting costs in mountainous areas of Japan. It is concluded that different bottom-up measures including capacity building and awareness raising need to be developed.

1 INTRODUCTION

I Background and Motivation for a Multi-level Approach

Biomass from forestry

During the last decade, biomass-based energy systems have become ever more important in the climate change mitigation pathways of the Intergovernmental Panel on Climate Change (see inter-alia IPCC 2007; IPCC 2014). Large amounts of additional biomass for bioenergy will have to be sourced globally in order to achieve ambitious climate change mitigation targets (2ºC and now even 1.5ºC), as defined by the objectives of the United Nations Framework Convention on Climate Change (UNFCCC 2014). In particular, staying within the 2°C (or even 1.5°C) limit at high levels of probability will require strong mitigation action across all sectors, with greater effort needed the further mitigation is delayed. Future warming will depend strongly on the cumulative CO_2 emissions released through to the end of this century (Allen et al. 2009, IPCC 2013). A finite quota of CO_2 emissions, no more than 900 Gt CO_2, is needed from 2016 onwards in order to stabilize climate below a global average of 2°C above pre-industrial conditions by 2100 with a likelihood of 66% (Jackson et al. 2015). This corresponds to less than 30 years at current emissions levels (Friedlingstein et al. 2014). However, during the past decade, emissions from fossil fuel combustion and cement production have increased substantially, reaching 36.1 ± 1.8 Gt CO_2/year in 2013 (Boden et al. 2013), 61% above their 1990 level – though no increase was estimated for 2015 (Le Quéré et al. 2015). At the same time, the international community strives to guarantee food security and sustainable economic development to a still growing population (cf. UNFCCC 2014; SE4All 2015).

According to recent literature (cf. Kindermann et al. 2008a; 2008b; Shvidenko et al. 2005), biomass (the quantity of living plant material) is - with a share greater than 80% of the total - most abundant in forests. Tropical forests account for 50% of the total global plant biomass, although they only occupy 13% of the land area. All other forest types contribute an additional 30% to global biomass

(Chapin et al. 2002). In total, forests cover around 30% of the global land surface (FAO, 2010) and provide over 90% of the carbon sink of terrestrial ecosystems (Pan et al. 2011; Le Quéré et al. 2015). In addition to these biophysical facts, forest biomass conversion into heat and electricity is a common and wide-spread renewable energy technology, and sustainable supply chains can minimize the impact on food production and other ecosystem services such as biodiversity. For these reasons, this thesis concentrates on forest, its sustainable management and optimal feedstock generation for bioenergy.

Clearly, in order to maximize biomass for bioenergy, reliable knowledge on the current geographical distribution of forest cover and biomass is crucial for the assessment of potentials. Furthermore, such geographical information is key to understand general forest dynamics, to estimate and monitor carbon sources and sinks, and to enable measurement of forest area change over time. The required information on global forest systems is not static and forest biomass may vary independent of changes in forest area, e.g. through forest management and other anthropogenic and natural disturbances (Schepaschenko et al. 2015; Houghton 2005).

Even though spatially explicit information on global forests is considered highly important, maps of available forest area and biomass is currently available only from a wide mixture of sources, including local in-situ measurements, national forest inventories, municipal level statistics, model outputs and biomass distribution derived from regional satellite products. The latter information is often regional or national, based on different methodologies and usually not easily accessible (Kindermann et al. 2008b).

Furthermore, the facts that a) forests are under intense pressure from anthropogenic and natural disturbances (Canadell and Raupach 2008) everywhere on the globe and that b) changes in area and biomass happen continuously, quickly outdate current information. Hence, reducing the uncertainties surrounding geographic forest information is of utmost urgency to the scientific community, which has therefore called for more use of satellite data (Hese et al. 2005). First products to use satellite output for the extrapolation of ground measurements have been launched at regional level (Laporte 2006). Figure 1 features the first global hybrid (remote sensing combined with crowd sourcing) forest

map which is, in addition, calibrated with FAO statistics, developed at the International Institute for

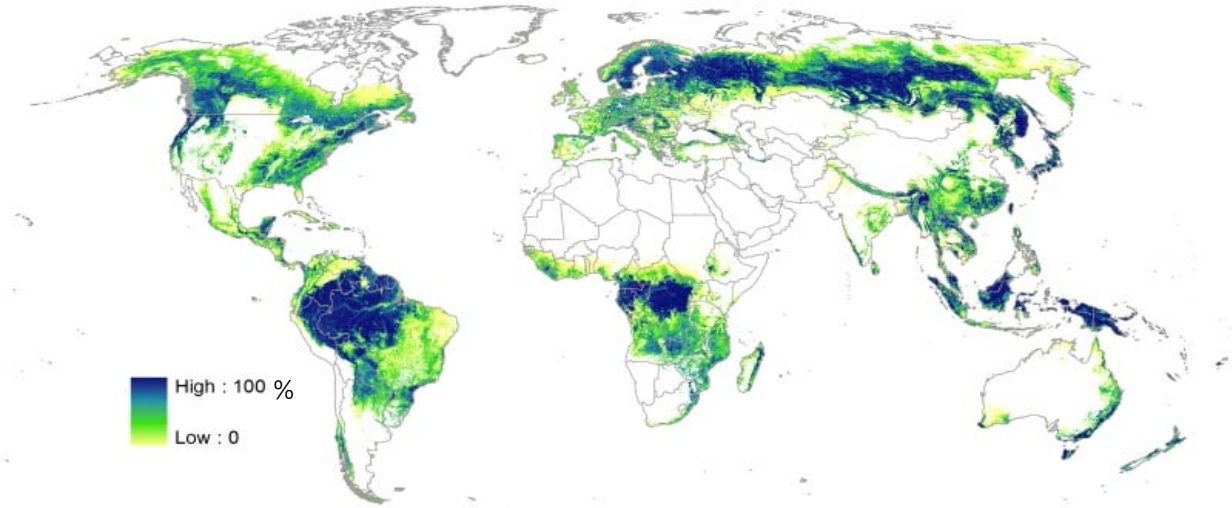

Figure 1. Global Hybrid Forest Map. The color ramp in the legend indicates percentage of forest cover from 0–100% per 1km grid cell (white color means no forest). Source: adapted from Schepaschenko et al. (2015).

Applied Systems Analysis (IIASA) by Schepaschenko et al. (2015).

Satellite imagery is nowadays mostly used for measuring forest area (see e.g. Hansen et al. 2013) and other biophysical parameters such as net primary productivity (NPP), canopy density and – with the help of Radar and Lidar technologies - also certain parameters of biomass (Sun et al. 2015). In order to project developments under policy scenarios and, particularly, assuming different forest management types, use is made of global economic, biophysical and land use models, such as GTAP, IMAGE, GLOBIOM, G4M and IMPACT (Nelson et al., 2014). These are complementary alternatives to satellite technology and are often applied to project afforestation and deforestation decisions. For compatibility and validation reasons, both satellite products and models are often used jointly. Both products are usually calibrated with FAO statistics. Forest maps calibrated with FAO statistics build hence most often the baseline for modeling activities as is the case in the study demonstrated in the global-level Chapter 2.1 of this thesis. With the help of models, a broader assessment of biomass availability for bioenergy purposes can be carried out. Figure 2 shows the availability of cumulative biomass for bioenergy over the course of this century, directly converted into calorific values per grid cell derived from the G4M model, formerly known as DIMA model (Rokityanskiy et al. 2007).

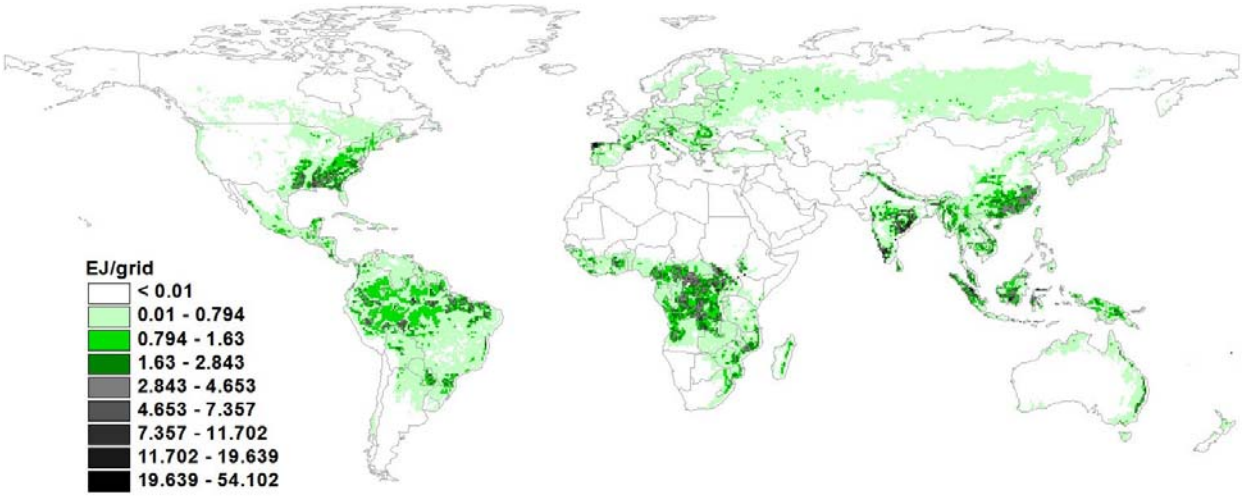

Figure 2. Cumulative biomass production for bioenergy between 2000 and 2100 under the revised IPCC SRES A2r scenario. The color ramp in the legend indicates the accumulated energy per grid cell [EJ/grid]. Source: adapted after Rokityanskiy et al. (2007).

The role of bioenergy in the global energy portfolio

With respect to the global energy portfolio, biomass accounts for about 10% (51 EJ) of the global primary energy consumption. Kraxner et al. (2016) state that in developing countries, traditional use of biomass plays a larger role, whereas in industrial countries biomass accounts on average for 3-4% of the total primary energy consumption only. Industrial countries such as Sweden, Finland or Austria even show shares of up to 15-20%, while e.g. Japan with a share around 1% is placed at the other extreme of the spectrum (IEA 2014; 2015a; 2015b).

As mentioned above, most scenarios of future energy demand feature an increasing share of energy from biomass – especially in ambitious mitigation scenarios (IPCC 2014) - in which bioenergy is an important element both as a means to reach ambitious climate stabilization goals and as a cost-effective measure to fulfill future energy needs. These scenarios are generally relying on carbon-neutral bioenergy or even consider carbon removals by combining bioenergy with carbon capture and storage (BECCS), cf. (Smith et al. 2015; Fuss et al. 2014).

Such carbon removal is often called ‘negative emissions’. Along with afforestation, BECCS is the most widely deployed technology for carbon removal in the majority of Integrated Assessment Model (IAMs) scenarios aiming at keeping warming below 2°C (AR5, WG3 2014). Indeed, in these

scenarios, IAMs often foresee absorption of CO_2 via BECCS up to (and in some cases exceeding) 1,000 Gt CO_2 cumulative over the course of the century, effectively doubling the available carbon quota.

The deployment of large-scale bioenergy faces biophysical, technical, and social challenges, and CCS has yet to be implemented widely. According to Fuss et al. (2014), there is a major need to resolve uncertainties with respect to the physical constraints on BECCS, including sustainability of large-scale deployment relative to other land and biomass needs, such as food security and biodiversity conservation. This thesis addresses this need.

From global to regional to local

This thesis is organized in three parts, which refer to three levels of analysis starting with biomass availability at the global level in chapter 2 and analyzing regional BECCS potentials in chapter 3. In chapter 4, the focus is on the local knowledge on sustainable bioenergy. Kraxner et al. (2016) project that more than 50% (3,167 millions) of the global population is now living in cities, and between 50-75% of global final energy use (180 - 250 EJ) is urban. Three more billion people are projected to live in urban settlements by 2050 - a doubling of urban population within 35 years, implying corresponding increases in urban energy demand. At the same time, given the large mitigation needs described above, much of the urban energy need will have to be met by bioenergy sourced mainly in the rural "hinterland". This means that the rural population might decline and future policies will have to combine rural revitalization with sustainable production of biomass for bioenergy (Kraxner et al. 2013) while providing safeguards for non-carbon ecosystem services related to recreation or protection of biodiversity (cf. Grubler et al. 2012; Kraxner et al. 2013) .

Global bioenergy potentials based on global assessment tools with low geographic resolution (i.e. world regions) might look greater than the aggregated figures of local and regional bioenergy potential, especially if these have been carried out with high spatially resolving tools. Local analyses can better consider local specifics such as sustainability aspects with respect to ecosystem services, local acceptance by the public, or vegetative productivity – based on e.g. cultural differences in management.

The thesis thus attempts to reconcile the global demand for bioenergy for climate change mitigation with regional realities of potentials (chapters 3.1 and 3.2) and local needs – not only in terms of energy supply, but also for socio-economic objectives such as revitalization of rural areas (chapters 4.1 to 4.3). In particular, chapter 4.1 provides an overview of how Austria, one of the bioenergy pioneer countries, has developed a sustainable bioenergy system which - despite of being located in the middle of the European Alps – proves to be competitive with other renewable energy carriers and fossil fuels. Austria has a long history of success stories, with positive effects of bioenergy with respect to e.g. the rural development at local level. It is a small land-locked country in the center of Europe and in the second half of the 20th century it faced stable economic development starting in the post-war decades. 50% of its surface is covered by forest that has been traditionally managed in a sustainable way for hundreds of years without major interruption. Most of the forest area is located in the mountains, where the steepness of slopes has not allowed for agricultural production. Due to its long borders with the former Eastern bloc countries of Europe during the cold war (i.e. former Czechoslovakia, Hungary and former Yugoslavia), rural areas in Austria have been facing a rapid decline and ageing of population comparable to the developments in Japan. In addition, the inhabitants of rural areas have been forced to accept long commuting distances to the next bigger towns and cities in order to make their living.

Already before the end of the cold war, remote rural border communities decided to improve their strong dependency on fossil-based imported energy by investing into their energy self-sufficiency. The introduction of renewable energy with locally grown feedstock (e.g. in the area of bioenergy) has been one of the consequences. By concentrating on domestic "home-grown" energy carriers, the energy costs for the rural population could be controlled and substantially lowered. Furthermore, the value added that has been created through establishing the entire energy supply chain locally could be captured for the region. Another positive consequence has been that new industry could be attracted step by step to local areas based on these lower energy costs. In return, the new industry offered new job opportunities to the rural population and with that – based on the low-carbon energy – the first "green jobs" were introduced in Austria.

The public acceptance and knowledge of sustainable forest management and certified forest management – in particular for the rural areas – is discussed in chapters 4.2 and 4.3, where surveys for two Japanese rural towns are presented and analyzed.

Similar to other developed countries, Japan is facing severe problems with respect to its rural future. The dominating Japanese rural land use - traditional small-scale farming - is presently maintained through substantial subsidies targeting a rapidly aging rural population, while the young residents have been moving from the country-side to the bigger towns and cities, becoming physically and mentally de-coupled from rural live. One reason is that the Japanese economy has been stagnating since the eighties. This has affected the rural areas and its inhabitants more strongly than citizens in more densely populated areas. Especially the lack of structural investments over the past decades seems to have added to the problems (Kraxner et al. 2010b). Furthermore, rural life is dominated by hard work on the fields without major support by machinery and other technical comfort –and this also applies to house work. The perception of a hard rural life is widely spread among the Japanese population (Kraxner et al. 2010b).

On the other hand, almost 70% of Japan's land area is covered by forest – a mixture of plantations that were mostly established in the 50ies and 60ies and natural forest vegetation. Similar to Austria, forested area is mostly found in mountainous areas, since the fertile valleys are used for agricultural production. Following the 1-2 decades of post-war reconstruction, the Japanese society faced an unprecedented economic growth during the 60ies and 70ies of the 20th century. One of the consequences of becoming a world leading industry nation was that the previously large forest areas under management have been abandoned with respect to proper forest management, since forestry could not match the fast pace of the high-tech industrial development and lost much of its profitability and economic attractiveness.

Both, Japan and Austria are thus showing strong similarities with respect to their rural development challenges and their opportunities to respond to those. Both countries have a high forest cover of their land area, and thus seem to be good candidates for a bioenergy-led rural revitalization. Also topographically, both countries have a very mountainous landscape. Moreover, both countries have

also strong reasons to try and keep their rural population vital in order to maintain the traditional beautiful landscapes for multiple uses such as agriculture, tourism and spiritual reasons.

The thesis will try confer lessons learned from the Austrian experience to Japan and test the receptiveness of the Japanese society for such strategies through surveys. It will be argued that more analyses at local level looking into these rather non-technical and rather socio-economic dimensions will be needed if potentials of the amounts needed for global climate change mitigation are to materialize regionally and locally.

II Objectives

The over-all objective of this thesis is to examine forest-based bioenergy feedstock potentials and to assess bioenergy expansion at global, regional and local scales. As explained in the motivation section, in order to develop detailed planning into this direction, it is necessary to a) examine the factors that have enabled this development in Austria and b) investigate to which extent their application can be translated to bioenergy potentials in Japan. Bioenergy potentials are also influenced by the wider support of the public. While the Austrian public is largely in favor of bioenergy production and a corresponding energy strategy, this thesis will also investigate, what the public opinion and their support in Japan is. It will contribute to this research gap by investigating public rural opinion in Japan in this context.

Further to these two focus countries, this thesis aims at c) linking different scales of developments, decision making and biophysical potentials, i.e. from global to regional and local aspects in the area of biomass and bioenergy.

By drawing on some lessons learned from the Austrian case as described earlier, it is hypothesized that the existing vicious cycle of a rapidly over-aging and declining population in Japan can be slowed and possibly halted and that bioenergy diffusion and sustainable forestry can be important elements

in such an endeavor. The more detailed, corresponding research questions are listed by investigation level below and repeated again with each core chapter of this thesis (Chapters 2-4).

Research questions at the global level

1. What is the global situation of forests under different bioenergy scenarios?
2. What are suitable bioenergy policies that would allow for increased bioenergy production?
3. What are the tradeoffs under increased bioenergy scenarios?
4. What is the status quo in global and regional sustainable production of bioenergy feedstock and what are the trends to be expected?

Research questions at the regional level

1. Why is further bioenergy diffusion important at regional and global level?
2. What is the role of regions in low-stabilization pathways?
3. What is the bioenergy potential for the region of Korea and Japan?
4. Can we eventually go negative and how does such a strategy look like?

Research questions at the local level

1. What is the key of success for the Austrian bioenergy system?
2. What is the situation in local-rural Japan with respect to bioenergy and certification? To what extent does public opinion in local-rural Japan support a development pathway based on sustainable renewable energy strategies for rural revitalization?
3. Does the situation in different rural communities in Japan allow for similar development pathways like in Austria?
4. Why are socio-economic studies at local scale needed to achieve climate change mitigation targets also at regional and global levels and what does this imply for central policy making?

Last but not least, this thesis will contribute to the existing research literature by deriving possible (policy) conclusions and lessons learned across the levels of the thesis.

III Structure and Outline Preview

The main part of this thesis is embedded by detailed introduction (Chapter 1) and conclusion sections (Chapter 5). The Introduction provides the basic background information in order to explain the necessity of an integrated and multi-scale approach when considering bioenergy.

The structural logic of the thesis is described in Figure 3 in the form of an assessment tree. The three parts of this assessment tree stand for the 3 geographic investigation levels from global via regional to local. The intensity of the green color and area size indicate the overall importance with respect to target and objective of the thesis. Whereas the global part is absolutely necessary for regional and local bioenergy assessments, the most important conclusions and results (lessons learned) are derived from the regional and local parts of this integrated assessment. In addition, the key focus of each level is indicated (e.g. at the regional level the thesis concentrates on studies carried out in Korea and Japan).

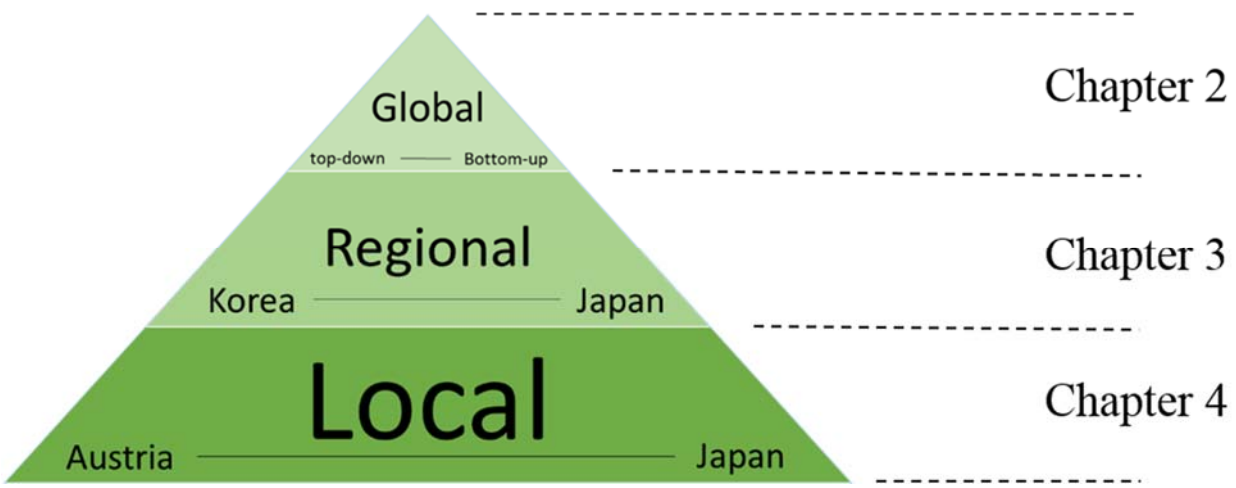

Figure 3. Visualization of the thesis' multi-scale character, indicating the spatial focus of each chapter.

In chapter 2, the thesis concentrates on the global importance of bioenergy, both socio-economically and with respect to climate change mitigation. Especially with global assessments, the environmental sustainability plays an important role which is paid attention to by a specific sub-chapter on forest management certification (FMC). In this chapter it is demonstrated that "top-down" approaches need to be completed by "bottom-up" applications.

In chapter 3, the thesis puts focus on the regional scale. Here, two forest biomass-rich countries of the East Asia region - Korea and Japan - are analyzed with respect to their bioenergy potential. These countries have been selected because of their large forest area and equally large bioenergy potentials that have not been tapped yet at a wider scale to contribute to the individual country's renewable energy portfolio. Furthermore, the potential these countries to achieving a 2°C target is assessed and discussed.

In the final core chapter 4, emphasis is put on the Japanese rural-local situation with respect to bioenergy, its public acceptance and environmental sustainability. Elements and lessons learned from the global and regional level assessments are synthesized in this chapter with the local scale, while being completed with the experiences and lessons gained from studies carried out in local and regional Austria.

In close linkage with the findings and conclusions from the individual core chapters, the conclusions and outlook chapter (5) forms, together with the Introduction (Chapter 1) the framework and provide the relations in between the individual chapters and their specific topics as well as put this thesis in the context of contemporary challenges.

This thesis is conducted in a cumulative form. Four peer-reviewed and first-authored articles, published in renowned scientific journals that are listed in the Science Citation Index (SCI) form the backbone of this work. The original articles are attached at the end of the main body of the thesis and are listed below in full reference. For some chapters – in addition to original and duly referenced peer-reviewed articles, information from published and non-published reports and working papers has been used.

In all cases, the journals, authors and publishers kindly granted the rights to reproduce text and figures for the purpose of this thesis.

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4. **Florian Kraxner**, Jue Yang, Yoshiki Yamagata, **Attitudes towards forest, biomass and certification – A case study approach to integrate public opinion in Japan**, *Bioresource Technology*, Volume 100, Issue 17, September 2009, Pages 4058-4061, ISSN 0960-8524, http://dx.doi.org/10.1016/j.biortech.2009.03.056.

IV Research Methods

General approach

The cumulative style of this thesis implies that parts of the text and figures of the articles listed above are used as input to the thesis which is carefully completed with original work by the thesis author or by additional literature. Most of the latter is either co-authored by the thesis author or further recent literature, duly referenced according to scientific standards. Wherever possible, peer-reviewed literature is used. However, since this thesis contains also data-intensive work, reports and working

papers have been used in exceptional cases where no articles from journals could provide similar information.

Please note that every core chapter (Chapters 2-4) has its own introduction, and each sub-chapter features in addition a methods section as well as conclusions. The introduction sections of the main chapters aim at linking to the previous chapters and parts of the work and by such are forming a bridge between the chapters which underlines the inter-linkage between the different parts of the thesis, where one section builds up upon the previous one.

The chapter at the global level is mostly referring to modeling work – either derived from "top-down" – style Integrated Assessment Models (IAMs) or – with respect to the corresponding journal article – using biophysical and economic "bottom-up" land use models. Additionally, a literature-based statistical overview on the global situation and development of forest certification is provided.

The interlinked land use models "Global Forest Model (G4M)", "Global Agro-Ecosystem Model (EPIC)" and "Global Biosphere Management Model (GLOBIOM)" are shortly described in this section for the reader's overview. A detailed model description is part of the Annexes I to III of this thesis.

The Global Forest Model "G4M"

The Global Forest Model (G4M) is applied and developed by IIASA (Kindermann et al., 2006; Gusti et al., 2008; Kindermann et al., 2008a; Gusti, 2010a, 2010b; Gusti and Kindermann, 2011) and estimates the impact of forestry activities (afforestation, deforestation and forest management) on biomass and carbon stocks. By comparing the income of managed forest (difference of wood price and harvesting costs, income by storing carbon in forests) with income from alternative land use at the same place, a decision of afforestation or deforestation is made. As G4M is spatially explicit (currently on a 0.5° x 0.5° resolution) the different deforestation pressure at the forest frontier can also be handled. The model can use external information (such as wood prices, prescribed land-use change) from other models (i.e. IIASA's global economic land use model GLOBIOM) or data bases, which guarantees food security and land for urban development or accounts for disturbances. As

outputs, G4M produces estimates of forest area change, carbon sequestration and emissions in forests, impacts of carbon incentives (e.g. avoided deforestation) and supply of biomass for bio-energy and timber.

The Global Agro-Ecosystem Model "EPIC" (short description)

EPIC (Environmental Policy Integrated Climate; Williams et al. 1989) is an agro-ecosystem model originally developed by a modelling team of the US Department of Agriculture. The major components in EPIC are plant growth and competition, weather simulation, hydrology, soil erosion, nutrient and carbon cycling, pesticide fate, soil temperature and moisture, tillage, cost accounting, and plant environment control. EPIC operates on a daily time step and can simulate plant growth for hundreds of years. The concept of radiation use efficiency (RUE) is used in EPIC to simulate plant growth. Potential plant biomass is calculated daily as a function of photo-synthetically active radiation and leaf area index, while the amount of solar radiation captured as biomass is driven by crop-specific RUE. Different management options are available, including tillage operations, irrigation scheduling, fertilizer application rates and timing.

The Global Biosphere Management Model "GLOBIOM" (short description)

The Global Biosphere Management Model (GLOBIOM) (Havlík et al. 2011; 2014) is a global recursive dynamic partial equilibrium model of the agriculture and forest sectors, where economic optimization is based on the spatial equilibrium modelling approach (Takayama and Judge 1971). The model is based on a bottom-up approach where the supply side of the model is built-up from the bottom (land cover, land use, management systems) to the top (production/markets). The agricultural and forest productivity is modeled at the level of gridcells of 5 x 5 to 30 x 30 arc minutes, using biophysical models, while the demand and international trade occur at regional level (30 to 53 regions covering the world, depending on the model version and research question). Besides primary products, the model has several final and by-products, for which the processing activities are defined.

The chapter at the regional scale is mainly based on a techno-economic engineering model for the optimization of renewable energy systems, called "BeWhere". This model is using biophysical

information on the regional forest derived from G4M. Again, the BeWhere model is shortly described in this section while a detailed description can be found in the Annex IV of this thesis.

The Techno-Economic Engineering Model "BeWhere" (short description)

The BeWhere model (Schmidt et al. 2011; Leduc et al. 2012; 2015) minimizes the costs of the complete bio-energy supply chain of the studied system, including biomass harvest, biomass transportation, conversion to bio-energy, transportation and delivery of biofuel to the consumers, and sales of excess heat and electricity. Fossil CO_2 emissions are also considered, by including a cost for emitting CO_2, such as a tax or tradable emission permits. At the European level and global level, each country is divided into grid cells with a half-degree spatial resolution (approximately 50 × 50 km). The grid can be adapted with regards to the studied region. Feedstock and biofuels can be transported by truck, train or ship. Interchange of those commodities between the countries can only take place at defined trade points, situated at major harbor locations or at strategically located border points. The trade is based only on the cost of transportation.

The chapter at the local scale consists of a literature-based description of the Austrian bioenergy success case. For the description of the Japanese cases, questionnaire-based drop-off surveys were conducted at household level in two Japanese rural towns in 2007 and 2008 respectively. The questionnaire was divided into 5 sections (general info, forest, forestry, biomass, and environment) in each of which 4–8 questions were asked with main focus on forest certification and biomass for bioenergy. The answers were made on a 5/6 point scale, or in dichotomous-choice form and analyzed by using SPSS. The valid response rate was around 40%. In order to facilitate an evaluation and improve the interpretation of the perceptions and attitudes derived from the statistical analysis, results were compared with other national surveys where appropriate.

2 GLOBAL SUSTAINABLE BIOMASS FOR BIOENERGY

The introduction has made the case for an increased biomass need for bioenergy in the context of climate change mitigation. However, there are competing demands for the land on which this biomass would be cultivated. Other, non-climate policy goals include inter-alia ensuring access to sufficient and nutritious amounts of food for a growing population, conservation of ecosystems services such as protecting biodiversity and managing scarce resources (e.g. water and fertilizer) sustainably.

This chapter is dedicated to analyzing the tradeoffs between these different policy goals at global level and determining to which extent they might constrain the availability of biomass for bioenergy (Chapter 2.1). Clearly, rather than focusing policy-making at hierarchies of priorities, it is more helpful to better understand the dynamics underlying land use change and the implications that the different tradeoffs have for managing scarce resources. For example, bringing deforestation down to net zero rates does help to conserve areas that are rich in species, yet it puts pressure on water resources, which are needed to irrigate food crops that need to be cultivated in a more intensive manner, as expansion into forests to increase agricultural area is no longer an option. Consequently, biomass for bioenergy coming from forestry will be subject to a number of restrictions respecting these tradeoffs. Different economic and biophysical modeling techniques, described in the subsequent chapter, help identifying and analyzing these tradeoffs.

One response to these sustainability concerns is the sourcing of forest biomass from Sustainable Forest Management (SFM) designed to respect the tradeoffs analyzed in chapter 2.1 and to exploit opportunities for synergies. Chapter 2.2 will define the foundations of SFM and put it in the global context. From a policy perspective, incentivizing SFM is an economically sensible strategy, as it enables foresters to reap the benefits of their extra investments (that might not be priced in, as many policy goals at the global level such as biodiversity protection and enhancing carbon sinks are not marketed) through the consumers' willingness to pay more for sustainably produced commodities. The regional modeling approach presented in Chapter 3 will then consequently consider insights gained throughout Chapter 2 (SFM, CFM etc.) in its modeling assumptions.

Research questions at the global level

1. What is the global situation of forests under different bioenergy scenarios?
2. What are suitable bioenergy policies that would allow for increased bioenergy production?
3. What are the tradeoffs under increased bioenergy scenarios?
4. What is the status quo in global and regional sustainable production of bioenergy feedstock and what are the trends to be expected?

2.1 Global Future Bioenergy Development

Introduction

We are facing a future where a sustainable use of the planet's resources calls for renewable and carbon-neutral energy sources to meet increasing demands for energy. According to the International Energy Agency (IEA), a major opportunity to reduce fossil CO_2 emissions is the transition to alternative sources of materials for energy production, including biomass from forests or agricultural crops (IEA 2010). Biomass can be used for heating, cooling, producing electricity and liquid biofuels, and the use of biomass may help to reduce greenhouse gas (GHG) emissions. Emissions from biomass are generally accounted for as carbon-neutral, for example, see the European Union (EU) Renewable Energy Directive 2009/28/EC (EC 2009b). However, whether biomass is entirely carbon-neutral is disputed and very much dependent on system boundaries; in addition to induced land-use change (iLUC), there are always some emissions from processes like cultivation, transport, or fuel production.

In 2011 more than 60 countries had some type of national renewable energy target or support policy, according to the Global Renewable Policies and Measures Database (IEA/IRENA 2013). Climate change mitigation, energy security, and protection of national industries and agricultural sectors are the major rationales for supporting renewable energy. However, the extent of social and environmental regulations for the production of bioenergy feedstock varies very much according to country. Many developed and developing countries have ambitious bioenergy targets but lack sound supporting legislation. Where legislation exists, it is often confused, fails to address socioeconomic and environmental aspects properly (Frank et al. 2013), and may create perverse incentives (Jull et al. 2007). Country-level requirements for GHG emissions reductions are also highly variable, as is the assessment of compliance. Moreover, in most countries, forestry legislation does not contain specific regulations concerning harvesting and the use of forest biomass for bioenergy (Stupak et al. 2007).

Deficiencies in policies, in legislation, and in management guidelines in both developed and developing countries indicate that especially on global level, basic social and environmental values are at serious risk from increasing bioenergy production. Pristine forests, biodiversity, agricultural

land, as well as soil and water resources will all be under additional pressure from a substantially increased use of biomass from agriculture, forestry, and waste for producing energy (FAO 2008a). This development may also counteract other environmental policies and objectives, such as waste minimization or organic farming. Lack of proper planning and management of feedstock production could also have severe socioeconomic effects such as conversion of farmland and forest at the expense of small farmers and people living in the forest, concentration of land ownership, increasing food prices, and additional pressure on food supply in already vulnerable regions (FAO 2008b).

Based on these insights, this study concludes that it is of utmost importance to define and analyze scenarios of global feedstock supply for the production of bioenergy to identify boundaries for future development and to guide further research and policy-making. As this is done, economic development, population growth, and social and environmental safeguard provisions should be taken into account. However, few studies have so far addressed this issue on a global scale (Stupak et al. 2007), the reason being that this kind of analysis calls for integrated modeling, that is, an interdisciplinary approach that combines economic and biophysical land use models. For large-scale and global analysis of land-based sectors, the economic models used are general and partial equilibrium models. These models comprise demand for and supply of commodities, trade flows between different regions, and land use competition. In a general equilibrium model all economic activities and sectors are considered, while a partial equilibrium model is specialized in one or a few specific sectors like forestry or agriculture, and elaborates them in more detail. In integrated modeling, a biophysical land use model is usually linked to the equilibrium model to provide information on constraints on supply and the actual, spatially explicit effects of land-use change processes. A limited number of equilibrium models of truly global scope have been used for modeling land use and land-use change (Heistermann et al. 2006; Lotze-Campen 2008). Most of these are focused on agriculture, and only a few comprise the forest sector (Hertel 1997; Cardellichio et al. 1989; Buongiorno et al. 2003; Havlík et al. 2011). To the best knowledge, there has been no attempt to use integrated modeling for a global and spatially explicit assessment of bioenergy feedstock combining both the forestry and agricultural sectors.

The objective of this chapter is to provide an outlook on the potential feedstock for bioenergy as a contribution to the decarbonization of the energy sector

- with a global perspective using an integrated modeling approach,
- to frame the boundaries for lower scale assessments and to justify research on bioenergy on various scales,
- to identify potential trade-offs to be considered in future research.

Scenarios similar to those presented in this chapter were developed jointly with WWF and used for analysis of future forest development with focus on deforestation. In this chapter, additional results and more in-depth analysis are provided along with interpretation for the bioenergy feedstock relevant selection of scenarios.

Method and main model descriptions

Modeling biomass supply at global scale – an integrated modeling approach

The models GLOBIOM, EPIC, and G4M have been used for a long time in an integrated modeling framework at IIASA (and readers interested in details going beyond the scope of this study or the short descriptions in the introduction section are invited to visit the Annexes I-II of this thesis and/or www.globiom.org, www.iiasa.ac.at/g4m, www.iiasa.ac.at/epic). The economic model GLOBIOM (Havlík et al. 2011; 2013) encompasses all countries of the world, aggregated to 28 world regions (IIASA 2013), and bases its crop and forest sector details on biophysical parameters supplied by the more specialized models G4M for forestry and EPIC for agriculture. The global agricultural and forest market equilibrium is computed by choosing land use and processing activities to maximize the sum of producer and consumer surplus subject to resource, technological, and policy constraints, as described by McCarl and Spreen (1980). The general concept and structure of GLOBIOM is similar to the US Agricultural Sector and Mitigation of Greenhouse Gas (ASMGHG) model (Schneider et al. 2007).

EPIC (Williams 1995; Izaurralde et al. 2006) supplies to GLOBIOM detailed information on management-related yields according to fertilizer and irrigation rates. EPIC is set up globally for 20 crops (barley, dry beans, cassava, chickpea, corn, cotton, cowpea, ground nuts, millet, oats, potatoes, rapeseed, rice, rye, soybeans, sorghum, sugarcane, sunflowers, sweet potatoes, and wheat). Four management systems are simulated by EPIC and implemented in GLOBIOM (irrigated, high input – rainfed, low input – rainfed and subsistence management systems). For each management system, EPIC provides GLOBIOM with information about yield, fertilizer, and water requirements, as well as various environmental parameters including carbon and nutrient balance, and the connected greenhouse gas emissions, nitrogen leaching, soil erosion, and other biophysical indicators (Table 1).

On the forestry sector side, G4M (Kindermann et al. 2008a; Gusti and Kindermann 2011) supplies GLOBIOM with information on mean annual increment, maximum share of biomass usable as saw logs in the mean annual increment, and harvesting costs. G4M also supplies GLOBIOM with consistent accounts of carbon stocks in forests which are then used to assess GHG emissions related to deforestation. In an iterative procedure, G4M in turn uses GLOBIOM projections on wood and agricultural land prices, and wood demand quantities (Kindermann et al. 2008b) to consistently estimate future forest dynamics at relatively high spatial resolution (currently at a 0.5° x 0.5° resolution) (Rametsteiner et al. 2007; Böttcher et al. 2012; Gusti et al. 2009).

Additionally, GLOBIOM is linked to the JRC global energy model POLES (Prospective Outlook for the Long-term Energy System) (Russ et al. 2007) for regions outside Europe and the PRIMES model (Capros et al. 2010; EC 2011a) for EU27 countries through information on macroeconomic indicators and bioenergy demand. Alternatively, other energy models, for example, MESSAGE (Messner and Strubegger 1995), can be linked to GLOBIOM (Reisinger et al. 2013). Bioenergy demand is split into first-generation biofuels, second-generation biofuels, bioenergy plants, and direct biomass use for energy. The same population and GDP projections that are used for input to the POLES and PRIMES models are also used as exogenous drivers for the G4M baseline. Food (calorie) consumption per capita mimics projections from FAO (FAO 2006).

For a more detailed description of the modeling framework see, for example Havlík (2011; 2013) or (Mosnier et al. 2010) or the thesis' Annex III.

Table 1. Parameters exchanged between the different models of the modeling framework. Source: modified after Kraxner et al. 2013.

Model linkage	**Parameters exchanged**
EPIC → GLOBIOM (Williams 1995; Schneider et al. 2007)	For 20 crops (>75 percent of harvested area) and 4 management systems (high input, low input, irrigated, subsistence) - crop yields - water balance (including irrigation water) - carbon, nitrogen and phosphorus balance
G4M → GLOBIOM (Kindermann et al. 2008b; Gusti and Kindermann 2011)	- Mean annual increment - Share of biomass suitable for sawnwood - Harvesting cost - Carbon stock in forests
POLES (or other energy model) → GLOBIOM (Russ et al. 2007)	- Bioenergy demand (fuel wood, biomass for energy industry, biofuels)
GLOBIOM → G4M (Havlik et al. 2011; 2013; IIASA 2013)	- Wood price projections - Land price projections - Agricultural commodity price projections - Demand for forest biomass by type

Scenario settings, assumptions and definitions

The vision of "Zero Net Deforestation and Forest Degradation (ZNDD) by 2020" in accordance with WWF's Living Forests Report (Taylor 2011a) is a substantial component of the scenarios. ZNDD means that there is no net forest loss through deforestation and no net decline in forest quality through degradation. Thus, for the scenarios a future development of feedstock is compared under i) the assumption that there are no restrictions with respect to deforestation, with the exception of protected areas, to ii) the assumption that there is a strong restriction on deforestation (*RED* = Reducing Emissions from Deforestation). However, ZNDD does not mean that there can be no forest clearing at all; it recognizes people's right to clear some forests for agriculture and the value in occasionally "trading off" degraded forests, provided that biodiversity values and the net quantity and quality of forests are maintained. Note that short rotation tree plantations are not equated with natural forests, as many ecosystem services are diminished when a plantation replaces a natural forest.

The scenarios are summarized in Table 2 and described in more detail in the following subsections.

Table 2. Overview of the five scenarios Source: modified after Kraxner et al. 2013. Source: modified after Kraxner et al. 2013.

Scenario name	**Description**
BAU	”Business as usual”: Projection of future development in line with historical trends
BE2010	As for BAU, but the production of bioenergy fixed at the level in 2010
BEPlus	Projection of bioenergy demand by 2050 as in the 100 percent renewable energy vision by the Ecofys Energy Model (Singer 2011)
BEPlusRED	As for BEPlus, but with target "no net deforestation” (RED=Reducing Emissons from Deforestation)
BiodivRED	Stricter biodiversity protection combined with target "no net deforestation"

“BAU” scenario

The *“business as usual”* (*BAU*) *scenario* assumes that current and future behavior can be extrapolated from historical trends. Under the *BAU scenario*, land-use change is anticipated due to (a) demands for land to supply a growing global human population with food, fiber, and fuel; and (b) continuation of historical patterns of poorly planned and governed exploitation of forest resources. Key assumptions in this scenario concerning growing world population and increasing GDP, which drive demands for commodities and energy, are drawn from the European Commission (EC 2011b). Assumptions about agricultural productivity gains and human diet changes are based on FAO data on historical trends (FAO 2006; Grethe et al. 2011).

“BE2010” scenario

In the *“Bioenergy 2010”* (*BE2010) scenario* it is assumed that the bioenergy feedstock demand is “frozen” at its 2010 level and does not change beyond 2010. The *BE2010 scenario* contains no restriction with respect to deforestation, as explained earlier, and is used as a comparison scenario in the results section of this chapter.

“BEPlus” and “BEPlusRED” scenarios

In the *"Bioenergy Plus"* (*BEPlus) scenario*, the bioenergy feedstock demand is based on the "global 2ºC scenario" derived from the POLES model (Russ et al. 2007; EC 2011b) and is an approximation of the projected bioenergy demand by 2050 in the 100 percent renewable energy vision generated by the Ecofys Energy Model (Singer 2011). This scenario projects demand for bioenergy from land-based feedstock (excluding those not competing for land, such as municipal solid waste, industrial waste, and algae) of 75.6 EJ final energy supply in 2050, of which 16.9 EJ are liquid biofuels.

The *BEPlus scenario* helps explore implications for global land availability and productivity of producing sufficient bioenergy feedstock to meet future demand.

Some important assumptions of the *BEPlus scenarios* include:

- A higher carbon price and more ambitious GHG emission reduction targets are used as input from the POLES and PRIMES models, compared to the *BAU scenario*. This makes bioenergy more competitive relative to fossil fuels, provided bioenergy use delivers genuine, full life-cycle carbon savings. This competitiveness is hampered, however, by higher bioenergy feedstock prices as more bioenergy is used.
- The land-based bioenergy feedstock is produced in natural forests managed jointly for biomass and timber production, in timber plantations, and in croplands. Harvesting in natural forests is modeled on a sustained yield basis. The model assumes that tree tops, branches, and stumps (harvesting residues) are not removed from forests to ensure soil protection and long-term fertility.
- Current harvesting practices that cause deforestation or forest degradation are phased out. This shift is assumed to take place, despite population growth, by fuelwood for domestic use being increasingly sourced from sustainably managed forests and dedicated plantations and reducing per capita fuelwood demand through introduction of more efficient stoves and heating systems that are less detrimental to human health.

"Biodiv RED" scenario

The *"Biodiversity" (Biodiv) RED scenario* was developed to explore the impact of stricter biodiversity protection. Here it is assumed that remaining natural ecosystems are protected (i.e., no further conversion of these ecosystems to cropland, grazing land, or plantations in areas identified as important for biodiversity by any one of the conservation mapping processes mentioned in the following. This scenario assumes that current land uses (e.g., cropland or forestry) in these areas remain constant, or decrease, in the biodiverse zones and continue to produce food or timber. The UNEP-WCMC World Database on Protected Areas (UNEP-WCMC/IUCN WCPA 2010) lists most existing protected areas; the Model uses 2009 data, with no land conversion allowed within these areas even under the BAU scenario. Other data sources on areas important to biodiversity include WWF Global 200 Ecoregions (Olson and Dinerstein 2002), WWF/IUCN Centres of Plant Diversity (WWF/IUCN 1994), Amphibian Diversity Areas (Duellman 1999), Conservation International's Hotspots (Mittermeier et al. 2008), BirdLife International Endemic Bird Areas (2008), and Alliance for Zero Extinction sites (Ricketts et al. 2005).

Bioenergy potential under different scenarios

Table 3 shows the bioenergy production under the different scenarios as assumed based on input from the POLES and PRIMES models. In this chapter, the four main carriers of bioenergy are heat and power, direct biomass use, and first and second generation liquid fuels. Heat and power generation takes place in plants where primary energy from mostly woody biomass is turned into electricity or heat (or both, i.e., combined heat and power - CHP). Direct biomass use means that primary energy from wood is turned into heat for domestic cooking and heating. First generation liquid fuels are mainly bioethanol and FAME (Fatty Acid Methyl Esters) produced from agricultural crops; the main crops are sugarcane, corn, wheat, rape seed, soya, and palm oil. Second generation liquid fuels will be produced mainly from wood and turned into transport fuel, gas, electricity, and heat.

The bioenergy production will increase more under the *BEPlus* and *BEPlusRED scenarios* than under the *BAU* and *BiodivRED scenarios*. The main reasons for this are the assumptions about higher carbon price and more ambitious emission reduction targets under the *BEPlus* and *BEPlusRED scenarios*. The same total bioenergy production is assumed under the *BEPlus scenarios*, irrespective of whether

or not there is a deforestation restriction. The main difference is that under non-*RED* most of the bioenergy will be sourced in unmanaged or pristine forest while under *RED* most of the bioenergy production will be sourced by intensification (short-rotation plantations) and partially through conversion from unmanaged to managed forest.

Table 3. Production of bioenergy in PJ under the different scenarios as given by the POLES and PRIMES models. Source: modified after Kraxner et al. 2013.

Carrier of bioenergy	**Scenario**	**2010**	**2030**	**2050**
Heat and power generation	BAU	3 391	18 288	36 372
	BiodivRED	3 391	18 288	32 686
	BEPlus	3 517	22 108	44 451
	BEPlusRED	3 517	22 108	43 185
	BE2010	3 391	3 391	3 391
Direct biomass use	BAU	14 135	14 887	15 713
	BiodivRED	14 135	14 887	15 713
	BEPlus	14 133	14 763	14 235
	BEPlusRED	14 133	14 763	14 235
	BE2010	14 135	14 135	14 135
Liquid fuels, first generation	BAU	1 103	2 335	1 732
	BiodivRED	1 103	2 335	1 732
	BEPlus	1 069	2 175	1 864
	BEPlusRED	1 069	2 175	1 864
	BE2010	1 103	1 103	1 103
Liquid fuels, second generation	BAU	161	2 835	10 853
	BiodivRED	161	2 835	10 853
	BEPlus	156	2 250	15 065
	BEPlusRED	156	2 250	15 065
	BE2010	161	161	161
Total bioenergy	BAU	18 790	38 344	64 670
	BiodivRED	18 790	38 344	60 985
	BEPlus	18 875	41 296	75 614
	BEPlusRED	18 875	41 296	74 348
	BE2010	18 790	18 790	18 790

There are different patterns for the different categories of bioenergy. For all scenarios except the *BE2010 scenario* production of bioenergy for heat and power will be increasingly important in the future and will form a large part of the total bioenergy. Around 2030-2040 a shift from first- to second-generation biofuels is assumed to take place. The production of second-generation biofuels was very low in 2010 but is assumed to increase considerably in all scenarios except for *BE2010*. This shift to second-generation biofuels also means a shift in feedstock, from mainly agricultural crops to forest or plantation-based feedstock. Consequently, there will be higher pressure on

unmanaged forest to be converted into managed forest to provide bioenergy feedstock. Both natural and cultivated land will also be converted into plantations for the same purpose. Moreover, an overall intensification of agriculture and forestry is to be expected.

Bioenergy definition for this chapter

Under the different scenarios – especially with respect to ZNDD – the (bio-)energy markets and policies will be differently affected regarding land availability for bioenergy crops, fast-growing tree plantations, and the supply of wood from existing natural or semi-natural forests. Bioenergy is seen as an inevitable component of future energy portfolios and as a result carries significant environmental and social risk (Azar et al. 2010).

This chapter distinguishes between wood-based bioenergy and crop-based bioenergy. All biomass used for electricity, heating, and second-generation biofuels is wood-based, while first- generation biofuels are produced from crop-based biomass. In the first case, bioenergy can either be produced from forests or from fast-growing short-rotation plantations. Depending on the source and on the current characteristics of standing biomass (i.e., growth rate, disturbances, soil carbon, and management activities, etc.), the climate balance of wood-based bioenergy can vary. For example, intensive management practices like whole tree harvesting and use of fast-growing exotic species or of fertilizers generally have worse carbon balance and ecological impacts than bioenergy which is supplied from fast-growing plantations on degraded lands, using sustainable forest management practices and is hence able to provide climate-friendly fuel and increase carbon storage.

In the case of crop-based bioenergy, there is a clearly competitive situation for the world's productive arable land. With respect to GHG-saving potentials, biofuels from agricultural origin should ideally be sourced from land that causes neither direct nor indirect forest conversion. Some of the currently produced bioenergy products (i.e., some first-generation biofuels) generate substantial environmental and social costs through their irrigation needs or by displacing essential food crops causing deforestation as the ultimate consequence (Havlík et al. 2011). Thus, a careful balancing between all these factors and their clearly positive aspects in terms of GHG emission reductions was considered

for this analysis. By taking a global perspective, it is possible to track any sort of leakage or indirect land-use change.

Results

The scenarios produce a multitude of information; here, the chapter's aim is not to present a full overview of the results but rather to focus on some specific aspects and how they are interlinked. First, an outlook on forest development in general is provided. Then, results concerning land-use change caused by feedstock production and effects on ecosystem services from bioenergy production (i.e., regional effects, effects on GHG emissions and water consumption) are presented.

Outlook on forest development

When analyzing the general development of global biomass feedstock from a deforestation point of view, a comparison between the different scenarios shows that under the *BAU scenario*, 286 million hectares of forest are lost through land-use change between 2010 and 2050 (accumulated area). Slightly more forest will be lost under the *BEPlus scenario*: 303 million hectares (Fig. 4). This comparatively small difference between the baseline and the increased bioenergy scenario can be explained by the fact that under *BAU* almost the same demand for bioenergy exists in 2050 as under the *BEPlus*. In other words, by 2050 most options for the energy portfolio include huge shares of bioenergy to meet the increasing global energy demand (see also comparison of the energy portfolios by Azar et al. (2010)). Figure 4 shows that even when keeping bioenergy demand at a constant level between 2010 and 2050 (*BE2010 scenario)* the accumulated deforested area is 260 million hectares in 2050, almost as high as for the *BAU* and the *BEPlus scenarios*. This phenomenon can be explained by the fact that there is no restriction on deforestation under the *BE2010 scenario*, and the bioenergy demand may indirectly affect (non-protected) pristine forest. The difference in area between *BEPlus* and the *BE2010 scenarios*, 43 million hectares, represents the area deforested due to additional bioenergy production under the *BEPlus scenario*, which roughly corresponds to an area the size of

Sweden. In contrast, under those scenarios combined with *RED* less than 20 million hectares of forest will be lost.

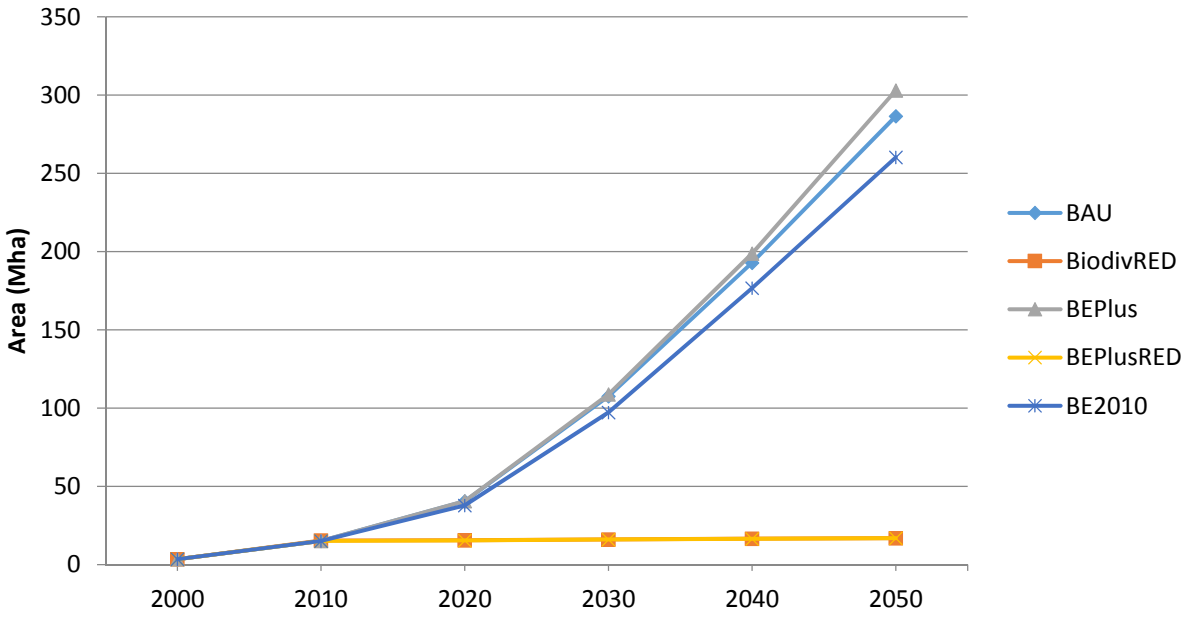

Figure 4. Cumulative deforestation 2010-2050 caused by land-use change according to the different scenarios. Source: adapted after Kraxner et al. (2013).

Since conversion of unmanaged forest into sustainably managed forest is allowed under all scenarios, the area of managed forest will increase (Fig. 5). The largest increase, of more than 300 million hectares, takes place under the *BEPlus* and *BEPlusRED scenarios*, while the increase under the *BE2010 scenario* is less than half of this—only 124 million hectares. Again, in Figure 5 differences can be explained by additional bioenergy production under the *BEPlus* and *BEPlusRED scenarios* and the fact that under those scenarios combined with *RED*, no net deforestation takes place but conversion from unmanaged into managed forest is possible.

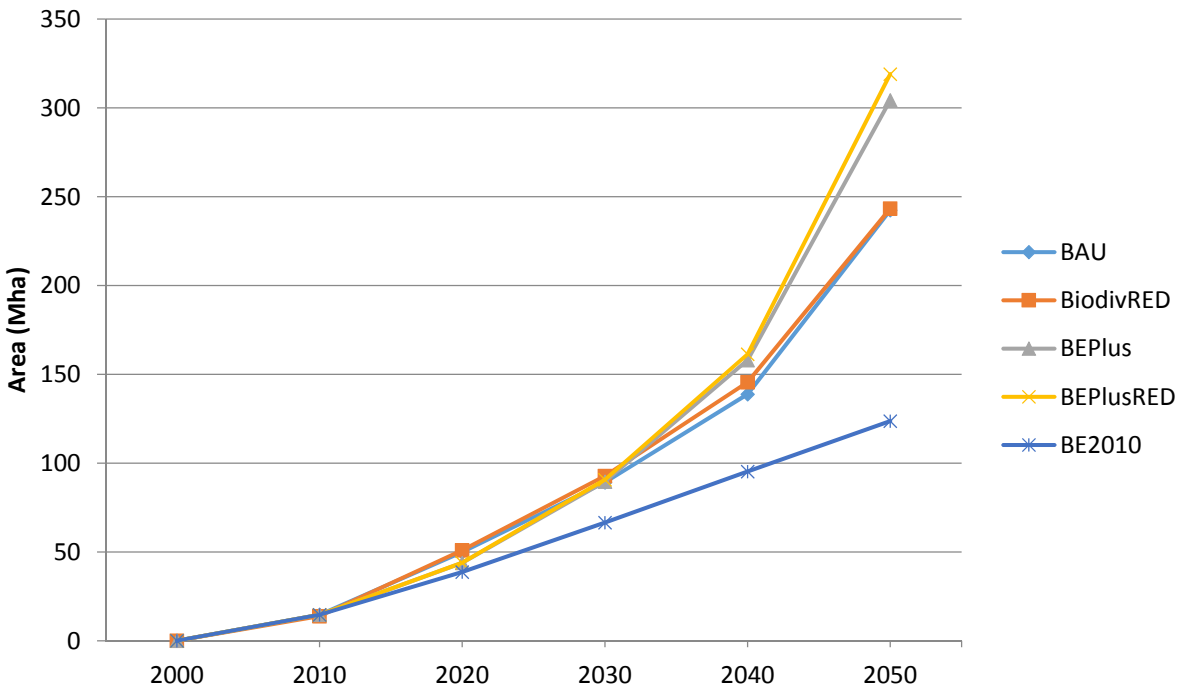

Figure 5. Cumulative increase in area of managed forest 2000-2050 according to the different scenarios. Source: adapted after Kraxner et al. (2013).

Land-use change under additional bioenergy demand

Under the *BAU scenario*, the pattern of land-use change shows increasing areas of cropland, short-rotation coppice, managed forest, and grassland, while the areas of unmanaged forest and other natural vegetation are decreasing (Fig. 6). This conversion of pristine forests and other natural habitats is caused by an increased demand for food and energy by a growing world population with no strict measures being taken to stop deforestation. Under the *RED* scenarios, the pattern is somewhat different. The areas of cropland, short-rotation coppice, and managed forest are increasing, while the decrease in unmanaged forest area is smaller at the expense of grassland area, which is decreasing, and other natural vegetation, which is decreasing more than under the *BAU scenario*.

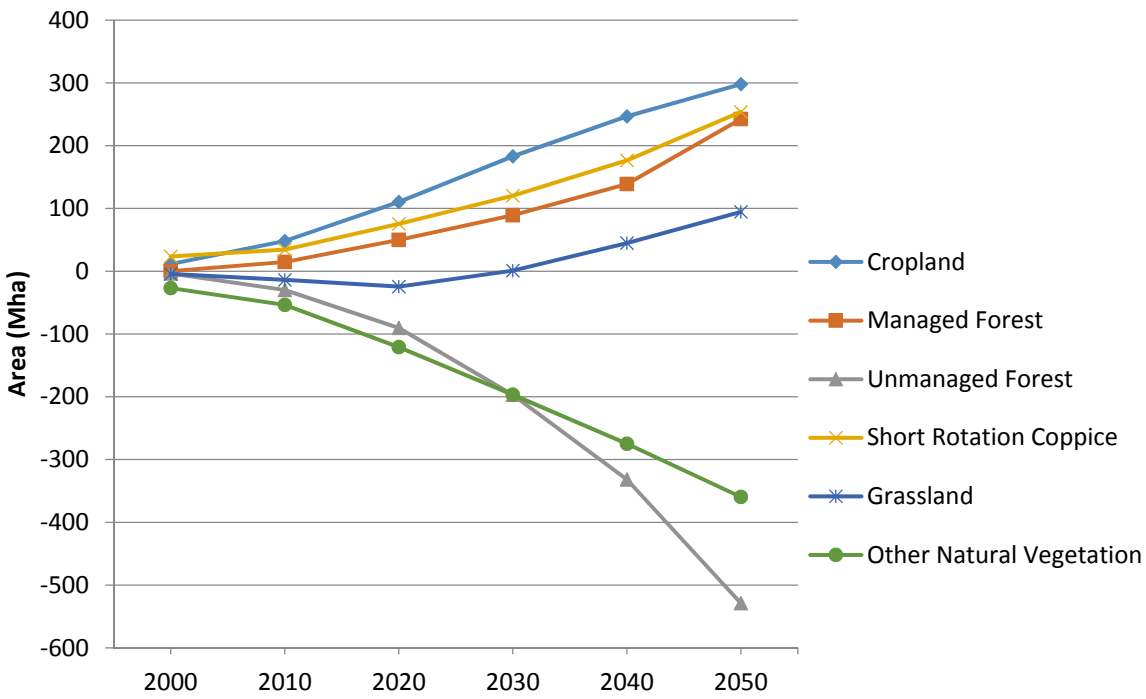

Figure 6. Cumulative land-use change under the BAU scenario. Source: adapted after Kraxner et al. (2013).

Now it is looked at what the effects of a demand for bioenergy higher than the one in 2010 could be. In this case, land-use change under the *BE2010 scenario* is used as the baseline and by calculating the difference between this baseline and another scenario, the possible land-use changes can be identified. Relative to the *BAU scenario*, this comparison reveals that the area of short-rotation coppice will increase by 192 million hectares and the area of managed forest by 119 million hectares until 2050 due to additional bioenergy feedstock production (Fig. 7). By using the land-use change under the *BE2010 scenario* as a baseline and calculating additional land-use change in the other scenarios, the effect of increased bioenergy feedstock production compared to the 2010 level can be assessed. Under the *BAU scenario*, this comparison reveals that the area of short-rotation coppice will increase by 192 million hectares and the area of managed forest by 119 million hectares until 2050 due to additional bioenergy feedstock production (Fig. 7). The area of other natural vegetation will decrease by 133 million hectares and areas of unmanaged forest will decrease even more, by 145 million hectares. Cropland and grassland areas will also decrease slightly. Thus, much of the total increase in area of short-rotation coppice (see Fig. 6) can be explained as caused by increased future bioenergy demand. Similarly, about half of the total increase in managed forest area is also caused

by bioenergy demand. Fig. 7 also shows that there is a loss of total forest area (net forest change) of 26 million hectares which is caused by additional bioenergy production when there is no restriction on deforestation. However, bioenergy is not the direct driving factor behind the loss of pristine forest and other natural habitat. Rather, the exploitation of these habitats is caused by other factors; for instance, expansion of agricultural land for food production and inefficient land use.

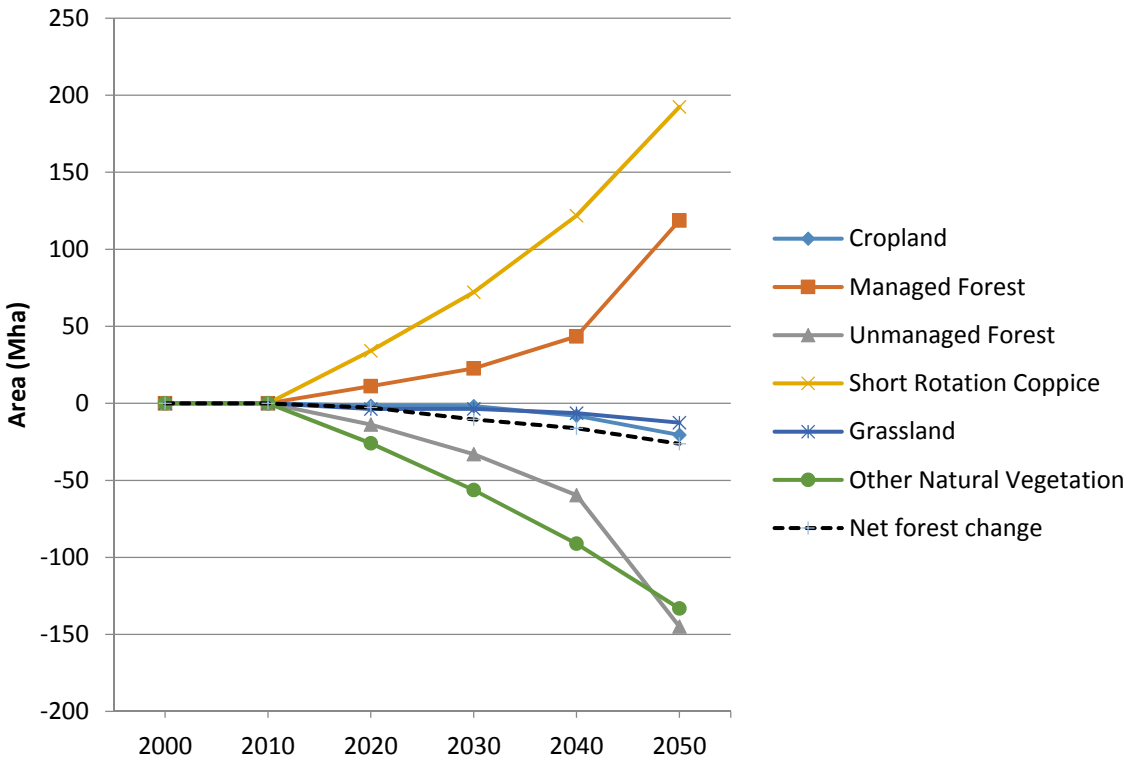

Figure 7. Cumulative land-use change and net forest cover change (managed + unmanaged forest area) caused by additional bioenergy production under the BAU scenario (compared to the 2010 level of bioenergy production). Source: adapted after Kraxner et al. (2013).

Land-use change caused by bioenergy production displays a similar pattern under the *BEPlus scenario,* although the changes are of a larger magnitude.

The additional land-use change due to bioenergy production under the biodiversity-protecting *BiodivRED scenario* shows that the *RED* target of avoiding deforestation creates a typical pattern of land-use change with respect to the different land-use types. In 2050 areas of other natural vegetation have decreased by 210 million hectares, grasslands by 167 million hectares, and croplands by 56

million hectares (Fig. 8). Areas of short-rotation coppice have increased by 191 million hectares and managed forest by 120 million hectares. Unmanaged forest area has also increased by 124 million hectares; this expansion of unmanaged forest takes place with a certain time lag in formerly managed forests and croplands where management has ceased. Overall, the *RED* restriction on deforestation results in an increase of forest area under additional bioenergy demand compared to the baseline 2010 level (see net forest change in Fig. 8). The protection of biodiversity within pristine and other types of forest would clearly be at the costs of other ecosystems, for example, grassland and savannah (which are mostly located in the southern hemisphere).

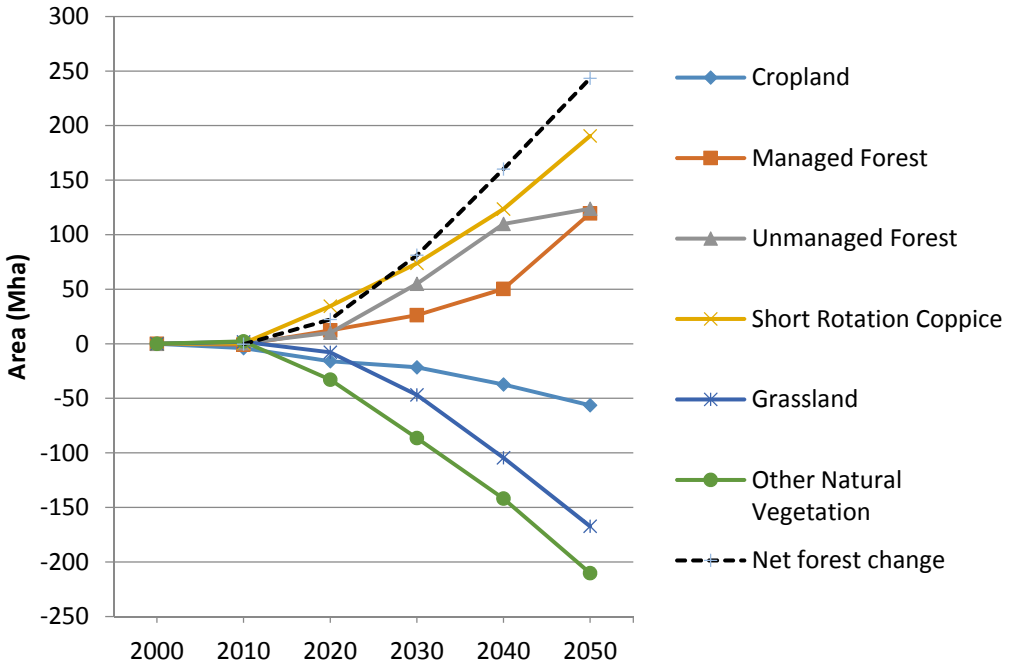

Figure 8. Cumulative land-use change and net forest cover change (managed + unmanaged forest area) caused by additional bioenergy production under the BiodivRED scenario (compared to the 2010 level of bioenergy production). Source: adapted after Kraxner et al. (2013).

Regional effects on ecosystem services from additional bioenergy demand

Increased bioenergy feedstock production directly affects land use and land-use change and thereby various ecosystem services like biodiversity, carbon fixation and water resources.

The effects of feedstock production on biodiversity cannot be directly assessed with the model cluster used. However, here the area of unmanaged forest is used as a proxy for biodiversity of forest ecosystems. In 2000 the area of unmanaged forest was 3146 million hectares, compared to the area

of managed forest, which was 719 million hectares and the area of short-rotation plantations which was 47 million hectares. Unmanaged forest will be lost under all scenarios but under the *RED* scenarios the loss is only half that under the *BAU scenario*.

Under the *BAU scenario*, most of the loss of unmanaged forest takes place in the tropical areas of South America, Africa, and Asia (Fig. 9). Compared to that, under the *BEPlusRED scenario*, the loss of unmanaged forest is not only considerably smaller but also more evenly distributed from a global perspective (Fig. 10). This is also the general pattern under the *BiodivRED scenario*. One reason for this is that since much of the world's unmanaged forests are located in the tropical areas, the greatest effects of the *RED* target will naturally also be seen in these areas. Nevertheless, under the *BEPlusRED scenario*, loss of unmanaged forest takes place relatively late in some of the modeled regions (i.e., PlannedAsiaChina, LatinAmericaCarib and OtherPacificAsia), where unmanaged forest is converted into managed forest and, to some extent, short-rotation coppice. This development is forced by an increasing energy demand from a growing world population.

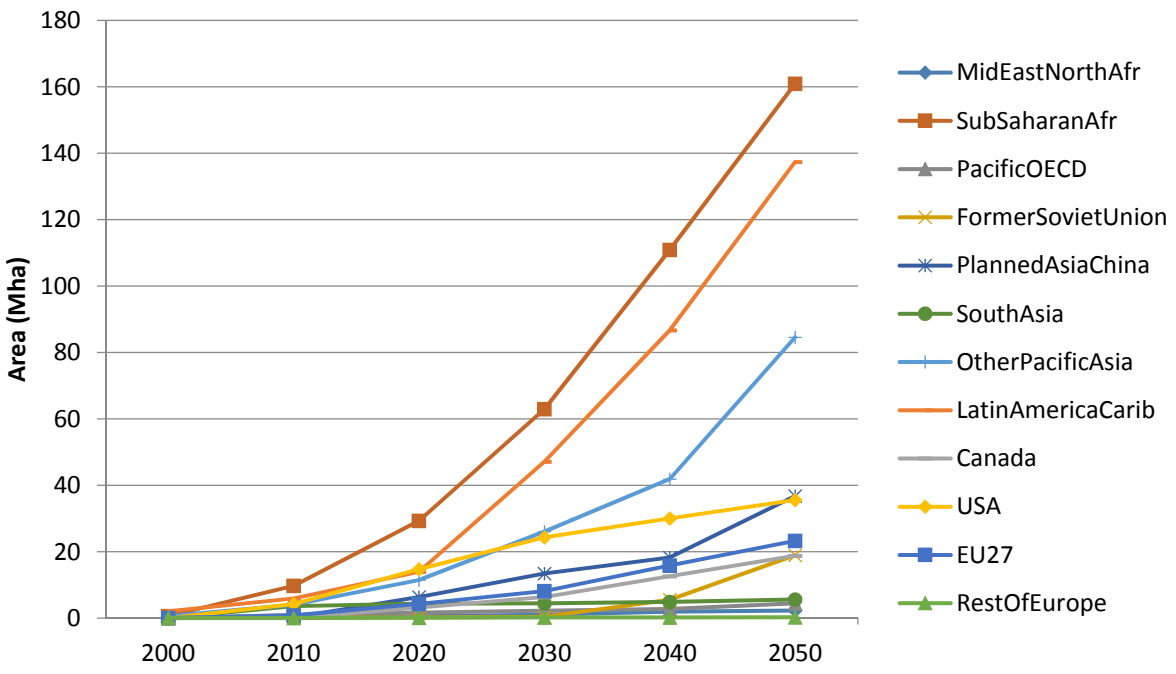

Figure 9. Cumulative loss of area of unmanaged forest 2000-2050 in different regions under the BAU scenario. Source: adapted after Kraxner et al. (2013).

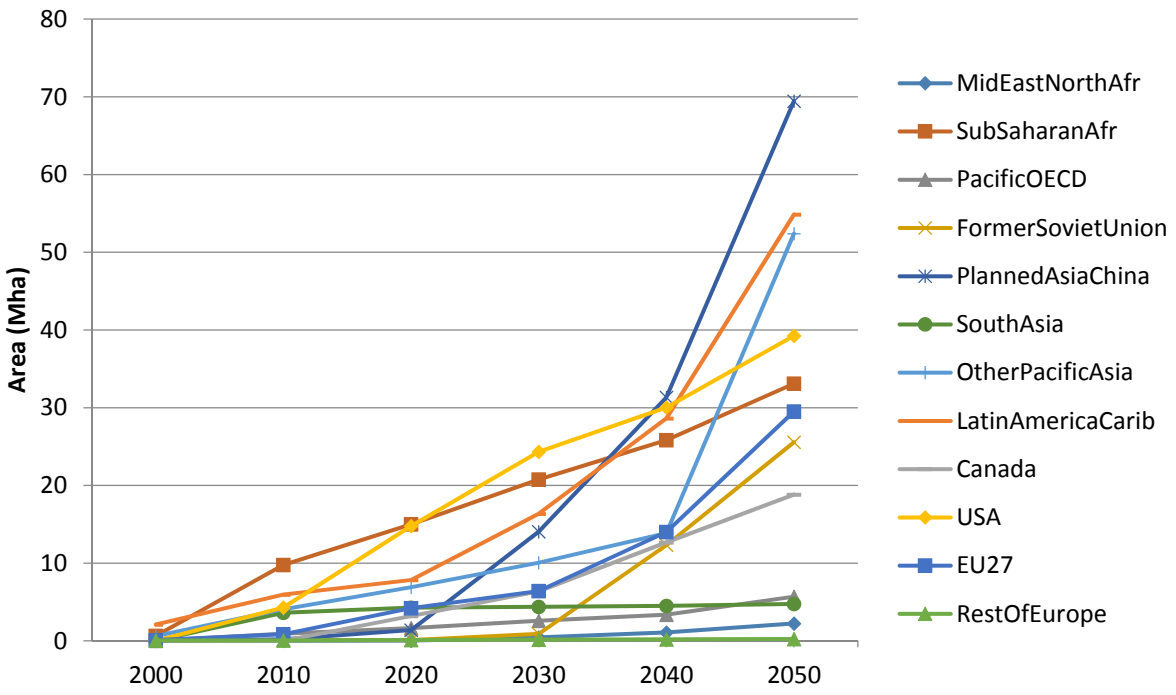

Figure 10. Cumulative loss of area of unmanaged forest 2000-2050 in different regions under the BEPlus RED scenario. Source: adapted after Kraxner et al. (2013).

Total land use GHG emission effects

A comparison of the GHG emissions from total land use under the different scenarios shows that although bioenergy is a better alternative than fossil fuels, bioenergy production indirectly affects GHG emissions considerably through deforestation. Under the *BE2010 scenario*, the bioenergy use is small compared to the other scenarios, and the GHG emissions measured as CO_2 equivalent are the highest, 8.091 Gt y^{-1} in 2050. The GHG emissions are lower under the *BAU* and *BEPlus scenarios*, where bioenergy use is more extensive. However, under the *BEPlusRED* and *BiodivRED scenarios* the GHG emissions measured as CO_2 equivalent are lowest, around 5 Gt y^{-1} in 2050, due to the restrictions on deforestation (Fig. 11).

Background calculations to Fig. 8 show that the GHG emissions from deforestation are highest under the *BEPlus scenario*, increasing notably, especially between 2020 and 2030. One reason may be that unmanaged forest is converted to cropland for bioenergy feedstock production and food production. Another critical factor in terms of GHG emissions is the agricultural sector, that is, soil emissions (N_2O), livestock (CH_4) and rice cultivation (CH_4). Overall, additional bioenergy production does not change the general pattern of emissions from agriculture compared to the other scenarios. In other

words, deforestation can be seen as the largest emission factor even under pressure for intensification in the agricultural sector.

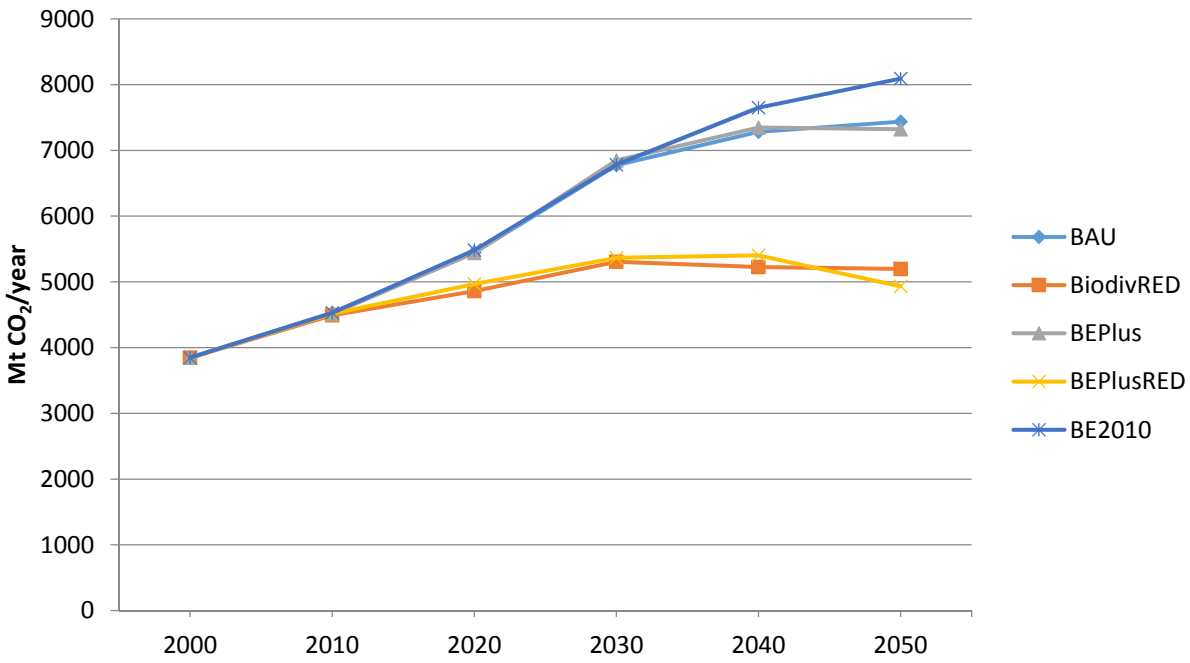

Figure 11. GHG emissions measured as CO_2 equivalent from total land use 2000-2050 under the different scenarios. Source: adapted after Kraxner et al. (2013).

Effects on water from additional bioenergy demand

Water resources will be affected by increased bioenergy feedstock production directly but also indirectly through higher pressure on agricultural land due to intensification and optimization of use. Consequently, the water consumption for agriculture is lowest under the *BE2010 scenario* (only 0.97 Mt in 2050) because of the low level of bioenergy production (Fig. 12). Under the *BAU* and the *BEPlus scenarios*, with higher bioenergy production, the water consumption for agriculture is 1 Mt in 2050. However, under the *BEPlusRED* and *BiodivRED scenarios* the water consumption is even higher. One explanation for this is that the *RED* target implies that less land is available for food production which leads to more intensive use of the agricultural land, including the need for increased irrigation.

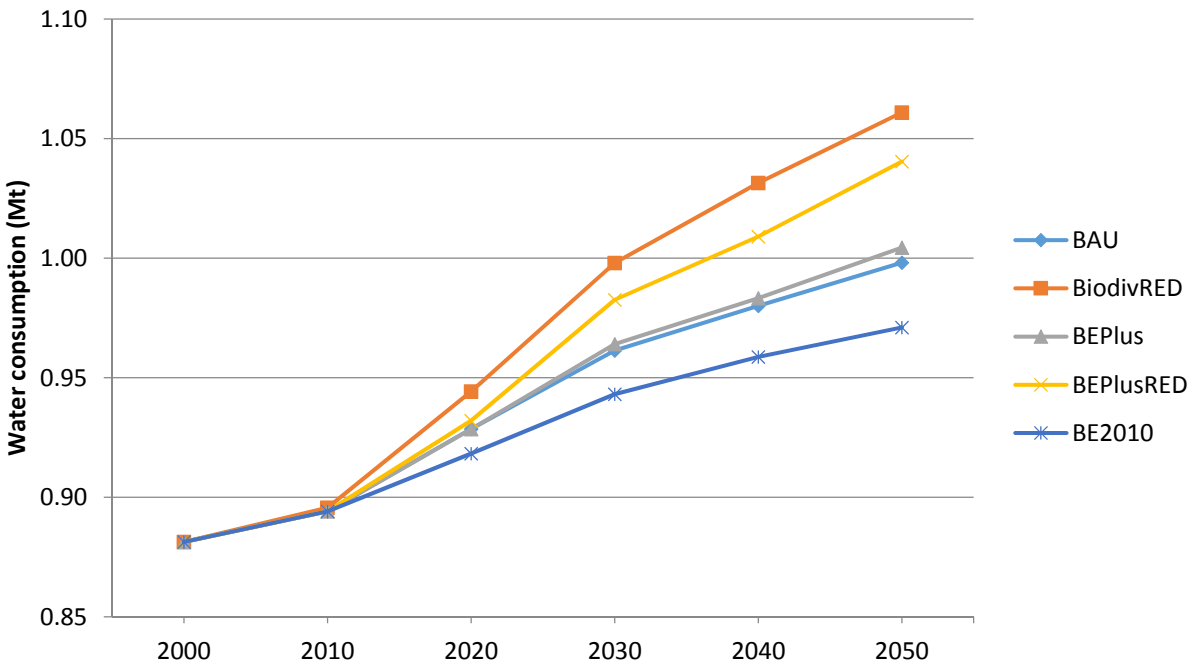

Figure 12. Water consumption for agriculture 2000-2050 under the different scenarios. Source: adapted after Kraxner et al. (2013).

Discussion, conclusions, and outlook

According to the scenarios presented here, bioenergy production is not a major driver of forest loss (see also Taylor (2011b)) but it does have significant influence on other negative or potentially negative land-use change dynamics. However, determining the direct drivers of deforestation and forest degradation is complex. Forests are cleared for a range of reasons and by individual families as well as by some of the world's largest corporations.

The scenarios also show us that it is possible to avoid large-scale deforestation, even under expanded bioenergy production. Today 1,200 million hectares, or 30 percent of forests, have production designated as their primary function (FAO 2010). The projected expansion of forest management based on the model results is driven primarily by demand for bioenergy. The aim of minimizing deforestation does not have much impact on the rate of expansion of forest management, as the scenarios in question assume that the expansion is via sustainable forest management that does not cause forest loss or degradation. Moreover, especially in degraded forests management may substantially improve the forest condition and also the value of ecosystem services.

Forest management certification is one of the key tools that could be applied to ensure sustainable management combined with control of illegal logging, yet still encourage local forest owners to produce biomass for bioenergy (Kraxner et al. 2009). However, most of the certification activities in forestry are still only carried out in the northern hemisphere while certification needs to be clearly focused on the tropical belt of the southern hemisphere (Kraxner et al. 2011a). In addition to improving and certifying forest management, credible standards are also required for commodities driving deforestation to ensure that commodity production does not take place at the expense of forests. This is also supported by the regional analysis included in this chapter which shows that most forest losses and conversion (to the cost of other land-use type) are happening in the south.

Between 2040 and 2050, the food and energy demands of a rising global population put land competition at its most acute. The increased pressure on agricultural land will mean that management has to become more intense in terms of irrigation and fertilization, which may in turn lead to high pressure on water resources, as is shown in the scenarios. Impacts on other ecosystems are greater if forests are more strictly protected; under the high bioenergy scenario with minimization of deforestation, the projected loss of other natural habitats between 2000 and 2050 will be 263 million hectares, with more than half of that due to bioenergy.

The scenarios show that with rising populations and projected consumption levels, there will not be enough land to simultaneously conserve natural areas completely, halt forest loss, and switch to 100 percent renewable energy. Land, water and, possibly, food prices may rise as a consequence of this competition for land (Popp et al. 2011; Schneider et al. 2011). To ensure a sustainable and equitable development, it is assumed that either an overall reduction in resource consumption will have to take place globally, but especially in the northern hemisphere, or substantial increases in land use sectors productivity, especially in the southern hemisphere are needed. It has been assumed that the more pristine forest and biodiversity one wishes to conserve, the more important it will be to look for solutions that can address the limitations of biophysical and technical options by, for example, influencing demand patterns. In addition to the obvious trade-offs identified for the energy sector in this article, demands in other sectors, such as food consumption of food and other products, will be

important policy targets in the future. Another possible consequence of these protection efforts could be the increasing introduction of socioeconomic tools, with behavioral change being targeted on a global level.

There will be relatively high GHG emissions even under high bioenergy use due to deforestation, agriculture, and natural decomposition processes. However, the scenarios show that a deforestation minimization target will help to reduce the GHG emissions substantially. Consequently, well designed mechanisms for reducing emissions from deforestation and forest degradation (REDD) will be crucial for GHG emission reductions and may also contribute to protection of forest biodiversity (Strassburg et al. 2012). When assessing the relative benefits of bioenergy one also has to consider that sustainable bioenergy is renewable, unlike fossil energy. Moreover, in the future, development of technologies like biomass energy with carbon capture and storage (BECCS) may make bioenergy carbon-neutral or even carbon-saving (Obersteiner et al. 2001; Kraxner et al. 2003; 2014a; Fuss et al. 2013). However, since this chapter focused only on land-use emissions, no conclusions on the total effect of bioenergy on GHG emissions can be drawn. For this, an evaluation of a full life cycle assessment of GHG emission impacts would be needed.

This chapter is based on global integrated modeling of biomass production and land use. By necessity, certain assumptions and simplifications have to be made as compared to stand-level and landscape-level modeling. Availability and quality of data as input to the models is one important restriction to the feasibility of global modeling. Moreover, the scenarios should be regarded as projections, rather than predictions of the future. It is notoriously difficult to predict what will be the leading technologies, products and markets of the future. In this chapter, for instance, a large part of our future bioenergy consumption is assumed to be second-generation biofuels, and thus research and development need to focus on technical and practical solutions today to ensure that future energy demands can be satisfied in this way (Sims et al. 2010). Nevertheless, it is desirable that this chapter will serve as an example of the kind of studies needed for guiding future policymaking and research.

To conclude, this chapter aims at highlighting some factors that are crucial to the outcome of an integrated global assessment like the present chapter. First, to enable intensified production of

agricultural commodities as well as intensified production of bioenergy, mainly from forest plantations, production is allocated to areas with the highest productivity globally. Thus, well founded assumptions have to be made on agricultural and forest productivity. Consequently, and only under the condition of functioning trade, optimization of land use and zoning can be achieved (e.g., land sharing vs. land sparing (Phalan et al. 2011)). Second, the production of bioenergy might be allocated to managed forests, to plantations, or even to pristine forests. Thus, to achieve both an efficient and sustainable production of bioenergy it needs to take into account i) how much biomass can be mobilized additionally from managed forests; ii) how much the forest area under management can be expanded, and where this expansion is to take place; and iii) sustainability criteria for global, national, and regional levels. Third, safeguard mechanisms have to be considered, such as certification, and land cover uncertainty (i.e., what is the real land reserve on which one can, for instance, produce additional bioenergy). Finally, it is necessary to take into account the access to these land resources in terms of biophysical, legal, logistic, economic, and socioeconomic accessibility.

The projections presented in this chapter regarding trade-offs between deforestation, land-use change, and other climate effective aspects such as GHG emissions or water consumption make urgent action with respect to policymaking and good governance inevitable. Renewable energy policies and forest policies should directly address deforestation and forest degradation linked to bioenergy production in order to avoid undesirable effects or even perverse incentives (Searchinger et al. 2010). Moreover, the need for transdisciplinary research in this field is immense (McCarl 2010). To work toward a broad and mainly renewable resources-based energy portofolio by 2050, focus on intensification, and technological and behavioral shifts are needed to minimize the negative effects of trade-offs from deforestation and forest degradation. Various policy areas, inter alia, energy, climate, land-use and rural development, need to be coordinated at all geographic levels and supported by integrated assessments to ensure sustainable use of our common resources.

2.2 Global and Regional Forest Management Certification

The previous chapter has identified possible tradeoffs between the increased production of biomass for bioenergy and environmental concerns or food security and accelerated land use. The objective of this chapter is to provide - with the help of statistical analysis of data derived from recent literature – and overview on the certification tool which is considered a potential global safeguard for the sustainable development of bioenergy systems.

MacDicken et al. (2015) describe the production of forest goods and services for the present and future generations as what is commonly understood as "Sustainable Forest Management" (SFM). According to their research, the promise of sustainability is rooted in the two premises: a) that ecosystems have the potential to renew themselves, and b) that economic activities and social perceptions or values that define human interaction with the environment are choices that can be modified to ensure the long term productivity and health of the ecosystem. SFM addresses a great challenge in matching the increasing demands of a growing world population while maintaining ecological functions of healthy forest ecosystems. Consequently, SFM can be considered as crucial challenge for any sound use of forest biomass-based bioenergy systems as considered throughout this thesis.

However, determining progress toward SFM at the global scale is difficult. This is in part because the definition of what makes forest management sustainable is not universally agreed. On the other hand, data on SFM is scarce and monitoring still a large challenge. One way to deal with these shortcomings is to use forest certification (FC) as a proxy for SFM, since criteria and indicators used for SFM and for forest management certification are closely connected (ITTO 2007; Rametsteiner and Simula 2003) – and forest certification is a reasonable indicator of trends in SFM.

The following chapter aims at providing an overview on forest certification at the global and regional scale since all studies and their assumptions included in this thesis are operating on the principles of SFM and FC. While the global bioenergy scenarios have been elaborated jointly with WWF who is a driving power behind FC, the modeling activities for the regional articles on South Korea and Japan

have been based on SFM assumptions and the local studies for rural Japan indicate the importance of public knowledge on FC with respect to the rural development opportunities.

Forest Certification Background

In forest management, there are always tradeoffs between the different uses of forests such as timber production, recreation, habitat for biodiversity, water management, animal husbandry, or the rights of indigenous people and local communities. To capture all different services and uses of forests and balance them, the concept of SFM was developed. The failure of the United Nations Rio Summit to agree upon a forest convention on sustainable forestry inspired the first private certification schemes to start in 1993 (Rametsteiner and Simula 2003). Consequently, forest certification was initially pushed by environmental groups to address concerns about deforestation and forest degradation and to promote the maintenance of biodiversity. From there, it developed into a tool for the implementation of sustainable forest management. Many certification schemes have since emerged, two of which are clearly dominant: the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC).

According to Kraxner et al. (2015a), much has been published on comparisons and assessments between the two schemes (cf. Gulbrandsen 2005; Romero et al. 2013). A long list of literature concentrates on certification and environmental governance, performance, ecosystem services, as well as trust and cooperation between relevant NGO's and forest owners (cf. Elbakidze et al. 2011; Roberge et al. 2011; Johansson et al. 2013; Visseren-Hamakers and Pattberg 2013). Other authors have investigated the questions of price premia for certified timber, consumer awareness and sustainability in the production chain, or conducted cost-benefit-assessments of certification as a market-based tool for forest products (Hansen et al. 2006; Ebeling and Yasué 2009; Kraxner et al. 2009; Bouslah et al. 2010; Cubbage et al. 2010; Fernholz et al. 2013). Some of the literature also tackles the attitudes of the public and forest owners towards certification and sustainable forest management (cf. Rametsteiner and Kraxner 2003;Humphries and Kainer 2006; Oliver and Kraxner 2009; Chen et al. 2010; Creamer et al. 2012). However, in general there is only very limited useful and reliable statistical data available that would allow for inclusion of certification in empirical or

modeling-related research. The Forest Products Annual Market Review published by the United Nations' Economic Commission for Europe (UNECE/FAO) is considered the single independent and holistic statistical overview on FC data globally (Fernholz et al. 2015), which also builds the framework of the following sub-chapters.

Global Certification – Status-Quo

By May 2015, the major certification schemes – FSC and PEFC – reported a total global gross area of 446.5 million hectares (Fig.13) under their individual (endorsed) certification standards – about 10% of the total global forest area. Compared to the previous year's observation, the total certified forest area grew by 6.2 million hectares (Fernholz et al. 2015). This is about 10 million hectares less absolute growth than it could be indicated in the last year's observation. Moreover, the absolute growth has been shrinking already over the past 2 years while during the observation period 2012 - 2013 still an absolute growth of more than 30 million hectares were observed. In relative figures, this means a total up by only 1.4% from the previous year.

With respect to the individual performance of the schemes this means that from May 2014- May 2015, the FSC could increase its certified area by 1 million hectares (0.6% up) which is about half the growth during the previous period. The PEFC certified some additional 5 million hectares (2% up) which also means that their growth shrunk by about half compared to the previous period. However, please note that PEFC data only up to and including December 2014 is included in these calculations. A large difference has been noted with respect to the countries in which the two schemes are active. While the PEFC reported to be actively certifying totally 263.2 million hectares in 31 countries (3 countries more than in the last survey), the FSC certified its 183.3 million hectares in the same 81 countries like during the previous year.

The estimated overlap of 7.5 million hectares due to double certification did not change from the year before. More than two thirds of the double certification occurs in Europe (3.5 million hectares) and North America (2.6 million hectares). When accounting for this double certification, the world's total

certified forest area by mid-2015 amounts to about 439 million hectares which is 10.9% of the total global forest area (4,033 million hectares).

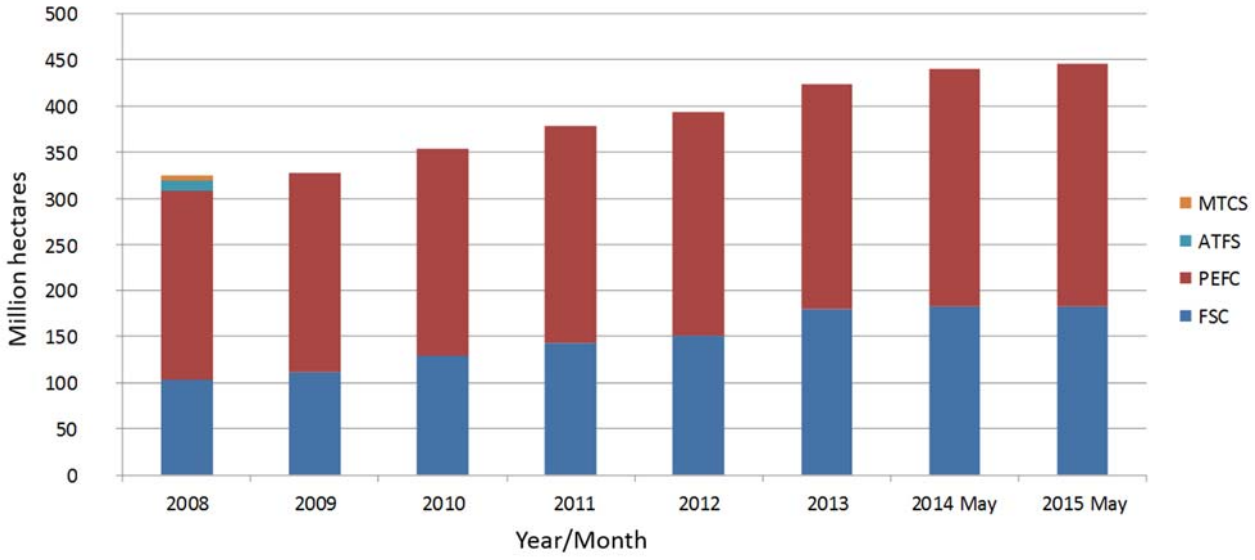

Figure 13. Forest area certified by major certification schemes 2008-2015. Notes: Data cover all FSC- and PEFC-certified forest land together with land certified under the following large national certification systems: Malaysian Timber Certification System (MTCS), American Tree Farm System (ATFS). Data for national systems subsequently endorsed by PEFC (MTCS, ATFS, SFI, CSA) are amalgamated into the PEFC data and not shown separately after the date of endorsement. The shown statistics do not consider an estimated overlap of 7.5 million hectares (by May 2015). FSC data by May 2015. PEFC data up to and including December 2014. Source: adapted after Fernholz et al. (2015).

Based on the publicly available statistics provided by the two major certification schemes it might be concluded that both schemes are presently struggling with certifying additional area. This might be a consequence of having already certified most of the western part of the northern hemisphere that is operating with comparable forest management regimes. When it comes to countries of Eurasia or the tropical/southern hemisphere (see next sub-chapter), the success and speed of forest management certification - as it could be faced during the earlier years - seems not to be the same anymore. Development data and curves as shown in Figures13 - 15 underpin such assessments. A significant change with respect to the northern hemisphere might come again with a stronger involvement in Russia and Siberia/Far East. However, this would not yet solve the clear underrepresentation of the

southern and tropical hemisphere within the country portfolios of both schemes. The so-to-say “low-hanging” fruits have been already certified or their schemes have been endorsed and further growth - especially in the south - seems still to be far away. It seems to be the time for a “re-invention” of forest management certification or at least the present statistics would recommend a diversification such as a further development of forest management certification into e.g. a safeguard monitoring tool under the Reduced Emissions through Deforestation and forest Degradation (REDD+) schemes presently under discussion. Certainly, this would need to be based on further scientific assessment of the schemes and potentially also a more diversified representation by the schemes themselves. The schemes might clearly benefit from an increased data transparency e.g. by supporting the necessary scientific analysis through providing the geographically explicit locations of certified forest area, combined with an enhanced collaboration with relevant experts in a trans-disciplinary manner.

For a possible inclusion of certification schemes into REDD+ schemes in order to e.g. ensure sustainable forest management and monitor illegal logging etc., further certification drivers and incentives might need to be assessed and investigated in a joint effort by the large certification bodies and the related Research and Development sectors.

Regional Aspects and Trends

According to Fernholz et al. (2015), slightly less than 90% of the globally certified area is still located in the northern hemisphere (Fig.14). This fact might be seen as an indicator for the success of forest management certification in northern regions such as Europe or North America. However, forest certification could not yet become established in the southern hemisphere with its abundant tropical and sub-tropical forest areas that are especially exposed to threats such as deforestation and forest degradation through official licensing and illegal logging.

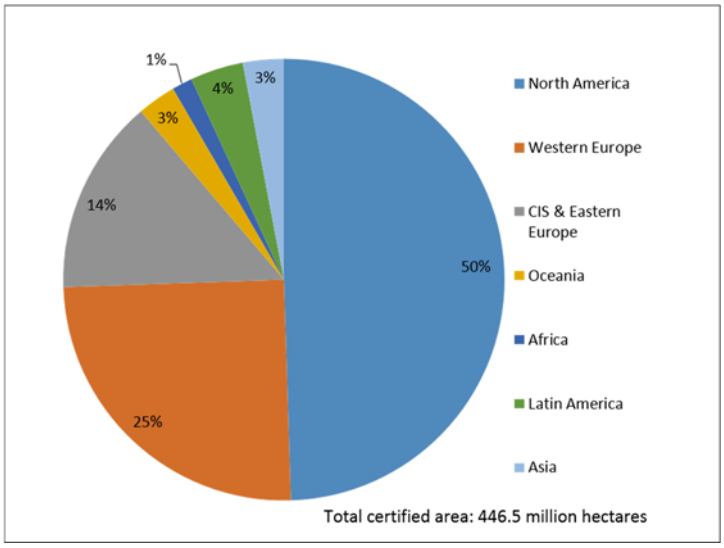

Figure 14. Regional Shares of Total Global Forest Management Certification 2014-2015. Notes: Data cover all FSC- and PEFC-certified forest land. Data for national systems subsequently endorsed by PEFC (MTCS, ATFS, SFI, CSA) are amalgamated into the PEFC data. The shown statistics consider an estimated overlap of 7.5 million hectares (by May 2015). FSC data by May 2015. PEFC data up to and including December 2014. Source: adapted after Fernholz et al. (2015).

Figure 15 indicates the certification development trends by the two large certification schemes in each of the 7 world regions over the past 3 years of observation (2013-2015).

The forest area certified by PEFC clearly dominates the scene. The PEFC holds most of its certified forest area in North America with twice as many hectares certified than in Western Europe while certifying only smaller areas in CIS and Eastern Europe, Oceania, Asia and Latin America. Figure 15 also shows that, to date, there is still no certified forest area endorsed by PEFC in Africa. In contrast to previous years, and also with respect to its competitor, the PEFC could report additional certified area in all regions of its activity – even though rather small increases. The highest increase – usually located in North America - the PEFC could show during the last year for Western Europe, followed by CIS & Eastern Europe and Latin America, and almost stagnating rates in Asia and Oceania.

The regions of CIS with Eastern Europe and Western Europe have been the growth areas for the FSC, while Africa stagnated and the other regions showed a negative growth. The FSC still holds its largest share in North America, followed by the countries included in the CIS & Eastern European region

and Western Europe. However, further to CIS & Eastern Europe, also in Latin America, Asia and Africa, FSC is significantly superseding the PEFC, although at relatively low levels (Fig. 15).

Note that small losses in certified forest area over a year can always occur due to non-extension or review of existing certificates.

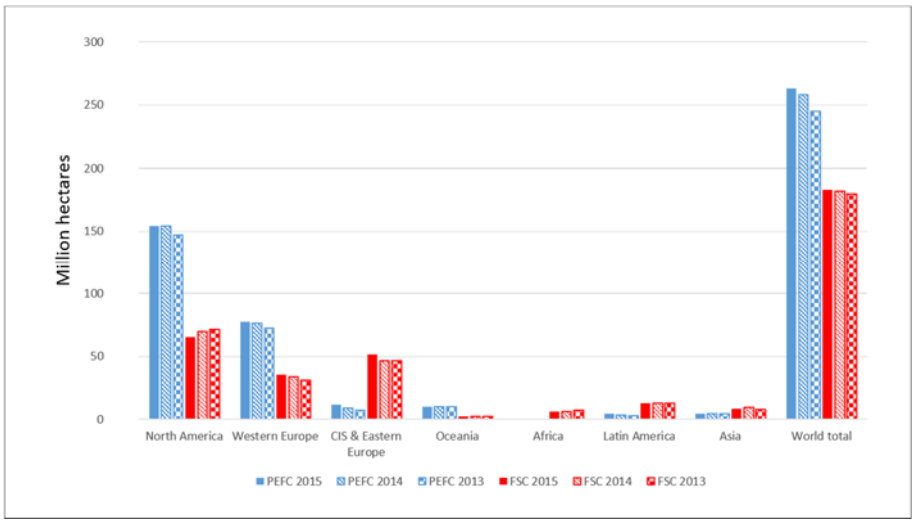

Figure 15. Certified forest area development by region and certification scheme 2013-2015. Notes: Data cover all FSC- and PEFC-certified forest land. Data for national systems subsequently endorsed by PEFC (MTCS, ATFS, SFI, CSA) are amalgamated into the PEFC data. The shown statistics consider an estimated overlap of 7.5 million hectares (by May 2015). FSC data by May 2015. PEFC data up to and including December 2014. Source: adapted after Fernholz et al. (2015).

Overall, it can be said that during the period of May 2014 – May 2015, the (FSC and PEFC) certified forest area in the CIS & Eastern Europe category featured the highest gains in absolute (plus 7.4 million hectares) and relative terms (plus 13%), followed by Europe and Latin America. On the other hand it is demonstrated in Figure 15, that the highest absolute loss could be identified (mainly based on FSC - losses) in North America (minus 4 million hectares, minus 2%), and the largest relative losses (also based on a reduction of FSC certified area) with Asia (minus 1 million hectares, minus 6.5%).

Certified Forest Timber Production Potential

Even though there has been constant increases of about 20 to 30 million m^3 per year in the estimated amount of industrial roundwood production from certified forest area, Table 4 indicates that this trend

has clearly slowed over the past two observation periods (2014/2015) from total 523.5 million m^3 to 527.1 million m^3 (Fernholz et al. 2015). Still, slightly less than 30% of the total global roundwood production might originate from certified forest management. Due to losses in certified forest area in North America, there have been also losses in the produced roundwood from the remaining areas, resulting in a production of only 13.9% of the total global roundwood production from certified origin. During the past 2 years, the production from Western Europe clearly exceeded the one from North America, amounting to 14.6% of the roundwood production originating from certified forest area. While the production from the CIS and Eastern European region slightly gained, there has been a slight loss in the Asian production (Tab. 4).

Table 4. Potential global and regional supply of roundwood from certified resources, 2013-2015. Notes: The reference for forest area (excluding "other wooded land") and estimations for the industrial roundwood production from certified forests are based on FAO's State of the World's Forests 2010 data. The subregions' annual roundwood production from "forests available for wood supply" is multiplied by the percentage of the regions' certified forest area (i.e. it is assumed that the removals of industrial roundwood from each ha of certified forests is the same as the average for all forest available for wood supply). However, not all certified roundwood is sold with a label. 2015 covers May 2014 - May 2015, and 2013 and 2014 are also from May to May. "World" is not a simple total of the regions. Sources: Individual certification systems, Forest Certification Watch, the Canadian Sustainable Forestry Certification Coalition, 2015, FAO, 2010, and authors' compilation. Information valid as of May 2014. FSC data by May 2015. PEFC data up to and including December 2014. Source: adapted after Fernholz et al. (2015).

Region	Total forest area (million ha)	Regional forest area certified (million ha)			Regional share of global forest area certified (%)			Estimated industrial roundwood produced from certified forest (million m3)			Estimated certified industrial roundwood as share of total global roundwood production (%)		
		2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
North America	614.2	215.8	221.3	217.3	35.1	36.0	35.4	244.2	250.5	245.9	13.8	14.1	13.9
Western Europe	168.1	100.2	106.6	109.6	59.6	63.4	65.2	236.1	251.1	258.1	13.3	14.2	14.6
CIS	836.9	53.4	55.5	62.9	6.4	6.6	7.5	10.2	10.6	12.0	0.6	0.6	0.7
Oceania	191.4	11.9	12.6	12.5	6.2	6.6	6.5	3.4	3.6	3.6	0.2	0.2	0.2
Africa	674.4	7.5	6.4	6.5	1.1	1.0	1.0	2.2	1.9	2.0	0.1	0.1	0.1
Latin America	955.6	15.7	16.3	17.1	1.6	1.7	1.8	1.2	1.2	1.3	0.1	0.1	0.1
Asia	592.5	12.5	14.1	13.1	2.1	2.4	2.2	4.0	4.5	4.2	0.2	0.3	0.2
World total	**4033.1**	**417.0**	**432.8**	**439.0**	**10.3**	**10.7**	**10.9**	**501.4**	**523.5**	**527.1**	**28.3**	**29.6**	**29.8**

Chain-of-Custody Certification

Similarly to the forest area certification, the trend with chain of custody (CoC) certification is also slowing. If we have still seen a growth of 12% during the observation period 2013-2014, we have been facing a reduction during the last period to some 6% and further slowing down to 4.7% during the present observation period – amounting to 39,609 certificates in total which is a plus of 1,771 certificates from the previous year (Fig.16).

While both schemes could increase their growth by about 5%, the FSC clearly dominates to absolute CoC comparison through adding 1,258, totaling now 29,081 certificates. The PEFC could add 513, totaling now 10,591 certificates.

Also in this certification field, the schemes might be alerted by the slowing trends and additional efforts might need to be put into the promotion as well as into the scientific assessments of such loss in speed.

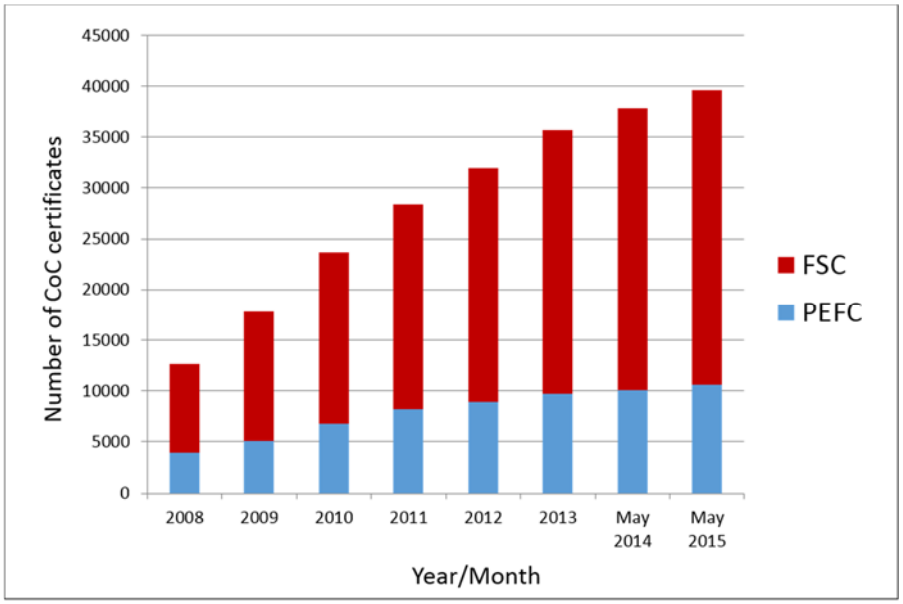

Figure 16. Chain-of-custody certified trends worldwide 2008-2015. Notes: The numbers denote CoC certificates irrespective of the size of the individual companies or of volume of production or trade. Information valid as of May 2015. FSC data by May 2015. PEFC data up to and including December 2014.Sources: FSC and PEFC, 2015. Source: modified after Fernholz et al. (2015).

Discussion and Conclusions

The use of wood and the management of the forest resource from which it is derived have influence across policies, markets and economies. The certification trends show that there are clear shortcomings to be resolved if a FC tool is considered to work as a global safeguard for SFM. Especially the imbalance between the different development and certification diffusion on the two hemispheres are reasons for concern. Tropical forest contains the largest biomass accumulated on its territory and has – given the excellent growth rate – also the highest potentials for biomass production for an increasing bioenergy sector. However, sustainability is at stake since SFM is a rare occasion in these areas and so is FC. Stronger focus has to be put on further increasing SFM in the tropical areas – with the clear and pro-active support of the certification schemes such as PEFC and FSC. On the other hand, certification is a voluntary action by the forest owner and a market-based tool that is most promising if price premia for forest products, or at least improved market access can be granted. In order to do so, the certification business needs to pro-actively develop their system further and put focus on global areas that are most vulnerable. In order to do so, a close collaboration with sustainability sector, industry and also science is desirable. The latter can provide valuable indications e.g. which areas are most promising to be addressed by focused promotion of certification. In turn, science needs to be provided with improved data and statistics from the certification schemes in order to build up tools that can be of mutual interest and benefit for the sustainability sector. In the northern hemisphere and highly industrialized countries, such activities need to be supported not only through official procurement regulations but also through capacity building in their own geographic area and beyond. There are many "northern champions" in the area of FC – e.g. Canada, Sweden, Finland, Austria (to only name a few) – but there are also highly forested countries such as Russia or Japan, where the certification development is lacking far behind its potential and so is knowledge about SFM and FC (e.g. Kraxner et al. 2009). Generally, improved knowledge about the forest, wood and wood products – e.g. as substitution for CO_2 intensive construction materials such as concrete – could help making the right choice by the consumers and raise their willingness to pay for sustainably produced

and certified products. One way to achieve improved knowledge among the general public are promotional activities and strong collaboration of the different forest sector industries.

The transition towards a green economy depends on the development of policies and market-based instruments that support further innovation and diversification in forest products markets (Fernholz et al. 2015). The EU Forest Strategy – as an example - and international trade agreements and timber regulations can have significant influence, along with non-regulatory systems such as voluntary certification programs, markets for ecosystem services, research findings, and green building innovations.

3 REGIONAL BIOMASS AND BIOENERGY IN KOREA AND JAPAN – ASSESSING THE MITIGATION POTENTIAL THROUGH BECCS

The previous chapter has focused on the global level assessment of sustainable biomass for bioenergy for the achievement of ambitious climate change mitigation targets. In this context, several sustainability tradeoffs have been identified and quantified. In order to take into account these tradeoffs and to ensure the sustainability of biomass cultivation for bioenergy, SFM has been forwarded as one of the most promising avenues to secure future biomass supply.

Yet, with climate change mitigation targets becoming ever more ambitious (tightening the 2°C goal further to 1.5°C in the latest climate negotiations of the UNFCCC in Paris in 2015), the role of bioenergy has gained even more importance in the global mitigation mix. In particular, with concentrations already being at 400 ppm, the remaining budget at 900 Gt CO_2 cumulative (Jackson et al. 2016) and many emissions already committed in terms of existing and planned infrastructure (Davis et al. 2010), it should not come as a surprise that many 2°C scenarios involve the option to extract CO_2 from the atmosphere. This can be achieved e.g. through an extension of terrestrial carbon sinks, for example by large-scale afforestation, but the technology mostly deployed in the pathways described in the latest IPCC report (IPCC 2014) is the combination of carbon-neutral bioenergy with carbon capture and storage (BECCS).That is, more CO_2 is captured and stored than actually emitted into the atmosphere. This is depicted in Figure 17 from the Handbook of Clean Energy Systems below (cf. Kraxner et al. 2015b; Fuss et al. 2014).

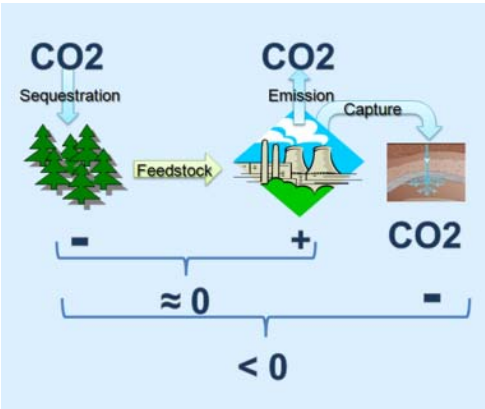

Figure 17. BECCS Concept. Source: modified after: Kraxner at al. (2015b).

While the concept of BECCS is behind most of the end of the century net negative emissions of ambitious climate stabilization pathways of the IPCC's latest Assessment Report (IPCC 2014) as illustrated in Figure 18, it is important to be aware of the fact that many of these pathways already include BECCS in the middle of the century. They only do not show up as net negative because they are not sufficiently negative in order to offset the remaining positive emissions earlier in the century.

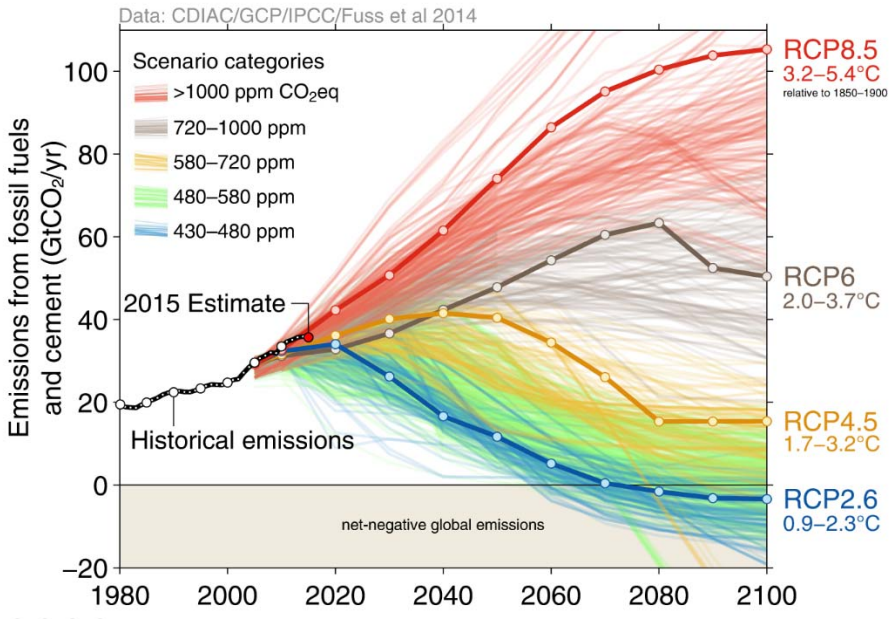

Figure 18. IPCC Fifth Assessment Report (AR5) emissions pathways for the four Representative Concentration Pathways following historical emissions until 2014 and the 2015 Global Carbon Budget estimate (Le Quéré et al. 2015). Source: adapted after Fuss et al. (2014)

This shows that the importance of biomass for bioenergy might be even more pronounced in the future. Yet, how does this play out at regional level? The introduction to this thesis has illustrated that many of the more productive regions in terms of biomass lie in the tropical basins. However, these are also the areas that feature the highest potential for conflict with other policy goals as concluded from Chapter 2. It is therefore necessary to look into regional level realities beyond the tropical basins. In this section such analyses are performed for the cases of Korea and Japan, which are not located in the tropical belt, but which do nevertheless feature (1) willingness to increase the share of renewables as part of their national energy plans, and (2) untapped potential from forestry biomass (in the case of Korea especially from newly afforested areas, in the case of Japan from existing, yet

unmanaged stocks, as well as from plantations that have reached their rotation length or are already over-aged such that natural disturbances might cause their loss) with opportunities for substantial co-benefits for environment and society.

This analysis requires also to go a step further and consider the proximity to suitable storage sites. Clearly, geographical analysis needs to be coupled to cost optimization and policy analysis in this case.

For both cases, a similar methodology has been applied in order to keep the assumptions as well as the results consistent for comparison. The models employed have been both tested and calibrated either in many national case studies or globally. For a detailed description and model webpages with additional explanations with respect to structure, calibration and validation, please see Annexes I and IV of this thesis.

Research questions at the regional level

1. Why is further bioenergy diffusion important at regional and global level?
2. What is the role of regions in low-stabilization pathways?
3. What is the bioenergy potential for the region of Korea and Japan?
4. Can we eventually go negative and how does such a strategy look like?

3.1 Bioenergy Modeling in Korea and Assessing its BECCS Potential

Introduction

The use of bioenergy in combination with carbon capture and storage (BECCS) could make a substantial contribution to achieving low atmospheric CO_2 concentration levels. As a result, there is an active debate on the potential of BECCS in the scientific community (Kraxner et al. 2014a). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) considers BECCS as "a potential rapid-response prevention strategy for abrupt climate change" and thus as one of the options for achieving compliance with the targets agreed under the Kyoto Protocol (IPCC 2005; 2014). Also the International Energy Agency (IEA) advocates the special advantages of BECCS in their recent policy strategy report (IEA 2012) and various economic assessments state that by the inclusion of negative emission technologies in the energy portfolios substantive cost reductions in climate stabilization strategies could be achieved (e.g. Lemoine et al. 2011). During the last decade various authors (Obersteiner et al. 2001; Kraxner et al. 2003, Azar et al. 2010) have demonstrated that terrestrial ecosystems can offer a permanent carbon sink if biomass is used to produce energy and the carbon from biomass conversion facilities is captured and permanently stored in geological formations. However, compared with conventional fossil fuel systems plus carbon capture and storage, very little information can be found in the scientific literature on the technical aspects of BECCS or its potential applications. Moreover, apart from engineering papers presented at energy conferences such as the World Renewable Energy Congress (WREC) in 2011 (Kraxner et al. 2011d), or at special BECCS conferences and workshops, for example the Bio-CCS workshop series held in 2010 at the University of Orleans (Kraxner et al. 2010a), France, and in 2011 at Cardiff University in UK (Kraxner et al. 2011b), or at the IEA-IIASA BECCS Experts Workshop held in 2011 in Laxenburg, Austria, there was no literature identified that features geographically explicit BECCS applications, especially for non-European countries. With respect to literature on renewable energy in Korea, the biomass-based bioenergy sector is mostly not included in recent studies (e.g. Jun et al. 2010) or it plays a minor role in the assessments (e.g. Kim et al. 2011). The fact that the focus in the

relevant Korean literature is not put on bioenergy might be due to a) a still low share of the total energy production, and b) the recent attention to nuclear power after the Fukushima incident in nearby-Japan.

South Korea is an interesting study area for BECCS, as the country's forestry sector has only recently regained ecological and economic importance. Although the land base of South Korea is small, as much as 64% of the country is forested. As a result of the highly efficient and rapid national reforestation program of the 1970s in South Korea, the majority of forests have now reached age classes of 30 and 40 years, which means they need "intensive care" in terms of thinning and pruning or other sustainable forest management (SFM) activities such as harvesting and replanting. Silvicultural and forest management activities like these can generate a significant amount of raw material which can be used, for example, to produce wood chips and wood pellets.

South Korea is trying to build up its bioenergy sector for various reasons. On the one hand bioenergy should contribute to improve energy security by increasing the energy portfolio and simultaneously drive green economy (Kim et al. 2011), while on the other hand the energy sector should help reducing CO_2 emissions. The introduction of SFM is seen as the linking key between both paths and also as a crucial driving force. The government has introduced ambitious policies and plans for bioenergy production, for example, the "Low Carbon—Green Growth" initiative which is part of the National Energy Plan (KEMCO 2010). However, a lack of forestry infrastructure, such as adequate forest roads for important management activities like harvesting or replanting, makes biomass and related energy production too costly to undertake (Kraxner et al. 2009). Among others, the renewable energy sector is also facing strong competition from the lower-cost fossil and nuclear energy sectors - in 2009 the share of fossil electricity from Korea's total electricity generation was 65%, the nuclear electricity's share 29% and the fossil heat share of Korea's total heat production was 90% (IEA 2009). To develop and support improved and better-targeted policies in the area of energy, climate, and environment, while supporting related co-benefits such as rural development and activation/reactivation of sustainable forest management, policymakers in Korea must improve their ability to quantify the country's sustainable bioenergy potential. This would involve identifying

economically and biophysically optimized locations for new bioenergy plants and also adding value to this information by selecting locations with in situ potential for combining bioenergy with CCS technology.

The aim of the technical part of this section is threefold. First, it helps identify, in a geographically explicit manner, the biomass available from forests for bioenergy production under sustainable management conditions in South Korea. Second, it indicates the optimal size and location of green-field, forest biomass-based bioenergy CHP (coupled heat and power) technology plants. Third, it identifies the potential number and capacity of in situ BECCS units in South Korea.

Method and Models Applied

There are various types of CCS systems, such as underground geological storage, ocean storage, mineral carbonation, or for industrial use (e.g. enhanced oil recovery, EOR). In this chapter, CCS with post-combustion capture technology is considered for underground storage in geological formations in direct "in situ" storage, namely, storage in the immediate vicinity of the combustion units (CHP plants) such that transport costs and other obstacles are minimized. For this case study, it has been also assumed that all CO_2 emissions generated by a BECCS unit (in this case a CHP plant coupled with in-situ CCS) will be captured and stored. Furthermore, an assessment to examine the technical potential of bioenergy production from domestic forest biomass has been undertaken. This was used as the basis for a policy discussion on the suitability of BECCS as a mitigation tool in South Korea. In a first step, the biophysical global forestry model G4M (Kindermann et al. 2008b) has been applied to estimate biomass availability. In a second step, the biomass results from the forestry model has been used as input data to the engineering model BeWhere (Leduc et al. 2009) for optimized scaling and locating of CHP plants. The geographically explicit locations and capacities for forest-based bioenergy plants thus obtained were subsequently overlaid with a map of geological suitability for carbon storage in a third step. From this, a theoretical potential for "in situ" BECCS was derived.

The Global Forest Model (G4M)

IIASA's Global Forest Model (G4M) was used to calculate the forest growing stock and the sustainable biomass extraction rate. G4M, as described by (Kindermann et al. 2008b and in the

introductory part as well as in the Annex I of this thesis) and, was developed to predict wood increment and stocking biomass in forests. As an input parameter it uses yield power, which is derived from the net primary productivity (NPP) for a specific region. This NPP can be supplied by existing NPP maps (e.g. Running 1994) or, for higher accuracy, estimated using driver information of soil, temperature, and precipitation. The model can be used like common yield tables to estimate the increment for a specific rotation time. It can also be used to estimate the increment-related optimal rotation time and to provide information on how much biomass can be harvested under a certain rotation time as well as how much biomass is stocking in the forest. G4M also supplies information on harvesting losses like needles, leaves, and branches which typically remain in forests under sustainable management. Other economic parameters such as harvesting costs—depending on tree size and slope—can also be calculated using G4M (for details on model structure, parameterization, calibration and validation see the extended description in Annex I to this thesis as well as the model webpage www.iiasa.ac.at/g4m.

The BeWhere Model

The BeWhere model, a spatially explicit optimization model depicting the supply chain of bioenergy industries, was used for the in situ BECCS assessment and has been described by Leduc et al. (2009), and further explained in the introductory and Annex IV section of this thesis. The model, developed at IIASA, considers industries that compete for wood resources. On the supply side, forest wood harvests, sawmill co-products (SCP), and wood imports serve as biomass resources for possible new bioenergy plants. On the demand side, the demand for wood of pulp and paper mills, existing bioenergy plants, and private households was considered. The model assumes that the existing wood demand has to be filled, and allows new plants to be built only if there is a surplus of wood available. The model is spatially explicit, and the transportation of wood from biomass supply to demand spots by truck, train, or ship is considered. The model selects optimal locations for green-field bioenergy plants by minimizing the costs of biomass supply, biomass transport, and energy distribution. The full costs and emissions at the optimal locations were calculated such that it was possible to indicate the technical BECCS potential for South Korea. G4M estimated and provided spatial distribution of

forestry yields, the harvesting costs (as a function of tree size depending on site quality and rotation time), and the slope steepness.

Results

Three main complementary sets of results were derived from this chapter and indicated at country level. These were: 1) the sustainably available biomass potential for harvest, together with the national heat demand, as the main prerequisite for installation of green-field CHP plants; 2) the geological suitability for carbon storage (CS); and 3) the locations identified for BECCS units, together with their individual bioenergy production capacity and their carbon capture and storage capacity. All the geographically explicit data sets presented were compiled at a 0.25-deg (degree grid cell) resolution (25 x 25 km). A commonly used conversion factor of 0.5 (cf. Leduc et al. 2009) has been applied to estimate dry matter biomass (tons of dry matter, tdm) from stem volume, irrespective of tree species. The forest harvesting scenarios defined were based on the amount of biomass extracted, while the baseline for harvesting was considered under a sustainable forest management regime, assuming that the average annual harvesting rate is substantially lower than the annual allowable cut. Furthermore, it has been assumed that only stem biomass was extracted from the forest stands and that 100% of the extracted biomass was used for energy production. The following conversion factor for the national currency was applied for economic calculations of harvesting, transport, and energy (heat) costs: 1 Korean Won = 0.000908987 USD (2008).

Biomass availability and energy demand

For this analysis, a managed forest area of 4,852,330 hectares (about 78% of the total South Korean forest area) has been assigned for biomass extraction dedicated to energy production. This forest area was modeled as an aggregated forest cover map based on GLC 2000 (JRC 2000), the Relative Human Influence concept for each terrestrial biome (WCS-CIESIN 2005), and a classification of pristine and non-pristine forest (FAO 2005) and protected area (UNEP-WCMC 2009). In order to restrict the source of wood supply mainly to managed forest (sustainability criteria), any forest area where the Relative Human Influence was less than 50% and locations of protected areas designated by Categories I–VI of the International Union for Conservation of Nature (IUCN) has been excluded.

For the geographical distribution of the actual growing stock 555,363,300 m^3 (protected area excluded) have been calculated, using the global biomass map (Kindermann et al. 2008b) harmonized with 2005 statistics of the Food and Agriculture Organization (FAO) (FAO 2005) — the official national statistics of South Korea report a total growing stock of 506,376,806 m^3 for 2005 (KFS 2009). Derived from Korean forest statistics in 2008, the biomass extracted annually for energy production has been limited to 0.36% of the total growing stock (sustainable forest management criteria), amounting to 999,653 tdm/year (on average 1.62 tdm/ha per year). See Figure 19 for spatial distribution. Further information for the economic optimization process with respect to costs (wood chip and stumpage price, harvesting and extraction costs) were derived from various South Korean resources referred to during this section and adapted to local slope conditions for harvesting operations with different technologies (cf. Leduc et al. 2009).

In South Korea the total heat energy consumption was 625,915 GJ/year in 2008 (KEMCO 2010). As input to the energy demand calculations, the heat demand has been geographically weighted with the population for 2005 at a 0.25 degree resolution and assumed that the average heat demand per person was 0.0127 GJ/person (Fig. 19). The average energy prices for Korea in 2008 were adapted from the national statistics.

The supply–demand optimization routines of the BeWhere model were also used to consider transportation costs (truck, train, ship: derived from (Börjesson and Gustavsson 1996)), as well as the existing road and railway networks for South Korea which were taken from vmap0 (VMAP0 1997), as well as different travel speeds.

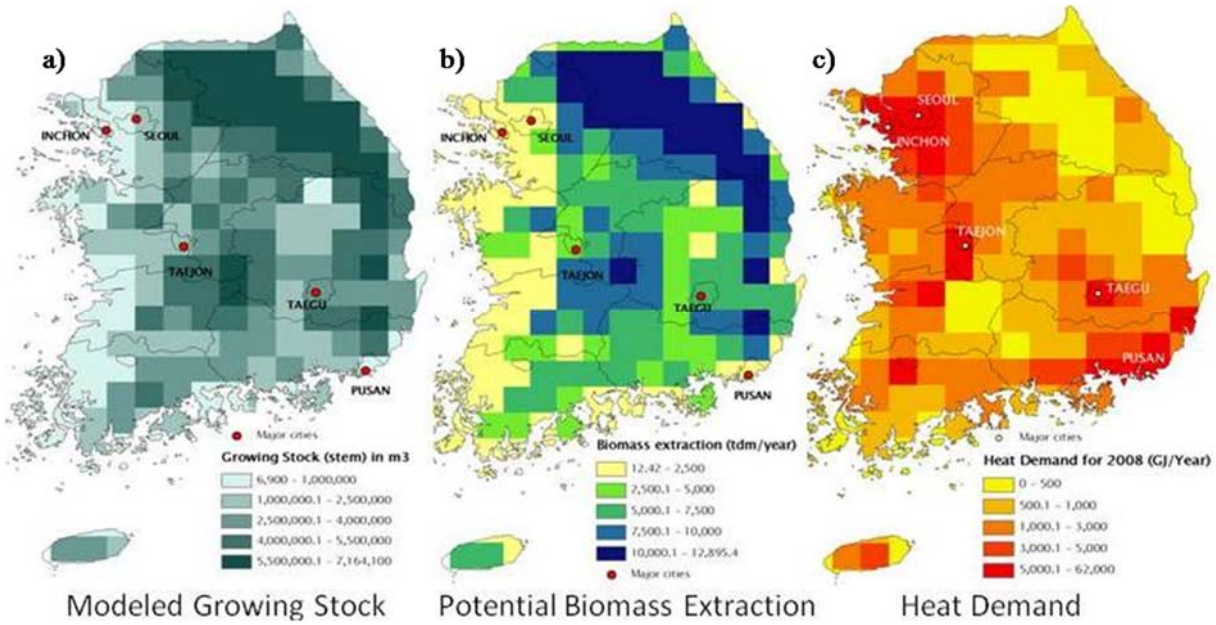

Figure 19. Geographically explicit supply–demand situation for Korea. The map on the left hand side (a)) indicates the modeled spatial distribution of the growing stock (m^3) in South Korean forests (biomass supply). The highest growing stock could be identified in the northeast and center of South Korea (dark pixels). The map in the center (b)) indicates the modeled potential biomass extraction rate (tdm/year)—under sustainable conditions— from South Korean forests (biomass supply). The highest biomass extraction rates could also be achieved in the northeast and center of the country. The map on the right-hand side (c)) indicates the modeled spatial distribution of heat demand (GJ/year). The highest heat demand was identified around the large urbanized areas (e.g., Seoul) in the western and southeastern parts of the country. Source: modified after Kraxner et al. (2014a).

Identification of geological suitability for carbon storage

A geological CS facility can be installed only under specific conditions; for instance, the geological characteristics (e.g., tectonic activity, sediment type, geothermal, and hydrodynamic regimes) of an area must be suitable and the infrastructure mature enough to build CCS units. In general, sedimentary basins are the sites with the highest potential for geological CS. Suitable sites for geological CO_2 storage can be found in: 1) basins formed in mid-continental locations; 2) basins formed near the edge of stable continental plates; 3) basins behind mountains formed by plate collision, such as the European basins immediately north of the Alps and Carpathians; 4) fold belts; and 5) other elevated areas (e.g. IPCC 2005; IPCC 2014). Other geological formations such as shield areas (e.g., Scandinavia) or tectonically active areas (e.g., Japan) are less suitable for geological CO_2 storage.

However, geological suitability for CS depends to a large extent on local conditions. In South Korea, basins as the potentially most suitable locations for geological in situ CS have been identified. The geological map shown in Fig. 20 was based mainly on the studies by Bradshaw and Dance (2004) and USGS (2001). It is possible for CO_2 injection sites to be physically remote from the bioenergy plant sites where CO_2 emissions occur. In the case of South Korea the geological Gyeongsang Basin located in the southeast of the country was identified as the main site that could be suitable for in situ CS.

Figure 20. Potential locations (geological province) suitable for geological CO_2 storage in South Korea (onshore only). Source: modified after Bradshaw and Dance (2004), USGS (2001), and Kraxner et al. (2014a).

Potential in situ BECCS units identified for South Korea

To identify the optimal locations for green-field bioenergy plants, three different scenarios (5, 20, and 70 MW CHP plant capacities) are considered. It has been assumed that diversification with respect to plant size would result in a better distribution of plants within the country, as this usually also increases the co-benefits of bioenergy plants. It has also been expected to identify more bioenergy plants suitable for in situ CS. Within each scenario (plant capacity) the aim was to meet the target for the maximum sustainable biomass extraction (about 1 million tdm/year).

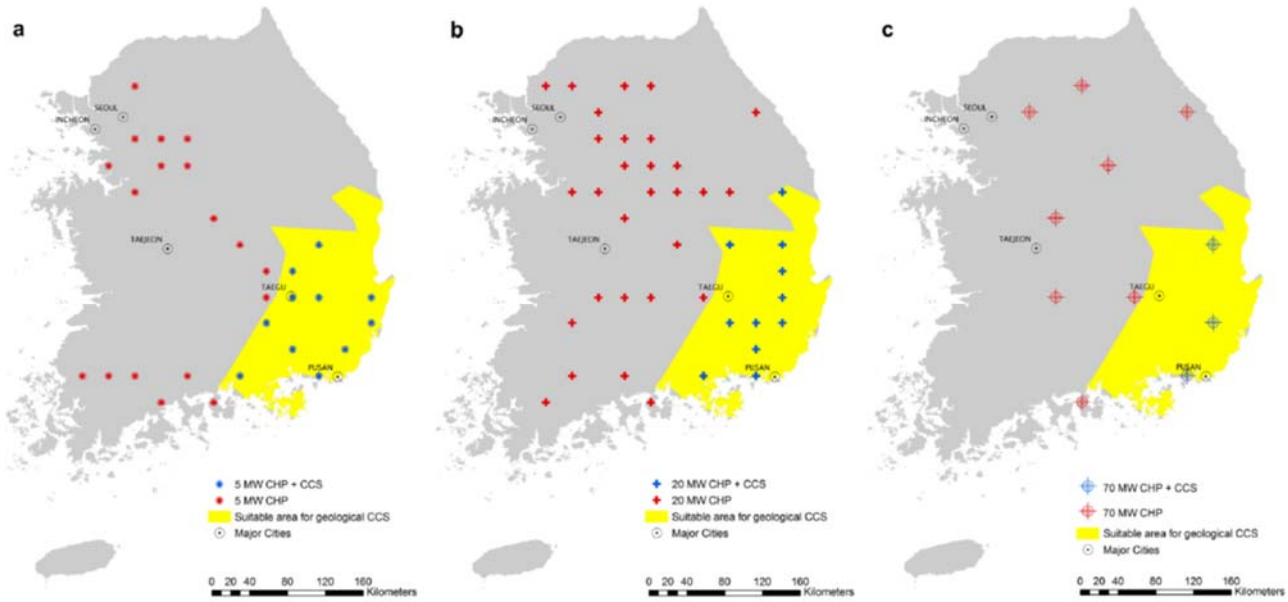

Figure 21. Three different scenarios (from left to right 5 (a)); 20 (b)); 70 (c)) MW) for optimized green-field biomass plant locations in South Korea. The geographic explicit location of bioenergy plants without CCS is indicated in red and the BECCS unit locations are indicated in blue on a light yellow background (geologically suitable formation for CS). Source: modified after Kraxner et al. (2014a).

For this chapter, it has been defined that in situ CS suitability in terms of the bioenergy plant needing to be located within a 0.5 degree grid cell (about 55 x 55 km) of the suitable geological province so that CO_2 could be directly injected underneath a plant or at any location up to a maximum of 25 km radius distance from the plant (e.g., using a short pipeline).

Based on these assumptions, Figure 21 shows the optimized location in a geographically explicit manner in each scenario. Table 5 indicates the optimized amount of green-field bioenergy plants for Korea, listed by plants with and without in situ CS suitability, divided into the different plant capacity scenarios.

Table 5. Energy produced, emissions substituted, and CCS capacity by forest biomass CHP plants with/without BECCS system under a sustainable forest biomass production regime. Source: modified after Kraxner et al. (2014a)

Plant size Technology	5 MW **NO** CCS	20 MW **NO** CCS	70 MW **NO** CCS	5 MW CCS	20 MW CCS	70 MW CCS
Plant #	18	29	8	11	11	3
Biomass used (tdm/year)	117,000	716,300	712,400	71,500	271,700	267,150
Heat produced (GJ/year)	1,190,475	7,288,353	7,248,670	727,513	2,764,548	2,718,251
El. produced (GJ/year)	757,575	4,638,043	4,612,790	462,963	1,759,258	1,729,796
Subst. emissions (tCO_2/year)	215,516	627,050	625,036	131,704	237,847	234,389
CCS Capacity (tCO2/year)	***0***	***0***	***0***	***131,704***	***237,847***	***234,389***

This study was able to identify a maximum of 40 green-field bioenergy plants under the 20 MW scenario, of which 11 plants were located on geologically suitable ground in accordance with the criteria for BECCS units. Under the 5 MW scenario, 29 bioenergy plants were optimally distributed over the country, of which 11 also qualified as BECCS plants. Under the 70 MW scenario a total of 11 bioenergy plants were computed, three of which met the criteria for BECCS units. Among the three scenarios the one with the 20 MW CHP capacity has been identified as the best case for the following reasons: a) The "BECCS effect" (emissions accounted for as negative) the 20 MW scenario reaches a potential capacity of 238,000 tons of CO2 for direct permanent storage underground per year and is hence slightly superior to the 70 MW scenario. Compared to the 5 MW scenario, it shows a 100 MW higher capacity. b) In the 20 MW scenario, the CHP plants make optimal use of the supplied resources in almost reaching the target for the maximum sustainable biomass extraction (about 988,000 tdm/year) and therefore also produce the highest amount of heat and electricity. c) Also with respect to achieving an even distribution of CHP plants over the country, the 20 MW scenario shows the best result while having at the same time 11 CHP plants placed on CS suitable geological ground. An even distribution over the country is assumed to be favorable for increasing the sustainable use of the forests and reduces the transport ways of wood to the CHP plants. Furthermore, it drives the value added in the rural areas which leads to a higher incentive for using thinning materials and other waste for bioenergy generation. Last but not least is assumed to be conducive for and over-all sustainable rural development.

However, based on different assumptions (e.g. the inclusion of industry of scale) the decision might shift to the 70MW scenario which is ranked second. Finally note that in this exercise, CO_2 emissions or energy losses caused by the technical processes involved within the BECCS unit (energy penalty) were not considered.

Discussion and Conclusions

This BECCS study offers several new insights into the bioenergy sector in South Korea and provides crucial information for policy support and design. First of all, it is important to note that even under rather conservative assumptions, especially with respect to sustainable biomass extraction, it still was

possible to theoretically produce around 10% of the present heat demand (equivalent to a 20-fold increment in the current bioenergy share for heat production in Korea (IEA 2009)), and 1.3% of the total electricity produced in South Korea (15 times the present bioenergy share for electricity production (IEA 2009)). These results indicate that there is a substantial potential for bioenergy growth in South Korea, especially given the present policies and targets of the National Energy Plan to, for example, increase the bioenergy share in total energy production from 0.2% (2007) to 3.4% by 2030 (KEMCO 2010). In addition, the broadening of the country's energy production portfolio with improved bioenergy and the closely linked BECCS technology would contribute to reduce investment risks in technologies under uncertainty given that the saved emissions are rewarded under a carbon credit (trading) system (Fuss et al. 2012). However, any bioenergy production should only be considered in the context of SFM and Avoiding Deforestation (AD) principles and criteria as outlined for example in Chapter 2 "Forests and Energy" in WWF's Living Forests Report in 2011 (WWF 2011). As also highlighted in a recent global study on feedstock for bioenergy by IIASA (Kraxner et al. 2013), there is a strong link of bioenergy production and Reducing Emissions from Deforestation and Degradation (REDD). Different REDD and Avoiding Deforestation policy schemes in a global context have been developed and suggested (e.g. Obersteiner et al. 2009).

Of the three different scenarios (plant capacities), the 20 MW scenario turned out to offer the best country-wide coverage with its 40 green-field bioenergy facilities, which consequently could provide direct and indirect co-benefits such as driving the green economy (i.e. providing job opportunities both at the facility and in the biomass production). Another major benefit of growth in the bioenergy sector would be the resulting investments in forest and forest management primarily by small-scale forest owners, for example, in forest infrastructure. These benefits would come from pricing biomass from thinning and other forest residues so that at least collection and transport would be covered. This would in turn help forest owners to invest in stabilizing forest health (e.g. through adequate forest management such as thinning or forest certification) and into forest infrastructure (e.g. forest roads to facilitate access and harvesting activities), which would consequently lower harvesting costs and by such increase the competitiveness of the local/regional forest sector. A strengthened forest sector

is seen as a crucial condition for sustainable development and contributes to a country's green economy (Kraxner et al. 2009).

Although the geological formations suitable for in situ CS in South Korea are limited to about one-fifth of the country area (the Gyeongsang Basin), this study could be used to show a theoretical potential for between 3 (70 MW plants) and 11 (5 or 20 MW plants) green-field BECCS plants with in situ CS. Based on this chapter's assumptions, the BECCS effect could remove 130,000–240,000 tons of CO_2 per year from the atmosphere, and a similar amount could be substituted for fossil fuel emissions. This means that about 3–4% of the total demand for heat energy in South Korea could be produced in BECCS plants with in situ CS. As a result, 3–4% of fossil fuel emissions could be substituted and additionally accounted for as negative, as they would be actively removed from the atmosphere by BECCS plants. The BECCS effect is in addition to the biomass co-benefits mentioned earlier and could be used as one key issue for future policy design and decision making.

In reality, this BECCS effect could be much higher since in this chapter only theoretical potentials without considering the costs and efficiencies of the actual CCS process have been considered. If bioenergy plants with higher capacities were introduced, costs could be substantially decreased (scale effect or poly-production). Further, although the geological formations suitable for geological and in-situ CCS in South Korea are limited (because, for example, of earthquake and volcanic activity), there are wide offshore prospective areas in this region (e.g., Japan Sea). Using further capacity for CS (i.e., not in situ), more or less all the emissions substituted from bioenergy production could additionally be stored and accounted for as negative. The use of a (transnational) CO_2 pipeline could actually boost the BECCS effect and lower the costs, but further research needs to be done in this field. The joint use of offshore CS together with, for example, Japan or Indonesia would substantially increase BECCS capacity. This would require similar research being extended to Southeast Asia, potentially using a higher data resolution than 0.25-deg.

The chapter concludes that policy-targeted bioenergy-based reactivation of forest management in South Korea would produce a real win–win situation. First, bioenergy production and BECCS would directly contribute to meeting ambitious climate change mitigation targets. Second, the forest

ecosystem would benefit from sustainable management (including thinning, etc.) for example, in terms of improved forest health, stand stability, and lower exposure to threatening hazards like wind throw or pests. Third, the forest owners—and with them the forest sector industry—would benefit from the forest property increasing in value, from better-priced forest products, from the grown timber being of higher quality, and from the competitive harvesting conditions resulting from investment in forest infrastructure. Last not least, society would benefit through, for instance, the forests' improved protective function (against flooding, landslides, avalanches, and other events) and an increase in its recreational value.

3.2 Bioenergy Modeling in Japan and Assessing its BECCS Potential

Introduction and Background

Similar to the Korean case study by Kraxner et al. (2014a), a BECCS assessment for Japan has been carried out in order to follow-up on the recommendations made by the Korean chapter – i.e. to seek for collaborative exploitation of geologically suitable CO_2 storage areas off-shore in the Japanese Sea. In order to do so, however, it is important to have a comparable study carried out on the bioenergy and BECCS potentials in Japan. Consequently, the study described below has been set up with the same methodology like the one developed for Korea in order to achieve utmost compatibility and a good basis for comparison.

Among an increasing list of scientists, e.g. Fuss et al. (2014) or Canadell and Schulze et al. (2014) state that bioenergy in combination with carbon capture and storage (BECCS) could remove CO_2 from the atmosphere in order to contribute substantially to achieving low levels of concentration (cf. Obersteiner et al. 2001; Kraxner et al. 2003, Azar et al. 2010; Kraxner et al. 2014a; Kraxner et al. 2014b). However, compared to fossil CCS (Carbon Capture and Storage), very little information can be found in scientific literature so far for both the technical and potential application of BECCS. Despite the urgent need of further insight and information on negative emissions and BECCS in particular, rather little studies with country or regional focus are available (cf. Sanchez et al. 2015a; 2015b). Moreover, apart from engineering papers presented at special BECCS conferences in Europe (e.g. Kraxner et al. 2010b; Kraxner et al. 2011a; Kraxner et al. 2011b; Kraxner 2011 c; Kraxner et al. 2014a), and the negative emissions workshops carried out by the Global Carbon Project (GCP) Tsukuba Office in Japan under their research initiative towards Managing Global Negative Emissions Technologies (MaGNET, cf. Yamagata and Sharifi 2015), to date no comprehensive study on biomass supply, demand and its combination with CCS has been carried on Japan (Kraxner et al. 2014b).

Further to the information on Japan in the thesis introduction, it is worth mentioning at this place that as a consequence of the strong economic growth during the 60ies – 80ies, the Japanese industry

moved towards fossil-based and nuclear energy supply. As a consequence, Japan's energy self-sufficiency rate fell from 20% to 6% after the Great Tohoku Earthquake followed by the Fukushima Daiichi nuclear disaster in 2011. Since then, basically only the renewable sector increased from 1% share of the total primary production (14,126 Petajoule, PJ) in 2012 to 4% in 2014. This steep increase has been due to an aggressive feed-in tariff system introduced in 2012, which showed strongest effects with respect to wind and PV power (IEA 2015b). In the area of bioenergy, there is a large potential indicated by the Ministry (METI) in Japan. To increase the share of renewable energy use in Japan, continuous and effective policy support is needed, especially a well-designed energy policy which is also economically viable. Furthermore, special incentives are needed in order to accelerate the development of the bioenergy sector in Japan. One of these incentives has been identified in BECCS.

The aim of the technical part of this chapter was threefold. 1) to help identifying - in a geographically explicit manner - the available biomass potential from forest for bioenergy production under sustainable management conditions in Japan (Kraxner et al. 2013); 2) to indicate the optimal size and location of green-field forest biomass-based bioenergy CHP (Coupled Heat and Power technology) plants; 3) to identify the amount and capacity of potential in-situ BECCS units in Japan.

Method

Given the intention to apply the same methodology in Korea and Japan, the section for the description of this methodology has been shortened to a minimum at this place of the thesis but can be read in detail in Chapter 3.1.

Also this chapter on Japan is especially aiming at direct "in-situ" storage of CO_2. It is assumed that the storage happens in direct vicinity to the combustion units (CHP plants) in order to minimize transport costs and complications. Further it has been assumed that the total amount of CO_2 - emissions generated at a BECCS unit will be captured and stored in-situ. A technical assessment was used to support a policy discussion on the suitability of this mitigation tool. First, the technical potential of bioenergy production from domestic forest biomass has been investigated. For this exercise, in a first step, the biophysical Global Forestry Model G4M (Kindermann et al. 2008b) was applied in order to estimate the biomass availability. In a second step, the biomass results from the

forestry model were used as input data for the engineering model BeWhere (Leduc et al. 2009) for optimized scaling and locating of CHP plants. The obtained geographically explicit locations and capacities for forest-based bioenergy plants were consequently overlaid with a geological suitability map for carbon storage. From this, a theoretical potential for "in-situ" BECCS was derived.

Results

There were 3 complementary main sets of results derived from this chapter and indicated at country level: 1) the sustainably available biomass potential for harvest together with the national heat demand as a main prerequisite for the installation of green-field CHP plants; 2) the geological suitability for CS (Carbon Storage); and 3) the identified locations for BECCS units together with their individual bioenergy production capacity as well as their CCS capacity.

About 41% of forest area in Japan is plantation forest. For sustainability reasons, this chapter focuses on the forest biomass as energy feedstock from coniferous plantations only. The model results for the sustainable amount of annual biomass extraction were calculated to range between 8-10 m^3/ha-year for Japanese cedar, 5-6.6 m^3/ha-year for Japanese Cypress and 3-4.6 m^3/ha-year for Japanese Larch. It has been assumed about 1.33 million m^3 (665,000 tdm/year) of stem biomass are utilized for heat and electricity production every year. This amount is about 0.05% of the total growing stock of coniferous plantations (2,335 million m^3) in 2007 (Forestry Agency 2007; Kraxner et al. 2010a).

Although the suitable geological formations for geological CS available in Japan seem to be limited (the land is mostly covered by volcanic terrain or craters), there are wide off-shore prospective areas in this region (e.g. Japan Sea). Especially basins have been identified as potential in-situ on-shore locations suitable for CO_2 geological storage in Japan and South Korea based on the studies by Bradshaw and Dance (2004) and USGS (2001) and Kraxner et al. (2014a).

To identify the optimal locations for green-field bioenergy plants, two different sizes of CHP plants are considered (10 and 50 MW). It has been assumed that diversification with respect to plant size would on the one hand result in a better distribution of plants within the country, which increases usually also the co-benefits of bioenergy plants. On the other hand it has been expected to identify

more bioenergy plants suitable for in-situ CS. Within each scenario (plant capacity) the aim was to meet the target for the maximum sustainable biomass extraction (about 665,000 tdm/year).

For this study, in-situ CS suitability has been defined such that the bioenergy plant needs to be located within a 0.5 degree grid cell (about 55 x 55 km) of the suitable geologic province in order to directly inject CO_2 underneath a bioenergy plant or at any place up to a maximum of 25 km radius distance (e.g. with the help of a short pipeline).

Based on these assumptions, Figure 22 shows the optimized location in a geographically explicit manner by plant size.

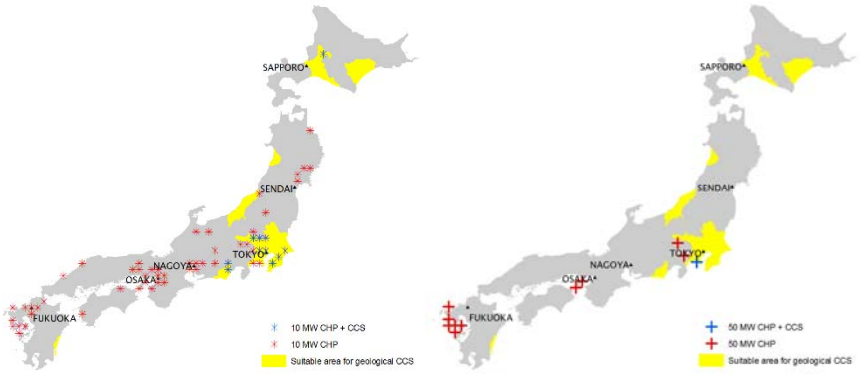

Figure 22. Two different scenarios (left: 10 MW, right: 50 MW) for optimized green-field biomass plant locations in Japan. Geographically explicit locations without BECCS shown in red color. In-situ BECCS unit locations indicated in blue color on light yellow background (geologically suitable formation for CS). Source: adapted after Kraxner et al. (2014b).

Table 6 indicates the optimized amount of green field bioenergy plants for Japan, listed by plants with and without in-situ CS suitability, divided into the different plant capacity categories.

The Japan chapter could identify a maximum of 77 green-field bioenergy plants, of which there are 66 under the 10 MW-scenario, indicating 10 plants on geologically suitable ground in order to meet the criteria for BECCS units. Under the 50 MW scenario, 11 bioenergy plants were optimally distributed over the country, among which only 1 plant qualified as BECCS plant. In the best case (10 MW scenario), the “BECCS-effect” (emissions accounted as negative) could reach a potential

capacity of some 1.5 million tons of CO2 to be directly stored permanently belowground per year and to be accounted as negative emissions.

Table 6. Energy produced sustainably, emissions substituted, CCS Capacity by CHP plant with/without BECCS. Source: adapted after Kraxner et al. (2014b).

Plant size/capacity	10 MW **NO** CCS	50 MW **NO** CCS	10 MW CCS	50 MW CCS
Plant #	50	10	11	1
Biomass used (tdm/year)	554,125	487,957	630,957	552,957
Heat produced (GJ/year)	6,613,750	6,613,750	8,068,775	7,275,125
El. produced (GJ/year)	4,208,750	4,208,750	5,134,675	4,629,625
Subst. emissions (tCO_2/year)	1,214,525	1,214,525	13,203,450	11,904,750
CCS Capacity (tCO2/year)	***0***	***0***	***1,481,721***	***1,335,978***

Discussion and Conclusion

This BECCS exercise offers several new insights to the bioenergy sector in Japan and provides crucial information for policy support and energy resilience design. First of all, it is important to note that even under conservative assumptions (e.g. sustainable biomass extraction, allowing only for the use of 0.05% of the total growing stock of coniferous plantations) - Japan could double the energy produced biomass and waste. These results indicate a substantial potential of bioenergy growth in Japan – especially given the present policies and targets of the National Energy Plan to e.g. increase the bioenergy share in total energy production and decrease the total GHG emissions by 25% in 2020 and 80% in 2050 (target as of 2010). However, this chapter also indicates, that a much higher share of the actual growing stock might need to be tapped for bioenergy production in order to achieve larger effects on the energy portfolio and energy security of such a highly industrialized country.

From the 2 different scenarios (plant capacities), the 10 MW scenario turned out to offer the best country-wide coverage with its 61 green-field bioenergy facilities, which consequently could provide direct and indirect co-benefits such as driving the green economy, i.e. providing job opportunities both at the facility and in the biomass production. Another major benefit of growth in the bioenergy sector would be the resulting investments in forest and forest management primarily by small-scale

forest owners, e.g. in forest infrastructure and sustainable forest management certification (Kraxner et al. 2009). These benefits are based on the assumption that forest biomass would see a price increase, which justifies investments into forest infrastructure (to improve forest access) which lowers harvesting costs and increases competitiveness.

Although the suitable geological formations for in-situ CS in Japan are limited to less than 10% of the country area (mainly concentrating on the Kanto Basin), with the help of this chapter it was possible to show that there is a theoretical potential for 1 (50 MW plants) to 10 (10 MW plants) green-field BECCS plants with in-situ CS. Based on this study's assumptions, the in-situ BECCS-effect might amount to 1,3 – 1,5 million tons CO_2 per year in addition to an amount of 12-13 million tons CO_2 per year substituted fossil fuel emissions. These BECCS- and emission reduction effects come in addition to the biomass co-benefits discussed earlier and could be used as a key issue for future policy design and decision makers.

However, the BECCS-effect - and with it a crucial lever for climate, environment and rural development policies - could be substantially increased and strengthened. An important caveat to bear in mind is that with this study only the theoretical potential could be pointed out without considering the costs of the actual CCS process. If bioenergy plants with higher capacities would be applied, costs could be substantially decreased (scale effect or poly-production). Further, although the suitable formations for geological CCS in Japan are very limited (e.g. earthquake and volcanic activity) there are considerable off-shore prospective areas in this region (e.g. Japan Sea). Using further capacity for CS (non in-situ), basically all substituted emission from bioenergy production could additionally be stored and accounted as negative. The use of a (trans-national) CO_2-pipeline could actually boost the BECCS effect and lower the costs, but further research needs to be done in this field. Also the joint use of off-shore CS together with e.g. South Korea (Kraxner et al. 2014a; b) would substantially increase Japan's BECCS capacity, which requires similar research to be extended to South East Asia, potentially using a higher data resolution than 0.25-deg. Compared to the assessment results from the Korea chapter, Japan shows a six times higher "BECCS" effect than Korea – and absolutely conservative assumptions (in both cases). Further research with refined assumptions and costing

modules need to be carried out in the region in order to achieve more robust results and increase the benefit for energy security, climate and sustainable management at the same time.

The chapter concludes that policy targeted bioenergy-based re-activation of forest management in Japan would evoke a real win-win-situation. First, bioenergy production and BECCS would directly contribute to meet ambitious climate change mitigation targets. Second, the forest ecosystem along with the final consumer of forest products would benefit from sustainable management and its certification (Kraxner et al. 2009). Third, the forest owners - and with them the forest sector industry - would benefit from an increased value of the forest property. And last not least, society would benefit through e.g. an improved protective function (from e.g. flooding, landslides, avalanches etc.) and an increased recreational value of the forest.

For possible future energy policies in Japan it seems to be most suitable to concentrate on bioenergy in a de-central small to medium scale – also from an economic view point and in order to realize most of co- and cross-benefits of bioenergy production. Carbon Capture and Storage (CCS), however, might be optimally clustered and potentially combined with large scale power plants and biomass co-firing technology.

4 LOCAL INSIGHTS IN RURAL AUSTRIA AND JAPAN

The previous chapter has been dedicated to reconciling the demand for negative emissions through BECCS with the realities at regional level, explicitly picking cases – Korea and Japan – which have ambitious renewable energy plans and opportunities for increasing their biomass harvests in a sustainable way. However, this analysis has remained at a rather technical level and the realities were of a biophysical and purely techno-economic nature. In order to achieve a transition towards bioenergy at local level, more detailed analysis is required, including an assessment of barriers to implementation due to adverse public opinion. In the case of Austria, many locations have managed to exploit synergies between bioenergy deployment and other goals, e.g. at municipality level (Chapter 4.1). For example, a carefully calibrated bioenergy strategy can help to create jobs and attract both tourists and young people to rural areas, thus revitalizing problem areas and integrating them back into the economy. Whether similar win-win strategies can be developed for locations in Japan is the main research question of the remainder of this section (Chapters 4.2 and 4.3).

As a background to this research, note that even though Japan is a highly forested country, only a small share of the timber demand is covered from domestic forest and a very minor share of it is used for bioenergy. However, the future forest sector will be strongly influenced by energy policies, which are designed to mitigate climate change and diversify the national energy portfolio to enhance energy security at the same time.

The study presented in Chapter 4.2 aims at analyzing Japanese awareness and attitudes towards forest bioenergy in order to discuss in a forward looking manner, how public opinion might influence the implementation of this promising energy sector including its multiple co-benefits in Japan. By using an integrated analysis of Japanese public opinion studies and experiences from forestry, bioenergy and green building from Central Europe, crucial drivers for the development, economy and innovative green business in rural areas of Japan have been identified. Logit models are used for analyzing the public opinion survey carried out in the southern rural town Yusuhara, Kochi Prefecture, in 2007.

Results show that bioenergy activities can positively impact political and socioeconomic conditions of local communities (carbon-neutral region, sustainable forest management, job creation, increase of community revenue, creation of regional value etc.). Regenerative heat and power production using regional forest biomass creates multiple regional values and might induce new markets, such as one for low-quality timber and wood residuals (e.g. sawdust and bark in the wood industry), which consequently steers vital forest management actions such as thinning. In addition, renewable energy supply systems can create new jobs and innovative green businesses in both feedstock and energy supplies. As a result, the local economy is stimulated and new job markets for additional services, e.g. in eco- and bioenergy tourism, might be created.

Chapter 4.3 describes a similar survey that had been carried out in Shimokawa Town, Hokkaido, in 2009. Rather similar methodology and questionnaires have been used in order to both validate the results of the Yusuhara study and to detect location-specific conditions important for an improved policy planning.

Both studies are unique for Japan in their character. The surveys among the rural public in these two towns combine forest management with sustainability aspects, and bioenergy questions with knowledge on certification systems for forests – in order to investigate the local attitudes of the public. A shrinking rural population makes such research very attractive since a successful revitalization of rural areas will to a large extend depend on the careful involvement of the local people and the abundant resource forest.

The studies conclude with advocating a synergetic approach by providing a set of essentials for a successful implementation of a vital and sustainable forest bioenergy sector in Japan, comprising policies, policy tools, public opinion and capacity building, and forest management and certification.

Research questions at the local level

1. What is the key of success for the Austrian bioenergy system?
2. What is the situation in local-rural Japan with respect to bioenergy and certification? To what extent does public opinion in local-rural Japan support a development pathway based on sustainable renewable energy strategies for rural revitalization?
3. Does the situation in different rural communities in Japan allow for similar development pathways like in Austria?
4. Why are socio-economic studies at local scale needed to achieve climate change mitigation targets also at regional and global levels and what does this imply for central policy making?

4.1 Austria and the Historical Bioenergy Development

Introduction, Objectives and Methods

Energy from forest biomass, commonly described as near carbon neutral, can be turned into heat, biofuels and various chemical materials. Renewable energy from biomass will play an essential role in reducing the carbon intensity of energy and decoupling energy use from CO_2 emissions (IEA 2015a; IEA 2015b). The wood energy sector will be strongly influenced and supported by energy policies aimed at mitigating climate change and diversifying the national energy portfolio to enhance energy security (e.g. Olsson et al. 2009). The objective of this section is to provide some special experiences from the Austrian bioenergy sector - which is largely based on forest biomass - that might serve as examples of regional sustainability. Anecdotal experiences have been collected in a literature review and are also largely based on Yamagata et al. 2010.

Results: overview and history of major forest bioenergy utilization in Austria

Austria is one of the pioneers of modern forest biomass utilization, with a history of market development for energy and fuelwood resources reaching back many centuries (Kraxner et al. 2007a; Yamagata et al. 2010). As a forest-rich country, fuelwood has always played a key role in industry, especially salt mining and steel production. The first sustainability regulations for forestry date back several centuries to when massive deforestation for mining and steel-making activities resulted in catastrophic soil erosion, mud slides, flooding and avalanches. In parallel with industrial development, the domestic use of fuelwood became increasingly sophisticated. Iron stoves replaced tile stoves to minimize wood fuel inputs, maximize heat output and increase user convenience (e.g. requiring refills only once a day).

In the early 1950s, forestry-related industries such as large sawmill companies started large-scale renewable heat production using biomass derived mainly from forestry and sawmill residues (Nemestothy 2006). In the mid-1980s, heating projects of various scales began to supply biomass energy to rural villages and towns. These projects usually began by supplying public buildings such

as schools, hospitals, nursing homes or town halls, and institutions such as village centers (Weiss and Rametsteiner 2005).

In the second step of expanding district heating, increasing numbers of private homes are being connected to extended heating grids for comfort reasons, and because heating with wood is seen as traditional in Austria. The installation of decentralized district heating plants has both co- and cross-benefits, such as steering local economies by paying for thinning products and other previously valueless forest residues, and job and value creation in rural areas. This development helped make vital forest-thinning measures economically feasible for local, small-scale forest owners, which contributed to improving forest quality and health.

Further technological advances in wood pellet heating systems have led to increased biomass utilization in private households since 1995. Biomass-fired combined heat and power (CHP) plant projects for both district heating and electricity production have been introduced throughout Austria since 2003.

Renewable energy use in Austria

Further to the information on Austria provided in the introduction to this thesis, it is relevant to mention at this place that by 2013, 30% of Austria's primary energy demand (1425 PJ) is covered from renewable energy out of which 14% is from forest-based bioenergy. Bioenergy itself is the most important renewable energy type with a share of 58%, followed by e.g. hydro power at a share of 36%. The biomass itself – 245 PJ is composed of fuelwood (25 %), wood chips and sawmill residues/bark (36%), , black liquor from paper production (13%), pellets (6%) and other resources such as biofuels, biogas, solid municipal waste and energy crops (20%). The share of renewable energy in gross electricity consumption was greater than 50% in 2013, which placed Austria top among the European Union (EU) countries (Statistik Austria 2015). Based on technology innovation in the bioenergy sector (i.e. certified biomass boilers, pellet stoves etc. in the domestic/private use), it could be demonstrated that the total Austrian emissions of PM10 and PM2.5 each could be reduced by 20% during the time period of 2001-2013 (LKNOe 2014), while the installed devices increased by 4 times. Modern biomass boilers often show very low PM10 and PM2.5 emissions while the

efficiencies of pellet and wood chip stoves could be almost doubled from 50% to 95% during the time period of 1980 t 2012. At the same time, the CO emissions could be reduced to almost 0 (Rathbauer and Lasselsberger 2016).

Background on the forest environment in Austria

Austria is a country with abundant wood resources and vast experience in forest management. Of the total land area, 3.96 million hectares (ha), or about 47%, is forested, and the country has an estimated growing stock of 1.1 billion solid m^3. The area of protected forest is 20% (BFW 2016).

A clear advantage for a successful development of the bioenergy sector is that forest management in rural Austria has always been considered as a stable investment into the future – even at low return rates compared to other industry sectors. Constantly, the forest infrastructure – i.e. forest roads – has been further developed, which has helped keeping the harvesting costs at a level that could compete with other large forest/timber producers such as Germany or the Nordic countries – even though harvesting under alpine conditions is considered much more difficult. In Austria, the road density is 49.1 m/ha for small forests less than 200 ha, 41.8 m/ha for private forests, 33.27 m/ha for federal forests and average 45 m/ha overall (cf. Ghaffarian et al. 2009; BFW 2016). Forest management operations such as thinning generated sufficient (low-quality/small dimension) feedstock for energetic use in local, decentralized bioenergy plants, which supplied the local communities with relatively cheap heat and power, e.g. through district heating grids. Forest thinning helped keeping the forests healthy and productive for growing high-quality timber. At the same time, the farmers and forest owners could sell their thinning material to the local bioenergy plants, which provided low-cost and low-carbon energy to the rural population and attracted new industries to invest into rural communities, as explained by the European Centre for Renewable Energy (EEE 2015), headquartered in Güssing, Austria. However, key to this successful development in Austria has been sustainable forest management (SFM) and it has been only a logical consequence that the Austrian forest sector (including forest owners, forest companies, the forest products related industry and their associations) was among the first supporter of founding the forest management certification system Programme for the Endorsement for Forest Certification (PEFC), which has been developed in parallel to the Forest

Stewardship Council (FSC). Since Austrian forests have been managed – by law – in a very sustainable way since centuries, it has been relatively easy for forest owners to have their management certified and by that improve their market access for forest products or – in special cases such as veneer hard wood – a slight price premium vis-à-vis their competitors. Shortly after the foundation of PEFC, the entire Austrian forest area under management became certified (cf. Rametsteiner and Kraxner 2003).

Innovation of biomass heating plants in Austria

The development of biomass district heating took off in Austria during the 1990s, when the country achieved significant increases in biomass heat production. The number of newly established biomass district heating plants has risen constantly since 1980. By 2008, there were over 7,100 biomass heating plants with capacities ranging from 101 kW (kilowatt) to 1 MW (megawatt), and about 1,000 biomass systems with capacities larger than 1 MW across Austria (Furtner and Haneder, 2008). In the same year, the cumulative heat capacity of biomass heating plants above 0.1 MW reached around 4.7 GW.

With respect to CHP plants, there were 20 woody biomass systems (electricity production of more than 0.4 MW) in 2002. These biomass-fired CHP plants were used by private pulp and paper industries (using black liquor and bark) and wood-processing companies. Since then, the number of biomass CHP plants has increased remarkably. By 2008, about 100 biomass CHP plants generated about 348 MW of renewable electricity and almost 2 GW of heat (Nemestothy 2008). To date, energy is generated in more than 2,000 bioenergy heat plants and 140 bioenergy plants that produce power and heat in a coupled manner (CHP). These plants are mostly decentralized, small-medium scale, with a maximum capacity of 65 MWth, connected to district heating (DH) grids. Total heat generation from biomass amounted in 2013 to 177.5 PJ and electricity to 17 PJ (cf. ÖBMV 2015).

Pellet home-heating systems in Austria

Estimates indicate that more than 90% of all pellet boilers installed in Austria are of domestic origin. Around 14 pellet boiler manufacturers produced about 11,100 units for the domestic market in 2008.

The total production of pellet stoves in Austria totalls over 50,000 units, of which around 80 per cent are exported. About 100,000 households and industrial companies currently use pellets to heat their homes, offices and workshops. About 700,000 households use fuel wood, wood chips, wood briquettes or pellets for heating in Austria. The total capacity of household bioenergy heating system (<100kW) amounts to 6,700 MW, out of which one-third comes from pellet boilers, another third from wood chips and the rest from fuel wood boilers (ÖBMV 2015). In 2014, the domestic demand for pellets has been 880,000 tons while the production (950,000 tons) clearly superseded the demand. About 350,000 tons of pellets were imported mostly from Germany, Czech Republic, Slovakia and Romania, while some 480,000 tons were exported predominantly to Italy (world's largest pellets user for domestic heat), Switzerland and Slovenia. In the global context, Austria is one of the largest pellet producing countries. In 2015, out of globally 27 million tons of pellets about half comes from Europe (13.5 million tons). 8.2 million tons are use in Europe in the private heat sector and 2.8 million tons of pellets are used by the European industry. 7.8 million tons are used in power plants (mostly co-firing systems with coal in the UK, Belgium and Denmark). However, most of the pellets used in power plants originate from North America (5.2 million tons). The pellets used for heating are predominantly from European production. The largest demand for heating pellets comes from Italy, Germany, Sweden, France, Austria and Denmark (proPellets Austria 2015).

Wood resources and their allocation

The share of raw timber used for biomass district heating has been constantly increasing over the last 10 years. Projections even indicate an increase of up to 100% for this particular sector, a common development in the pellet and CHP sectors, based on the annual results seen over the past decade. Conventional biomass on the other hand will stagnate during the same period and will not be able to keep up with the increases in other sectors, based on predictions for coming years. It seems as if other modern forest-based feedstocks will increasingly replace fuelwood by 2020 (Yamagata et al. 2010).

Conclusions and lessons learned from Austria

Importance of entrepreneurship, innovation and the creation of local value

Biomass energy activities can bring positive political and socioeconomic impacts to local communities (carbon-neutral region, sustainable forest management, job creation, increase in community revenue, creation of regional value, etc.). By 2015, an impressive bioenergy sector has been build up in Austria including about 1,000 small-scale enterprises that are specialized in installing bioenergy heat devices, 60 educational institutions including specialized universities and research centers, as well as 100 small to medium-scale enterprises that are developing and producing bioenergy technology. The sector includes also 270 stove-fitters, 40 pellets producer (producing about 1 million ton of pellets per year) and 21 biofuel producers. The sector of solid bioenergy contributes as much as 40% (2.4 billion Euro) to the total turnover of the renewable energy sector. Furthermore, almost every second job (18,100 out of 36,200 jobs) of the renewable energy sector is in the area of solid bioenergy production (Biermayr 2014).

These figures clearly demonstrate, that regenerative heat and power production using regional forest biomass creates multiple regional values and can induce new markets, such as for low-quality timber and wood residuals (e.g. sawdust and bark in the wood industry), which consequently steers vital forest management actions such as thinning. In addition, renewable energy supply systems create new jobs and businesses in the feedstock (e.g. forest biomass delivery, chipping firms) and energy (e.g. grid connection, operation, maintenance) sectors, thereby stimulating local economies. Some regions have successfully created a job market for additional services, such as eco- and bioenergy tourism, with the regions receiving large numbers of visitors to see their innovative activities (Yamagata et al. 2010; Madlener and Koller 2007).

The qualitative analysis carried out in this chapter has focused on the evolution of biomass plant establishment in Austria, and why, how and in what socioeconomic circumstances new biomass plant projects can successfully be launched in order to utilize local forest resources to supply renewable, and hence carbon-neutral, bioenergy on a regional basis.

Lessons to be learned from the Austrian experience

(1) Policies:

Decision- and policymakers need to provide the right incentives and create an environment enabling the initiation of local biomass projects by placing a high priority on renewable energy sources, to combat climate change and ensure future energy security. Such policies need to be combined with those addressing sustainable rural development, the environment and local societies.

(2) Policy tools:

A decisive instrument for the support of regional bioenergy development is the provision of special subsidies. In Austria, these policy tools, initially intended to subsidize local economies and the energy autarchy, have recently evolved into climate policy tools aimed at tackling Austrian CO_2 emission targets. Many subsidies exist for establishing decentralized biomass plants in combination with district heating grids (local, regional, national and EU funds). On the other hand, financial support also exists for those willing to change their present (fossil fuel based) heating system into forest biomass (wood pellets, wood chips or fuelwood) systems or to connect their homes to one of the numerous public heating grids. Further economic incentives include, inter alia, cheap credit.

(3) Knowledge and public opinion:

The public's knowledge of forest, forestry and bioenergy as well as of local history and traditions has turned out to be crucial for the successful establishment and maintenance of forest-based bioenergy projects. Additionally, it is extremely important for local initiators to be aware of public opinion in project areas in order to steer and support targeted educational measures and other events to disseminate knowledge.

(4) Sustainable forest management and forest certification:

Effective forest management taking into consideration sustainability criteria and consequent forest management certification turned out to be a positive incentive when conducting thinning measures and harvesting activities for biomass use.

(5) Synergetic approach:

A local forest-based bioenergy project might be the perfect basis for adopting a synergetic approach to multiple issues such as the climate change problem by sequestering carbon in standing forest biomass and long-lasting forest products, by using wood as a healthy and regenerating construction material under the green building aspect or by substituting fossil-based energy with forest-based bioenergy. Addressing rural development issues by combining sustainable forest management and its certification with environmental protection and the (local) forestry industry, in addition to closing the loop by linking recreational issues and eco-tourism by creating positive public opinion about planned or existing bioenergy projects, can be an important part of such synergies (Yamagata et al. 2010).

4.2 Sustainable Woody Biomass for Bioenergy in Rural Southern Japan

Introduction

As explained in the thesis introduction and also the introductory text to chapter 4, the presented survey has been carefully carried out in 2007 under respective levels of knowledge and framing conditions. Both, this survey in Yusuhara Town, Kochi, and the complementary study that has been carried out in the following year in the north of Hokkaido – Shimokawa Town – (presented in Chapter 4. 3 of this thesis) have been unique enterprises in Japan. Therefore, it has been decided to keep text and literature broadly in the context of the time concerned (as published in Kraxner et al. 2009) – especially also to not lose the valuable insight provided by the large amount of people involved as stated in the methodology below and shown by the sample size and excellent return rate. Furthermore, it has been assumed that local conditions in the areas surveyed remained more or less unchanged from external influence – i.e. the earlier mentioned Great Tohoku Earthquake and resulting changes in e.g. energy policies. However, in the thesis introduction and conclusion it has been tried to provide updated insights and combine achieved knowledge from the past with present thinking. For this survey, the reader is kindly asked to refer also to the thesis' Annex V where a translation of the original questionnaire into English language is provided. This move is considered especially valuable for science since it provides full documentation of a rare survey and gives future initiatives the opportunity to build up on questions and answers from the past in order to derive comparative conclusions over time in their assessments. The Annex VI also features the detailed analysis of the questionnaire – beyond the condensed assessment that could be published by Kraxner et al. (2009).

Overview and Background

Fossil fuel substitution with biomass for heat and energy generation is seen as one measure to decrease the emissions of greenhouse gases and thereby mitigate global warming. In an analysis of global biomass energy futures, it has been estimated that biomass, under certain assumptions, has the technical potential to supply the energy needed by 2050 and also behind (Hoogwijk et al. 2005; Singer 2011). Especially when looking at the different world regions, the supply might be equivalent to

several times the energy that currently derives from mineral oil, as also outlined by Keppo et al. (2007), and Rokityanskiy et al. (2007).

Renewable energy can be generated from a variety of biomass feedstock. These include both residues of agricultural crops such as sugarcane, corn and wheat, and multi-purpose grown tree species (Brett et al. 2008). In the United States, e.g. power generation from biomass has remained stable throughout the past years, accounting for 56% of all renewable energy generated (excluding hydropower) (EERE 2008). In the EU, biomass showed a share of 44-65% from the renewable energy in 2005 (EC 2005). Compared to the US and the EU, the Japanese energy system is much stronger based on fossil fuels – especially petroleum, which alone reached a share of 44% in the total energy production in 2006 (METI 2008). The current share of biomass energy use is about 1%, of which most derives from waste biomass, while thinned wood and other wood residues are nearly unused biomass resources in Japan (IEA 2008).

More than 60% of Japan's land cover is forest, but most of this domestic resource has not been used during the past 3 decades due to high labor costs and low wood prices, which economically did not justify expensive harvesting measures in the mountainous areas. Japanese forests show an annual increment of some 100 million m^3 of which only 15% is harvested. In Germany, about 15% of the harvested wood is used for bioenergy, and in Austria, the share reaches even 25%. Compared to those high shares, in 2006 there was less than 4% of the total harvested wood used for bioenergy in Japan (Kumazaki 2008). On the other hand, about 81% of the total wood supply originates from boreal and tropical overseas, and wood export does practically not exist (MAFF 2008a). This wide gap between wood demand and supply from domestic sources needs urgently to be addressed by policy.

Table 7 provides an overview of the forest data from Japan, Germany and Austria. It is explained that in the Central European countries almost half of the increment is harvested, but in Japan it is actually less than 10%.

Table 7. Overview on the forests of Japan, Germany and Austria. Source: modified after Kumazaki (2008).

country	forest area (10,000 ha)	harvest 2006 (10,000 m^3)	m^3 / ha			m / ha
			forest stock	wood increment	harvest	road density
Japan	2,486	1,700	207	7.4	0.7	17
Germany	1,108	6,200	317	12.1	5.4	118
Austria	386	1,900	325	9.3	4.9	87

Japanese forestry is facing lower timber prices and 2-5 times (in 2003) higher harvesting costs than e.g. those in classical European forestry countries. These high harvesting costs might again be driven by the missing infrastructure for carrying out competitive forest management. Especially, the low forest road density is to be blamed (Tab. 7). Mountainous countries such as Japan require a higher forest road density, similar to e.g. Austria, or Germany in order to apply cost effective harvesting and thinning techniques (e.g. mobile cable yarding systems for logging operations) in a highly competitive sector (Kraxner and Yamagata 2007a)

However, given the rapidly increasing oil price and the highly controversial debate on biofuels from agriculture, a low wood price could be seen as advantageous in a competitive energy market. Recent national energy and environmental policies aim at an increased use of domestic wood for bioenergy (MAFF 2008b). Following the idea of achieving a Low Carbon Society (NIES 2008), existing bioenergy plants should be fired with domestic forest residues rather than with wood chips shipped from Canada at lower prices than the ones available in Japan.

Objective and Motivation

The Japanese Ministry of Agriculture, Forestry and Fisheries launched the Biomass-Nippon Strategy in 2002 (Kuzuhara 2005), addressing four basic reasons and needs for adopting it: Prevention of climate change; Development of a recycling-oriented society; Incubation of new industries; and the activation of rural areas.

In order to tackle several of these issues dealt with in the Biomass Nippon Strategy, this work aims at identifying the potential for an increased forest use and to dedicate this biomass to bio-energy production in rural regions of Japan. This chapter focuses on the public awareness and people's

knowledge on biomass and related ecological and socio-economic incentives for increasing the forest use, and also the public's willingness to pay (WTP) for alleviating climate change has been considered.

An in-depth literature review has shown that in Japan to date no public opinion surveys have been conducted in the field of mitigating climate change through the reduction of fossil fuel emissions and greater energy security through increased use of domestic biomass for energy, both combined with forest certification. Rather few public opinion surveys have been carried out focusing at forests, e.g. described in Ota (2001; 2005), which were most often commissioned on behalf of the Japanese Forestry Agency (MAFF 2003) or the government, e.g. (Cabinet Office of Japan 2006). Some of the survey-questionnaires also have been directed to companies in the field of the forest sector industry and certified forest products (CFPs), e.g. (Owari and Sawanobori 2006).

Organizations such as the Global Carbon Project (GCP; Dhakal and Betsill 2007) or also Haas et al. (2006) that the economies of rural communities are on the one hand threatened most by the end of cheap fossil-based energy and global climate change, while on the other hand the same communities could benefit most and in multiple ways from increased forest use for bioenergy – inter alia through improved forest stand stability, biodiversity, cheap renewable energy, economic growth, or future carbon credits. For instance in Sweden, one of Europe's leading countries regarding the use of wood-based bioenergy, around 60% of private forest owners produce and sell woody biomass, which has proven to contribute significantly to job creation, rural development, and development of local economics (Hillring 2002).

These aspects together with the fact that woody biomass in Japan does not only attract a great deal of attention due to its abundant amount, but also because an increased energy supply generated from woody biomass is expected to contribute to revitalizing the forest and the entire Japanese forestry sector (Yoshioka 2005), made an examination of the Japanese rural public opinion worthwhile.

Study Site

Yusuhara Town, located in the Kochi Prefecture on Shikoku Island, is a traditional Japanese rural mountain community with 91% forest coverage and a population of 4,625 people in 1930 households

(Yusuhara Town 2008). Mountain communities such as Yusuhara Town cover 50% of Japan's total land area and own 60% of Japan's forest area (MAFF 2007). Mountain villages have various biomass feedstock as potential alternative energy sources to fossil fuel, including forest residues from thinning, branches and leaves, as well as agricultural residues such as from rice plants and straw. According to Japan's Forestry Agency, especially in mountain villages it is possible to form a society where the local resources are effectively and sustainably utilized at multi–stages, which is an optimal precondition for a Low Carbon Society (MAFF 2008a; MAFF 2008b; NIES 2008).

The certification of the environmental and social characteristics of a product's production process is emerging as a significant transnational, nongovernmental, as well as market-based approach for promoting sustainable forest management (SFM), environmental regulation and development. After only a decade, environmental certification of forests has spread to cover a significant portion of the world's forests under management (Klooster 2005; Rametsteiner and Simula 2003). Major wood retailers increasingly require forest management or chain of custody (CoC) certification, and international environmental organizations strongly support it (Kraxner et al. 2006). However, in Japan, where only 277,320 ha (equals to 1.1% of the total forest area) of forest is certified (FSC 2008), forest managers, owners, as well as local authorities are required to make substantial improvements to the social and environmental aspects of forest management and its certification. On the other hand, the number of CoC certificates in Japan has increased since the early 2000s and reached 633 in early 2008, by which Japan has become the major driver on the certified forest products market in South-East Asia (Kraxner et al. 2007b; 2008).

The Yusuhara Forest Owners' Cooperative achieved FSC certification of its forest area (11,371 ha) as one of the first owners in Japan, hoping for an improved market access for its products (Ota 2002). The predominating forest species are Japanese Cypress (Hinoki, *Chamaecyparis Obtusa*) and Japanese Cedar (Sugi, *Cryptomeria Japonica*) (Rainforest Alliance 2005). Frequent thinning operations produce a constant supply from the local forest and since the forest certification showed effect in terms of increased sales, more forest owners began to join the cooperative (Ota 2006).

Yusuhara Town and its Forest Owners' Cooperative has been identified as an optimal case study, given the fact that this town does not only aim at increasing timber and forest product sales, but also tries actively to increase the use of forest biomass for bioenergy in order to initiate a shift towards renewable energy. Furthermore, the town has been subject to several studies published in the field of small scale forestry and certification, e.g. Ota (2007).

Methodology

Drop-off surveys were conducted among all households of Yusuhara Town during 16 January and 15 February 2007. The questionnaire, asks for the public opinion and knowledge on a relative wide field regarding wood, forest, forest management, certification, biomass for bio-energy as well as general environmental problems and the WTP for mitigating climate change. However, this analysis mostly concentrates on biomass for bio-energy. Of the 1930 questionnaires sent out, 774 samples are used for this analysis. The valid response rate is 40% and 79% of the respondents are forest owners.

It is assumed that i) people who are forest owners have different perceptions on and attitudes towards forest management and the increased use of biomass, than people who do not own forests. It is further assumed that ii) people who have a better knowledge on forest management, certification, and bioenergy have also different perceptions on and show different attitudes towards forest management and an increased use of forest biomass. Additionally, the changes in perception are compared before and after providing information on SFM and forest certification.

To confirm the hypothesis', logit models are used, similarly to existing literature, where also logit models are applied to analyze survey data from companies to investigate factors that cause firms to prefer or choose a particular certification scheme, e.g. Cashore et al. (2005). In this chapter, logit models are employed for identifying the reasons that affect people's attitudes towards increasing the use of forest biomass for bioenergy as well as for examining the factors that explain the probability that people agree to increase woody biomass use. By comparing the differences between forest owners and non-forest owners, χ^2-test is applied for identifying the different perceptions which exist within different job-profession of people. A regression analysis is performed to assess the factors

which affect people's WTP for using renewable energy to solve global warming. The details of variables, their characteristics and their use in the model development are presented in Appendix VI.

Following functions are used for the logistic regression models:

$$F(X_i'\beta) = \frac{\exp(X_i'\beta)}{1+\exp(X_i'\beta)} \tag{2.1}$$

The log likelihood function is given by

$$\ln L = \sum_{i=1}^{N} y_i \ln F(X_i'\beta) + \sum_{i=1}^{N}(1-y_i)\ln[1-F(X_i'\beta)] \tag{2.2}$$

and the pseudo-R2 is according to McFadden (1973).

$$R^2 = 1 - \ln L_{fit} / L_0 \tag{2.3}$$

In this study, the model equation is defined as

$$V_{awarenessofbiomassuse} = \alpha + \beta_{age} X_{age} + \beta_{gender} X_{gender} + \beta_{knowSFM} X_{knowSFM} + \beta_{knowFC} X_{knowFC} + \ldots + \beta_{satisfaction} X_{satisfaction} \tag{2.4}$$

where "knowSFM" is a dummy variable showing the knowledge of SFM; "knowFC" means the knowledge of forest certification; other variables are presented in the thesis' Annex VI.

In another model which is defined in (2.5), those forest owners are selected who prefer to increase the wood biomass use as a dependent variable.

$$V_{cross} = \alpha + \beta_{age} X_{age} + \beta_{gender} X_{gender} + \beta_{knowSFM} X_{knowSFM} + \beta_{knowFC} X_{knowFC} + \ldots + \beta_{satisfaction} X_{satisfaction} \tag{2.5}$$

Additionally, a cost-benefit analysis, based on a WTP question, has been carried out in order to test the potential for shifting the local energy systems towards a local woody biomass-based system in Yusuhara Town.

Results

Gender and Job specific results

The gender distribution shows that 66% (502) of the respondents are male and 34% (264) are female. The average participants is slightly older than 57 years. The majority of the respondents are aged 50 or older, and about 30% are younger than 50 years.

The survey data further indicates that about one quarter of the respondents (24%, 218) have their job in the agricultural sector, followed by company workers (17%, 154), students (15%, 138) and those who are working in the forestry sector (10%, 91). Most of the respondents are forest owners. As Yusuhara Town is a typical Japanese rural town with aging problems, unemployed - that includes retired people - reach a share of about 16%. For further details on the general parts of the questionnaire see the thesis' Annex V.

Forest Functions

Results from the frequency analysis of the forest related questions prove that a clear majority (86%) of respondents agrees to the statement that the forest industry is important for Japan. However, on a question regarding the importance of different forest functions, most respondents state the protective functions such as protection from disasters (83%) and provision with clean water (79%) to be most important. Also very important are rated the carbon storage function (76%), the ecosystem function (74%) and forest as a source of biodiversity (72%). Less important seem to be the wood production function (55%), forest as a source for employment and jobs (47%), and especially the recreation function, which is only rated important by 30% of the respondents. In Figure 23, these results are presented by 4 different job groups. It is illustrated that over all 4 job groups the recreation function of the forest is considered to be least important, especially this is true for company workers. When it comes to the functions of employment and wood production the importance is also considered to be lower than other functions. Again the company workers do not regard these being important. However, all other technical and natural functions are receiving high recognition. Highest importance is attributed to the function of water provision by the company workers.

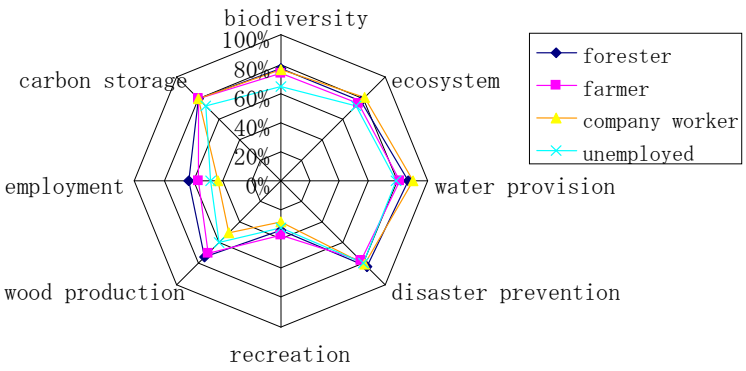

Figure 23. Importance of forest functions by different job groups. Source: adapted after Kraxner et al. (2009).

Similar results had been achieved earlier from surveys carried out in Europe. However, the biggest difference between European and Japanese perceptions regarding forest functions are identified in the recreation function. Whereas Japanese respondents do not consider forests to be important for their recreation, in Europe this function often is considered to be particularly important (Rametsteiner and Kraxner 2003).

Being asked to agree or disagree on certain statements regarding the forest and its meaning to the people, it turns out that there is agreement among the job groups with respect to forest being good for environment and climate and that forest is a symbol of nature. However, situation is not that coherent with respect to the statements that forest needs to be protected, forest should be used, or forest should be protected and used at the same time. Here, e.g. foresters clearly agree with the idea of using the forest and also with the statement of use and protection at the same time, but do not so much agree with pure protection. To the contrary, company workers strongly agree with the protection statement and do less agree with the use and protect notion. Just about 20% of the company workers want to see the forest to be used only.

With respect to the meaning of forest to the public it might be noticed that there is general acceptance that forest has to be protected. However, the use of forest is perceived controversially within the different job categories. Generally it might be said that the acceptance to use forest decreases with the physical distance of a job from the forest, e.g. only a minor share of company workers and

unemployed people agree to use the forest (Fig. 24). Such perceptions might psychologically affect the options and reasons for the use of forests in an indirect way.

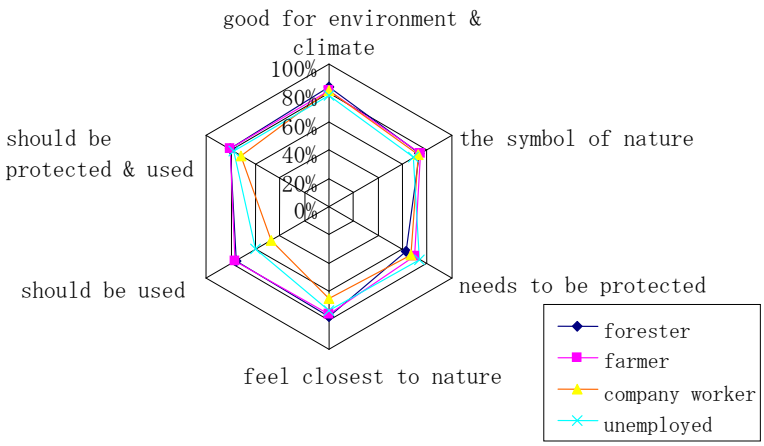

Figure 24. Agreement to statements on the meaning and use of forest by different job groups. Source: adapted after Kraxner et al. (2009).

Sustainable Forest Management and Forest Certification

The public awareness of renewable energy, forest certification, and SFM is tested since it has been assumed that these factors will be highly related to the acceptance of increased forest use and harvest for biomass (Fig. 25).

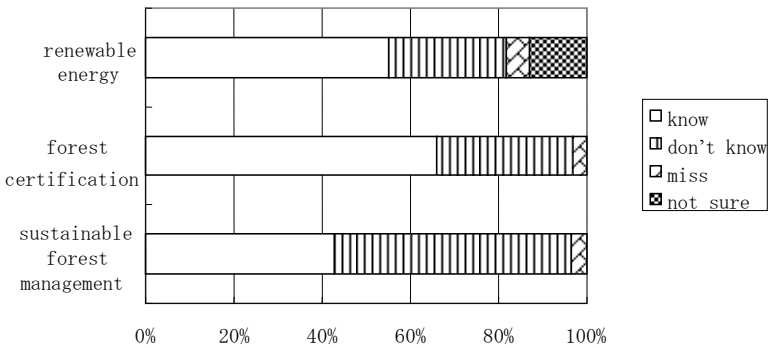

Figure 25. Public recognition of renewable energy, forest certification, and sustainable forest management. Source: adapted after Kraxner et al. (2009).

Results indicate that more than 60% of the respondents are aware of forest certification, but less than 50% have heard about SFM. This high recognition of forest certification might be explained by the fact that the Yusuhara Forest Owners' Cooperative has been among the first forest associations in Japan to certify their forest. On the other hand, SFM seems not to be recognized as related to forest certifications which again let conclude that forest certification might have been communicated more as an economic market tool rather than an assurance for SFM. Renewable energy is recognized by slightly more than 50% of the public respondents.

In order to test the harvesting options for an increased biomass production for bioenergy, the public's agreement to harvesting actions under "normal", sustainable managed, and certified conditions has been tested (Tab. 8).

Table 8. Agreement to different levels of harvesting under normal/SFM/certified conditions.

question	increase	no increase	not sure	total
harvesting	196	211	321	728
harvesting under SFM conditions	421	89	243	753
harvesting under certified conditions	360	139	260	759
χ^2 – test: P,0.001				

The outcome shows that the calculated means are statistically different at any level within the different harvesting conditions. On the question, whether an increased forest use (in terms of more trees harvested) would be justified in case of SFM, more than half (54%) of all respondents agree with an increased use under such special conditions. Some 11% were against it, even under SFM conditions and about one third (34%) could not answer this question.

After receiving a short explanation on the term forest certification, two thirds (66%) of the people confirm to have heard about the term forest certification, whereas 31% deny the question. 3% cannot not give any answer on that question.

Consequently, similar results as with SFM are received regarding harvesting under certified forest conditions. Almost half of the respondents (47%) agree to an increased harvest. About one third

(34%) does not accept increased harvesting of wood even under this special condition, and some 20% cannot not give any answer on that question.

When concentrating on attitudes by forest owners and non-forest owners towards increasing the use of domestic forests and intensified harvesting actions, significantly different results are obtained with respect to the assumptions under which forest condition an increased use is carried out. Under "normal conditions" - without explicitly mentioning SFM conditions for the local forests – only some 40% of forest owners agree with an intensified use of the forest, while almost 70% of the non-forest owners would agree to more harvesting under "normal circumstances" (Fig. 26).

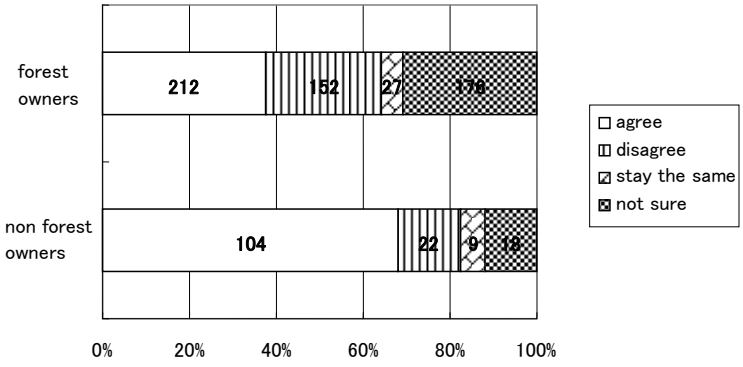

Figure 26. Forest owners' versus non-forest owners' levels of agreement (significant) regarding an increased use of the forest (harvesting more trees) under "normal conditions" (SFM has not been mentioned explicitly). N=720. Source: adapted after Kraxner et al. (2009).

On the other hand, when explicitly pointing out to SFM conditions under which an increased use of the local forest should happen, the obtained responses are turned upside down. More than 60% of forest owners are now agreeing to an intensified use, while only 35% of the non-forest owners have the same opinion (Fig. 27).

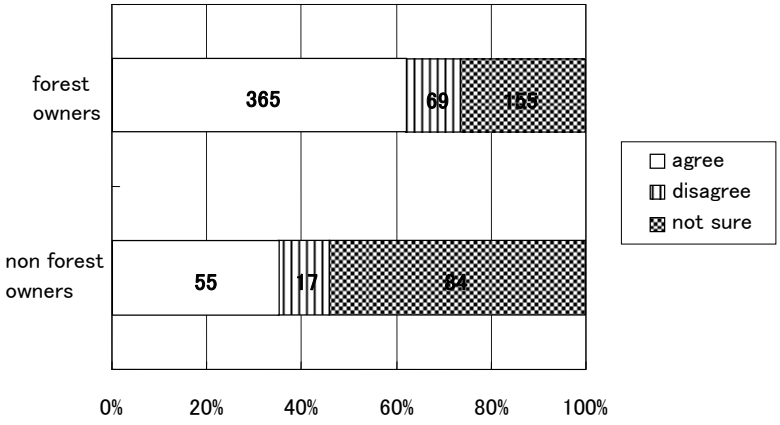

Figure 27. Forest owners' versus non-forest owners' levels of agreement (significant) regarding an increased use of the forest (harvesting more trees) under "SFM conditions" (SFM has been explicitly mentioned). N=745. Source: modified after Kraxner et al. (2009).

In order to further examine the differences between forest owners and non-forest owners before and after providing additional information on forest certification, t-testing has been applied. The results indicate that the differences obtained are statistically significant. The same information provided to the different target groups of forest owners and non-forest owners show different effects regarding their attitudes towards an increased harvesting intensity and domestic forest use.

One possibility of interpreting such findings might be that forest owners perceive the information regarding forest certification and SFM as a "green light" to increase their harvest and to realize possible benefits on new markets. On the other hand, non-forest owners, who are not so much used to deal with forestry issues, might perceive explanations of forest certification and SFM rather as a "red light" and a signal for stopping harvesting because the forest might be in danger and needs to be protected as explained earlier. However, another interpretation might be that the provided information on certification and SFM rather confuses the non-forest owners.

Further analysis of differences between forest owners and non-forest owners supports tendencies derived from earlier findings. Some 60% of forest owners clearly prefer to increase the biomass use from their local forest resources for bioenergy production whereas only 45% of the non-forest owners opt for an increased use of biomass and an impressive share of 50% is not sure whether to agree to an intensified use ore not (Fig. 28).

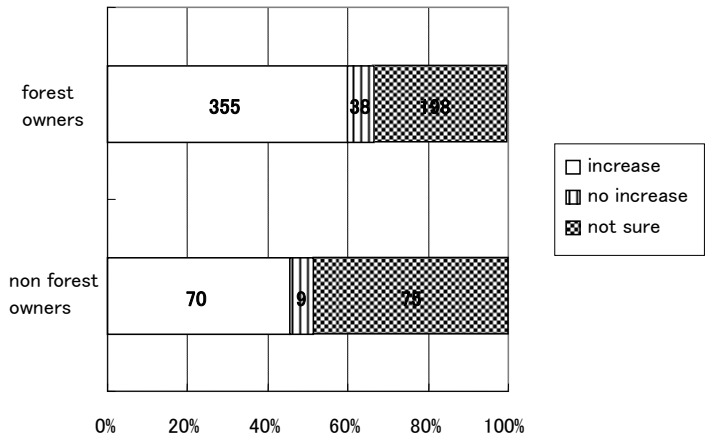

Figure 28. Forest owners' versus non-forest owners' opinion (significant) regarding an increased forest use for more biomass/bioenergy production. N=745. Source: adapted after Kraxner et al. (2009).

The respondents' attitudes towards an increasing biomass use are analyzed in detail with the help of logit modeling (Tab. 9). According to the model results, especially women, older people and those respondents who consider the forest to have an important function in the employment sector, tend to prefer an increased domestic forest use for biomass production.

The logit model results further indicate that the public attitudes and thoughts regarding the assumed amount of fuel wood or pellets, which the local Yusuhara forests might provide, show positive statistical significance with the assumed potential use of biomass in Yusuhara Town. This also means that e.g. respondents who do not believe that biomass for bioenergy can be used as a heating source in their town, nevertheless prefer to increase the use biomass. Such results might be interpreted in a way that even if people do not necessarily consider a bioenergy system based on locally produced biomass suitable for their homes or elsewhere in their town, they may still want to help developing the forest industry which can then consequently "export" the more on biomass resulting in economic benefit to the entire region. These attitudes might be especially influenced by geographical reasons. Yusuhara Town is situated relatively south in Japan which also might let imply that winters and heating periods are shorter than in many other regions of Japan.

Findings from the logit modeling also show that respondents, who believe that biomass for bioenergy from local forests might be an appropriate solution and contribution to the energy portfolio in a future Yusuhara, are especially in favor of increasing the local biomass production.

Table 9. Logit-model results for cross-testing significances of the results. Notes: *, **, *** represent significance at the levels of 10%, 5%, and 1%. A detailed explanation of the variables used in this table is provided in the Annex VI.

Forest use for biomass/bio-energy	Coefficients	Standard. Error.	z	P-value
Gender	-0.496*	0.251	-1.980	0.048
Age	0.018*	0.009	2.020	0.044
Job(farmer)	-0.206	0.328	-0.630	0.530
Cross(forester landowner)	0.536	0.469	1.140	0.252
attitude 1	-0.157	0.179	-0.880	0.380
attitude 2	0.275	0.243	1.130	0.258
attitude 3	-0.200	0.188	-1.060	0.288
attitude 4	0.094	0.166	0.570	0.570
attitude 5	-0.088	0.107	-0.820	0.412
satistcation1	-0.113	0.134	-0.840	0.401
satistcation2	0.288*	0.132	2.180	0.029
satistcation3	0.139	0.154	0.910	0.365
satistcation4	-0.047	0.126	-0.370	0.712
satistcation5	-0.100	0.119	-0.840	0.404
Knowledge 1(FC)	0.395	0.281	1.410	0.160
Knowledge 2(SFM)	0.380	0.298	1.280	0.202
Harvesting after FC	0.053	0.160	0.330	0.741
c8industry	0.294	0.283	1.040	0.299
d2renewable	0.676**	0.255	2.650	0.008
c6dimmy	0.851**	0.262	3.250	0.001
bio-energyD33	0.794**	0.247	3.220	0.001
use firewood for hospital or school	0.907*	0.461	1.970	0.049
d54	-0.989***	0.253	-3.910	0.000
ASC	-1.293	0.694	-1.860	0.063
Log likelihood	-236.446			
Pseudo R^2	0.226			
N	477			

The outcome from a logistic regression model is presented in Table 10. The model findings indicate that especially forest owners who are aware of forest certification and who prefer to increase domestic forest use, like at the same time to increase the biomass use. However, since the ASC - constant variable also proves to be significant, there may exist additional relations which were not tackled in this chapter.

Table 10. Logistic regression model results focusing on forest owners opting for increasing the biomass use. Notes: *, **, *** represent significance at the levels of 10%, 5%, and 1%. A detailed explanation of the variables used in this table is provided in the Annex VI.

Crossforestowner&d6	Coefficients	Standard. Error.	z	P-value
a2age	0.032***	0.008	3.990	0.000
attitude1	-0.260	0.178	-1.460	0.143
attitude2	0.265	0.246	1.080	0.281
attitude3	-0.063	0.196	-0.320	0.748
attitude4	0.023	0.165	0.140	0.891
attitude5	-0.104	0.105	-0.990	0.325
attitude6	-0.103	0.134	-0.770	0.440
attitude7	0.137	0.127	1.080	0.279
attitude8	0.151	0.154	0.980	0.327
b33	-0.029	0.122	-0.240	0.811
b35	0.143	0.119	1.200	0.230
b4area	-0.539	0.356	-1.510	0.130
Knowledge1(FC)	0.512*	0.256	2.000	0.045
Knowledge(SFM)	0.164	0.270	0.610	0.542
Harvesting after FC	0.087	0.157	0.550	0.581
c5increased	0.461*	0.213	2.160	0.030
c6dimmy	0.699*	0.276	2.530	0.011
c7afterfsc	0.055	0.181	0.300	0.761
c8industry	0.205	0.301	0.680	0.495
d2renewable	-0.098	0.257	-0.380	0.703
d33energybio	0.793**	0.230	3.440	0.001
d44	0.133	0.472	0.280	0.778
d54	-1.331***	0.277	-4.810	0.000
ASC	-3.175***	0.571	-5.560	0.000
Log likelihood	-246.446			
Pseudo R^2	0.239			
N	468			

Willingness to Pay

In the last part of the questionnaire, also a question on WTP is included. The public in Yusuhara Town is asked how much more they would be willing to pay, additionally to their current electricity bill, if this would help mitigating climate change.

Since this chapter aims at investigating the public opinion on biomass for bioenergy throughout the questionnaire and analysis, it is consequently assumed that the amount achieved by WTP in addition to the current electricity bill might be used to support changing the local conventional heating and energy systems towards renewable bioeenergy systems supplied by locally grown biomass. The calculated average WTP available for the assumed change of the energy systems is about ¥ 500 (ca. € 3.20, January 2007) per household and month, summing up to a total WTP in Yusuhara Town of ¥ 929,000 (ca. € 6,000) per month, respectively ¥ 11,148,000 (ca. € 72,000) per year.

According to (Inoue 2007), the energy costs in Yusuhara Town, when using locally grown woody biomass for the production of electricity and heat, can roughly be split up into 3 components: 1) costs for a new heating device (pellets stove or woody biomass boiler); 2) the pellets/biomass costs (fuel) for heating; 3) the electricity costs for daily life have to be considered. Following this approach (assuming that there is a combination of central district heating and private pellet stoves) and using the data provided by (Inoue 2007), the total costs for the components 1 – 3 amount to some ¥ 277.5 million (ca. € 1.8 million) per year.

The total amount of WTP in addition to the existing energy bill for tackling climate change by switching to bioenergy would hence make up some 4-5% of the total energy costs produced from locally grown biomass in Yusuhara Town (B/C = 0.04). This share indicates that there is a significant basis of WTP that might be realized and used for a change towards bioenergy on communal and/or household level. However, such a private contribution needs to be triggered by directed policies and respective complementary tools such as subsidies.

Generally might be said that women are identified to be more likely willing to pay more for solving the global warming problem than men. Further, those respondents who are aware of forest certification and who agree to an increased domestic forest use under the condition that the forest is certified tend to be willing to pay more for contributing to solve the global warming than others

Discussion and Conclusions

Japanese forests show a growing increment rate and also the total forest area is increasing (FAO 2005), whereas at the same time the forest area certified is very low and stagnating (Kraxner et al. 2007b; Purbawiyatna and Simula 2008). On the other hand, Japan is importing more than 80% of its wood consumption, the forestry sector is facing high competition from close-by tropical countries as well as from far-away Canada (FAO 2008a; FAO 2008b), and - simultaneously - Japan is driving the market for CFP in the Asian region (Kraxner et al. 2007b). These facts might point us to an unrealized economic potential for domestic forest certification in close linkage to an increased forest use for bioenergy.

Domestic forest-based bioenergy is needed to reach Japan's climate mitigation targets and energy security, and it is beginning to find support by the upcoming policies that aim at bridging different climate-relevant sectors such as energy, environment and forest. Findings by Kinoshita et al. (2009a; b) and Domac et al. (2005) indicate that there is a sufficient biomass potential in Japan. Consequently, a stronger connection between local forestry and renewable energy seems to be a first step towards an increased use of the domestic forest under a Low Carbon Society, providing multiple benefits such as employment or other socio-economic aspects, GHG mitigation etc. (Kraxner et al. 2003; Domac et al. 2005).

In this study it is explain that people – and especially rural forest owners - who are aware of SFM and forest certification, tend to be positive towards an increased use of their local forests for biomass - particularly, if SFM and forest certification is also applied in the local forests. These findings might provide a solid starting point for local rural policy makers to consider and establish a close relation between forest, energy and certification.

This study also indicates that people, who are aware of forest certification, tend to show higher WTP for contributing to mitigate the climate change problem. It is demonstrated that the WTP for tackling climate change by switching to forest-based energy amounts to a share of 4-5% of the total bioenergy costs needed to supply the rural community. Consequently, policy tools, such as special subsidies, might be used for motivating, utilizing, increasing, and realizing such WTP potentials for transforming local energy systems from fossil sources towards biomass for bioenergy and other renewable resources.

Bioenergy heating systems on the other hand might drive the local demand for wood and consequently contribute to lower harvesting costs by putting a price on forest residues. An additional cross-benefit might be seen in motivating the forest owners to carry out vital forest management operation such as thinnings in order to improve and maintain the forest stand stability and increase the wood quality. Similar tendencies might then consequently be supported by subsidies or tax incentives for forest infrastructure in order to generate local economic growth (Kennedy et al. 2001) and overcome the barrier of a non-competitive forestry sector in Japan causing high costs of biomass for bioenergy.

Future rural bottom-up policies that ought to tackle the problems of low forestry activities and climate change issues, might need to aim at increasing local people's knowledge and positive attitudes towards an increased use of domestic forests by explicitly promoting SFM and forest certification as a necessary driver. Especially when considering that certification procedures that are currently used for certifying timber products could also help to solve some of the sustainability questions and site-specific issues related to biomass production for bioenergy (Obersteiner et al. 2001). Targeted information campaigns and other communication channels need to be set off by policy makers, taking into account that the new ways in which forests are used have diversified, such as in the form of forest therapy, which uses forests to improve health, and forest environmental education.

As a further central issue for local rural bottom-up policies, the integration of women in the communication-capacity-building process can be suggested. It has been demonstrated that especially women tend to overcome traditional barriers and are open for the ideas of increased use of domestic forest and biomass, as well as willing to pay more than men for mitigating climate change.

Enhanced and diversified public opinion research is suggested for Japan in order to further increase the comparability and applicability of local survey results as presented by this chapter.

4.3 Sustainable Woody Biomass for Bioenergy in Rural Northern Japan

In order to provide a sound basis for comparison and deriving the necessary conclusions, a similar study as shown in Chapter 4.2 (Yusuhara Town) has been carried out in the northern part of Hokkaido, which is described in detail in the following section. Since the concept has been to publish each of them in separate articles, overlaps in background and methodology are intentional. The reader is kindly requested to also refer to the introductory text of Chapter 4.2.

Introduction and Background

The Eco-Model City Concept of Japan

The ideas and experiences with developing and establishing sustainable and environmentally friendly regions and cities go back to the late 1980s/early 1990s when e.g. cities in Germany such as Freiburg (County of Baden Württemberg) or the city of Malmö (Skåne County) in Sweden were facing raising green movements (e.g. against nuclear power stations planned in the region), often combined with social problems coming along with e.g. the decline of important local and regional (heavy) industry sectors, which made new orientations and perspectives necessary for the society.

For Japan, Takeuchi et al. (1998) described the designing of eco-villages with the main purpose of revitalizing Japanese rural areas and to study the possibility of establishing and developing pilot communities to encourage people to settle in agricultural and mountainous areas. An eco-village is defined as a self-supporting area in which, with the support of environmental conservation technologies, both a productive economy and the maintenance of semi-natural environmental systems can be realized. This is based on the view that ecologically sound agricultural and forestry practices can be economically viable if the external economy is incorporated (Kada 1990).

Another effort was the attempt to create the industrial and urban symbiosis in Japan under the “Eco-Town Program” during the years 1997 and 2006. The aim of this program was twofold: to extend the life of existing landfill sites and to revitalize local industries. It was one program for the recycling oriented society focusing at the innovative recycling industries in particular in cities with ageing

industrial infrastructure through voluntary initiatives and financial support from the national government. The Eco-Town program did not evolve in isolation. The Japanese Ministry of Agriculture, Forestry and Fisheries supported since 2002 centralized utilization of waste biomass in cities, towns and villages designated as "Biomass Towns" (Kuzuhara 2005). However, mostly these pilot projects were driven by resource economics and industrial needs, developed and designed to enhance innovation and competitiveness of rural areas.

Additionally to the economic requirements of the past decades, increasingly more attention had to be paid to the issue of climate change, which also was highlighted as one of the main reasons to follow up on the idea of "Eco-Model Cities" in Japan. To transform Japan into a low-carbon society, lifestyles, urban and traffic situations and other social systems needed to undergo fundamental change. Japan's Eco-Model Cities program was identified to pioneer such change. A "Working Group for Eco-Model Cities and Creating a Low-carbon Society" was established under the "Advisory Panel on the Problem of Global Warming" by the prime minister's Cabinet Office to address the selection of Eco-Model Cities. Applications for Eco-Model Cities were accepted between April 11, 2008 and May 21, 2008, with responses from eighty-nine cities and municipalities from throughout Japan, ranging in size from large ordinance-designated cities down to small towns with a population of only a couple of thousand people. Of these applicants, Yokohama city of Kanagawa Prefecture and Kita-Kyushu city of Fukuoka Prefecture at the large city level, Obihiro City in Hokkaido and Toyama City of Toyama Prefecture at the regional center level and Shimokawa Town of Hokkaido and Minamata City of Kumamoto Prefecture at the small town level were selected and certified Eco-Model Cities. Seven more "cities" were chosen as candidates for additional selection including Kyoto City, Sakai City of Osaka Prefecture, Iida City of Nagano Prefecture, Toyoda City of Aichi prefecture, Yusuhara Town of Kochi Prefecture , Miyako-jima City of Okinawa Prefecture and Chiyoda Ward of Tokyo (Chiba 2008).

One of the special features of the Eco-model Cities policy, which aimed at promoting conversion to a Low-carbon Society, was that it requested results for and integration of a range of discrete and sectoral approaches such as energy efficient buildings, traffic measures, energy supply-demand

measures, waste disposal measure and forest protection, that all local governments have been accumulating until then. The selection criteria for Eco-Model Cities were "significant reductions in greenhouse gases", "leadership and reproducibility", "regional suitability", "achievability" and "sustainability". At the same time, to bring about a more wide-ranging reduction effect, specific regions were identified and their initiatives were incorporated into the socioeconomic system, so that actions evolve with a cross-sectoral "integrated approach" with autonomous action initiated based on the special characteristics of a city or region (Chiba 2008).

The overall objective of the central government's Eco-Model Cities policy was to encourage the creation of extremely high-quality low-carbon communities by focused application of policies and measures to municipalities that lowered the barriers between administrative authorities and would become a trigger for integrated initiatives. For example, in terms of urban issues such as residential housing, traffic, garbage collection, the environment and water, it was an ingrained habit of each responsible department to consider the issues discretely and it was a rare case when the issues were dealt with in an integrated manner. An integrated approach was required, whereby all of these initiatives and independent agents are integrated and implemented in the social economic structure within a definite area such as a "city" or "region". An integrated approach should demonstrate concrete plans for initiatives that cut across different areas, but at the same time it should serve as a collection of initiatives that exploit local peculiarities. The method for tackling this was the development "Eco-Model Cities" program. By indicating major targets for Eco-Model Cities such as the aim to improve energy efficiency by more than 30% by 2020 or reduce greenhouse gases by more than half by 2050, the enthusiasm and incentive to apply by integrating policies and overcoming internal barriers worked through in a spontaneous manner. Another idea of the program was also that the efforts and actions of these model cities should be transmitted around the country and even overseas – with special emphasis on Southeast Asia - so that their unique approaches toward establishing the low-carbon society become widely known (Chiba 2008).

Objective and Motivation

There is growing political attention paid to issues of a "green economy" due to the present economic crises in combination with the threats by climate change. Decision makers in all fields of policies (e.g. environment, climate, energy, socio-economics etc.) realize that promoting economic activity based on improving environment and controlling climate change is not, as often argued, a constraint on the economy but an economic opportunity to steer society to a more sustainable low carbon economy (Hanley 2009). For example in the EU, many existing environment policies and actions have already contributed to creating a flourishing green economy with about 4.4 million jobs created in the environment sector which are contributing to the GDP by 2.3% with an annual growth rate of 8%, outperforming many other traditional industry sectors. Hence, green economy with its objective to create a low-carbon society can be seen as central for tackling climate change and key element in economic recovery plans for future prosperity and job creation.

Similarly to and jointly with the ongoing Eco-Model Cities Program, new and innovative tools have to be created in order to further promote green economy, such as investment into research, government expenditure (directly into e.g. public transport or renewable energy; indirectly via subsidies for relevant efforts towards a Low-Carbon Society), improved legislation (e.g. energy efficiency standards or renewable targets), and fiscal measures (such as taxes, emission trading or feed in tariffs).

In Japan, both the transportation sector and the industrial sector are showing good progress in terms of reducing greenhouse gas emissions and contributing to a Low-carbon society – mainly due to Japan's extremely high energy efficiency. But in the civic sector, on the contrary, emissions have risen by about 20% since 1999. In this research it has been concentrated on the civic sector which is directly connected to the lifestyles of people and hence is a sector where it is difficult for the government to put policy into effect.

Further information from empirical social sciences and related evaluation research need to be provided to, and integrated by, local and regional policy makers - especially with respect to successfully tackle the pressing problem of a small share in bioenergy and little use of the domestic

forest resource. Despite its relevance for forest-, environmental-, energy- and social politics, relatively little is known about the attitudes of the Japanese public towards the topics of forests and biomass, their sustainable management and certification, or the use of this renewable resource for energy. Only a few surveys including forest related questions have been carried out by governmental or research institutions by e.g. Owari and Sawanobori (2006), MAFF (2007), or Kraxner et al. (2009). Hereby, special emphasis needs to be put on investigating the public opinion in Eco-Model Cities since these cities fulfill best the role of "visualizing" past and future policy efforts as well as civic movements, and if, in the future, local governments continue to share information and approaches that work well, it will be possible to increase activities toward a low-carbon society in all municipalities in Japan.

Thus, the main objectives of this chapter were i) to contribute to filling the knowledge gap in public attitudes and knowledge about forest, forestry, biomass and its certification, and ii) to identify effective ways of how the obtained knowledge of public opinion could contribute to integrated bottom-up policies for an enhanced use of domestic forest resources of rural Eco-Model Cities, complementary to the top-down policies established recently in the area of bioenergy.

Study Site

Shimokawa is a town located in the Kamikawa District of Hokkaidō, the most northern main island of Japan (Fig. 29). The town is a traditional Japanese rural mountain community with 90% forest coverage on a total area of 644.20 km² and a population of 3,866 people (July 2009) in 1,950 households. Shimokawa was originally a mining town, extracting copper and gold. The mines are now exhausted and the primary industries are forestry and farming. Since the acquisition of national forests in 1953, the town has extended its forest area and has implemented a broad variety of forestry activities, mostly in a profit-sharing agreement with the national forest. The local forest association established so called "Recycling Forest Management" which equals the idea of SFM. In this way, the local government tried to supply resources to local communities on a sustainable basis and secure employment opportunities.

Shimokawa Town came somewhat into the spotlight due to the fact that the associated industries are formed organically, with forestry at their base. The town organized an industrial cluster research group, in which business owners, housewives, forestry association workers, retailers, forestry administration officers and people from numerous other professions participate as individuals to develop a comprehensive regional economic system that pursues sustainable regional industries. In this way, the comprehensive design for creating a "Low-carbon Model Society in Symbiosis with the Northern Forest" was developed. These activities have also formed the basis for applying to receive the status of an Eco-Model City in 2008. Long years of effort and investments have turned the forests into a regional advantage for the town. Based on these assets, sustainable forestry operations are promoted and fast growing willow trees are cultivated in a short rotation system, which are a resource providing crop. The Eco-Model City proposal also included a regional biomass-based heating system for CO_2 absorption and fixing and reducing CO_2 and at the same time, ideas from residents should also be incorporated for the development of a low-carbon society. In this way, initiatives to combat global warming are being engaged in, while at the same time attempting to promote regional industries through the introduction of a regional heating system, the promotion of super insulated houses and the achievement of a comfortable living environment. These efforts have led to regional cost reductions, new industry creation and enhanced employment opportunities and have proven that even small towns can come up with novel and effective initiatives. Moreover, Shimokawa Town planned to utilize the forests and forest biomasses in the area for developing a system for carbon offsetting, in order to cancel out the CO_2 that is not reduced in urban areas. In this way, environmental exchanges will be promoted between the urban and rural mountainous regions.

Mountain communities such as Shimokawa Town cover 50% of Japan's total land area and own 60% of Japan's forest area (MAFF 2007). Mountain villages have various biomass feedstocks as potential alternative energy sources to fossil fuel, including forest residues from thinning, branches and leaves or agriculture. According to Japan's Forestry Agency, especially in mountain villages it is possible to form a society where the local resources are effectively and sustainably utilized at multi–stages,

which is an optimal precondition for a Low Carbon Society (MAFF 2008a; MAFF 2008b; NIES 2008).

Figure 29. Shimokawa-town is located about 100km north of Asahikawa-city, the second-largest city in Hokkaido, next to Sapporo. Source: author's compilation.

The Shimokawa Forest Owners' Cooperative achieved FSC certification of its mixed ownership (national/town/private) forest area (6,480 ha) as the first town in Hokkaido in August 2003, hoping for an improved market access for its products (Ota 2002). The Cooperative manages semi natural forest and natural forest and the accumulated forest biomass of Shimokawa forest is some 700,000 m³. Given Shimokawa's northern latitude, the local tree species primarily comprise oak, white birch, and larch. There are 5 sawmills in Shimokawa which produce a total of 60,000 m³ of lumber in a year. The lumber is used both in Japan and exported to Canada, Finland, New Zealand and other places. Some examples for FSC certified products are housing timber ("Born and raised in Shimokawa") and chopsticks. Additionally to Forest Management (FM) Certification, Shimokawa holds also 7 Chain-of-Custody (COC) certificates for the management of wood processing and its distribution. Also a Forest Therapy Association was established in 2005 (information derived from personal interviews and discussions with company staff members and local administration in Shimokawa Town).

Additionally to the fact that Shimokawa Town has been selected as Eco-Model City for the creation of a northern low-carbon society in harmony with forest, the town and its Forest Owners' have been identified. Cooperative as an optimal case study, given the fact that this town does not only aim at

increasing timber and forest product sales, but also tries actively to increase the use of forest biomass for bioenergy in order to initiate a shift towards renewable energy.

Methodology

A questionnaire-based drop-off survey was conducted from 3-31 August 2009 among all households of Shimokawa Town. The questionnaire was divided into 4 sections (general info, forest, forestry, biomass and bioenergy) in each of which 4-16 questions were asked with main focus on forest, forest certification and biomass for bio-energy. The answers were made on a 4 point scale or in dichotomous-choice form and analyzed by using the Statistical Package for the Social Sciences (SPSS). The valid response rate of the total sample number (1,847) was 27% (499 valid responses). In order to facilitate an evaluation and improve the interpretation of the perceptions and attitudes derived from the statistical analysis, results were compared with other national surveys where appropriate.

Additionally, a willingness-to-pay analysis has been carried out in order to test the potential for shifting the local private heating systems towards a woody biomass-based system in Shimokawa Town.

It is assumed that i) people who are forest owners have different perceptions on and attitudes towards forest management and the increased use of biomass, than people who do not own forests. It is further assumed that ii) people who have a better knowledge on forest management, certification, and bioenergy have also different perceptions on and show different attitudes towards forest management and an increased use of forest biomass. Additionally, the chapter compares the changes in perception before and after providing information on SFM and forest certification.

Results and Discussion

Gender, Job and General Results

As for the general questionnaire results, the majority of the respondents were male (67%) and about one third were women (33%). Since Shimokawa Town is a typical Japanese rural town suffering from

weak or stagnating development, the findings indicated an aging problem. Three quarters (75%) of the respondents were older than 50 years old and 39% of the local people stated to be retired or unemployed. There was 1 student among the respondents and about 45% declared to work for a company, the local administration, or were running their own business. 8% stated to work in the agricultural sector and only 2.5% indicated the forest itself as their working place. But 12.5% were working in the forest sector industry such as sawmills or other wood processing companies. However, one quarter (25.6%) of the respondents declared to be forest owners, out of which some 15% indicated to also manage their own forest. Similar results were observed with the farmland ownership. Almost all forest owners were also identified as member of the local forest cooperative, while only some 3% of the respondents stated to be a member of a forest-related non-governmental organization.

In order to learn about the public's general awareness, the respondents were asked to state the 3 issues most threatening the environment. Most often, "Global Warming" was ranked first, followed by "Ozone Depletion", "Air Pollution", the "Population Problem". "Deforestation" got mostly ranked second in front of issues such as "Increasing Food Prices", "Over Fishing" or "Ecosystem Loss". These results indicate that – even though there is an unbalanced age structure towards old people among Shimokawa's public, topics related to climate change are on every body's mind, possibly also driven by the frequent mentioning in the media in the course of the Eco-Model City topic and the activities initiated by the local authority. Issues such as deforestation and overfishing seem to be less important due to the fact that in Hokkaido the population density is quite low on the hand and on the other hand there are abundant forest resources and the Okhotsk Sea and fishery is close.

Forest Functions

Reflecting the importance of forest industry in the area, this industry sector was thought to be especially important for Japan by the vast majority (92%) of the respondents. This clear statement of highly valuing the local key industry turned into a somewhat different view when asking about various forest functions. Here the perception among the public shifted from a more product-oriented view when talking about the importance of the forest industry, towards the preference of ecosystem services as the most important forest function. To be more precise, 84% of the respondents stated that

the protective and conservation functions such as the forest as a natural living space for animals and plants, or the protection from disasters (e.g. flooding, landslides, avalanches), the carbon storage function, as well as the provision of clean water were most essential. On the other hand, the classical forest function of wood production was judged less important by only 60% of the respondents and also the opinion that forest was a source for employment and job opportunities was rather weak at 61% (Fig. 30).

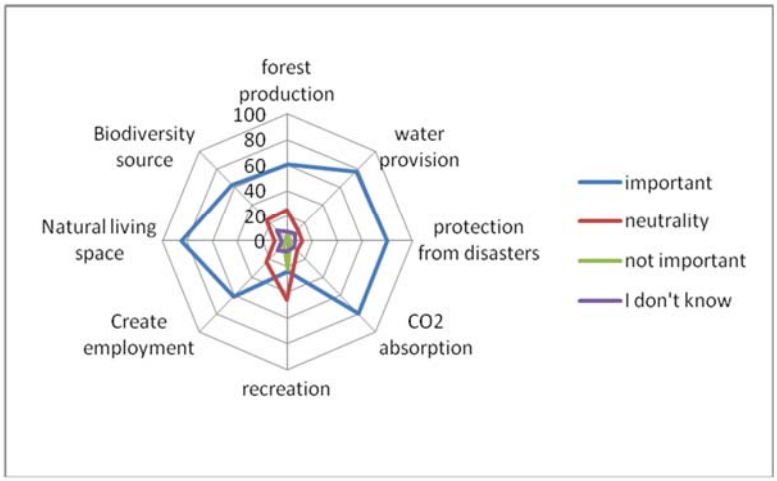

Figure 30. Ranking of forest functions in Shimokawa Town by their perceived importance. Source: author's compilation.

Figure 30 clearly shows that the highest agreement among all respondents as to what constituted the most important role of forest was found for natural-biophysical functions such as forest as important ecosystem and living space (77-85%). The lowest importance was attributed to forest's role as place for wood and biomass production and for creating jobs (60%) and especially as a place for recreation (23%). The other way round, the recreation function was rated highest among the neutral statements and peaked also with the not important notion.

This is a peculiar finding in a region which is dependent to a large extent on the forest as a resource for the production of biomass and timber, as well as work and income - directly or indirectly - to many local households. The fact that such kind of finding was not only a local exception, is supported by the results of a survey undertaken by the Japanese Cabinet Office on a national basis (MAFF 2007)

but is also supported by another local survey in Yusuhara Town, Kochi Prefecture, in more southern Japan (cf. Chapter 4.2; Kraxner et al. 2009).

As to agreement or disagreement on certain statements regarding the forest and its meaning to people, it turned out that there was as similar attitude as with the forest functions (Fig. 31).

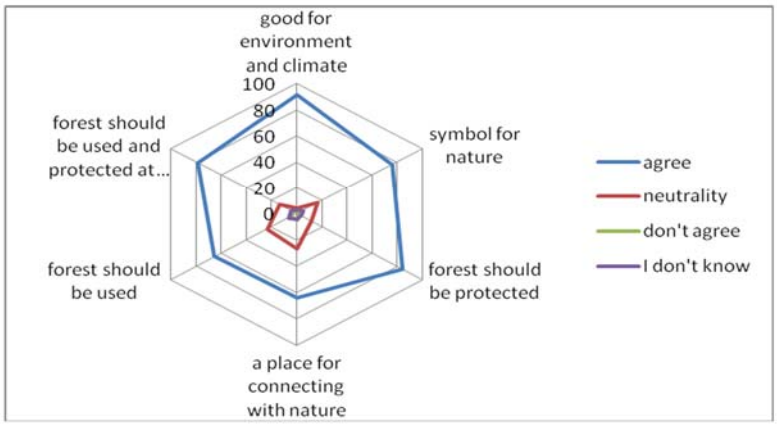

Figure 31. Public perception of forest in Shimokawa Town. Source: author's compilation.

Figure 31 indicates that highest agreement was stated for the notions forest being good for the environment and climate (91%), that forest should be protected and that forest was a symbol of nature. As soon as the production function is included to the statements – such as that forests should be used by man through forest management and harvesting, the agreement level goes down by some 30%.

Forest Management and Bioenergy

In this part, the recognition of different ways of using the resource forest – i.e. SFM and forest certification - were tested. These management-related issues are considered key-factors for public opinion integration into relevant bottom-up policies to increase the use of forest bioenergy and turn towards a Low-Carbon Society. Only slightly more than one third of the respondents indicated to know that some 80% of the total wood consumption in Japan is imported from abroad. This result again might be typical for a remote area far in the north of Hokkaido surrounded by abundant forest resources.

People in Shimokawa Town seemed generally to be satisfied with the way the forest is managed in their region and the kind of forestry activities carried out. However, there were slight variations between the different activities. On the one hand people were most satisfied with the general maintenance and tending of the forest including e.g. forest roads, as well as with thinning activities, whereas on the other hand people were least satisfied with the general forest health and especially with harvesting activities. These results seem to mirror the tendencies from the questions with respect to forest functions. Also in this area, the maintenance and conservation activities like the concern about the forest health or the less severe thinning which is preferred against the simple use and production like harvesting. However, it is remarkable that 40-50% of the respondents could not make any indication of their level of satisfaction with the different statements. With this respect it could be shown with the help of cross-analysis, that those people who visited the forest more frequently, have also higher satisfaction with the current forest management. The majority of the people who never visited the forest belonged to the group of those who also could not provide an answer with respect to their satisfaction with the local forest management. When looking at this cross-analysis with respect to the forest ownership, results indicated that there were clearly different perceptions between forest owners and non-owners (Fig. 32).

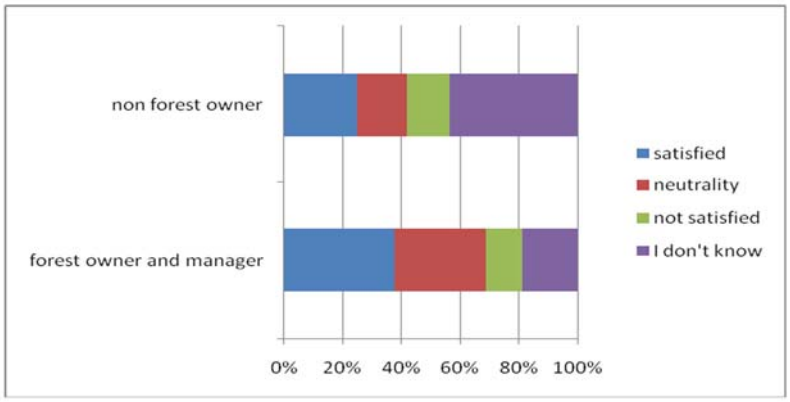

Figure 32. Satisfaction with forest management in Shimokawa Town (25.6% = 126 forest owners, 74.4% = 373 non forest owners; total respondents 499). Source: author's compilation.

Figure 32 shows that the forest owners who are also managing their own forest were much more satisfied with the situation of forest management in Shimokwa Town than those respondents who did not own a forest. Additionally it could be indicated that a clear majority of non-forest owners could not answer this question. This again might reflect the fact that although people were living very close to the forest, in an area where forestry played a decisive role for the local industry, and the city government was very actively pursuing SFM, the perceptions about the quality of forest management was not too good unless the respondent itself was responsible also for the forest management.

With respect to the public's knowledge on the local wood production, most of the respondents considered the harvested wood of the region going into the production of construction timber and the pulp and paper production. Far less people thought that the wood was going to be used for bioenergy production or as fuel wood for home heating. This seemed to reflect reality since there had been the production of housing timber pushed and promoted by the local government ("Born and raised in Shimokawa"). However, the plans to widely introduce the use of forest biomass for bioenergy generation or home heating over the long winter season was only designed in the Eco-Model City application. However, on the direct question whether the amount of harvested wood should have been increased, decreased or remain the same in the region, there was a clear tendency that if the harvesting is "only" done without any specific target, meaning that the wood might be used for any kind of products, people were rather reluctant to increase the harvesting. The other way round, if the wood would have been used for bioenergy production, the same amount of people was willing to increase the harvesting activities than those who preferred to decrease it. In any case, the majority of the people seemed to be not willing to change the harvesting activities and opted for keeping the actual harvesting amount stable. From this kind of answers, two messages could be derived: first of all, the respondents were willing to see a more of harvesting if the wood goes into the bioenergy production. Secondly, people would like to protect their forests and fear that a more of harvesting would disturb the balanced system that was carried out in Shimokawa Town.

Finally, the recognition of the terms renewable energy, forest biomass for bioenergy, forest certification, and sustainable forest management (SFM) were tested. Results indicated that more than 62% of the respondents were aware of forest biomass for bioenergy, and still more than half (55%) knew the term forest certification, but only slightly more than one third (38%) stated to have heard about SFM. The term renewable energy was recognized by only one quarter (26%) of the respondents. The relatively high recognition of forest certification can be explained by the fact that the local forest cooperation had been first in Hokkaido to certify their forest, which attracted a great deal of media covering. On the other hand, SFM did not seem to be recognized as directly related to forest certification which confirmed that forest certification had been communicated more as an economic market tool for achieving a price premium or better market access, rather than an assurance for ecologically responsible forest management which would have been an asset in order to improve the outreach – considering that people are increasingly concerned about "green" issues.

In order to learn more details about the effects of certification, and SFM in combination with bioenergy use on the public perception, a short explanation of the terms was provided and the respondents' attitudes were tested (Fig. 33).

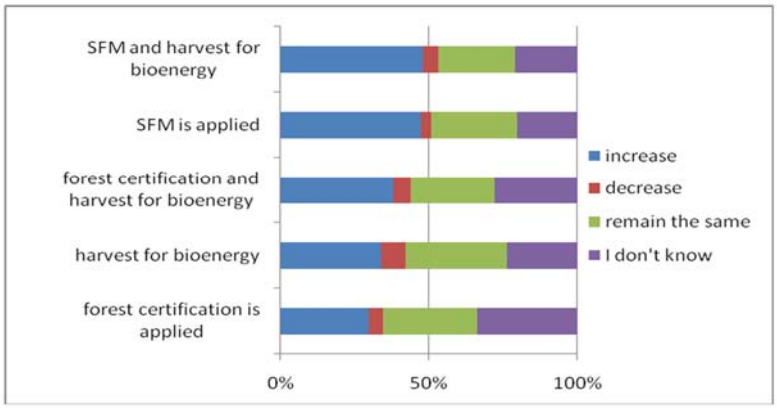

Figure 33. Pre-conditions under which harvesting intensity might change. Source: author's compilation.

Figure 33 clearly indicates that there were certain combinations that might favor or hinder the acceptance of increased harvesting in Shimokawa-Town. Unlike the expectations - based on the

experiences gathered e.g. from a survey carried out in Yusuhara Town (Shikoku Island) (cf. Chapter 4.2; Kraxner et al. 2009) - the pure aspect of certification did not fully convince people to accept an increase of harvesting. Also an increase of harvest that directly goes into bioenergy did not convince many more people to accept it. The situation changes, once a combination of e.g. certification or SFM with the objective of bioenergy production is introduced. In these cases, up to half of the respondents would have agreed with increased harvesting activities. It is further remarkable, that SFM - in combination with a bioenergy objective and alone standing – was evaluated better than certification. Such results again might reflect the concern of the people about the forest health and that certification was considered to be an economic lever and tool only. Most of the people (45%) also indicated that they did not really know, whether SFM was applied in their region or not. However, about the same amount of people (40%) were of the opinion that SFM was definitely applied.

A further cross-analysis revealed that people who were aware of the term forest certification, were also more likely to accept an increased harvesting for bioenergy under SFM conditions. Those who did not know forest certification, were more likely to keep the status quo with respect to harvesting activities. Such results might be interpreted in a way that it turns out to be crucial to provide appropriate information to the public, especially with respect to SFM and FC. However, people, when directly asked for certain information needs, did not mention forest certification to be of special importance. But they would have preferred to receive more information on SFM, the local forestry, biomass for bioenergy, tourism and forest and especially with respect to climate change. For all these issues, the respondents considered newspapers and magazines to be the best media to learn more about the themes, followed by radio, TV, education in the school, leaflets and direct information by staff of the forest companies.

Further, a willingness-to-pay analysis showed with respect to forest certification in Shimokawa Town, that the higher the income of the respondent, the better the knowledge and awareness with respect to forest use and management, the fact of being employed by the local government, and the better the general knowledge about forest was, the higher was the respondents' willingness to pay a price premium for certified wooden products.

Biomass for Bioenergy and Home Heating

Most people in Shimokawa Town stated to have a home heating system based on kerosene (85%), gas (44%) or electricity (32%). Only 8% of all households have their heating system based on wood and 2% are using also solar heat. Especially the use of wood – in a Town that is 90% covered by forest – seemed to be extremely low and hence offered clear room for improvement. This idea had been also successfully picked up in the Eco-Model City proposal to the Japanese government.

In the case that the respondents would have been able to easily switch to another heating system, almost 70% would have chosen to switch to a solar option, while switching to a heating system based on forest biomass would have been the second choice, selected by 28% of the public, followed by wind (27%) and pellet systems (24%). The information, that – under certain circumstances – about one quarter of the respondents would have been willing to change to a wood-based home heating system seems to be promising. The willingness-to-pay analysis indicated that male respondents, when they are older than the average and have a higher income, show most willingness to invest and switch towards a forest biomass based heating system. However, the solar option seemed to be somewhat unrealistic given the high northern latitude of Shimokawa Town and the resulting reduced duration and intensity of sun light.

Discussion

Another survey in southern Japan (Yusuhara Town; cf. Chapter 4.2; Kraxner et al. 2009) indicates that Japanese forests show optimal biophysical conditions such as a growing increment rate and increasing forest area, while the certified area of the managed forest is actually rather small – compared to other highly forested countries in the northern hemisphere (Kraxner et al. 2015). On the other hand, Japan is a large importer of forest products and is considered as the market driver for certified forest products (CFP) in the Asian region (Kraxner et al. 2008), which in fact shows large untapped potential for certification of domestic forest and their products. This in turn could help promoting and expanding the use of domestic forest biomass for bioenergy in Japan.

In this chapter it could be shown that there seems to be a certain paradigm shift from production towards protection and the increased environmental role for forests being e.g. a pool of biodiversity,

is identified when analyzing the results regarding forest functions. However, such an attitude cannot be seen as a local and isolated phenomenon. Also in other rural parts of Japan (e.g. Yusuhara Town on Shikoku Island) these tendencies could be identified (cf. Chapter 4.2; Kraxner et al. 2009). Moreover, these tendencies have been found also for Europe already during the 1990s (EC 2009a). Consequently, the perceived importance of forests was constantly reduced till the point where also in extremely forested areas the local forest industry sector is not seen to be of any importance to the well-being of society anymore. Such impressions and expectations can be perceived as symptomatic for a threatened industry sector that is facing difficult times and has been abandoned for a long period already. It may also mean that people do not see their personal or regional future made up from income from forest products. Additionally, one might say that such kind of attitudes and perceptions also reflect the raising environmental awareness in Japan during the past two decades (Barrett 2005). This also incorporates a certain distance that has been growing between people and forest in Japan. Especially younger people believe – and this is obviously also proven by Japanese reality - that timber and wood products are simple commodities – similarly to steel or petroleum - that need to be imported while resources at home need to be protected, and for that, left untouched.

Where results between European and Japanese surveys (e.g. Shimokawa Town or Yusuhara Town) differ most was the way how the public perceives the recreation function of their forests. Whereas Japanese respondents do not consider forests to be important for their recreation, in Europe this function often is considered to be particularly important (Rametsteiner and Kraxner 2003). This huge difference might have its reason in cultural issues as well as in biological reasons with respect to the forest type and respective suitability for recreation, but also in a different concept of tourism. In Europe, tourism in mountainous and forested areas is common and even receives a certain boom due to increasingly hot summers which bring more tourists in higher areas where the forest also contributes to a more comfortable micro-climate. Tourism in forested areas also requires special attention to forest management and carefully carrying out of thinning and harvesting activities, the continuous construction of forest roads e.g. for mountain biking and their maintenance etc. All these issues and necessary investment on the other hand would be highly beneficial to the forest sector and

increase their competitiveness by enabling forest management at reduced costs and with special focus on sustainable forest management and forest certification. Increased forestry activity would on the other hand also contribute to a better provision with local forest biomass from thinning which would then directly affect the bioenergy sector.

Bioenergy heating systems on the other hand might drive the local demand for wood and consequently contribute to lower harvesting costs by putting a price on forest residues. An additional cross-benefit might be seen in motivating the forest owners to carry out vital forest management operation such as thinnings in order to improve and maintain the forest stand stability and increase the wood quality. Similar tendencies might then consequently be supported by subsidies or tax incentives for forest infrastructure in order to generate local economic growth (Kennedy et al. 2001) and overcome the barrier of a non-competitive forestry sector in Japan causing high costs of biomass for bioenergy.

Harvesting operations in the forests are somehow perceived as not good for the forest which needs to be protected in the view of the public. With this respect, the local policy and decision makers might also consider to switch to modern "low-impact" harvesting methods which prefer cable-yarding and might find better understanding among the public and consequently might lead to public support for intensified, sustainable thinning and harvesting operations.

In this chapter it is explained that people – and especially rural forest owners - who are aware of SFM and forest certification, tend to be positive towards an increased use of their local forests for biomass - particularly, if SFM and forest certification is also applied in the local forests. These findings might provide a solid starting point for local rural policy makers to consider and establish a close relation between forest, energy and certification as well as building a bridge to local rural "eco tourism".

Future rural bottom-up policies that ought to tackle the problems of low forestry activities and climate change issues, might need to aim at increasing local people's knowledge and positive attitudes towards an increased use of domestic forests by explicitly communicating and promoting SFM and forest certification as a necessary driver. Especially when considering that certification procedures that are currently used for certifying timber products could also help to solve some of the sustainability questions and site-specific issues related to biomass production for bioenergy

(Obersteiner et al. 2001). Targeted information campaigns and other communication channels need to be set off by policy makers, taking into account that the new ways in which forests are used have diversified, such as in the form of forest therapy, which uses forests to improve health, and forest environmental education (MAFF 2006).

Enhanced and diversified public opinion research is suggested for Japan – with special focus put on the development in the Eco-Model Cities - in order to further increase the comparability and applicability of local survey results as valuable contribution to an integrated bottom-up policy design at the local level.

Conclusions

With the need of climate change mitigation, forest policy, environmental policy and energy policy have to converge in Japan. Complementary bottom-up policies that integrate public opinion are useful in bridging different sectors. This chapter provides insights into the public's opinion and knowledge about forest and biomass and identifies SFM and certification as key elements that could – together with forest-based bioenergy, local "green tourism" and targeted communication and promotion – provide multiple co-benefits. Bioenergy is the link between the forest, environment, and the energy sector which opens new markets to forest owners. SFM and forest certification can help reactivating forest use by providing the needed economic long-term perspectives to the forest owners and promoting positive aspects of an environmentally sound forest use. The latter is particularly important in an increasingly environmentally sensitive society. Future bottom-up policies need to consider the public opinion and aim at tackling the problems of low forestry activities and climate change issues by concentrating on increasing people's knowledge and positive attitudes towards an environmentally sound use of domestic forests by promoting sustainable forest and forest certification as necessary drivers.

5 DISCUSSION AND CONCLUSIONS

5.1 Synthesis and Final Concluding Remarks

Summarizing – and to directly answer the research questions of this thesis posed at the global level - it can be said that this thesis has demonstrated the overarching need of bioenergy in the current scenarios of the Intergovernmental Panel for Climate Change (IPCC) both as a means to reach ambitious climate stabilization goals and as a cost-effective measure to fulfill the energy needs of future society. The former is mainly achieved by reducing and removing CO_2 from the atmosphere, i.e. by combining carbon-neutral bioenergy with carbon capture and storage (BECCS) in geological formations.

Producing large quantities of biomass – e.g. for BECCS – will require careful land use and will put additional pressure on global forests, especially in tropical areas. It has been demonstrated, how global land-use modeling techniques can be used to examine these issues and quantify the respective co-benefits and possible tradeoffs for policy analysis. One of the main findings here extends beyond the climate change mitigation potential of bioenergy and sheds light on the implications for other resources that will be put under pressure by such a strategy, most notably water (for irrigation) and fertilizer (for intensified agriculture), especially when interacting with other climate change mitigation options competing for land such as Reduced Emissions from Deforestation and Degradation (REDD+) – a popular mitigation option for its supposed positive implications for conservation. The global bioenergy scenario modeling results also show that without the timely implementation of Avoiding Deforestation (AD) policies, almost twice as much pristine forest will be lost and mainly the tropics will suffer from increased deforestation. AD policies in combination with increase production of biomass for bioenergy clearly help to safeguard large quantities of tropical forest – also by distributing the burden of conversion more equally over other regions and forests all over the world. However, what on the one hand means a reduction of forest loss due to adequate policy implementation and governance improvement, means on the other hand a shift or leakage of the problem into other ecosystems such as grass- and shrub-lands like Savannah. The need

for intensification in the agricultural systems and areas is seen as another tradeoff and consequence of producing more sustainable biomass for bioenergy production and at the same time protecting the forest and providing sufficient food for a heavily populated world.

Note that while reducing the risks from increased climate impacts due to global warming, special care has to be taken to contain other risks (e.g. impairing other policy goals such as ensuring food security or conserving other ecosystems services such as biodiversity). Certification of forest management and biomass is one avenue to take other considerations like sustainability on board and give consumers the chance to actively choose products that optimize the inherent tradeoffs. About 10% of the global forest area has been certified by 2015 and countries like Canada, the US and the European Nordic countries are leading the certification charts. However, most of pressure – as explained earlier – is imposed on tropical forests and sustainable forest management (SFM) appears much more difficult in these latitudes than on the northern hemisphere – for social, but also biophysical reasons. This imbalance between north and south needs to be addressed with utmost priority if ambitious climate mitigation targets are to be reached in a sustainable manner.

On the other hand, the expansion of access to sustainable energy is an important goal of economic development, both in the previous process of the Millennium Development Goals and in the new Sustainable Development Goals (SDGs) currently in process of being adopted. Clearly, how this can be achieved in a sustainable way is subject to an array of similar risks outlined for the case of climate change mitigation and a risk-minimizing strategy for realizing these goals is very context-specific and needs to be studied with spatial approaches at high levels of resolution. That is, while the global approaches introduced in Chapter 2 of this thesis are essential for understanding global dynamics (e.g. impact of national policies also abroad through the existence of trade and other teleconnections), it is necessary to zoom into the regions in question with the use of other tools in order to arrive at reliable bioenergy potentials and concrete policy advice.

Chapter 3 therefore subsequently increases the resolution at the example of two countries of the region of East Asia - first into Korea (Chapter 3.1) and second to national Japanese level, where the focus is on national bioenergy modeling and deriving the BECCS potential (Chapter 3.2). In the following

text, the answers to the thesis' research questions posed at the regional level are summarized. Global scenarios such as the ones provided and discussed by IPCC provide the basis for decisions taken at global level. The Conference of the Parties (UNFCCC) in Paris, 2015, achieved agreement among all participating countries to limit climate change at 2ºC (1.5ºC if possible) and countries suggested in their Intended Nationally Determined Contributions (INDCs) their specific pathways on how to reduce emissions. In order to further improve such regional, national and even local pathways, higher resolving tools – as demonstrated in Chapter 3 – have to be applied. Global approaches with mostly low spatial resolution (e.g. sometimes not even national resolution but only "world regions" are applied by Integrated Assessment Models (IAMs)) do not allow for taking country specific regulations and limitations into account. This is why this thesis proposes the presented methodology - in a consistent manner – to be applied globally. Korea and Japan have been the first assessments with the aim to identify bioenergy potentials that are sustainable and take national demand and supply possibilities into account. Furthermore, focus has been put on consistency of the methodology and the sustainability of bioenergy feedstock production. Not only sustainable harvesting rules have been applied, but also local protection areas have been considered. This first approaches showed realistic and rather conservative BECCS potentials of up to 1.5 million tons CO_2 annually which is considered to be rather low compared to the needs. However, Chapter 3 also outlines possibility of how to increase the potentials in future research.

When continuing the argumentation along the logics of need for more detailed bottom-up information in order to provide answers to the thesis' research questions at the local level - including how much a region, a nation and a local area can contribute to achieving the climate mitigation targets - one needs to look also into the details of local communities such as cities or towns (Chapter 4). The rural "hinterland" is in most of the cases the area where an increased bioenergy feedstock can be sourced in the future. At the example of Austria – a champion with long lasting experience in sustainable forest management and bioenergy generation – some success cases are demonstrated and discussed. Here it is shown that a crucial role for a healthy bioenergy system development is without doubt a functioning forest sector of a country. In Austria, traditionally, the forest owners and their associations

are collaborating closely with the forest sector industry which is revealed itself e.g. in joint promotional activities and similar joint ventures. Austria has also been chosen due to its topographical and also otherwise similar characteristics to Japan, which then enables lessons learned to be translated to the Japanese context, with respect to sustainable forest management and forest biomass-based bioenergy and the possibility to apply similar policy tools as in Austria.

Usually, not only biophysical parameters and legislations or the system economy can be taken into account in order to derive sustainable bioenergy or BECCS potentials of a location, also and especially social parameters form part of a sustainable approach. Hence, Chapter 4 is investigating the public opinion with respect to knowledge and attitudes towards bioenergy, sustainability and certification in 2 rural areas of Japan. While it has been demonstrated in Chapter 2 that certification is a powerful tool to enable addressing the tradeoffs and risks studied in this thesis, careful planning and application in the Japanese context requires a more in-depth analysis of the exact locations in question. In chapter 4.2 based on Kraxner et al (2009), a study conducted for Yusuhara Town is presented. The main message to be carried forth from this is that however attractive the tool of certification turns out in other contexts, public opinion needs to be integrated in the formulation of the certification strategy in order to achieve full effectiveness. This result is further underlined in Chapter 4.3, where the situation in Yusuhara Town is compared to a similar survey that has been carried out in 2008 in Shimokawa Town/Hokkaido.

Clearly, it is a major challenge to disentangle the effects of the underlying biophysical and socio-economic factors from existing and overlapping policies. The main conclusion is that all three dimensions need to be considered in order to understand the differences in bioenergy diffusion across a community, country or region. For a translation of this experience to Japan, it is important to keep in mind that policy instruments such as feed-in tariffs need to be designed such that they do not incentivize the installation of new facilities at locations that would not be chosen if cost-optimization was the only criterion, as they need to be (financially) sustainable beyond the duration of the support scheme. Furthermore, aggressive feed-in-tariffs might cause non-desirable effects such as clear cutting around central large-scale bioenergy plants which might result further into non-sustainable

ecosystem management over vast areas. The support scheme should thus only be considered as helping a new installation over the initial hurdle of establishment and market entry, but cannot be expected to be sustained for the plant lifetime.

In sum, much can be learned for policymaking in the area of bioenergy from studying regions and countries similar to Japan, but it remains indispensable to study the exact context on the ground and set into perspective with respect to not only biophysical and economic developments, but also with respect to societal specificities that might differ between Austria and Japan and even between regions and cities within the two countries themselves. Public opinion is the most important example in this context and failing to actively consider this can make otherwise cost-optimal strategies ineffective or even stall progress completely. So while the tools developed in this thesis can be translated to the Japanese situation and calibrated and applied to bioenergy diffusion also here, careful pre-analysis is needed, as narrow-mindedly applying the tools to just cost factors and general topographical information might foreclose important avenues for change and development that might not have presented in the Austrian case.

5.2 Lessons Learned and Take-away Messages across the Levels from Global to Local

While the previous chapter has already reviewed the synthesis and main results presented in this thesis and established the relation with the Japanese context, this chapter is dedicated to summarize the main lessons learned from all levels of this thesis.

Global

Bioenergy is clearly seen as a substantial component of a future energy portfolio with focus on renewable energy technologies. On the other hand increased bioenergy feedstock production in forests might lead to unsustainable management practices and increased forest loss – along with losses in biodiversity and other resources. The thesis concludes that - at the global level - bioenergy

production from forests is not a major driver of forest loss but can have significant impact on land use change dynamics and other ecosystem services.

- It is possible to avoid large-scale deforestation, even under expanded bioenergy production if REDD+ and other AD policies are put in place and good governance is applied.
- SFM may substantially improve forest conditions and the value of ecosystem services. FMC is one of the key tools to ensure SFM
- Increased bioenergy production – without the introduction of safeguards such as REDD+ policies - might cause up to 160 million ha of unmanaged forest loss in different world regions, i.e. tropical areas.
- Increased bioenergy production under active safeguards such as REDD+ - might lead to 70 million ha of unmanaged forest loss in different world regions – with more equally distributed losses over the regions.
- Under increased bioenergy without REDD+ assumptions, CO2 emissions will be up to 8 Gt per year while the introduction of REDD+ policies might save up to 3 Gt of emissions.
- Food demand from rising population and bioenergy expansion will require more intense management in terms of irrigation and fertilization, causing e.g. high pressure on water resources. Agricultural water consumption might by up to 10% higher (1 million tons total) under REDD+ policies in place than without (0.9 million tons total).

Therefore, any scenario or potential calculation leading to policy support needs to base its assumptions strictly on SFM and further reduce damage by considering policies that help avoiding deforestation. Furthermore, the modeling of future scenarios can help identify tradeoffs of bioenergy systems while helping to select the least-impact or optimal policies for each region in the world. Such least-impact bioenergy systems consequently need to be picked up by assessments carried out on local and regional levels with the help of bottom-up analysis tools in order to consider social,

environmental and economic conditions and derive tailor-made solutions that are accepted by the local population.

Certified forest management can be seen as a proxy for ensuring sustainable use of forest resources. It is one of the few tools through which consumers can have impact on the market. Most of the certified forest area is located on the northern hemisphere where sustainable forest management is easier to apply than in the tropics.

- By May 2015, the major schemes –FSC and PEFC – certified a total global gross forest area of 446.5 million hectares.
- The PEFC-certified area totaled 263.2 million hectares in 31 countries and the FSC certified 183.3 million hectares in the 81 countries
- The total global certified forest area equals about 10% of the total global forest area.
- Two quarters of the certified area is located in North America and another quarter in Europe. One-eighth of the total area is located in CIS and Eastern European countries and only one eighth is shared by all other countries – mostly on the southern hemisphere.
- In 2015, about 250 million m^3 certified wood has been brought to the market from each of the certified areas in North America and Europe.
- By 2015, about 40,000 CoC certificates have been issued by the leading schemes FSC (30.000) and PEFC (10,000).
- Contrary to the needs in order to ensure SFM and contrary to the long-year-trends of previous years, both the increase of forest management and CoC certification is slowing at the global level.

Certification might thus help monitoring and even reducing illegal logging, logging impact and deforestation in tropical forests that are the most biodiverse ecosystems and contain most of the biomass globally. Better promotion could help increasing the success of this multi-objective market tool and improved documentation and statistical assessment through science can contribute to developing a future avoiding deforestation mechanisms.

Regional

To reach long-term climate stabilization at ambitious mitigation targets below 2ºC, negative emissions technologies are likely to be required in addition to a broad portfolio of complementary mitigation technologies (NETs) such as afforestation or technical solutions such as increased efficiencies of appliances. Under present knowledge the combination of bioenergy and carbon capture and storage (BECCS) is among the most promising NET technologies.

- The concept of BECCS is behind most of the end of the century net negative emissions of ambitious climate stabilization pathways outlined by IPCC.
- Many of these pathways include BECCS already in the middle of the century.
- This pronounces the importance of bioenergy even in the quite near future.

However, very few studies are carried out globally and limited research is carried out in assessing countries' or regions' suitability and potentials for BECCS and their possible contribution to mitigating negative effects of climate change. Bottom-up assessments at national and regional levels are needed to achieve realistic BECCS potentials at global level and being able to assess potential impacts on ecosystem services and people, as well as boosting the development of this new technology and lowering the systems costs of this technology.

Both East Asian countries, Korea and Japan, have large forest cover that is merely unused or managed in non-intensive way. Forests in both countries tend to over-age and need thinning to boost quality and health of the left-over trees, or final harvesting in over-aged forest stands. At the same time, both countries lack the necessary infra-structure in the forest – such as forest roads for logging systems and easy access for transport of wood and thinning material or machinery. Thus, building up a competitive forest sector along with a successful and sustainable forest biomass-based bioenergy system will require substantial investment. Nevertheless, the application of an engineering model – as outlined in this thesis - has shown that substantial bioenergy demand and supply could be generated that a) would substitute fossil fuel-based energy in order to help achieving the countries' emission reduction targets; and b) would, furthermore, enable to generate negative emissions through BECCS.

- High spatial resolution engineering models that optimize the supply chain of bioenergy systems (e.g. BeWhere) are required to calculate realistic BECCS potentials under different scenarios assumptions.
- Engineering models need to be coupled with geographic explicit biophysical forest and/or agricultural models (e.g. G4M or EPIC) in order to identify the potentials for sustainable biomass harvesting and their location under different management options (forest management varies by region, country, tradition and other parameters).
- Under extremely conservative and sustainable assumptions, the modeled BECCS potential for Korea amounts to some 250,000 tons CO_2 per year, while under similar assumptions the potential for Japan shows a six times higher amount (1.5 million tons CO_2 per year).
- The potentials are relative small since only "in-situ" BECCS systems were modeled (no CO_2 transport). Substantial system expansion is expected by considering on-shore or off-shore transport of CO_2 from the point sources to geologically suitable storage reservoirs.
- The studies presented in this thesis recommend joint regional approaches for CO_2 storage between Korea and Japan.
- Highest storage potentials for the region have been identified off-shore.

However, the most limiting factor in the region might not be the geological suitability for CO_2 storage but rather the limited preparedness by the forest sectors in both countries. A successful bioenergy system – and consequently also an optimally functioning BECCS system – requires a vital forestry along with an innovative forest sector as a pre-requisite. In order to ramp up a large BECCS system in the region, upfront investment in forestry seems indispensable.

Local

Japan and Austria share many characteristics in terms of topography (mountainous and forested areas) and in terms of their policy objectives to ensure a growing energy supply that makes the economy less dependent on fossil fuels and nuclear energy in the long run. The Fukushima incident in this respect has had impacts on the mindsets beyond the borders of Japan and Asia and set off serious

discussions on the phase-out of nuclear energy in Europe. The lessons learned for Austria in this thesis are thus to a certain extent applicable to Japan as well.

Austria has a long history of successful bioenergy implementation with positive effects of on e.g. the rural development at local level. Especially after the introduction of the Eco-Electricity Law in 2003, it came to a very dynamic development of the eco-electricity sector. This policy did not only reduce emissions but also helped creating jobs:

- 700,000 households in Austria use fuel wood, wood chips, wood briquettes or pellets for heating their homes.
- 90% of all pellet boilers installed in Austria (about 100,000) are of domestic origin.
- In 2014, the domestic demand for pellets has been some 900,000 tons while the pellet production exceeded the demand.
- By 2015, the Austrian bioenergy sector comprised of 1,000 small-scale enterprises specialized in installing bioenergy heat devices, 60 educational institutions (including universities), 100 small-medium scale enterprises developing and producing innovative bioenergy technology, 40 pellets producers (total capacity 1 million tons per year), 270 stove-fitters and 21 biofuel producers.
- The sector of solid bioenergy contributes 40% (2.4 billion Euro) total turnover of the renewable energy sector.
- Every second job of the renewable energy sector (total 36,200 jobs) is in the area of solid bioenergy production.

Furthermore, some of the forest products, such as small diameter harvesting residues, wood residues, bark etc., that earlier would not have been used at all, finally could be sold by the forest owners to the bioenergy plants. This new competition on the wood market for resources has also led to a prominent “wood mobilization” discussion. Wood that was not worth to be harvested before shall now be harvested and mobilized in order to satisfy the market. However, a precondition for cost effective harvesting conditions in Austria is to combine innovation such as cable-yarding or fully mechanized harvester-forwarder systems for steep terrains (15% of total wood harvest) with an

optimized infrastructure, mainly in terms of access to the forest and to the harvesting area itself. In order to further reduce the labor intensive harvesting costs, the Austrian forest owners consequently improved the forest road grid. Nowadays, Austria has one of the highest forest road densities worldwide – 150,300 km of forest roads accessible for trucks (= 45 m/ha). Some 2,200 km of this forest road category are constructed every year and additionally there are some 150,000 km of temporary transportation tracks in Austria's forests. Japan features a permanent forest road density of 13 m/ha. On the other hand, improved market access is ensured in Austria through 100% certified forest area, while Japan features around 1.6% certified forest area. Last but not least, the perception of forest by the local people is quite different between Austria and Japan. While Austrians tend to see the importance of the recreational value of forests more often, according to surveys among Japanese rural population this aspect is considered not to be important. This might indicate a large potential for Japan with respect to tourism contributing to rural revitalization, which is already the case in Austria. The public opinion and attitude of rural population towards bioenergy and sustainable biomass production is considered to be crucial for the successful implementation and expansion of bioenergy systems. Therefore, in order to explore to which degree the Austrian experience can be replicated in Japan, a careful analysis of Japanese attitudes, perceptions and knowledge with respect to bioenergy and its benefits has been carried out:

- 86% of the questionnaire respondents from a local rural town in the south of Japan (Yusuhara, Kochi) state that the forest industry is important for Japan, many of them also see the main function of the forest in protection from disasters and provision of clean water and air. Only some 40-50% of the respondents consider the production function or the employment function as important and 30% consider forest as important for recreation.
- While foresters and forest owners favor the production function, company workers prefer the protection of forests.
- More than 60% of the respondents are aware of certification, but they do not see so much a link between certification and SFM.
- Forest owners and non-owners have different attitudes with respect to increasing harvesting in the local forest. Certification seems to provide a positive signal for enhanced wood

production to forest owners while non-owners would rather agree with an increased use of forests if these are not certified.

- When it comes to use the forest for bioenergy production, forest owners show more agreement with this suggestion than non-forest owners.
- Most positive attitudes with respect to an increased biomass use for bioenergy are forest owners who are aware of forest certification and at the same time want to increase the general use of forests.
- The local correspondents showed willingness to pay 4-5% higher energy bills for switching to bioenergy and helping to protect the climate.

Similar results were achieved from a survey in a rural town of Hokkaido (Shimokawa), indicating that knowledge about forest certification, SFM and bioenergy, as well as understanding their interaction, might be key for developing a bioenergy system that lives up to its full potential of multiple co-benefits such as climate protection, energy security and job creation.

A good example of how such knowledge improvement has been triggered in Austria was the reaction of the forest sector to a severe crisis that followed the "acid rain discussion" in the 80s and early 90s of the last century, which made people avoid using forest products. One of the most important keys for strengthening the forest sector was identified in the urgent need to actively use the domestic forest resources in order to maintain good forest management – since only a well-managed and profitable forest could assure the required maintenance of the multiple purpose forest (production, protection, recreation etc.). A concerted public relations campaign based on the platform "Pro Holz" (Pro Wood) between forest owners, the sawmilling industry and the pulp and paper industry created the slogan "Stolz auf Holz" (Proud about our wood). Since the late 1980s, this platform is responsible for the marketing, promotion and knowledge-creation with respect to forest products i.e. wood and its advantages in construction, furniture etc. From a broad approach, the campaign consequently started to focus also more on the younger generations.

Looking into the future, there should be substantial additional potential for biomass feedstock for bioenergy from introducing sustainable forestry at larger scale in Japan – starting with the necessary investments in an infrastructure that allows for (price-) competitive harvesting and management operations.

Applying spatial modeling tools should enable Japanese areas to take into account the risk to impair other ecosystems services in their planning strategies, both urban and rural, where recreation often has an additional spiritual component in Japan compared to Austria. As has been demonstrated in this thesis, such spatial analysis is greatly impaired by the unavailability of comprehensive data, which is either not available over time or insufficiently disaggregated to identify areas of conflict. For Japan, it is therefore important to concentrate efforts on data acquisition early on, as without a meaningful calibration, the help provided by the tools developed for this purpose in this thesis will at most remain impressionistic.

Rural areas in Japan also need revitalization in an economic sense, as ongoing urbanization and socio-economic trends draw the younger generations to the cities thus depriving rural areas of important capacity. Bioenergy can re-connect urban areas by providing more than just energy access in remote areas: employment and the knock-on effects for further development of e.g. recreational strategies. Alpine provinces have been successful at this and more research into how this experience can be translated to Japan is definitely warranted though beyond the scope of this particular thesis.

Japanese policy can be complemented by marketing tools that have proven to be powerful in Europe and other regions in the world. Forest certification will enable the green-minded consumer and industry to make conscious choices about their purchases and use of forestry products thus influencing developments to a certain extent.

While topography and some socio-economic developments might be comparable, Japan is also different from Austria in some respects. This needs to be taken into account when formulating policy strategies. For example, the effective use of certification depends crucially on public opinion, which is also not homogenous among different countries in Europe and across the federal states of Austria, so it should not come as a surprise that Japanese citizens differ in that respect, too. While this thesis

has demonstrated this and discussed the implications for certification, more research will be needed for other tools and practices that might not easily be transplanted from the Austrian context to Japan.

5.3 Benefits to Different User Groups

The thesis provides new tools and insights that are of benefit to different branches and fields of the scientific community. In particular, integrated assessment modeling has to rely on a thorough understanding of system dynamics of potential bioenergy expansion. This manifests itself in the ongoing trend to couple integrated assessment and energy systems models with land use models or to develop more detail in already existing land use modules. Having demonstrated how bottom-up modeling can contribute to arrive at more realistic biomass potentials, the thesis therefore also paves the way for new climate stabilization pathways e.g. to be included in IPCC's 6th Assessment Report. In addition to the benefits for science, another important user group of the findings of this thesis is comprised of policy makers across the different governance levels: the insights concerning trade-offs between bioenergy expansion for climate change mitigation and other sustainability goals are important information to negotiation processes and coordination between countries, e.g. in the frame of the UNFCCC - ultimately benefitting civil society at large to the achievement of these goals. While previous negotiations have followed a top-down approach, the agreement that came forth from COP 21 in Paris is of a hybrid nature, where in addition to global coordination, countries are requested to put forth their INDCs. In those INDCs countries can include any emission saving plans for the negotiations which could also include national renewable energy plans and therefore an expansion in bioenergy. Hence, the tools for bottom-up assessment of bioenergy potentials and life cycle analysis using techno-economic modeling, are of high value for elaborating these commitments.

Furthermore, the thesis has examined a tool for sustainable forest management and analyzed its applicability in different parts of Japan. The insights on the perception of the public can be directly used for informing policy plans at municipal level.

Finally, private sector stakeholders form an important user group of the thesis' results. For example, companies need to take the perception of their consumers about sustainability more and more into account. At the 2014 Climate Summit in New York, for instance, many large companies became signatories to the Declaration on Forests striving to make their supply chains deforestation-free. Also

at COP 21 in Paris last year companies have played a larger role in forming climate change mitigation strategies. Certification can serve as a signal to their customers and this makes the results of the public opinion survey on certification a valuable input to their business strategy planning. Similarly, forest owners will benefit from the detailed information on potential new markets provided in this thesis. The latter can then be accessed more easily. Certification has also been shown to be an important entry point for consumers to influence the supply side. Moreover, companies will also benefit from the thesis' insights on tradeoffs and biomass potentials as these scenarios help them to detect upcoming trends.

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ANNEX I THE G4M MODEL

Detailed description of the Global Forest Model "G4M"

This model description has been compiled by the thesis author and is inter-alia based on IIASA-internal G4M descriptions and text from various peer-reviewed articles as described under further information in this section.

What is G4M?

The Global Forest Model (G4M)[1] has been developed by IIASA and is being applied to estimate forest growth, potential harvest amounts, and the impact of forestry activities (afforestation, deforestation and forest management) on biomass and carbon stocks. G4M provides biophysical estimates and environmental indicators of forests use, as well an economically sound basis for decision making, either independently, or in conjunction with other models.

The G4M consists of two main parts. One part is dealing with forest growth, estimations of forest increments and forest management options on forest stand scale, while the other part deals with afforestation and deforestation and country scale forest management as well as estimation of respective emissions. As such, G4M is a versatile model in which each of these two parts of the model can be used separately or also integrated with other models to gain greater clarification of land use potential. G4M also uses information from other models or databases to produce forecasts of land-use change, carbon sequestration and/or emissions in forests, the impacts of carbon incentives (e.g., avoided deforestation), and supply of biomass for bio-energy and timber. The model can incorporate many factors or needs, for instance, the need to provide food security, to understand future urbanization patterns, and to gauge how wildfires or insects might potentially affect forest productivity. For these types of analysis, G4M is commonly linked with IIASA's GLOBIOM[2] model.

[1] See also: www.iiasa.ac.at/G4M

[2] See also: www.iiasa.ac.at/GLOBIOM

Some general features of the model are summarized in the bullet list below:

- Geographically explicit forestry model
- Estimates afforestation, deforestation and forest management and associated emissions and removals per EU Member State and non-EU countries to the degree of data availability
- Is calibrated to historic data reported by Member States on afforestation and deforestation and therefore includes policies on these activities. Explicit future targets of forest area development can be included
- Informs GLOBIOM about potential wood supply and initial land prices
- Receives information from GLOBIOM on the development of wood demand, wood and land prices, and land use for agriculture.

Estimating forest increments

One of the main features of G4M is its possibility to analyze forest related biophysical processes and the outcome of various management possibilities. Potential forest productivity is estimated by using temperature, precipitation, irrigation, soil type, water holding capacity, altitude, latitude, CO2 concentration and forest type. This potential productivity is reduced if the rotation time is not the increment optimal and the forest is not fully stocked. Also the age structure of forests can be handled what allows to show e.g. how the carbon stock of a new afforestation is developing over time. Beside the increment, harvest amounts and carbons stocks can be calculated. Main management options are the selection of a specific rotation time and a target stand density. See Fig. 1 for an illustration of how the model can estimate stem carbon development for various management possibilities and change climate scenarios.

For EU, the model estimates forest growth on a 1 x 1 km resolution for the following eight tree species: Pine, Spruce, Beach, *Pinus Pinaster*, Fir, Oak, Birch, and Larch. The graphical location of

tree species is based on the tree species maps as provided by the JRC Institute for Environment and Sustainability. Globally, the model provides estimates down to a 30 x 30 sec. resolution for four categories of forests (evergreen needle-leaved, evergreen broadleaved, deciduous needle-leaved, deciduous broadleaved) and for four regions (Boreal, Temperate, Tropical, Subtropical).

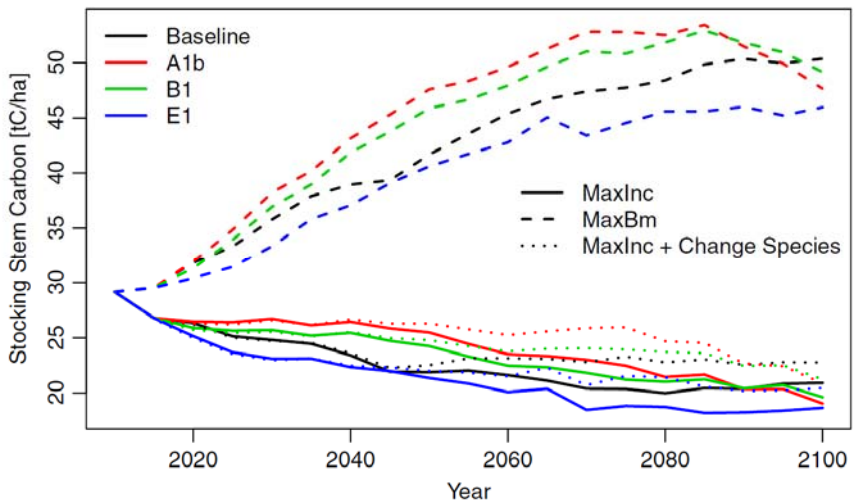

Figure 1: Stem carbon development under conditions of baseline and three climate change scenarios (A1b, B1 and E1) and three management scenarios (maximize stocking biomass, maximize increments with and without change of species).

Predicting afforestation and deforestation

The G4M-model can also be used to estimate forest related land use change. This is done by comparing net present value (NPV) estimates of keeping the land as forest, in comparison to potential NPV estimates from alternative use of the same land, for example, to grow grain for food or biofuel. To do this, G4M estimates the NPV of the forest by calculating the amount and value of wood produced minus the harvesting costs (i.e., logging and timber extraction). By comparing the value of managed forest (difference of wood price and harvesting costs, income by storing carbon in forests) with the value from alternative land use on the same place, a decision of afforestation or deforestation is made. As G4M is spatially explicit the different deforestation pressure at the forest frontier can also be handled. The model can use external information (like wood prices, prescribed land use change from GLOBIOM) from other models or data bases, which guarantee food security and land for urban

development or account for disturbances. As outputs, G4M produces estimates of forest area change, carbon sequestration and emissions in forests, impacts of carbon incentives (e.g. avoided deforestation) and supply of biomass for bio-energy and timber.

Major innovative characteristics of G4M

Modelling afforestation, deforestation and forest management within the G4M framework makes it possible to take into account the important interactions between the processes and thereby make qualitative assessment of REDD policies in countries. As emissions from deforestation, afforestation and forest management are highly interdependent, it is important to model them simultaneously within one system to detect "carbon leakage" from one activity to the other. Furthermore, linking the G4M model with the other models within IIASA model cluster allows detecting leakages between economy sectors or even between GHG gases, for example the economic model takes into account "carbon leakage" from one region to another as well as increase of competition for land if bioenergy is highly demanded.

Currently, there is a lack of models for detailed larger scale geographically explicit simulation of REDD+ options that gives comparable estimates across countries. G4M fills this gap and allows elaboration of the development of plausible national baselines that take larger scale developments and competition between countries and sectors into account. Furthermore, for the consideration of national specific details and spatial explicit information, the model has at the same time been specifically designed to integrate and capture data available at different scales (from local, grid cell specific to global).

Applications of the model

IIASA's G4M has been widely used and applied to generate forest estimates in a large number of studies - both globally and regionally. Some examples for direct global implementation are the contributions to the forest part of the IPCC RCP 8.5 scenario development by IIASA (Riahi et al.,

2011), studies in the area of global cost estimates of reducing carbon emissions through avoided deforestation and REDD+ activities (Kindermann et al., 2008, Böttcher et al., 2011). Furthermore, the model has been used for estimations of a forest carbon index (Deveny et al., 2009) and impacts of incentives to reduce emissions from deforestation on global species extinction (Strassburg et al., 2012). Especially for global estimations for an increased bioenergy production combined with a possible halt to net deforestation by 2020, G4M has been used together with GLOBIOM by WWF (see inter alia Taylor, 2011; or Kraxner et al., 2013).

Regional case studies cover inter alia the EU for which a biomass increment study has been carried out (Kindermann et al., 2013). Recently the model has also been applied to project the future EU forest CO2 sink as affected by recent bioenergy policies at a national level that was used by several EU member states to construct their individual Forest Management Reference Levels (Böttcher et al., 2011). The model has also been used to estimate the potential forest carbon stock and increment for EU under different management and climate scenarios (Kindermann et al., 2013),

Central Europe with an assessment of balanced ecosystems services and bioenergy production in the Alpine region, Sweden on optimization of biofuel production, South Korea with respect to bioenergy production combined with carbon capture and storage (BECCS), and a carbon dynamics assessment for forest biomass in China (c.f. Svadlenak et al., 2013; Leduc et al., 2010; Kraxner et al., 2014; and Zhou et al., 2013).

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ANNEX II THE EPIC MODEL

Detailed description of IIASA's Global Agriculture Model "EPIC"

This model description has been compiled by the thesis author and is inter-alia based on IIASA-internal EPIC descriptions and text from various peer-reviewed articles as described under further information in this section.

What is the EPIC model

EPIC (Environmental Policy Integrated Climate; Williams et al. 1989) is an agro-ecosystem model originally developed by a modelling team of the US Department of Agriculture to assess the status of US soil and water resources (Williams et al., 1984), but has been continuously expanded and refined to allow simulation of many processes important in agricultural land management (cf. Gassman et al., 2005).

The major components in EPIC are plant growth and competition, weather simulation, hydrology, soil erosion, nutrient and carbon cycling, pesticide fate, soil temperature and moisture, tillage, cost accounting, and plant environment control. EPIC operates on a daily time step and can simulate plant growth for hundreds of years. The concept of radiation use efficiency (RUE) is used in EPIC to simulate plant growth. Potential plant biomass is calculated daily as a function of photo-synthetically active radiation and leaf area index, while the amount of solar radiation captured as biomass is driven by crop-specific RUE. CO2 fertilization effects are quantified through increases in RUE and stomatal resistance reducing transpiration (Stockle et al., 1992). Potential biomass is adjusted to actual biomass through daily stress caused by extreme temperatures, water and nutrient deficiency or inadequate aeration. The crop growth is importantly driven by air temperature and precipitation. Temperature represents a basis for plant phenological development: daily heat unit accumulation determines leaf area growth and senescence, canopy height, nutrient uptake, harvest index and date of harvest. Temperature also determines relative humidity, saturation vapour pressure, vapour pressure deficit, snowmelt and potential and actual ET. Precipitation contributes to hydrological cycle accounting for

surface runoff, subsurface flow and percolation, water table dynamics and ET. Soil organic carbon routine was introduced by Izaurralde et al. (2006) and phosphorus dynamics was adopted from (Jones et al., 1984). Different management options are available, including tillage operations, irrigation scheduling, fertilizer application rates and timing. With nutrient and soil moisture control EPIC can estimate current yield as well as yield potential.

Major innovative characteristics

IIASA's EPIC represents an up-scaled gridded implementation of the EPIC model operational globally at 5 arc-min and at 1-km grid for the EU (e.g. Balkovič et al., 2013; van der Velde et al., 2013; Xiong et al., 2014). For these purposes, EPIC (v.0810) was coupled with ArcGIS and SQL Server (Fig 2), and integrated with the most recent and complete information on cropland and crop cultivation currently available for the EU and globally (e.g. Monfreda et al., 2008; Mueller et al., 2012; Portmann et al., 2010; Ramankutty et al., 2008; Sacks et al., 2010; Wriedt et al., 2009). The spatial resolution is adjusted to gridded Simulation Units (SimU) assuming that weather, soil, topography, and region-specific management systems equal and are homogeneous in the SimU. In addition, the GEPIC modelling system (cf. Liu et al., 2007; Rosenzweig et al., 2014) has recently been integrated with the EPIC system of IIASA. IIASA's EPIC is currently setup for 16 crops globally (barley, cassava, ground nuts, maize, millet, potatoes, pulses, rape, rice, rye, sugar beet, sugar cane, sunflower, sorghum, soya, and wheat) and 12 crops for the EU (maize corn and fodder, potatoes, soya, spring barley, sugar beet, sunflower, winter rape, winter rye, winter wheat, rice and pulses), and is being continuously updated by IIASA's ESM-AES group. Current crop database contains spatially explicit information needed for regional crop growth simulations, such as sowing and harvesting dates, potential heat units accumulated by crops during the growing season, conventional N, P and K application rates, irrigation allocation and intensities, sowing densities, and optimum/basal temperatures.

The IIASA's EPIC modelling system is coupled with various daily datasets on historical weather and weather projections, including CGMS, Princeton, AgMERRA, WATCH, GRASP, WFDEI,

ENSEMBLES, EURO-CORDEX and ISI-MIP datasets. Site and soil domain integrates most of the existing standards, including SRTM and GTOPO, the Digital Soil Map of the World, WISE database, the Harmonized World Soil Database, and the European Soil Bureau Database. The IIASA's EPIC has been validated against reported historical yields (Balkovič et al., 2013; Xiong et al., 2014), see also Figure 2.

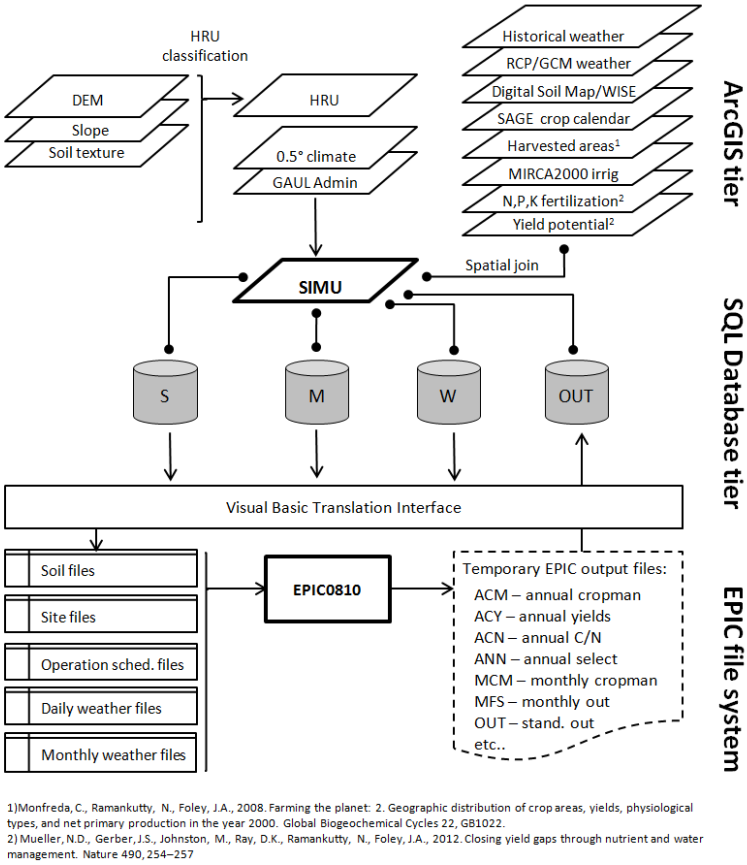

Figure 2. Schematic diagram of global EPIC implementation; S – soil and topographical database, M – crop management database, W – weather database, OUT – results database

Modelling strategy

IIASA's EPIC and GEPIC have widely been used to estimate crop production as well as agricultural impacts on the environment in numerous regional and global studies (e.g. Balkovič et al., 2013;

Folberth et al., 2014; van der Velde et al., 2014a; van der Velde et al., 2014b; van der Velde et al., 2013; Xiong et al., 2014). EPIC has been powered by a number of climate change and land use scenarios to simulate possible impacts on crop production and environmental externalities relative to the current conditions (Fig. 3). For these purposes EPIC is commonly forced by 1) climate change projections of various GCM-RCMs and SRES/RCPs scenarios, introducing different levels and realizations of global warming, 2) management intensification leading to closing yield gaps, including smart irrigation and fertilization strategies, 3) adaptation options to counteract negative impacts of changing climate on agriculture, and 4) mitigation measures intended to fight soil erosion and increase soil carbon content and overall soil quality, for instance by managing crop residue on the soil surface year round while reducing till operations (reduced till, no till) and by producing sufficient and timely quantities of crop residues from conservation crop rotations. Under the scenarios, EPIC can predict – inter alia – qualitative and quantitative changes in crop yields and biomass, nutrient and water cycles (including emissions) and soil erosion.

With using the same simulation units and data logic, IIASA's EPIC provides consistent inputs to the GLOBIOM model that is used by ESM to project future land cover and land use changes.

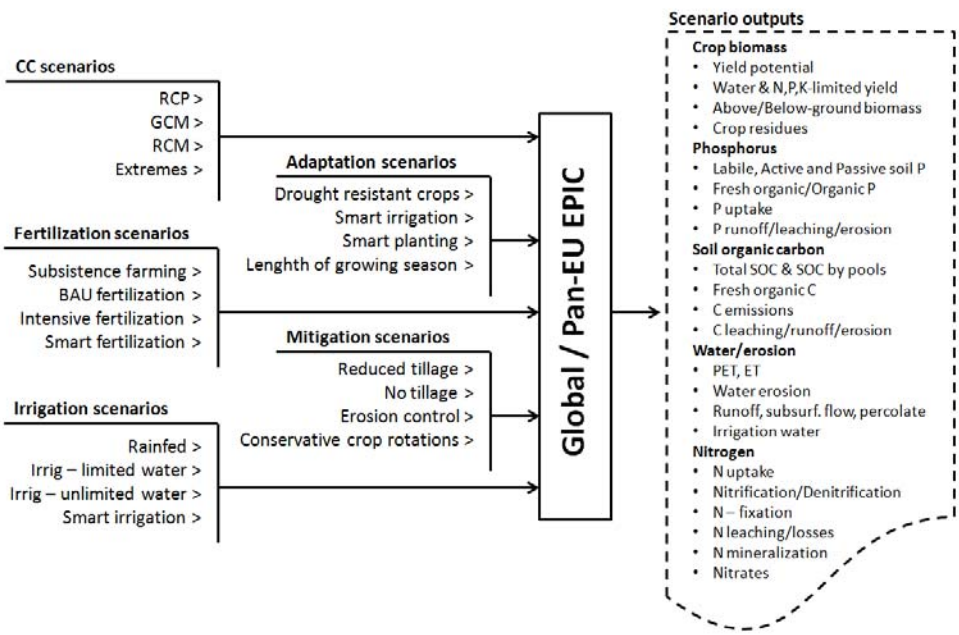

Figure 3. Overall modelling strategy of IIASA's EPIC.

Further Information

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ANNEX III THE GLOBIOM MODEL

Detailed description of the Global Biosphere Management Model "GLOBIOM"

This model description has been compiled by the thesis author and is inter-alia based on IIASA-internal GLOBIOM descriptions and text from various peer-reviewed articles as described under further information in this section.

What is GLOBIOM

The Global Biosphere Management Model (GLOBIOM)[3] (Havlík et al., 2011; Havlík et al., 2014) is a global recursive dynamic partial equilibrium model of the agriculture and forest sectors, where economic optimization is based on the spatial equilibrium modelling approach (Takayama and Judge, 1971). The model is based on a bottom-up approach where the supply side of the model is built-up from the bottom (land cover, land use, management systems) to the top (production/markets) (see Fig. 4 for an overview of the model framework). The agricultural and forest productivity is modeled at the level of gridcells of 5 x 5 to 30 x 30 arc minutes[4], using biophysical models, while the demand and international trade occur at regional level (30 to 53 regions covering the world, depending on the model version and research question). Besides primary products, the model has several final and by-products, for which the processing the processing activities are defined.

The model computes market equilibrium for agricultural and forest products by allocating land use among production activities to maximize the sum of producer and consumer surplus, subject to resource, technological and policy constraints. The level of production in a given area is determined by the agricultural or forestry productivity in that area (dependent on suitability and management), by market prices (reflecting the level of demand), and by the conditions and cost associated to conversion of the land, to expansion of the production and, when relevant, to international market access. Trade is modelled following the spatial equilibrium approach, which means that the trade

[3] See also: www.iiasa.ac.at./GLOBIOM

[4] The supply-side resolution is based on the concept of Simulation Units, which are aggregates of 5 to 30 arc-minute pixels belonging to the same country, altitude, slope, and soil class (Skalsky et al., 2008).

flows are balanced out between different specific geographical regions. This allows tracing of bilateral trade flows between individual regions.

The model includes six land cover types: cropland, grassland, other natural vegetation land, managed forests, unmanaged forests, and plantations.[5] Depending on the relative profitability of the different production activities, the model can switch from one land cover type to another. Biomassdemand for energy purposes enters GLOBIOM as an exogenous variable. It can be defined through quantities by linking with energy sector models like POLES or MESSAGE (Havlík et al., 2011; Reisinger et al., 2013), or by applying different biomass/bioenergy prices. For forests, mean annual increments and growing stocks for GLOBIOM are obtained from the Global Forest Model (G4M)[6], which is a spatially explicit process-based forest management model (Kindermann et al., 2006; Kindermann et al., 2013). For the agricultural sector, GLOBIOM draws on results from the crop model EPIC (Environmental Policy Integrated Climate Model)[7], which provides the detailed biophysical[8] processes of water, carbon and nitrogen cycling, as well as erosion and impacts of management practices on these cycles. GLOBIOM therefore incorporates all inputs that affect yield heterogeneity and can also represent a different marginal yield for different crops in a same grid cell. Plantations yields are based on own calculations, as described in Havlík et al. (2011).

[5] The term "managed forests" refers to forest area that is harvested once per rotation period, while "unmanaged forests" refers to forest area that is not harvested. There are other three land cover types represented in the model to cover the total land area: other agricultural land, wetlands, and not relevant (bare areas, water bodies, snow and ice, and artificial surfaces). These three categories are currently kept constant at their initial level.

[6] See also: www.iiasa.ac.at/G4M

[7] See also: www.iiasa.ac.at/EPIC

[8] Biophysical means related to living (animals, plants) and non-living (light, temperature, water, soil etc.) factors in the environment which affect ecosystems

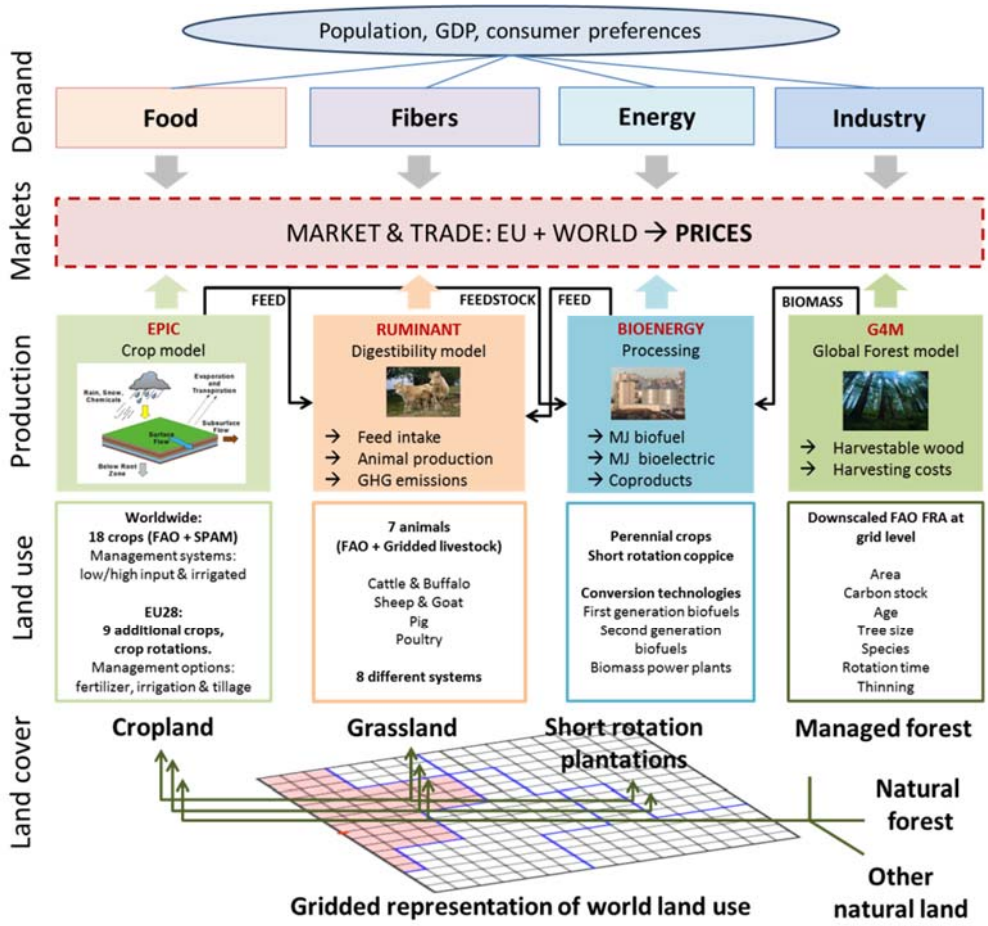

Figure 4: Illustration of the GLOBIOM model

By including cropland, livestock and forest management in a single framework, the model allows for a comprehensive account of agriculture and forestry GHG sources. GLOBIOM accounts for ten sources of GHG emissions, including crop cultivation N_2O emissions from fertilizer use, CH_4 from rice cultivation, CH_4 enteric fermentation emissions from ruminant, CH_4 and N_2O emissions from manure management, N_2O from manure applied on pasture. Changes in C stocks are also traced for above and below ground biomass when converting forest and natural land to cropland, as well as changes in soil. These emissions inventories are based on IPCC accounting guidelines (Valin et al., 2013).

Major innovative characteristics of GLOBIOM

GLOBIOM offers by its bottom-up economic structure and biophysical foundations a unique framework for integrated analysis of sustainability science issues.

The link between the economic dimensions and biophysical components allows for fine analysis of environmental implications of policies with a great level of detail on GHG emissions and more local impacts from management changes. At the same time, the model relies on a fully consistent economic approach in partial equilibrium. This allows to model interactions across sectors on the market side as well as the production side. A particular asset of GLOBIOM is indeed its integration in a single framework of the competition across the bioeconomy sectors, agriculture but also forestry and bioenergy sectors.

Following several years of collaboration efforts on the period 2009-2013, GLOBIOM now also provides an innovative detailed representation of the livestock (Havlík et al. 2014) sector with explicit representation of livestock systems based on (Herrero et al., 20132013). Animals are distinguished according to feeding practices and local climate conditions, leading to more than eight systems for ruminant and two for monogastrics, for which productivity has been estimated using a digestibility model, RUMINANT.

Stochastic GLOBIOM

The ERD group is developing a stochastic version of the Global Biosphere Management Model (GLOBIOM) (Havlik et al., 2011) which allows to analyze interdependencies among main land use sectors, such as agricultural, bioenergy and forestry aiming to provide policy analysis on global and regional issues concerning land use transformations driven by increasing demands for land products as well as adaptation to weather variability and climate changes, designed for the integrated analysis of food, bioenergy, environment security in the context of increasing population demands, technological progress, environmental goals, resource constraints, and emerging systemic risks. GLOBIOM Endogenous demand, price, trade flows are computed at aggregate level by countries (all countries) and/or aggregate world regions (30 regions), while decisions on production and land use allocation are taken at the resolution of simulation units of about 200km x 200km resolution.

The model incorporates crop yields stochasticity enabling to analyze impacts of shocks on crop production inducing systemic risks, which may cause market instability, price fluctuations,

destabilize food, environmental, energy, and water security provision especially in the presence of strict market regulations and environmental targets. For example, a shock to corn production may lead to a deficit of important feedstocks for biofuels. To fulfill the targets, corn may be substituted by costlier feedstock from wheat, what diverts wheat from direct food and feed consumption, may intensify production, require additional storage capacities and trading possibilities, raises prices both for biofuels and crops (for food and feed), destabilizes market flows. Instability of markets raises concerns about price level adjustments for food security, and so on. This shows that security management under systemic risks has to deal with ensuring joint robust functioning of interdependent complex multiagent food, energy, water supply networks, which disruption by the lack of strategic policies, natural extreme events, shocks of market prices, may cause malfunctioning of regional/local communities with potential global spillovers.

Applications of the model

The GLOBIOM model has been applied to many different issues related to land use change.

A first area of application has been mitigation policies through different sectoral options. First analyses have been looking at the potential effect of bioenergy deployment, with a global scope study (Havlík et al., 2011), and more regional focus on the European Union (Frank et al., 2012) or the United States (Mosnier et al., 2013). The extent to which the forestry sector could contribute to bioenergy supply has been analyzed in some more precise analysis decomposing the different forestry activities (Lauri et al., 2013), as well as the different trade-offs from such contribution, in terms of social and environmental provisions (Kraxner et al., 2013).

Reducing emissions from deforestation in tropical areas is a key component of mitigation strategies. Analysis with GLOBIOM illustrated how different development pathways could reinforce or challenge the efficiency of mitigation efforts. The model was applied in the Congo Basin (Mosnier et al., 2012) and has been more recently transposed to the situation of Brazil (Cohn et al., 2014). Future work is under preparation to expand the scope of analysis to South-East Asia in the context of the IIASA Tropical Flagship initiative.

Mitigation of agriculture and forestry emissions can however be undertaken jointly, as illustrated by GLOBIOM research on the livestock sector (Havlík et al. 2013, 2014) for which the potential of production system transitions has been clearly demonstrated. Crop intensification can also contribute to mitigation efforts although analysis with GLOBIOM illustrated such investment would contribute more primarily to food security purpose (Valin et al., 2013).

Beside climate change mitigation, climate change impact has been another topic widely explored with the GLOBIOM model. Analysis of these impacts on crop yield and implications for world food system has been conducted in the context of the AgMIP comparison project (Nelson et al., 2013; Valin et al., 2014) but also a more regional scale (Eastern Asia; Mosnier et al., 2014). More work is under progress to look into the impact of climate change on livestock, a largely overlooked issue, as well as adaptation strategies.

Agricultural prospective is a more recent area of application that has been deployed at the global level with analysis of future challenges on the production and demand side (Schneider et al., 2011); Valin et al. 2014). Some regional analyses have been undertaken, in cooperation with regional research centers and intense consultation of local stakeholders (Vervoort et al., 2014). The explicit inclusion of water as a resource (along with land and irrigated land) also makes GLOBIOM a particularly suitable tool for analyzing water related impacts of different development scenarios (Sauer et al., 2010).

Last, GLOBIOM was used to support different policy exercise on evolution of land use and carbon stocks in the European Union (Böttcher 2012; Frank et al., 2012; Böttcher et al., 2013; EC, 2014).

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ANNEX IV THE BEWHERE MODEL

Detailed description of the techno-economic engineering model "BeWhere"

This model description has been compiled by the thesis author and is inter-alia based on IIASA-internal BeWhere descriptions and text from various peer-reviewed articles as described under further information in this section.

What is BeWhere?

The techno-economic engineering model for renewable energy systems optimization "BeWhere"[9] has been developed since 2006, it was originally developed to identify the optimal location of biofuel production plants in regards with the location of the resources and the biofuel demand (Leduc, 2009). It is a geographic explicit model that minimizes the cost of the supply chain (harvest of biomass, transport of biomass, biomass process, biofuel transport to the gas stations, biofuel delivery to the consumers). Figure 5 presents an overview of the supply chain studied in the BeWhere model for woody biomass. The woody biomass comes from domestic production, sawmills or import, it has to be distributed between different energy industries. The existing industries (i.e. Pulp and paper mills, combined heat and power) have to be supplied in feedstock. At the same time the demand of heat, power and transport fuel has to be met either by the woody based industries and/or the reference technology which is fossil fuel based. If some raw material remains and if the new generated bioenergy commodity can compete against the fossil fuel price, new bioenergy production plants will be set up.

[9] See the BeWhere home page for more details: www.iiasa.ac.at/bewhere

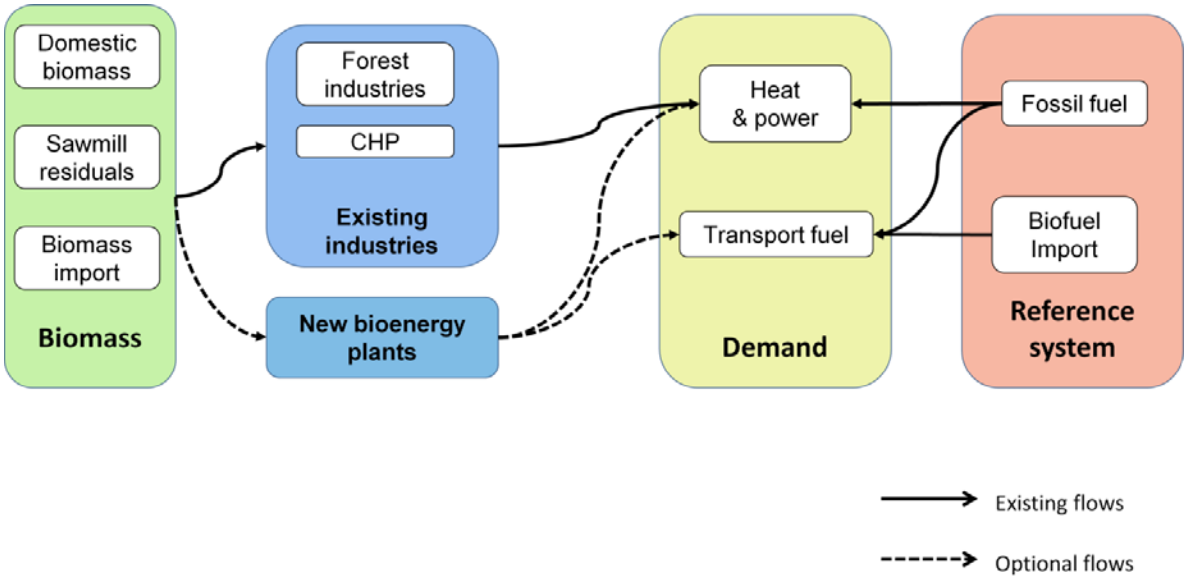

Figure 5: Supply chain studied in the BeWhere model for the biomass based technologies. Source: modified after Leduc, IIASA, 2015.

Information provided to the model is geographic explicit, such as biomass location, availability and cost, existing industries, energy demand, etc. A road map, railway map and shipping line are integrated in the model for a very detailed transportation cost analyses. Above the supply chain, different policy factors can be applied to the model, such as a carbon tax, biofuel supports, subsidies…

Based on the minimization of the cost of the supply chain, the model provides information on the location, number, capacity and technology of the selected bioenergy production plants. It also provides information on the cost and emissions of each flow of the supply chain.

Further innovative characteristics of BeWhere

The BeWhere model is a model that is constantly being developed; the localization of new biomass based production plant is one module of the model. It is also being developed to identify optimal locations for forest based second generation biofuel production plants integrated into existing industry, and can be used to e.g. analyze effects and costs associated with implementing regional or national targets on biofuels (Wetterlund et al, 2013). Figure 6 shows an example of the results from BeWhere

where: the location of new biofuel production plants as well as where the biomass used for biofuel production originates from in four scenarios.

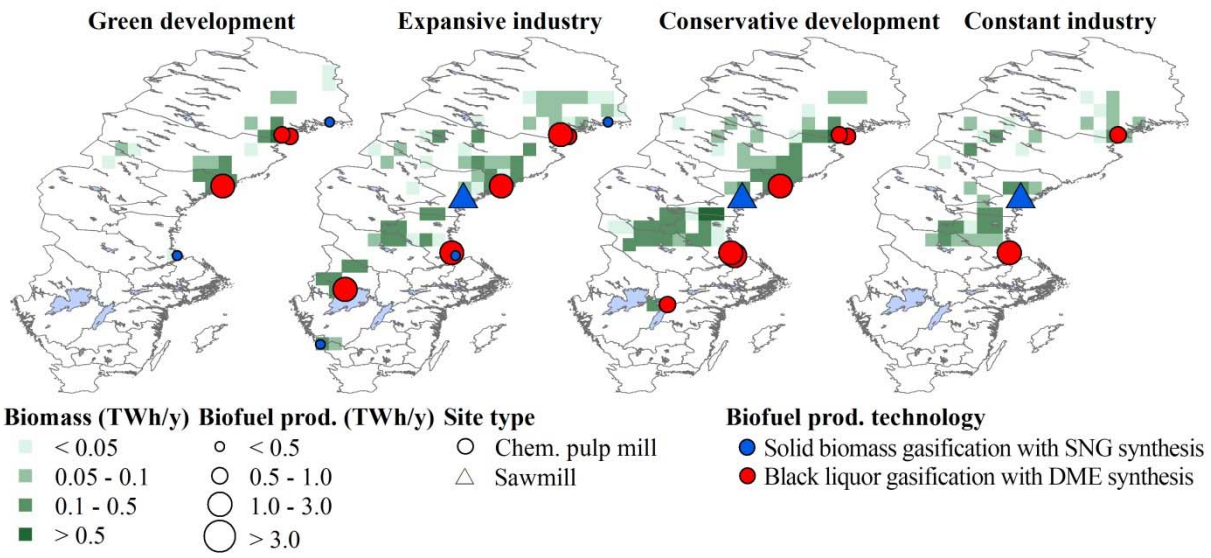

Figure 6: New biofuel plants and biomass origin for four roadmap scenarios. Source: adapted after Leduc et al. 2009

Besides woody biomass, the model is also being applied for the second generation biofuel production based on sugar cane residuals and sugar cane plants technology upgrade. The model is also developed to identify the optimal location of algae production plant that requires delivery of water and CO_2. And it is now being applied for identifying the optimal localization of solar energy plant, wind mills, or hydro power plants. The model will either apply one technology or combine all of them.

Application of the model

The BeWhere model is applied to provide information to the GLOBIOM model, where data on the cost of bio-energy production is exchanged, and availability of biomass will be fed back into the BeWhere model. Using such a process of iteration between the two models, each of them will converge towards an optimal value of biomass availability and cost of bioenergy production.

The BeWhere model has also been applied in various countries such as Japan, South Korea, Russia, India… to analyze the potential of bioenergy production under different policy scenarios. It is being developed in a wide range of national and international projects, and has been divided in many sub models such as BeWhere Sweden, BeWhere Finland, BeWhere Europe, BeWhere Algae…

The BeWhere model is applied as the core model for the Alpine-level modeling in the Alpine Space project recharge.green[10], where it has to identify the potential and cost of renewable energy under different constrains on the protection of the ecosystems services (i.e. protection of animal species, vegetation…). Within the FP7 project, S2biom[11], the BeWhere model is also used as the major model to identify the bioenergy potential of non-food feedstock for the EU, Turkey and Balkan countries.

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ANNEX V SURVEY QUESTIONNAIRE, PUBLIC OPINION YUSUHARA TOWN, KOCHI, JAPAN, 2007

Background information to the study site and methodology

As described in Chapter 4.2 of this thesis in more detail, Yusuhara Town, located in the Kochi Prefecture on Shikoku Island, is a representative Japanese rural mountain community with 91% forest coverage and a population of 4,625 people in 1930 households (Yusuhara Town 2008). Mountain communities such as Yusuhara Town cover 50% of Japan's total land area and own 60% of Japan's forest area. Mountain villages have various biomass feedstock as potential alternative energy sources to fossil fuel, including forest residues from thinning, branches and leaves, as well as agricultural residues such as from rice plants and straw. According to Japan's Forest Agency, especially in mountain villages it is possible to form a society where the local resources are effectively and sustainably utilized at multi–stages, which is an optimal precondition for a Low Carbon Society.

Drop-off surveys were conducted among all households of Yusuhara Town during 16 January and 15 February 2007. The questionnaire, asks for the public opinion (head of the household) and knowledge on a relative wide field regarding wood, forest, forest management, certification, biomass for bio-energy as well as general environmental problems and the WTP for mitigating climate change. However, this analysis mostly concentrates on biomass for bio-energy. Of the 1930 questionnaires sent out, 774 samples are used for this analysis. The valid response rate is 40% and 79% of the respondents are forest owners.

Requesting your cooperation in a survey on forests

January 16, 2007

To the Citizens of Yusuhara,

Please assist us with this survey.

The Environmental Management Division and the Industrial Promotion Division of Yusuhara Town, in cooperation with the National Institute for Environmental Studies, are implementing a survey to determine the citizen's awareness of forests, forest management, lumber and biomass, and the environment.

Yusuhara is a region that is engaged in proper forestry management, and it is the first and only place in Japan to receive certification from the Forest Stewardship Council for its management policies. The town is attracting attention, not just in Japan, but from around the world, because it has the potential to act as a model for forestry management throughout Japan.

The goal of this survey is to compare Yusuhara and Europe. Forest certification is quite advanced in Europe and the production of biomass energy plays an important role there.

We are planning on holding a meeting and inviting specialists to discuss the future of forest management in Yusuhara, so we would really appreciate your participation in this survey.

The survey will be distributed to the heads of the communities on January 23. We are planning on collecting the surveys from January 30. Please give your survey back to the head of your community.

Furthermore, we will give everyone an original card holder from the National Institute for Environmental Studies as a token of our appreciation.

Instruction:

- **Please select your answer by selecting one of the given options. Certain questions allow multiple answers (where indicated)!**
- **Sections where you are requested to write are indicated: (please specify)!**
- **Please answer the questions one by one in order and do not go back and change your answers. If you do not know how to answer a question or if you do not understand the question, skip that question and proceed to the next one!**

As this survey will be used in an international comparison, it is absolutely necessary that the person filling out the questionnaire states his/her own opinion. This is important when trying to find differences between male and female attitudes or perceptions!!

Part A: General questions regarding yourself and your household:

1) Please state your gender:

- male
- female

2) Please state your age: _____

3) What is your current job? (multiple answers possible!)

- agriculture
- forestry
- employed by the local government
- company worker
- company worker (management)
- civil servant
- self employed
- housewife
- part-time worker/housewife
- student
- unemployed
- other (please specify)_____

4) Do you or somebody from your household own forest land?

- Yes
- No
- I don't know

Part B: Questions on the forest:

1) If you think about the forest in your vicinity, what are the first spontaneous impressions, associations, emotions, feelings, colors or e.g. smells that come to your mind?

- o 1_____
- o 2_____
- o 3_____
- o 4_____
- o 5_____
- o 6_____

2) If you think about forests and what forests serve for, please indicate on a scale of 1 to 5 (where 1 is "not important" and 5 is "very important") – how important are the following forest functions to you?

- o source of high diversity and variety of animal and plant species 1---2---3---4---5---I don't know
- o natural living space for animals and plants 1---2---3---4---5---I don't know
- o provision of clean water 1---2---3---4---5---I don't know
- o protection from disasters such as flooding and land slides, avalanches 1---2---3---4---5---I don't know
- o space for leisure and recreation 1---2---3---4---5---I don't know
- o harvesting trees and wood production 1---2---3---4---5---I don't know
- o source of employment 1---2---3---4---5---I don't know
- o Carbon storage/Carbon sink 1---2---3---4---5---I don't know

3) On a scale of 1 to 5 (where 1 is "low agreement" and 5 is "high agreement") please indicate your level of agreement with the following statements:

- o Forests are good for the environment and climate 1---2---3---4---5---I don't know
- o Forests are a symbol of nature 1---2---3---4---5---I don't know
- o Forests need to be protected by humans (minimum impact and wood harvest) 1---2---3---4---5---I don't know
- o When I am in a forest, I feel closest to nature 1---2---3---4---5---I don't know
- o Forest should be used by man (forest management and harvesting of trees) 1---2---3---4---5---I don't know
- o Forest is nature which has to be protected and productive field for necessary resources at the same time 1---2---3---4---5---I don't know

4) According to your opinion and observations, how would you evaluate the forest area in your region?

- o The forest area is declining
- o The forest area is constantly increasing
- o The forest area is remaining stable
- o I don't know

Part C: Questions on forestry/forest management:

"Sustainable Forest Management" can be explained as "balanced wood removal in relation to growth" which means that only the same amount of wood should be taken out of the forest than is regrowing or replanted during the same time.

1) Are you familiar with the term "Sustainable Forest Management" or its definition?

- o Yes, I have heard of it
- o No, I have not heard of it

2) Do you think that "Sustainable Forest Management" is practiced in the forests around your area?

- o Yes, the principle of Sustainable Forest Management is practiced
- o No, the principle of Sustainable Forest Management is not practiced
- o I don't know

3) When you consider the forest in your area, are you satisfied with the following items. Please evaluate these items on a scale of 1 to 5 (where one is "not satisfied" and 5 is "very satisfied"):

- o Forest health 1---2---3---4---5---I don't know
- o The maintenance and tending of the forest 1---2---3---4---5---I don't know
- o Thinning (taking out some small trees in order to give more room and better conditions to the remaining bigger ones) 1---2---3---4---5---I don't know
- o The way of harvesting the trees 1---2---3---4---5---I don't know

4) What do you think about the harvesting of trees in your area?

- o It should be increased. More timber for construction and firewood should be harvested
- o It needs to be stopped, because too many trees are harvested and this endangers the forest ecosystem
- o It should stay the same as it is because according to my understanding the right amount of wood is extracted
- o I don't know

5) Do you think that an increased use of the forest (harvesting more trees) in your region is justified if the "Sustainable Forest Management" principle is applied?

- o Yes
- o No
- o I don't know

"Forest Certification" states that the wood from a certified forest area has been grown under appropriate and sustainable conditions. Such certificates are for instance issued by the FSC (Forest Stewardship Council) and the PEFC (Programme for the Endorsement of Forest Certification Schemes).

6) Are you aware of the term "Forest Certification"?

- o Yes, I have heard about "Forest Certification"
- o No, I have not yet heard about "Forest Certification"

7) Do you think that an increased use of the forest (harvesting more trees) in your surroundings is justified if the forest management is certified (e.g. by FSC or PEFC)?

- o Yes
- o No

- I don’t know

8) Do you think that the forest industry is important for your country?

- Yes
- No
- Don’t know

Part D: Questions on wood and biomass:

1) What do you like most about wood as a material? Please choose a maximum of 3 items:

- o I do not like wood as a material
- o Wood has a warm character
- o Wood has a nice color
- o Wood is a good construction material
- o Wood has a long life cycle and durability
- o Wood is easy to recycle
- o Wood has good heating value
- o The use of wood has a positive environmental impact on the climate
- o I don't know

2) Have you ever heard of "renewable energy"?

- o Yes
- o No
- o I don't know

3) Please choose from the following list those energy resources from which you believe they could serve for heating your house: (multiple answers possible!)

- o Sunlight
- o Wind
- o Biomass/wood
- o Water
- o Geothermic
- o None of all these

4) As you are living relatively close to the forest, do you think that enough firewood or wood pellets could be produced from Yusuhara forests (without endangering the future of the forests) in order to: (multiple answers possible!)

- o Heat all the houses of Yusuhara
- o Heat the schools and the hospital and other public buildings
- o Heat a limited number of the houses (e.g. 50-100)
- o none of these possibilities

5) Which of the following future-scenarios can you imagine? (multiple answers possible)

- o Wood from Yusuhara region is used for heat and electricity production
- o Together with some neighbors we are using one heating system that uses wood from the region for heat production
- o Yusuhara town offers a public biomass district heating system where I can connect my house
- o None of these scenarios I can imagine for the Yusuhara region

6) Do you think that the forest in your area should be used for more biomass/bioenergy production?

- o Yes, the forest should be used for more biomass for bioenergy production
- o No, there should be no additional use of the forest – even for bioenergy production
- o I don't know

Part E: Questions on the environment:

1) Consider the following environmental problems. Which is the most important problem facing Japan today? (Please select the two most important problems according to your opinion)

- o Acid rain
- o Smog
- o Ozone depletion
- o Overpopulation
- o Destruction of ecosystems
- o Endangered species
- o Urban sprawl
- o Toxic waste
- o Water pollution
- o Global warming
- o Overexploitation of natural resources

2) There is growing concern about increasing levels of carbon dioxide in the atmosphere. How do you think the following will contribute to these levels?

Windmills
- o Increases carbon dioxide
- o Decreases carbon dioxide
- o No impact
- o I don't know

Trees
- o Increases carbon dioxide
- o Decreases carbon dioxide
- o No impact
- o I don't know

Nuclear power plants
- o Increases carbon dioxide
- o Decreases carbon dioxide
- o No impact
- o I don't know

Home heating
- o Increases carbon dioxide
- o Decreases carbon dioxide
- o No impact
- o I don't know

Coal burning power plants
- o Increases carbon dioxide
- o Decreases carbon dioxide
- o No impact
- o I don't know

Factories
- o Increases carbon dioxide
- o Decreases carbon dioxide
- o No impact
- o I don't know

Biomass or wood burning power plants
- o Increases carbon dioxide
- o Decreases carbon dioxide
- o No impact
- o I don't know

Oceans
- o Increases carbon dioxide
- o Decreases carbon dioxide
- o No impact
- o I don't know

Agriculture
- o Increases carbon dioxide
- o Decreases carbon dioxide
- o No impact
- o I don't know

Breathing
- o Increases carbon dioxide
- o Decreases carbon dioxide
- o No impact
- o I don't know

Automobiles
- o Increases carbon dioxide
- o Decreases carbon dioxide
- o No impact
- o I don't know

3) If it solved global warming, would you be willing to pay the following amount more per month on your electricity bill?

- o Less than 200 Yen
- o 200 Yen

- 500 Yen
- 1000 Yen
- More than 1000 Yen
- Nothing at all

Do you have any further comments to this survey and questionnaire or to the forest and forest management in your region?

If you have any questions or comments, please send them to the following address.

独立行政法人 国立環境研究所
〒305-8506 茨城県つくば市小野川 16-2
地球環境研究センター　木下
電話番号：029-850-2567　FAX：029-850-2960
URL: http://www.nies.go.jp

Thank you very much for your kind cooperation and effort.

ANNEX VI DETAILED ANALYSIS, THE YUSUHARA SURVEY 2007

In the following text, a detailed analysis of all questions asked in the questionnaire (see Annex V of this thesis) is provided. The interpretation and embedding of the text and contemporary literature has been carried out in Chapter 4.2 of this thesis, which is based on Kraxner et al. (2009).

Results – Yusuhara Town Survey on Forest and Biomass

Frequency Analysis on Entire Questionnaire

General Findings, Part A:

A total of 774 questionnaires (out of 1,930 distributed and a return rate of 40%) could be used for the detailed analysis as they were filled correctly and all relevant questions have been answered. (A1)

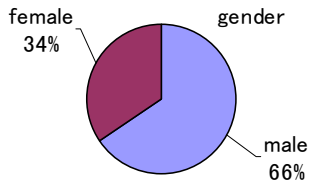
The gender distribution showed that 66% (502) of the respondents were male and 34% (264) were female. (A1)

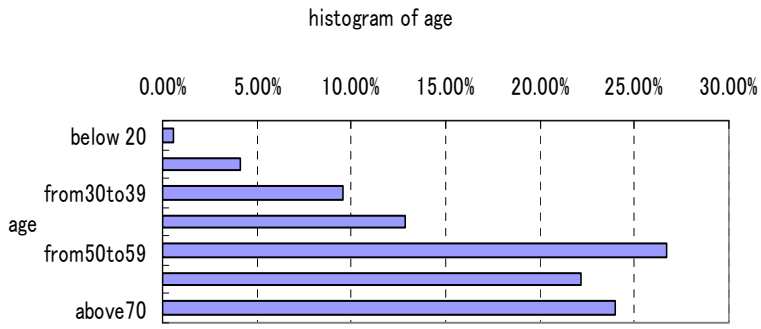
The average age of the participants was slightly more than 57 years. The majority of the respondents were aged 50 years and older and about 30% were younger than 50 years. (A2)

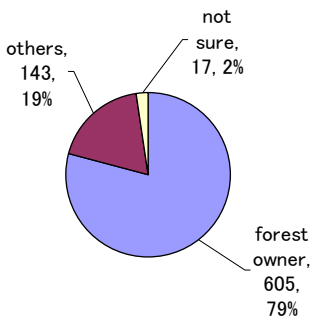
The survey data show that about one quarter of the respondents (24%, 218)stated to have their job in the agricultural sector, followed by company workers (17%, 154), students (15%, 138) and those who are working in the forestry sector (10.2%, 91). (A3)

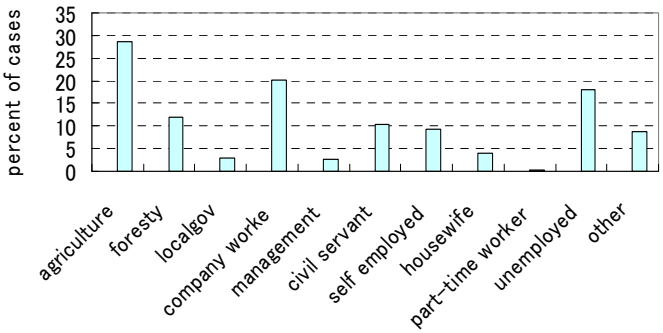
The majority of the respondents (79%, 605) stated their household to be a forest owner whereas 19% (143) were not and 2 % (17) were not sure about that. (A4)

gender	male	502	64.90%
	female	264	34.10%
	miss	8	1%
age	average	57.36	
	miss	44	5.70%
job	Farmer	218	24.40%
	Forester	91	10.20%
	Localgovernment	23	2.60%
	Companyworker	154	17.30%
	Manager	20	2.20%
	Civilservant	79	8.90%
	Self-employed	71	8.00%
	housewife	30	3.40%
	Part-time	2	0.20%
	student	138	15.50%
	unemployed	66	7.40%
	miss	12	1.55%
Forest owner	yes	605	78.17%
	no	143	18.48%
	Not sure	17	2.20%







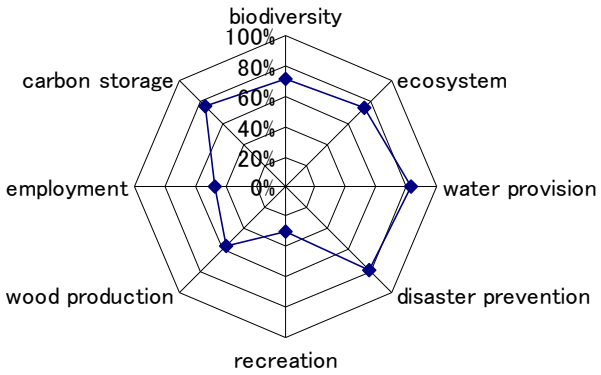


Findings Related to Forest, Part B:

	frequency	Pct of Responses
green color	321	20.76%
other color	68	4.40%
warm feeling	64	4.14%
cold feeling	35	2.26%
natual feeling	62	4.01%
recreation	88	5.69%
positive emotion	228	14.75%
negative emotion	112	7.24%
fear	23	1.49%
other feelings	82	5.30%
other associations	463	29.95%
total	1546	100.00%

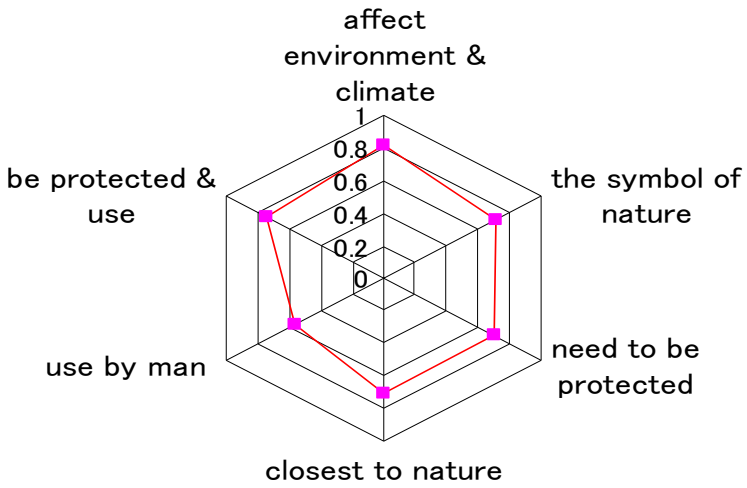
The question for the importance of different forest functions, most respondents stated the protective functions such as protection from disasters (83%) and provision with clean water (79%) to be most important. Also very important were rated the carbon storage function (76%), the ecosystem function (74%) and forest as a source of biodiversity (72%). Less important seem to be the wood production function (55%), forest as a source for employment and jobs (47%), and especially the recreation function, which was only rated to be important by 30% of the respondents. (B2)

the function of forest	importance
biodiversity	71.50%
ecosystem	73.90%
water provision	83.10%
disaster prevention	78.60%
recreation	30.10%
wood production	55.20%
employment	46.80%
carbon storage	75.70%



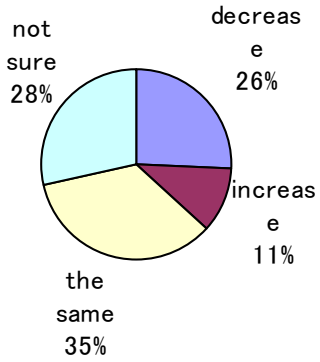
On the questions how forest is seen in Yusuhara Town, most people agreed that forest has good effect on environment and climate (81%) and that forest needs protection on the one hand and has to be used as a resource on the other side (74%). About 70% of the respondents agreed highly with the statement that forest is a symbol of nature, that they feel closest to nature when they are in the forest and that the forest needs to be protected by humans. Less agreement (56%) among people in Yusuhara Town found the simple statement that the forest should be used by man in terms of applying forest management and harvesting trees. (B3)

the agreement of your's forest feeling	
affect environment & climate	81.20%
the symbol of nature	70.90%
need to be protected	70.10%
closest to nature	70.70%
use by man	56.00%
be protected & use	74.00%



On the question whether forest area in the area is declining, constantly increasing or stable, most people (35%) observed the area to be stable. About a quarter (26%) saw the area decreasing and 11% were of the opinion that the forest area is increasing. More than one quarter (28%) stated not to be sure about that or had no opinion. (B4)

the forest area	frequency	Pct
decrease	193	25.56%
increase	84	11.13%
the same	265	35.10%
not sure	213	28.21%
total	755	100%

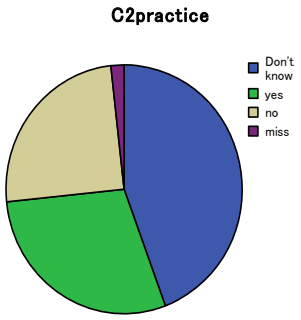


Findings on Forestry and Forest Management, Part C:

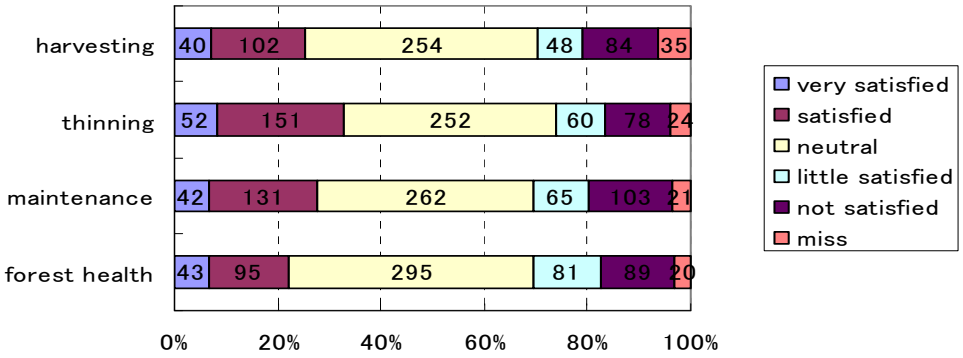
After providing a short explanation on the term "Sustainable Forest Management" (SFM), people have been asked about their familiarity with this expression. More than half (54%) of the respondents mentioned not being familiar with the SFM term and 43% knew this special term already before. (C1)

Being asked regarding their opinion on whether SFM is practiced in the forests of their area, almost half (44%) of the respondents pretended that they don't know. The other half was divided into slightly more than a quarter (29%) who stated that SFM is applied in the area and slightly less than one quarter (24%), being of the opinion that SFM is not applied in the region. (C2)

	frequency	Pct
Don't know	343	44.32%
yes	225	29.07%
no	192	24.81%
total of miss	14	1.81%
total	774	100.00%

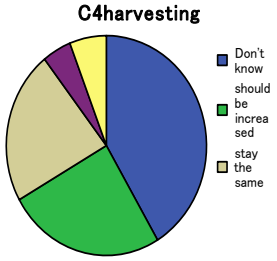


When the question comes on satisfaction with the forest condition in the area, most respondents were quite neutral in their answers. Slight differences could be shown in the fact that especially the condition of thinning and maintenance in the forests of the area are more appreciated than for instance harvesting and forest health. On the other hand, forest maintenance seems to be also the most controversial topic, as it is also the forest condition that received most votes among the category "not satisfied". (C3)



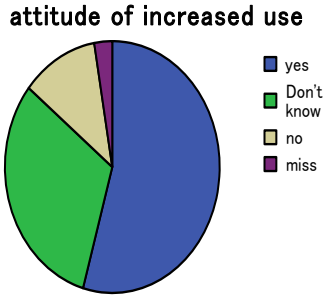
When being asked regarding the harvesting of trees in their area, one quarter (25%) of the respondents stated that it should be increased and slightly less than one quarter (23%) wanted the amount of harvesting to stay the same. Only a minor share of 5% wanted the harvesting being stopped. However, almost half of all respondents did not know any answer on that. (C4)

	frequency	Pct
Don't know	321	41.47
should be increased	196	25.32
stay the same	175	22.61
needed be stopped	36	4.65
total of miss	46	5.94
Total	774	100



On the question, whether and increased forest use (in terms of more trees harvested) would be justified in case of SFM, more than half (54%) of all respondents agreed with an increased use under such special conditions. Some 11% were against it, even under SFM conditions and about one third (34%) could not answer this question. (C5)

frequency	Pct	effective Pct
yes	421	54.39
Don't know	243	31.40
no	89	11.50
total	753	97.29
total of miss	21	2.71
total	774	100.00



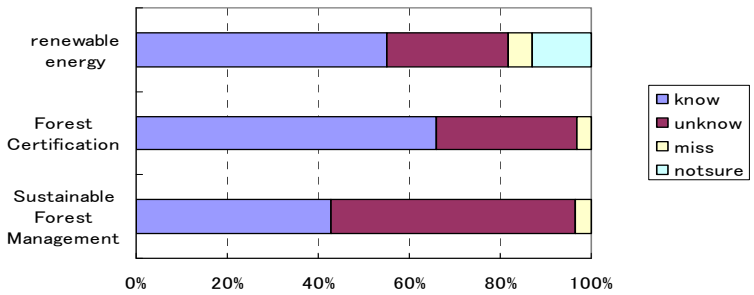
After providing a short explanation on the term “Forest Certification” (FC), the participants were asked to state their awareness of this expression. Two thirds (66%) of the people confirmed to have heard about the term CF, whereas 31% denied the question. 3% could not give any answer on that question. (C6)

When asking the citizens from Yusuhara Town if an increased use of the forest (in terms of more trees harvested) would be justified if CF is applied, almost half of the people (47%) agreed under this special condition. About one third (34%) did not accept increased harvesting of wood even under CF conditions, and some 20% could not give any answer on that question. (C7)

A vast majority (86%) of respondents agreed in the fact that the forest industry is important for Japan. Only 3% denied this question and some 11% could not answer the question. (C8)

	yes	Don’t know	no	miss
C7	46.51163	33.59173127	17.95866	1.937984
C8	85.65891	10.72351421	2.583979	1.033592

knowledge	know	unknow	miss	notsure
Sustainable Forest Management	42.80%	53.60%	3.60%	
Forest Certification	65.80%	31.10%	3.10%	
renewable energy	54.90%	26.60%	5.40%	13%



Findings Regarding Wood and Biomass, Part D:

D1preferation	frequency	Pct of response
do not like wood	46	0.022363
warm	585	0.284395
color	120	0.058337
material	509	0.247448
long life cycle	134	0.065143
recycle	154	0.074866
heating value	164	0.079728
climate	316	0.153622
don't know	29	0.014098
	2057	1

renewable energy	frequency	Pct	effective Pct
yes	425	54.90956	58.06010929
no	206	26.61499	28.1420765
Don't know	101	13.0491	13.79781421
total	732	94.57364	100
system miss	42	5.426357	
whole	774	100	

D3 energy	frequency	Pct of Responses	Pct of Cases
sunlight	495	0.385214	68.3
wind	192	0.149416	26.5
biomass/wood	347	0.270039	47.9
water	114	0.088716	15.7
geothermic	53	0.041245	7.3
none	84	0.06537	11.6
	1285	1	177.3

D4 firewood	frequency	Pct	
heat all the houses	219	28.8	33.1
schools hospital	360	47.4	54.5

limited number	121	15.9	18.3
none	60	7.9	9.1
	760	1	115

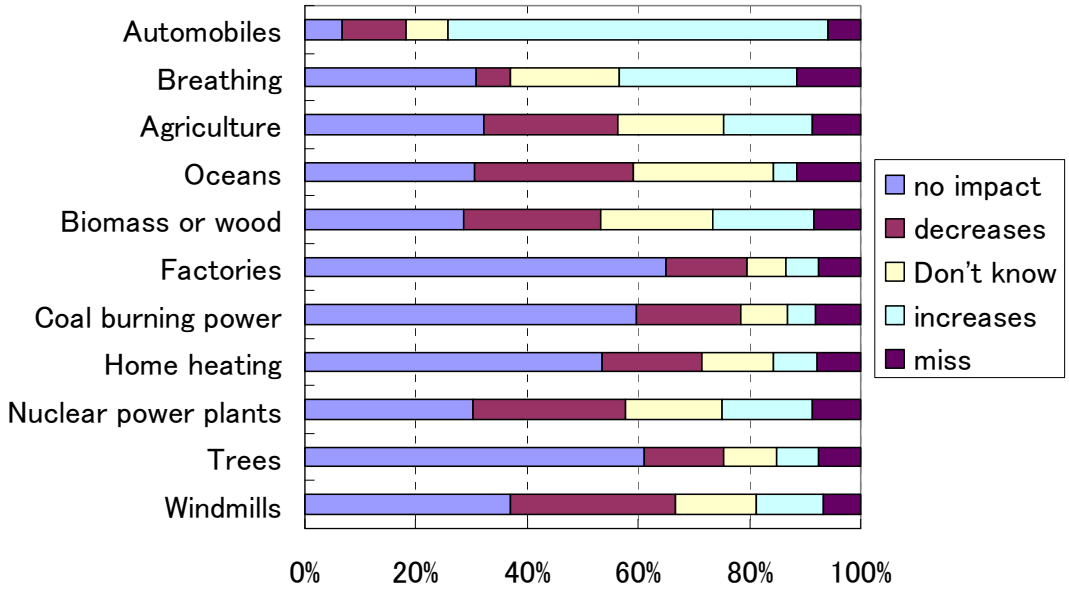
D5 future	frequency	Pct of Responses	Pct of Cases
heat electricity	345	0.464334	54.3
heat production	90	0.121131	14.2
public biomass	100	0.13459	15.7
none	208	0.279946	32.8
	743	1	117

D6biomass	frequency	Pct	effective Pct
yes	428	55.29716	56.76392573
Don't know	279	36.04651	37.00265252
no	47	6.072351	6.233421751
total	754	97.41602	100
system miss	20	2.583979	
total of miss	774	100	

Findings Regarding the Environment, Part E:

E1

Cagegory label	Count	Pct of Responses	Pct of Cases
Acid rain	67	0.051028	9.9
Smog	155	0.11805	23
Ozone depletion	211	0.160701	31.3
Overpopulation	19	0.014471	2.8
Destruction of ecosystems	98	0.074638	14.5
Undangered species	41	0.031226	6.1
Urban sprawl	42	0.031988	6.2
Toxic waste	45	0.034273	6.7
Water pollution	103	0.078446	15.3
Global warming	487	0.370906	72.1
Doverexploitation of nature	45	0.034273	6.7
	1313	1	194.5



E3

median	500	Yen
average	481.277	Yen
SD	447.162	Yen

Cross-Analysis on the Item "Job"

Job - Effects on Questions on Forest, Part B:

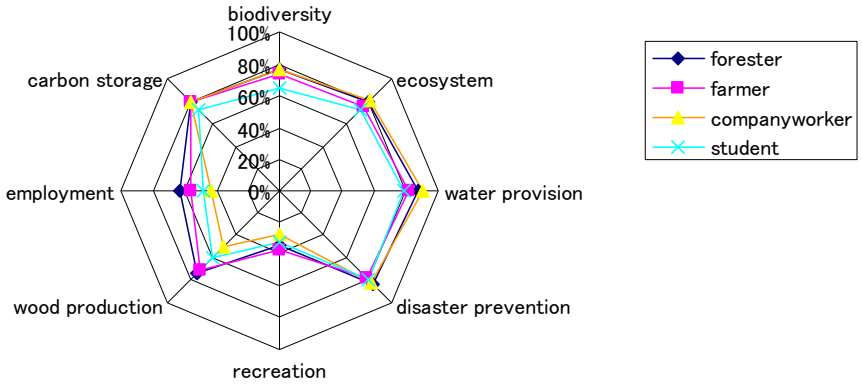
Forest Functions

Regarding forest functions, people working in the forest sector follow general patterns stated in the frequency analysis part. However, it seems that the items employment, wood production and disaster prevention are more important to them than to the people having their jobs in other sectors.

Farmer's opinion is within the general patterns, only the recreation function is slightly favored by farmers, when comparing with the other job categories.

Contrary to the findings about people working in the forest, those who are company workers see in the provision of employment, wood production and recreation the least important functions of the forest. Water provision and the ecosystem are favored by company workers compared to other job categories.

Students see less importance than the other categories in the provision of biodiversity and state also lower importance to the functions of carbon storage, employment and wood production.



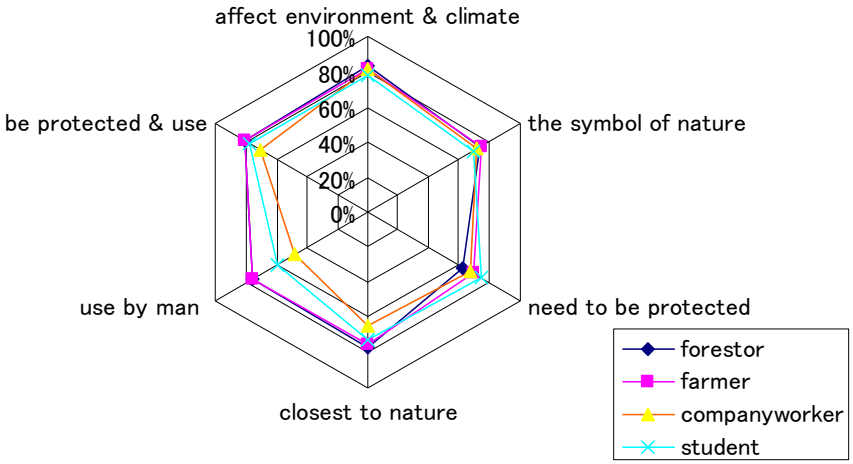
Attitudes towards Forests

People working in the forest sector see forests as especially positive elements for environment and climate, and, compared to the other job categories, they see less need in the protection of forests.

Those who are working as farmers especially feel the need that forests should be used by man and also, compared to other job categories, they think more often that forests should be protected and used as resources by man at the same time.

Less close to nature than people in the other job categories feel company workers, when they are out in the forest. On the other hand they feel much less that the forest should be used by man and that it should be protected and used at the same time.

Students feel strong attitudes towards the need of protecting the forests and consequently, students are also not so much in favor with the use of forest by man.



Job - Effects on Questions on Forestry and Forest Management, Part C:

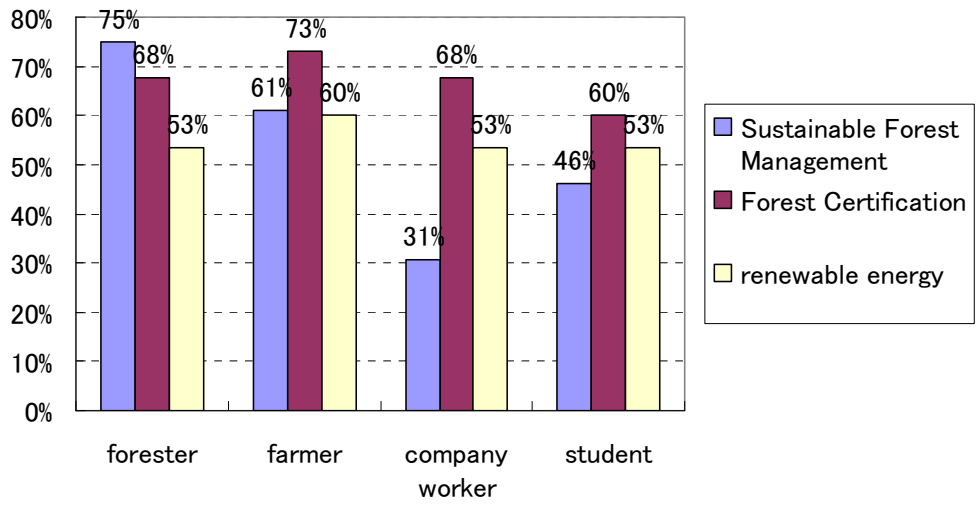
Knowledge on Sustainable Forest Management

When asked for their familiarity with the term SFM, of those people working in the forest sector, three quarters (75%) state to know the term. Those who are working in the agriculture sector are familiar with the SFM term at a share of 61%, followed by the category of students, where almost every second respondent (46%) could positively answer this question. Least familiarity show company workers with respect to SFM.

Knowledge on Forest Certification

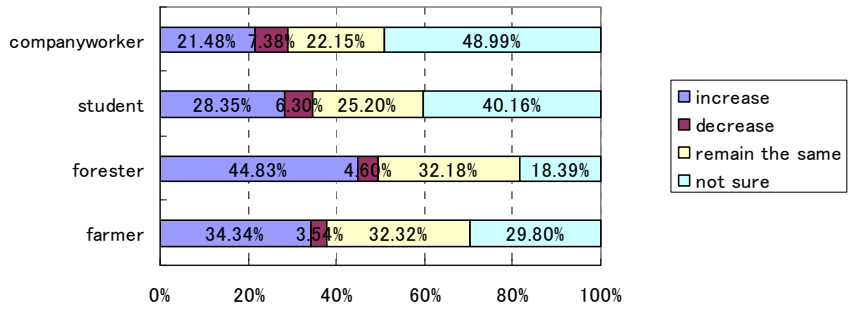
Unexpectedly, almost three out of four (73%) of those people working in the agriculture sector have already heard about FC before. This share is clearly bigger than the one of those people who are working in the forest sector, were only about two out of three (68%) have heard about FC, the same share as with the category of company workers (68%). The smallest share, regarding the recognition of the term CF, shows the category of students at 60%. The knowledge level of FC ranks between one third and three quarters. However, all job categories, except those working in the forest sector, show higher familiarity with the term FC than with SFM, at a generally high level of knowledge (60-73%).

knowledge	C1	C6	D2
	Sustainable Forest Management	Forest Certification	renewable energy
forester	75%	68%	53%
farmer	61%	73%	60%
company worker	31%	68%	53%
student	46%	60%	53%



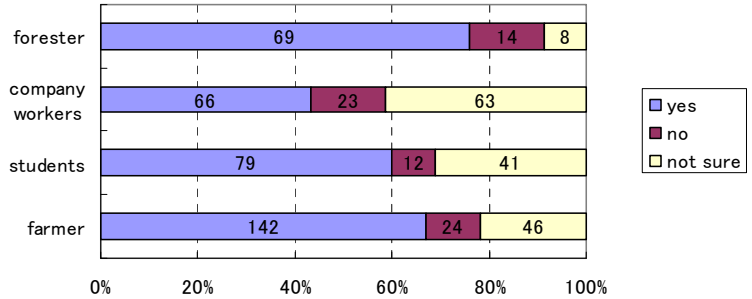
Attitudes towards Tree Harvesting

When comparing those respondents who work in the forest sector with the other job categories, it could be proven that about every second person (45%) was in favor of an increased harvesting, followed by the people working in the agriculture sector, where about one third (34%) wanted more harvesting. Students and company workers are not so much in favor with increased harvesting operations (28% and 21% respectively), but both groups showed on the other hand that they are not so sure about what to answer – 40% respectively 49% stated not to have any special attitude. Throughout the categories, those who wish the harvested amount to stay the same, move between around one quarter (22%) and one third (32%).



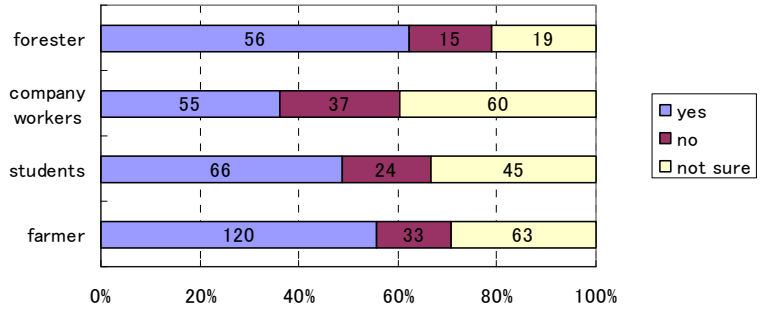
Attitudes towards Increased Forest Use under Sustainable Forest Management

When comparing the attitudes of the job categories regarding forest use (increased harvesting of trees) under sustainability restrictions (SFM), the category of people working in the field of forestry clearly dominate the group of being in favor of an increased use. About three quarters (75%) state that an increased use is justified if this sustainability principle is applied. Among the category of farmers, about two thirds (67%) would accept increased harvesting under sustainable conditions and also the majority of students (60%) would do so. Only within the category of company workers, less than half (44%) have positive attitudes towards and increased forest use under SFM. Almost the same share of company workers cannot state any special attitude regarding this question or do not know.



Attitudes towards Increased Forest Use under Forest Certification

When asking the same question regarding attitudes towards increased forest use, but in this case under a Forest Certification restriction, people throughout all categories are less willing to see an increased use justified. However, still more than 60% of all those working in the forest sector would also like to see increased harvesting under FC. Also more than half (55%) of the people working in the agriculture sector are positive towards more wood felling under the FC restriction, as are 49% of the students. Among the students, twice as much (20%) than under the SFM restriction are clearly rejecting the idea of increased forest use. Also among the company workers, the opposing group almost doubled. About half (45%) of the company workers still has positive attitudes towards increased harvesting operations also under the FC restriction.



Job - Effects on Questions Regarding Wood and Biomass, Part D:

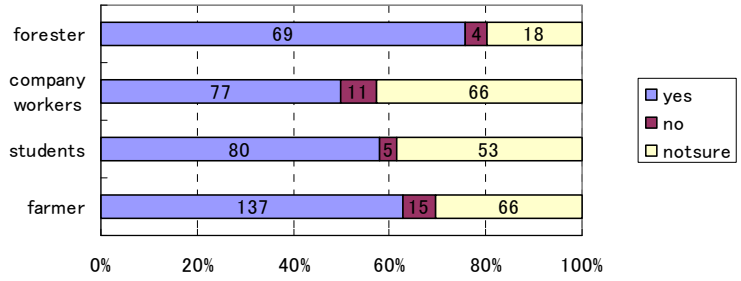
Knowledge on Renewable Energy

The answers on the knowledge-question whether the term "Renewable Energy" is familiar or not, show a relatively high level of knowledge throughout all job categories. Those respondents, who are working in the agriculture sector, show the best knowledge – 60% state to have heard the term before. The other three categories – forestry sector, company workers and students – all show the same share of positive answer (53%).

forester	farmer	company worker	student
53%	60%	53%	53%

Attitudes towards Biomass Use

After providing the short information on Sustainable Forest Management and Forest Certification, the 4 job categories have been again tested regarding their attitudes towards and increased use of biomass (for bioenergy production) from the forest of the region. Results indicated that again those who are working in the forest sector, are those showing most favor with this idea – about three quarters (75%) would like to see such an increased use. 5% of the respondents among this job category are clearly rejecting every increased biomass production for bioenergy. Almost two thirds (63%) of those working in the agriculture sector are also in favor of an increased biomass/bioenergy use from the regional forest. Among the students, 58% want more biomass production and only 3% are strictly against any additional use of the forest for this purpose. Still every second company worker (50%) has positive attitudes regarding increased biomass for bioenergy production, although also the group of those who do not know any answer on this question sums up to almost the same share (43%).



Job - Effects on Questions Regarding Environment, Part E:

Willingness to Pay

When testing the "Willingness to Pay" WTP for solving the global warming problem, those respondents working for a company state most often (52%) to be willing to pay 1,000 Yen or more in addition to their monthly energy bill. Almost every second person (48%) within those working in the forest sector state the same. The category of those working in the forest sector show the highest amount of people (18%) being willing to pay more than 1,000 Yen in addition. Farmers state a slightly lower willingness to pay 1,000 Yen or more (44%) in addition for solving the global warming problem and students show least WTP with this respect (40%).

Cross-Analysis on the Item "Forest Owner"

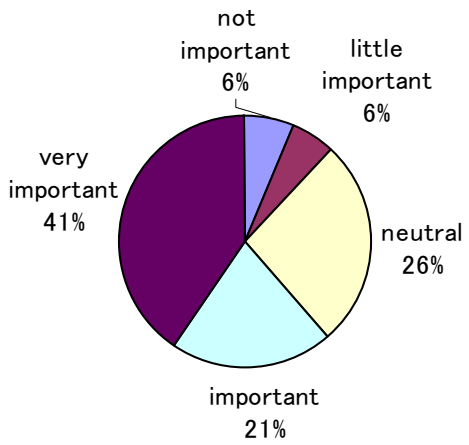
Forest Owner - Effects on Questions on Forest, Part B:

When cross-analyzing the categories of forest land owners and forest functions, it was shown that if people own forest land, the function of tree harvesting and wood production is evaluated to be significantly more important than when just looking at the results from the frequency analysis (41% voting "very important" and 21% voting important").

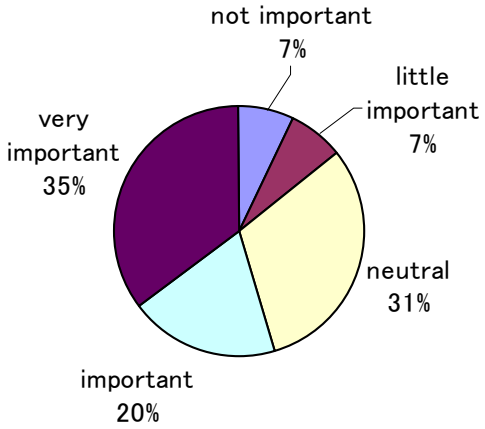
Similar effects could be identified for the forest function of employment. 35% of those owning a forest consider this function to be very important and another 20% to be important.

Both of these important forest functions have been evaluated lowest among all other functions stated.

harvesting trees and wood production

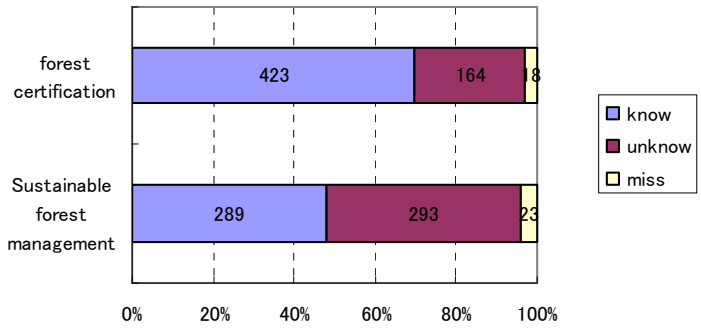


source of employment



B34	forest owners feel closest to nature when they are in forests
B35	forest owners believe that forest should be used by man
B36	forest is nature which has to be protected and productive field for necessary resources at the same time
B4	forest owners think their forest area is remaining stable

knowledge	know	unknow	miss
Sustainable forest management	289	293	23
forest certification	423	164	18



"Logit" Analysis (Logistic Regression)

Forest Certification

1. Those who state that there should be increased harvesting of trees in their area (before having received the information about Forest Certification), are more likely to be in favor of increased forest used under the Forest Certification restriction than others.

2. Those who state that increased forest use in their area is justified if SFM is applied, are more likely to be in favor of increased forest used under the Forest Certification restriction than others.

3. Those who are aware of the term "Forest Certification", are more likely to be in favor of increased forest used under the Forest Certification restriction than others.

4. Those who consider the forest industry to be important for Japan, are more likely to be in favor of increased forest used under the Forest Certification restriction than others.

C7

c7dimmy	Coef.	Std. Err	. z	P>|z|
c4harvesting	0.3207296	0.0607179	5.28	0.000
c5dimmy	2.083947	0.2108529	9.88	0.000
c6dimmy	0.5802782	0.215149	2.7	0.007
c8dimmy	1.112917	0.361019	3.08	0.002
_cons	−3.251481	0.3846783	−8.45	0.000

Sustainable Forest Management

1. The respondents from the job category “forest sector”, are more likely to have heard the term “Sustainable Forest Management” before.

2. The respondents from the job category “company worker”, are more likely to have heard the term “Sustainable Forest Management” before. – Maybe, significance not clear enough, but close!

3. The respondents from the group of forest owners, are more likely to have heard the term “Sustainable Forest Management” before.

c1dimmy	Coef.	Std. Err	. z	P>|z|
a1gender	−0.091	0.2175032	−0.42	0.676
a2age	0.003	0.0078467	0.39	0.694
a31jobagri~e	0.062	0.3059959	0.2	0.840
a32jobfore~y	0.978	0.3245092	3.01	0.003
a33jobloca~v	−0.264	0.5642581	−0.47	0.640
a34jobcomp~y	−0.658	0.3459533	−1.9	0.057
a35jobmana~t	−0.740	0.6002367	−1.23	0.218
a36jobcivil	−0.257	0.3864893	−0.67	0.506
a37jobself~p	−0.364	0.3882688	−0.94	0.348
a38jobhous~e	−1.064	0.5885193	−1.81	0.071
a310jobstu~t	−0.106	0.3482937	−0.31	0.760
a311jobune~d	−0.731	0.6605503	−1.11	0.269
a310jobother	0.010	0.2244338	0.04	0.964
a4landowner	0.702	0.2346127	2.99	0.003
c2dimmy	1.614	0.1986448	8.12	0.000
_cons	−1.128	0.5418272	−2.08	0.037

Willingness to Pay

1. Those who answered in the environment section of the survey, that nuclear power plants decrease carbon dioxide, are more likely to be willing to pay more for solving the global warming problem than others.

2. Those who answered in the environment section of the survey, that home heating increases carbon dioxide, are more likely to be willing to pay more for solving the global warming problem than others.

3. Women among all respondents are more likely to be willing to pay more for solving the global warming problem than others.

4. Those who answered in the forestry and forest management section of the survey, that they were satisfied with the forest condition regarding thinning, are more likely to be willing to pay more for solving the global warming problem than others.

5. Those who are familiar with the term “Forest Certification”, are more likely to be willing to pay more for solving the global warming problem than others.

6. Those who justify an increased use of the forest (harvesting more trees) if the forest management is certified, are more likely to be willing to pay more for solving the global warming problem than others.

e3wtp	Coef.	Std. Err	. z	P>|z|
e22trees	−0.7016038	0.4524986	−1.55	0.121
e23nuclear	1.534053	0.5965456	2.57	0.010
e24homehea~g	0.9638391	0.3901451	2.47	0.013
e25coal	0.6018482	0.4418565	1.36	0.173
e26factories	−0.0169661	0.4593509	−0.04	0.971
e28oceans	−0.2936568	0.3876629	−0.76	0.449
e29agricul~e	0.2042579	0.3992699	0.51	0.609
e210breath~g	−0.3190941	0.3409036	−0.94	0.349
e211automo~e	0.4714775	0.4966333	0.95	0.342
a1gender	−0.8126578	0.3775831	−2.15	0.031
a31jobagri~e	−0.0439426	0.3850212	−0.11	0.909
c2dimmy	0.1569883	0.4168491	0.38	0.706
a4c31	−0.0243689	0.2439516	−0.1	0.920
a4c32	−0.2106655	0.1760581	−1.2	0.231
c33	0.5900611	0.2157022	2.74	0.006
c34	−0.1624014	0.2168332	−0.75	0.454
c6dimmy	0.732507	0.3337251	2.19	0.028
c7dimmy	0.7742943	0.3465224	2.23	0.025
c8dimmy	−0.1919186	0.4548129	−0.42	0.673
e27biomass	0.0674245	0.4615117	0.15	0.884
b34	0.2883449	0.1544593	1.87	0.062
b35	0.11969	0.1579308	0.76	0.449
b36	−0.3291961	0.1906476	−1.73	0.084
_cons	1.227684	0.5325759	2.31	0.021