The Estonian forest sector in transition to sustainability?

Capturing sustainability with the help of integrated assessment

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Sustainability assessment tools and case study

Evelin Urbel-Piirsalu

Doctoral Thesis in Social and Economic Geography

LUND
UNIVERSITY

An academic thesis in fulfillment of the degree Doctor of Philosophy in Social and Economic Geography in the Faculty of Social Sciences. The thesis will be publicly defended on April 30, 2010 at 10.00 in Världen, Geocentrum I, Sölvegatan 10, Lund
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List of Abbreviations/acronyms

CFPS	Centre of Forest protection and Silviculture
CO_2	Carbon Dioxide
EIA	Environmental Impact Assessment
EPFU	Estonian Private Forest Union
ESA	Statistics Estonia (former Statistical Office of Estonia)
EU	European Union
FAO	Food and Agriculture Organization
GHG	Greenhouse gases
ISO	International Standardisation Organization
LCA	Life cycle assessment
MoE	Estonian Ministry of Environment
MCPFE	Ministerial Conference on the Protection of Forests in Europe
NFI	National Forest Inventory
NWFPS	Non-wood forest products and services
RMK	State Forest Management Centre
SEA	Strategic Environmental Assessment
SETAC	Society for Environmental Toxicology and Chemistry
SIA	Sustainability Impact Assessment
UNEP	United Nations Environment Programme
WCED	World Commission on Environment and Development
WKH	Woodland key habitat
WSSD	World Summit on Sustainable Development

Abstract

This thesis has two main objectives. The first is to analyse the potential of existing assessment tools and methods to incorporate the different dimensions of sustainability in an assessment. The second is to apply some of these tools in a case study in order to determine how forest sector can better contribute to sustainable development in Estonia. The first aim is addressed in a theoretical section that provides an overview and categorization of the existing tools and methods for assessing sustainability. In the case study a transition analysis of the forest sector's development over the last 20 years is performed together with a stakeholder analysis to determine the potential for improvements. Furthermore, a scenario analysis using a computer simulation in a life cycle perspective is performed to determine the sustainability impacts of the two sustainable forestry visions defined by Estonian forest stakeholders. The results revealed that even though the majority of tools and methods are non-integrated and thus not suitable for assessing sustainability in its broad sense, they can be combined in order to gain increased coverage of a variety of scales and integration of wider range of domains. Transition analysis revealed that Estonian forest sector has undergone rapid economic development with strong pressure on environment. There has also been a considerable drop in economic profitability, but an increase in sustainability-oriented initiatives. The modelling results revealed that current definition of sustainable forestry leads to a continuous separation of environmental and socio-economic aspects. It can be concluded that the Estonian forest sector faces two main sustainability challenges a) increasing the sustainability in private forests, and b) balancing the duality embedded in the definition of sustainable forestry applied in Estonia. Increasing certification, improving the woodland key habitat contracting system, empowering the non-harvesting private forest owners, identification of the needs and preferences of forest owners, a concretisation of the sustainable forestry definition, and implementation of clear, measurable long-term goals together with periodic assessment of progress toward sustainability are some of the suggestions proposed to increase the sustainability in the forest sector.

Kokkuvõte

Jätkusuutlikkuse hindamine on muutunud oluliseks valdkonnaks seoses suurenenud vajadusega jätkusuutliku arengu järele. Erinevate vahendite ja meetodite hulk ja mitmekesisus on tohutu ning nende hulgas orienteerumine ja valiku tegemine võib olla üsna vaevaline. Jätkusuutlikkus ning selle hindamine on oluline ka metsanduses. Selle doktoritöö eesmärk on analüüsida jätkusuutlikkuse hindamise vahendeid ja meetodeid ning nende sobivust metsasektori hindamisel. Täpsemalt püütakse selles doktoritöös kindlaks teha, milline on ja võib olla metsasektori panus Eesti säästvas arengus. Samuti hinnatakse erinevate vahendite ja meetodite kasutatavust kõikehõlmavas jätkusuutlikkuse hindamises integreerides erinevaid skaalasid ning valdkondi.

Eesmärgi saavutamiseks on töö jaotatud kahte ossa. Esimene, teoreetiline, annab ülevaate jätkusuutlikkuse hindamise vahenditest ja meetoditest ning pakub valiku lihtsustamiseks välja raamistiku nende rühmitamiseks. Analüüs näitas, et kuigi enamus vahendeid ei võimalda erinevaid jätkusuutlikkuse aspekte integreerida, on siiski võimalik erinevaid vahendeid omavahel kombineerides hindamise ulatust laiendada.

Teises, praktilises osas analüüsitakse Eesti metsanduse jätkusuutlikkust. Kõigepealt antakse ülevaade arengutest erinevatel tasanditel ning analüüsitakse nendevahelisi seoseid ja mõjusid metsasektoril. Samuti lahatakse, millisesse faasi on metsasektori areng jõudnud. Seejärel analüüsitakse metsanduse huvirühmade poliitilist mõjuvõimu ning huvi metsateemade vastu. Viimaks võrreldakse kahe jätkusuutliku metsanduse tulevikustsenaariumi mõju jätkusuutlikkusele. Analüüsi tulemusena võib öelda, et metsasektori kiire areng 1990tel aastatel oli üleminekuteooria kohaselt arengueelne faas, kuna metsaraie mahud ületasid jätkusuutlikkuse piire ning varimetsanduse osakaal oli suur. Hilisem raiete langus vähendas küll majanduslikku kasumlikkust, kuid sellega kaasnes mitmeid initsiatiive, mis jätkusuutlikkusele kaasa aitasid. Keskkonnakaitsjate võitlus varimetsanduse vastu, projektid metsasertifitseerimise ja –kaitse suurendamiseks olid olulisemad neist. Seega võib uue sajandi perioodi pidada lähtefaasiks jätkusuutlikkusele üleminekul.

Analüüsi tulemusena võib järeldada, et Eesti metsandusel seisab ees kaks suuremat väljakutset: a) suurendada jätksuutlikkust erametsanduses ning b) vähendada majanduslike ning keskkondlike aspektide eraldatust jätksuutlikkuse definitsioonis, mida metsasektor järgib. Sertifitseerimise suurendamine, väärtelupaikade lepingute süsteemi parendamine, metsaomanike õigusliku võimu toetamine, metsaomanike vajaduste ja eelistuste määratlemine, jätkusuutliku metsanduse definitsiooni konkretiseerimine, selgete ja mõõdetavate pika-ajaliste eesmärkide seadmine ja rakendamine ning progressi hindamine on peamised soovitused jätkusuutlikkuse saavutamiseks metsasektoris.

Table of Contents

List of papers

The thesis is based on the following four papers, which are referred to by their Roman numerals:

I Ness, B., Urbel-Piirsalu, E., Anderberg, S. and Olsson, L. (2007). "Categorising tools for sustainability assessment." Ecological Economics 60(3): 498-508

II Urbel-Piirsalu, E. and Bäcklund, A.-K. (2009). "Exploring the sustainability of Estonian forestry: the socio-economic drivers." Ambio 38(2): 101-108

III Urbel-Piirsalu, E. and Ness, B. (manuscript) Transition to sustainable forestry: the case of Estonian forest sector

IV Urbel-Piirsalu, E (manuscript) Sustainability impacts of Estonian forestry: comparison of two sustainable forestry scenarios in a life cycle perspective

1 Introduction

In the new century sustainability has become the goal for humankind. It is an aim that is one way or another pursued at most levels and domains in society. Along the increasing importance of sustainable development, measuring of the progress toward the sustainability goal has gained equal significance. During the last decades an increasing number of assessments on different scales and domains, using a variety of tools and methods, have been performed (Graymore et al, 2010, Graymore et al, 2009, Klöpffer, 2008, Partidario et al, 2009, Vierikko et al, 2010). To orientate among these tools and to choose the one that is the most appropriate in a particular situation has become increasingly difficult due to diversity of tools and methods available.

Sustainability has also become an important parameter in management of natural resources, including forest management. Sustainability assessment in forestry often includes the economic parameters (Agestam et al, 2006, Dykstra and Monserud, 2009) or ecological parameters (Klenner et al, 2009, Spanos et al, 2009, Vierikko et al, 2010). Assessing ecological, social and economic impacts in the same assessment is less practiced, even though some examples can be found. At the same time, the attitude toward forest has been changed in recent decades from emphasising forest quantity, mainly in terms of forest area and timber, to valuing the forest quality, involving biodiversity issues and ecosystem functionality (Innes and Hoen, 2005). However, economic results from forest sector are continuously important.

1.1 Research focus and questions

The aim of this research is to contribute to sustainability science by demonstrating how a number of tools can be combined in a single sustainability assessment in order to provide information for decision-making. Estonian forestry is used as an example. In the case study a variety of tools is used to assess the sustainability of Estonian forest sector with an aim to perform an integrated assessment including both environmental as well as socio-economic parameters. Before a case study the analysis of assessment tools has been carried out to categorise the sustainability assessment tools in order to facilitate the orientation among them.

The questions to be answered in the thesis are:

a. How can forest sector and forest land use better contribute to sustainable development in Estonia?

b. To what degree are the existing sustainability assessment tools and methods able to incorporate the different dimensions of sustainability and which ones are potentially suitable for assessing the sustainability in forest sector?

2 Research design and summary of papers

The research process started with an analysis of sustainability assessment toolbox. An inventory and categorisation of various assessment tools and methods was made. On that basis a framework for the assessment tool could be developed, as presented in Paper I. This paper forms a methodological part of the thesis with the intent to be a contribution to sustainability science.

In the process of categorisation of tools the choice of the appropriate methods for the case study was shaped. Consequently it was decided that an integrated computer modelling together with life cycle perspective should be used for the regional sustainability assessment combined with the sectoral one. Analysis of forest sector in Estonia was chosen to be the topic in the case study. The point of departure of the analysis was the Estonian paper production, as its life cycle includes forestry, which is an important economic sector in Estonia. The definition of sustainability requires that economic, social and ecological aspects are integrated in the assessment. It was decided that a computer simulation would be done for paper industry in Estonia to determine the environmental and socio-economic impacts derived from paper life cycle. Later recreation, as an alternative use of forest, was included into the study.

The data collection for the computer model required a preliminary analysis of the situation in Estonian forestry. To gain a thorough understanding of different sets of statistics and conflicting views on the situation in Estonian forestry a more in-depth knowledge and analysis was required. In order to understand the statistical data it was necessary to conduct interviews to provide further insight and information about Estonian forestry. The statistical evidence of felling and regeneration together with the results of interviews helped to create trends in forest management and its effect on sustainability. The interviews also helped to explain the socio-economic reasons behind the activities among different forest owners in the sector. This study of the forest management practices and its result was reported in Paper II.

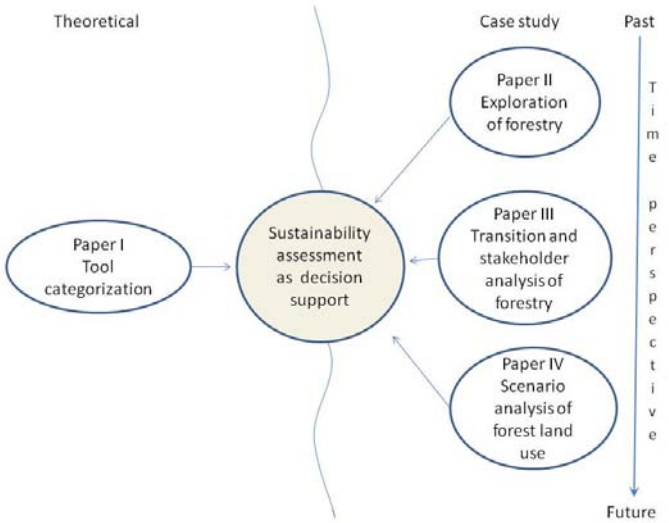

Figure 1 Conceptualisation of research design. The thesis consists of two main parts: theoretical (paper I) and case study (paper II, III and IV). Paper I contributes to sustainability science through categorisation of sustainability assessment tools. The case study papers are interrelated and form a sustainability assessment of forest sector. Paper II is a retrospective analysis of forest management practices. Paper III consists of retrospective analysis of the developments in the forest sector and the analysis of the current forestry stakeholders and their power and interest in forest related issues. Paper IV is a prospective analysis of sustainability impacts of two alternative visions of sustainable forestry.

Paper III reports an attempt to advance the assessment of the Estonian forest sector. Mere knowledge about the results of and an explanation of the reasons for the forest management practices was not enough to get a full overview over sustainability in forest sector. It was important to understand the developments in the forestry sector at

all levels and the interlinkages between these developments. A transition analysis was carried out from the transition theory perspective. Furthermore, an analysis of the forestry stakeholders was conducted by help of power/interest matrix and a multi-level framework.

Paper IV concludes the results of modelling the two alternative sustainable forestry scenarios and reports the subsequent environmental and socio-economic impacts. The scenarios were developed by using the results of the interviews with the stakeholders. Paper IV further included the discussion about the non-wood forest products and services as addition to timber production.

3 Theoretical background

3.1 Sustainability

Sustainable development[1] as an idea has been evolving for several decades. The idea is rooted in several reports from 1960s and 1970s, such as Carson's Silent Spring (Carson, 1962), Hardin's Tragedy of the Commons, (Hardin, 1968), The Blueprint for Survival by Goldsmith (1972), Club of Rome's Limits to Growth (Meadows et al, 1972), expressing the concern about human pressure on environment. The similar concern was expressed in 1972 in the Stockholm Conference on Human Environment where the human and environmental issues were simultaneously discussed in an international meeting and the question arose how to reconcile the advancement of the wealth of the world's poor with the environmental protection (UNEP, 1972). The sustainable development as a term was used for the first time in so called Brundtland report (WCED, 1987). Since then the sustainability issues have been an important part of discussions in political and public arena, as well as for the business and scientific communities.

Even though the need for sustainable development has been commonly acknowledged, the notion of sustainability has remained ambiguous. However, there is a widely accepted understanding of sustainability based on the definition proposed by the Brundtland report, which states that satisfying the essential needs of humankind now and in the future should not compromise the carrying capacity of life-supporting systems of our planet (WCED, 1987). Still, it has been difficult to apply this broad definition in specific cases and no common *operational* definition has yet been adopted. However, it has been suggested that sustainability has four common characteristics that are derived from attributes ascribed to sustainability – multiple levels of scales, multiple domains, multiple interpretations, and the intergenerational aspect of sustainability (Grosskurth and Rotmans, 2005, Martens, 2006). These common features determine the four characteristics of sustainability, namely *complexity*, *normativeness*, *subjectivity*, and *ambiguity*.

[1] The terms 'sustainability' and 'sustainable development' are randomly used. Whereas the very essence of both of these notions is similar, it can be said that sustainable development is the process toward sustainability, whereas the sustainability is the final desirable goal that sustainable development strives for. In other words, in order to reach sustainability our development has to be sustainable. In this thesis both terms are used according to need.

Complexity stems from the multiple character of sustainability. *First*, the sustainable development entails at least three interdependent dimensions (domains, pillars): ecological, economic and social, which were inherent, although vaguely, already in the Brundlandt report (WCED, 1987) but became explicit in the Johannesburg Declaration (WSSD, 2002). In addition to these three, other dimensions are used, for example institutional dimension (Spangenberg, 2002). *Secondly*, sustainability issues are dealt with at multiple spatial scales, such as local, national, regional, and global. The fact that sustainability at a local scale might not apply to sustainability at a global scale and vice versa, makes sustainability issues very complex. *Thirdly*, as the processes take place at different time scales, also the solutions must be considered in short, mid- and/or in long-term perspectives. All these together mean that sustainability issues cannot be dealt with only from one time perspective, one domain or at one spatial scale but at *multiple* and *cross* scales (Grosskurth and Rotmans, 2005).

Normativeness and *subjectivity* are connected to the final goal of sustainability that is related to intergenerational needs and should correspond to a certain standard or norm (Grosskurth and Rotmans, 2005) but is subjective. We can define the needs of the current generations but not of the future generation as these are defined by our current beliefs and knowledge, thus subjectively. Subjectivity also influences how the importance of these domains is interpreted. For example, whether natural capital can be substituted with manmade capital in case of weak sustainability or not, which is the of strong sustainability (Pearce et al, 1994). Our inability to define the future needs makes sustainability inherently *ambiguous*. Not only are we unable to objectively define the future needs, it is also unclear how the needs should be satisfied. It can be argued, however, that the very ambiguity of sustainable development, is actually the strength as it *enables participants at multiple levels, from local and global, within and across activity sectors, and institutions of governance, business, and civil society to redefine and reinterpret its meaning to fit their own situation* (Kates et al, 2005, p. 20). It therefore provides room for creativity in dealing with sustainability issues.

3.2 Sustainability science

Sustainability science stems from society's endeavour for sustainable development. The ultimate goal of sustainability science is to understand the interactions between human society and natural environment (Clark and Dickson, 2003, Kates et al, 2001). Furthermore, it seeks to guide the transition to sustainability by meeting the needs of a human large population and reduce the hunger and poverty while sustaining ecosystems' ability to support life in our planet (National Research Council, 1999). Sustainability science is a rapidly developing field (discipline) that is different from other traditional sciences. It is a paradigm that is able to address the complexity and multidimensional character of sustainable development, encompassing different magnitudes of scale (time, space and function), multiple domains and actors (Martens, 2006). The character of sustainability science mirrors the ambiguous, complex and subjective nature of sustainable development. Successful creation of sustainable solutions demands encompassing the economic, ecological and social domains as sustainability is connected to processes in all these domains. It also requires the involvement of natural, social, economic and political scientists who work together to find common solutions that lead to sustainability.

As sustainable science deals with problems caused by humans, their solution requires the involvement of stakeholders. The goals of sustainability science require different, so-called mode-2 knowledge production as opposed to mode-1 that is customary in traditional sciences. Mode-1 science is purely academic, monodisciplinary, technocratic and predictive whereas mode-2 science is exploratory, produces knowledge in a trans- and interdisciplinary manner and in a heterogeneous networks including not only scientists (Gibbons et al, 1994). Furthermore, sustainability science is also influenced by a paradigm known as post-normal science in which the knowledge is produced through participatory processes in which different kinds of knowledge, which are not only scientific, are important (Funtowicz and Ravetz, 1993).

According to Martens (2006) there are several approaches that are suitable in sustainability science. These are analytic methods, such as integrated assessment, participative methods and managerial methods such as transition management, which is based on transition theory. In this thesis some elements of these approaches are applied: transition theory (multi-level and multi-phase concept) and integrated assessment (computer modelling with life cycle perspective).

3.3 Transition theory and transition framework

In order to move toward sustainability we need fundamental changes in the society that involves all levels (Martens, 2006), in other words we need a transition. Transition is a shift from one dynamic equilibrium to another (Kemp et al, 2006) and is a result of many changes that simultaneously occur in different domains (dimensions) at different levels and that positively reinforce each other to the direction of structural transformation of the society or its sub-system (Rotmans et al, 2001, van der Brugge and de Haan, 2005). Transitions are gradual but continuous processes of change, which last at least one generation (25 years). Transitions are initiated and accelerated by some form of crisis or unexpected events (Rotmans et al, 2001) but are never *caused* by these events (Loorbach and Rotmans, 2006).

Transitions have been studied in various disciplines: in economy to explore the economic development (Rostow, 1990, Schumpeter, 2003); in social science to explain *demographic* transition from high birth and death rates to low birth and death rates (Davis, 1945, Thompson, 1929). The concept has also been applied to describe the shift from one qualitative stage to another of different types of systems in the context of *punctuated equilibrium* (Gould and Eldridge, 1977) and to explain the socio-technological shifts in the society (Geels, 2002, 2005).

Rotmans et al. have introduced the concept of transition in the context of sustainable development and governance toward sustainability and developed transition theory (Rotmans et al, 2001). Transition theory strives to bridge the gap between complex systems theory and real life societal phenomena. It departures from assumption that societal systems are complex adaptive systems and uses the knowledge about such systems to describe, understand and explore transitions in a society (van der Brugge and de Haan, 2005). Generally, transitions can be divided into two types: the *evolutionary* transition that have no predefined outcome and where the result is not planned, and the *goal-oriented* transition which follows a vision, has a predefined goal and an expected outcome (Loorbach and Rotmans, 2006). To become sustainable a society needs a goal-oriented transition. At the same time, the pace and direction of transitions in the society

cannot be managed or *controlled* by policies but they can be *influenced* and steered toward the goal of sustainability by transition management (Loorbach and Rotmans, 2006, Rotmans et al, 2001, Rotmans and Loorbach, 2009).

Transition theory makes use of two basic concepts: multi-phase, multi-level (Loorbach and Rotmans, 2006, van der Brugge and de Haan, 2005). Figure 2 denoted to the multi-phase concept; it divides the transitional processes into four general stages (thick line) that the system passes before a new dynamic equilibrium is achieved:

- P*re-development*, where the first signs of changes toward the new direction are visible at individual level but the visible status quo has not changed. Changes in that phase are very slow.
- T*ake-off*, where the system reaches a threshold and the process of change starts to build up.
- A*cceleration*, where the visible structural changes occur rapidly because socio-cultural, economic, ecological and institutional changes accumulate and reinforce each other. The changes in that phase are very rapid.
- *Stabilization*, the speed of social changes decelerates and the new dynamic equilibrium is reached (Loorbach and Rotmans, 2006, van der Brugge and de Haan, 2005, van der Brugge et al, 2005).

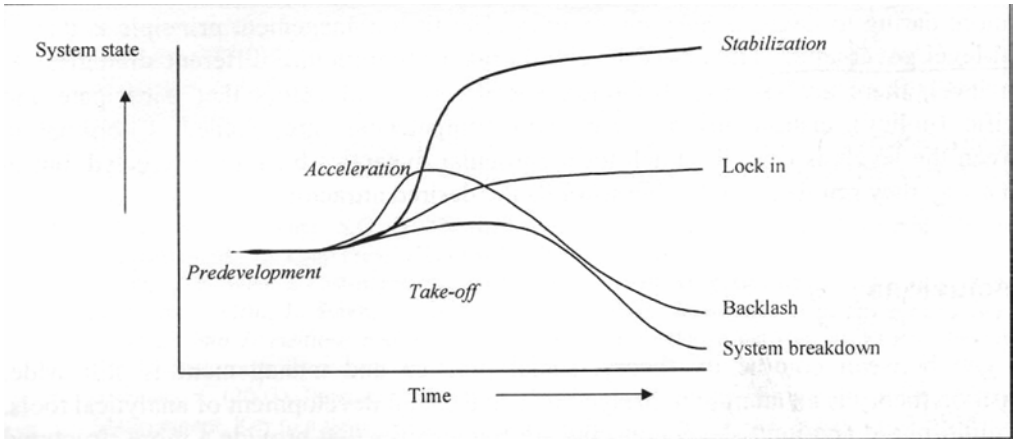

Figure 2 The *multi-phase* concept of transition theory defines four phases of the transitional processes: predevelopment (first changes start at the individual level can be observed), take-off (the process of change starts to build up), acceleration (rapid structural changes occur at all levels), and stabilisation (system reaches the new dynamic equilibrium). However, not all the changes in the system lead to transition; they can also lead system to breakdown (system does not enter into acceleration phase due to lack of resources), lock-in (system does not enter into acceleration phase due to many simultaneously developing regimes) or backlash (system goes through acceleration phase but no stabilisation occurs) (Source: Loorbach and Rotmans, 2006, van der Brugge and de Haan, 2005).

Transition theory also uses a multi-level perspective (Figure 3), where three different levels of functional scale are distinguished (Geels, 2002, 2006, Rotmans et al, 2001, van der Brugge et al, 2005). The *societal landscape* (or macro level) consists of material and immaterial elements such as physical infrastructure, political culture and coalitions,

social values, worldviews, paradigms, the macro economy, demography and natural environment. It is characterized by slow trends and large scale developments. The *regime* level (meso level) is made up of the patterns of artefacts, interests, rules and beliefs, norms and institutions that guide social and economic activities and public policy (Geels 2004). Regimes are the dominant practices, rules and shared assumptions embedded in companies, organizations, and institutions that are stable and often geared toward optimization and maintaining status quo rather than changing the system. However, regimes are 'dynamically stable' as changes do occur but they are relatively slow while still faster than at the landscape level. Once the regime starts to change, it induces the change at the societal landscape. The *niche* (or micro) level consists of the individual actors, technology and local practices. Transitions often start at the niche level where the sudden eruptions of various new initiatives arise. It is also at this level that the divergence from status quo of the system *and* deviation from the rules of existing regime take place due to new ideas and innovations. They take the form of new techniques and initiatives, alternative technologies, different social practices and preferences, and new concepts or ideas.

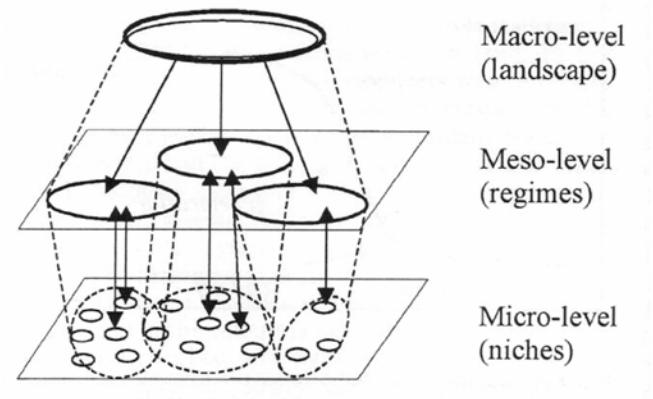

Figure 3 The *multi-level* concept of transition theory – the transition is a result of multiple reinforcing developments at three different levels: at the macro or societal landscape level, which is the overall societal setting where the developments occur, at the meso or regime level in which the dominant patterns of institutions and rules and norms of social and economic activities are defined, and at the micro or niche level where the individual actors and innovative initiatives take place (Source: Geels, 2002, Rotmans et al, 2001).

Multi-phase and multi-level concepts have been combined to explain the development of transitions (van der Brugge and de Haan, 2005). In the predevelopment phase the new initiatives start to emerge in niches often due to problems in the existing societal landscape and regimes whereas the dominating regime usually acts as impeding factor as it strives to maintain the status quo in the system. At the take-off phase the changes at the micro level interact with the positive developments at the macro level. That happens either because changes at the micro level find a fertile ground at the micro level, or changes at the macro level are supported by the new initiatives at the micro level. During the take-off the adjustments at the regime level are made but no fundamental changes occur. It is after the regime has exceeded the thresholds due to changes at the micro and macro level, the transition enters to the acceleration phase where the rapid changes at all three levels occur and dominant practices change fundamentally and irreversibly. The step from niche to regime-level does not occur at

once, but gradually, as radical innovations are used in subsequent application domains or market niches, i.e. a cumulating the niches (Geels, 2002). In the stabilization phase the transformations at all level slow down, new regime become dominant and the system stabilizes.

Social system can have different pathways but not all of them lead to transition. Depending on the socio-environmental conditions, the innovation in the society can end up in either of the pathways presented in Figure 2: in lock-in, system breakdown, back-lash or stabilization at the new dynamic equilibrium (transition) pathways (van der Brugge and de Haan, 2005). Lock-in occurs when many new regimes co-exist. System breakdown happens when the new regimes are weak and resources are limited. Both lock-in and system breakdown take a different pathway after the take-off and there will be no acceleration phase. If the system enters into and passes the acceleration phase but there will be no stabilization at the new dynamic equilibrium the new regime will not be established and back-lash occurs. For the transition to occur there is only one new regime that starts to develop and other networks reinforce the development of the new regime so that the system will transform and the stabilization after acceleration is reached.

3.4 Life cycle perspective

Life cycle assessment (LCA), is a tool for evaluating the existing and potential environmental impacts and utilization of resources of products, services, processes or activities (Curran, 1996). LCA provides information for product development, production system improvements, and product choice at the consumer level. The main characteristics of LCA are *cradle-to-grave* approach and the use of *functional units* (Wrisberg et al, 2002). Cradle-to-grave approach means that all life cycle stages of a product or a service, including raw material acquisition, production process, distribution, use, and disposal of the product are included into the assessment. Using the functional unit in the analysis is distinctive for LCA. Functional unit is a function of a product or service in quantitative terms, which allows the comparison of products or processes (Baumann and Tillman, 2004).

The history of LCA goes back to the end of 1960s but the wider acceptance of the approach did not occur until a couple of decades later when the LCA had been considerably improved (Klöpffer, 2006). The Society for Environmental Toxicology and Chemistry (SETAC) was the leading developer of the LCA methodology in the beginning in 1990s. Later the baton was passed over to the International Standardisation Organisation (ISO). The work of SETAC and later ISO was highly induced by the need for standardisation of LCA methodology due to variety of different interpretations for performing the LCAs (Klöpffer, 2006). Today there are series of ISO standards for conducting each step in the life cycle assessment (ISO, 1998, 2000a, 2000b, 2006). According to ISO standard a complete LCA has four iterative steps (ISO, 2006):

- *Definition of goal and scope* where aims and study boundaries are defined and product system, functional unit, and impact categories are selected.
- *Life cycle inventory* entails the identification of involved processes and the collection of input and output data.

- *Life cycle impact assessment* involves the evaluation of potential environmental impacts.
- *Interpretation* is the analysis of the results in line with the defined goal.

There are ongoing developments to improve the traditional life cycle assessment. One direction of development is expanding the range of impact categories to be more suitable for sustainability assessments. Originally the LCA is used for evaluating only environmental impacts related to products and processes but the latest assessments strive for analysing also social and economic impacts (Jeswani et al, 2010). The inclusion of economic impacts usually entails some kind of life cycle costing analysis. There are many tools for life cycle costing but all have the similar principle where all costs from cradle-to-grave are summed up to calculate the full costs of product and services (Gluch and Baumann, 2004). The other developments in the LCA aim for the inclusion of social impacts in LCAs (Dreyer et al, 2006, Hunkeler, 2006, Jorgensen et al, 2008, Weidema, 2006), which have lead to a discussion about life cycle sustainability assessment (Klöpffer, 2008). Another direction of development is widening the spatial scope of the tool. The traditional LCA is global i.e. site-independent but there have been attempts to make LCA more site-dependent mainly by regionalising the impact categories (Bellekom et al, 2006, Finnveden and Nilsson, 2005)

The life cycle perspective "considers the cradle-to-grave implications of different activities without going into the details of an LCA study" (Baumann and Tillman, 2004, p. 61), which is quite a complicated process. Therefore, in this thesis, namely in Paper IV only the life cycle perspective and some elements of the life cycle assessment tool are used. Furthermore, the scope is limited to a cradle-to-*gate* approach (Baumann and Tillman, 2004), which in this case can be described as a cradle-to-*boarder* perspective as only the life cycle stages that occur in Estonia are incorporated. In this way, a more regional approach of life cycle assessment is applied. Also socio-economic impacts are also included in the study in addition to environmental impacts.

4 Methods

4.1 Statistical data

The data about forest management activities are gained from forestry statistics. Two types of forestry statistics are available – those compiled by the Statistical Office of Estonia (ESA) and those of the National Forest Inventory (NFI). Until 1998 the forestry statistics produced by the ESA were the only available data. They are based on the forest notifications[2] that are submitted by forest owners to the Environmental Board. A National Forest Inventory (NFI), based on methods that measure forest resources on site, was established in 1999 and has been carried out annually since by the Centre of Forest Protection and Silviculture (CFPS). Currently, both the ESA statistics and the NFI are reported every year. The data from each source have not been comparable especially in the initial years. The discrepancies between the ESA and NFI statistics were explained by the information gained in the interviews with

[2] Forest notification is a document that forest owners are required to submit to the Environmental Board. It includes among other things information on the types of felling planned and regeneration (Karoles, 2003).

representatives of public authorities and forestry stakeholders (for lengthier discussion see in Paper II).

4.2 Scenarios

A scenario analysis is a method to explore possible futures and can be useful in sustainability science for dealing with complex societal problems (Wiek et al, 2006). The scenarios can be defined as "*coherent and plausible stories, told in words and numbers, about possible co-evolutionary pathways of combined human and environmental systems"* (Swart et al, 2004, p. 139). Scenarios are neither forecast nor prediction (Anastasi, 2003) but rather an aid to answer questions put forward by sustainability science (Swart et al, 2004). The variety of scenarios created and used is enormous. Van Notten (2003) has performed an extensive analysis of scenarios utilised in research and policy and developed a classification, which is used to describe the type of scenario analysis made in this thesis (see further Ch. 6.5).

4.3 Stakeholder analysis

The stakeholder analysis is carried out using the power/interest matrix combined with multi-level concept of transition theory. The power/interest matrix helps *"…classifying the stakeholder in relation to the power they hold and the extent to which they are likely to show interest in supporting or opposing…"* forest related decisions (Johnson et al, 2008). The matrix has two axes where the political power and the interest in forestry issues are crossed. The stakeholders are placed in the matrix in relation to their level of power to influence the political decisions and their interest in forestry issues. The stakeholders are further analysed in the multi-level perspective to determine the role and possibilities of each stakeholder in transition to sustainable forestry.

4.4 Interviews

Interviews were used to acquire information about the forest management and forest sector (Paper II, III and IV). Altogether two sets of interviews were carried out with representatives of public authorities as well as forestry stakeholders. Both sets had separate goals, different interviewees and technique for conducting the interviews.

The aim of the first set of interviews was to gain a better understanding of the sometimes contradictory statistical data and opinions in the literature concerning the management of forests and to validate the data sources. The results of the first set of interviews were also used to understand and explain the forestry dynamics occurring in Estonia. The interviews were conducted with representatives of the following forest related organisations: the Ministry of the Environment, State Forest Management Centre, Private Forest Union, Private Forest Centre, Estonian Green Movement, Estonian Forest Industries Association, and two forest companies (Stora Enso and Mets&Puu). The selection of the interviewees aimed at covering a wide spectrum of stakeholders at the national level. The interviews were carried out with people in management positions of forestry related organizations, authorities and departments. Altogether nine interviews were carried out in the first set. The interviews were conducted in an informal manner in the form of in-depth discussions. The questions covered the following topics: information about the statistical prime data, Estonian forestry in general, logging, forest regeneration, private forestry and forest owners, forest companies and their activities. Questions were prepared in advance and were

adopted to suit the specific interviewee. New questions arose along the course of interviews.

The second set of interviews was conducted among the representatives of the following forest related organisations: the Ministry of the Environment, State Forest Management Centre, Private Forest Union, Private Forest Centre, regional forest owners associations, Estonian Fund for Nature, and Estonian Society of Foresters, Tartu University and Estonian University of Life Sciences, also some private forest owners were included. The second round of interviews attempted to cover a broader target group than the first. Altogether 12 interviews were carried out. The second set of interviews had two aims: 1) to provide input to the multi-level analysis of the forestry transition between 1990 and 2010 and the stakeholder analysis (Paper III), and 2) to gain the views of sustainable forestry from different stakeholders, which was used in the scenario analysis in Paper IV.

For the multi-level analysis the first draft of the timeline graph about the developments at different levels was created based on literature, which was then used a starting point in each interview. The interviewees were asked to comment, add and change the graph where needed based on their best knowledge and experience. They had to give solid explanations and reasons for their additions and changes. In the second part of the interview the respondents were given an empty form of the power/interest matrix and asked to place all the forest stakeholders on the matrix based on their opinion about each stakeholder's political power and interest in forest related had to be backed with an explanation.

In the third part of the interview views of sustainable forestry were explored. The questions were based on the framework of Pan-European criteria for sustainable forest management (see Appendix 1) (MCPFE, 1998). All interviewees were asked the same questions, which had been sent out in advance. The interviews were conducted in the form of in-depth discussions. The main areas that were covered in the interviews were harvesting and regeneration, ratio between logging and increment, share of commercial and protected forests, structure of forest ownership, the role of national government in the forest sector and forest protection.

5 Tools for sustainability assessment

Sustainability assessment tools were analyzed and categorized in Paper I. In order to make a systematic inventory and classification of existing assessment tools a definition of sustainability assessment to guide the work was needed. Based on Devuyst et al's definition of sustainability assessment (2001) and the core questions of sustainability science research put forward by Kates et al. (2001), the following definition was made: *sustainability assessment is an evaluation of global to local integrated nature-society systems in short and long term perspectives in order to assist decision-makers and policy-makers to determine which actions should or should not be taken in an attempt to make society sustainable*.

Based on this definition a variety of tools that fall under the broad field of sustainability assessment were selected. The sustainability assessment tool framework (Figure 4) was developed on the basis of the tool inventory. It consists of three general categorisation areas; these areas are 1) indicators and indices (non-integrated and integrated), 2) product-related assessment tools, which focus on the material and energy flows of a product or service from a life cycle perspective, and 3) integrated assessments including a collection of tools usually focused on policy change or project implementation. At the bottom of the figure there is also the overarching category of tools when monetary valuations for non-market goods and services are needed in the tools. The tools are arranged on a time continuum based on if they are retrospective or prospective, forecasting tools.

The list of tools categorised in the framework is by no means exhaustive. The tools covered are not all the tools that exist for sustainability assessment, but the most significant ones found in the literature at the time of the inventory. Sustainability assessments are at an increasing frequency performed at different scales and a variety of domains; consequently new tools are continuously developed to respond to needs that arise. The suggested definition of sustainability assessment is based on three important elements. The first element is the integration of nature and society, or that the tools should be capable of integrating nature–society systems. The second element in the definition focuses on the spatial aspects of an assessment; therefore the tool should allow assessing different scales or spatial levels. The final element concerns the temporal aspects, or that the tools should able to address both the short- to long-term perspectives. But not all tools fulfil the wide objectives for sustainability assessment. Only seventeen tools (marked with dark, thick line in Figure 4 are capable of integrating nature–society facets. When all the approaches in the individual non-integrated boxes are considered, these seventeen tools represent only a minority of approaches that exist today.

However, there are examples in product related assessment where efforts have been made through combining two or more different tools to extend the focus of analysis and increase the level of integration (Wrisberg et al, 2002). Examples of this are the simultaneous analysis of a product or service function using life cycle assessment (environmental impact tool), life cycle costing (economic tool) and/or the social life cycle assessment (Dreyer et al, 2006, Jeswani et al, 2010, Klöpffer, 2003). Such an approach can have two options – either three separated non- integrated life cycle assessments or three impact assessments with a common inventory (Klöpffer, 2008).

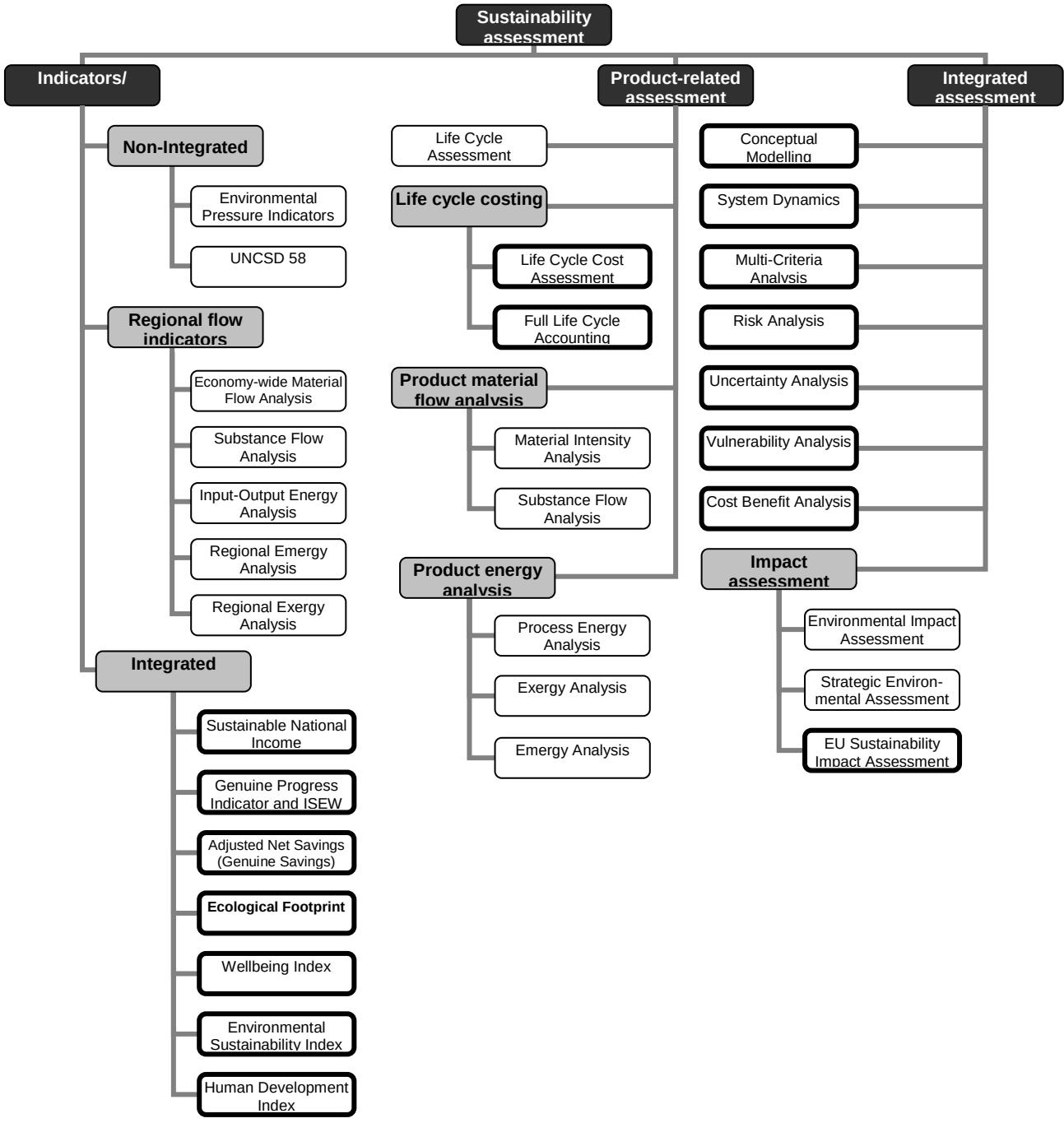

Figure 4 The proposed assessment tool framework is based on the temporal focus of the tool along with the object of focus of the tool. The first category, *indicators/indices*, consists of tools that do not incorporate nature-society systems and the tools that make an attempt to integrate them. Temporal focus of the tools in this category is retrospective. *Product-related assessment* tools in category two are either retrospective or prospective and focus on physical material, energy and cost flow assessments at the individual product level. The *integrated assessment* tools consist of a wide array of methodologies focused for forecasting future changes brought about by changes in a policy or project. The *monetary valuation* tools on the bottom are used when monetary valuations are needed in the above tools. Thick lines around the boxes indicate that these tools are capable of integrating nature-society systems into single evaluation.

Also impact assessment tools under integrated assessment are widening its scope and focus areas. For example, the EU's sustainability impact assessment (SIA) of policies is striving to better address the goals set in EU sustainable development strategy (European Council, 2006). The assessments are moving from the sectoral and often fragmented environmental impact assessments (EIA) and strategic impact assessments (SEA) to an integrated assessment covering environmental, economic and social parameters (EU Commission, 2002). The range of assessed impacts has been limited, and the most attention has still been placed on economic aspects and not on environmental or social (Bäcklund, 2009, Wilkinson et al, 2004). One of the most sophisticated forms of SIA is trade SIA applied during the trade negotiations to identify the potential environmental, economic and social impacts of trade agreements (EU Commission, 2006).

The spatial coverage of various tools is quite flexible. Although the national level is the most common focus, the tools under the first type of umbrella can be used at a variety of spatial levels, ranging from a region within a country, which can further be aggregated to national or even global impacts. Integrated sustainability assessments can be performed on human impacts on local ecosystems all the way up to dynamic global climate models. The category of impact assessment can also be modified to reflect the spatial focus required. The first two tools, EIA and SEA, are tools that are used mostly for determining the local or regional impacts of a proposed project; global impacts are normally not part of the scope of the assessment. Although the sustainability impact assessment of the EU has the intention to assess impacts of EU policy decisions on other nations as well as more localised impacts. With trade SIA the steps in such a direction has been made (Ruddy and Hilty, 2008). Most of the tools in the product-related assessment category generally focus the impacts tied only to the product function and not specifically to where the impacts occur, making it global or site-independent. However, there is work underway to make the tool more site-specific through the development of site-dependent impact characterisation factors (c.f. Bellekom et al, 2006, Finnveden and Nilsson, 2005, Huijbregts and Seppälä, 2000, Seppälä et al, 2006).

The temporal aspect classified in the framework is if the tools look forward or backward. Retrospective tools can be used for assessing future sustainability patterns, but they may not be optimal for gauging longer-term sustainability since they have been developed for analysing the past. Forecasting tools were designed to reveal impacts, benefits, risks, vulnerabilities, etc. resulting from some system change at a variety of temporal scales and are therefore perhaps more suitable for sustainability assessment. However, unlike the verifiable retrospective outcomes, forecasting tools have the disadvantage that their outcome is based on anticipations and proxies— making it more difficult for decision-makers to accept their credibility.

There are important differences among the tools concerning their degree of establishment and frequency of use. For many of the tools, e.g. LCA and EIA, there are relatively well established guidelines available for tool practitioners, whereas newer tools such as the EU sustainability impact assessment represent an area where guidelines still are under development. The same can be said about the availability of data to use with many of the tools. Although it can be argued that input data is generally a weak link with all of the assessment mechanisms, tools like LCA have developed data sets in a

number of areas. As the area of sustainability assessment matures, it is expected that some of the tools presented in the framework will be utilised significantly less or disappear; other tools will experience an increased standardisation and usage, while other completely new tools will emerge.

The interpretation of sustainability is also important for choosing which assessment approach will be used. Assessment tool practitioners and decision-makers have a choice to use a tool, or the assessment results that most closely reflect their political viewpoint. Simply speaking, how one defines sustainability and what is politically possible determines how one goes about assessing it (Bäcklund, 2009). An assessment can be done from a weak sustainability perspective, implying that manmade capital can be substituted for natural capital, or from a strong sustainability perspective, where the stock of natural capital must be preserved and is not substitutable. Example of weak sustainability assessment tools under the rubric of integrated indicators is Adjusted Net Savings, with the ecological footprint as an example of a stronger measure of sustainability (Hanley et al, 1999). The differing interpretations have implications for decision-making processes.

In the forest sector, that is a focus of this thesis, various tools can be used. The choice depends on the scope and goal of the study. Strategic environmental assessments are used for forest policy documents in Estonia. Product-related tools can be used in the forest industry. Indicators maybe applied to assessing the sustainability in the forest sector, including the forest management and forest industry. Monetary valuation tools are necessary to use when the value of forest ecosystem services, such as water and soil regulation, climate change, etc. are needed.

There is a contradiction within the future development of sustainability assessment tools. On the one hand there is the demand for approaches that have a more specific assessment performance, for instance more case- and site-specific. At the same time there is a demand for tools that are *broader* in order to be accessible to a wide group of users under different circumstances. There is also a need for more standardised tools that give more transparent results. Future assessment tool development need meet the challenges of better assessment guidelines and data availability and for succinct analyses on a more diverse range of assessment situations. Like the many facets of the concept of sustainability itself, proper tool development can only happen when all parameters are considered simultaneously.

6 Sustainability assessment of Estonian forest sector

6.1 Defining sustainable forestry

Sustainability has also become an important parameter in management of natural resources even though it has been debated what exactly needs to be sustained and to what extent. The ideas in forest management that we today would categorize as sustainability measures were recognised in European and Estonian forestry already two centuries ago (Relve, 2007, Wiersum, 1995). When overexploitation of forests became a serious problem in the 18th century, practices that aimed for a *sustained-yield of timber* were incorporated into forest management to reassure continuous supply of timber over a long time period (Seymour and Hunter Jr, 1999). Under this management regime the rotation of forests was set to maximize the yield of timber in a way that would not

reduce yields in the future. Another important component of the sustained-yield principle was that the harvest rate could not exceed the growth rate of forests. Furthermore, it was increasingly recognized that forests are not just the source of timber and timber products but provide other goods and services. As a result the idea of *multiple-use sustained-yield management* evolved in European forestry where two principles were important – to guarantee a continued production of diverse forest goods as well as to maintain the production capacity of forests (Seymour and Hunter Jr, 1999, Wiersum, 1995).

In late 1980s it was acknowledged that the services provided by forests, such as climate change mitigation, biodiversity and water control, are dependent on *ecosystems* rather than just trees. It became evident that not even multiple-use sustained-yield management was sufficient to gain sustainability. Consequently, the idea of *sustainable forest management* – also called sustainable forestry, ecosystem based management, ecological forestry – started to evolve. Sustainable forest management, which is the concept that will be used in this thesis, is defined as:

> …the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that it does not cause damage to other ecosystems (MCPFE, 1993).

Productivity, which was the main principle of sustained-yield practices, is also important in sustainable forestry, but entails also other aspects. Put shortly, the main goal of *sustained-yield management* is to sustain forests for long-term economic activity, whereas the aim of *sustainable forestry* is to sustain forests as *ecosystems* (Noss, 1993). The shift from traditional to sustainable forest management practices is still in process because the principles of sustainable forestry are under development (Seymour and Hunter Jr, 1999).

In this thesis both socio-economic and ecological functions are considered. The focus is mainly national, although the global impacts on Estonian forestry are discussed. At temporal level both historical and future perspectives are regarded.

6.2 Overview of Estonian forest and paper industry

Estonian forest sector started to develop in the beginning of 1990s after the end of the Soviet period when forestry was a minor industry. Currently, half of Estonia (see Figure 5) is covered with forest (CFPS, 2009). The forest cover has grown from 929 thousand ha in 1940 to 2212 thousand ha in 2007 (Adermann, 2008, Etverk et al, 1998). Estonian forest is divided between private owners and the State. In the beginning of 2009 the share of public forests was 43% of total forest cover and private forest was 41%, whereas one-sixth of the forest is in the process of privatization and has an unsettled legal status (CFPS 2009). The private forest is quite fragmented as there are about 50 000 private forest owners (Aitsam, 2009); most of which are smallholders with an average forest property of 12 ha (CFPS, 2008).

Figure 5 Forest cover in Estonia (based on Corine Land Cover 2006)

The forests in Estonia are mainly mixed, only 17% of forests have single species of even age (Adermann, 2008). The Global Forest Resources Assessment (FAO, 2006) report that 44% of forests are primary, 49% are modified natural and 7% are semi-natural forests[3]. Conifer forests cover 37% of forest land, deciduous forests 36%, and the rest are mixed. Dominating species in the forests are Scots pine (40%), silver birch (25%), Norway spruce (17%), aspen (6%), and alders (10%) (Adermann, 2008).

Forestry has developed into an important industry, and forest products have become important export articles – timber and timber products accounted for 9-18% of exports between 1995 and 2008 (Statistics Estonia, 2009). Paper industry consists of a kraft paper factory, a pulp factory and a small factory producing paper products from recycled fiber. The kraft paper production dates back to 1938 and its annual capacity is 65 000 tons of paper. The kraft paper production data is used in the analysis in paper IV. The aspen pulp factory was established in 2006 and its annual capacity is 140 000 tons of pulp. It is omitted from the quantitative scenario analysis but is included in the discussion. The recycled paper factory has a history of 300 years but as its production capacity is quite small, it is omitted from this study.

6.3 The stakeholders in the forest sector

The stakeholders are presented in Paper II and further analyzed in Paper III. To understand each stakeholder's role in the forest sector, an analysis of the interest and political power of each stakeholder in the sector is performed by help of a power/influence matrix (see Figure 5), which is combined with the multi-level perspective of transition theory.

The dominant regime in Estonian forest sector includes public authorities responsible for forest issues, the forest industry, forest scientists as well as representatives of private and public forest owners. The power to influence political decisions in this group is quite strong even though it is not the same for all the actors. The public authorities have the highest power but their interest is not seen as very high as the Government does not seem to realize and perceive the full potential of forest sector for Estonian economy, and thus the sector is not considered as a politically prioritized area. Forest industry and companies on the other hand have both high interest and high political power. The State Forest Management Centre (RMK) as a state-owned forest company has according to the respondents, equally high interest but higher political power than the other forest companies. The power of Estonian Private Forest Union (EPFU), the Estonian Society of Foresters and regional forest owner organisations is lower than the forest authorities and forest industry but their power has during the recent years increased considerably.

The position of forest scientists in the power-interest matrix was strongly disagreed among the responding stakeholders. The prevailing opinion however was that forest

[3] Primary forests are defined as forests of native species where there are no clearly visible indications of human activities and where the ecological processes are not significantly disturbed; modified natural forests are naturally regenerated with native species where there are clearly visible indications of human activities; and semi-natural forests are established through planting, seeding or assisted natural regeneration of native species (FAO, 2006).

scientists have quite low interest in general forest issues, as they often concentrate on quite specific issues. The scientists can be included in policy-making but according to the respondents not to a sufficient degree. Therefore their power to influence political decisions was considered as quite low. As forest scientists are not innovators in sustainable forestry practices but rather follow the ideology of the dominant regime, they are placed at the regime level.

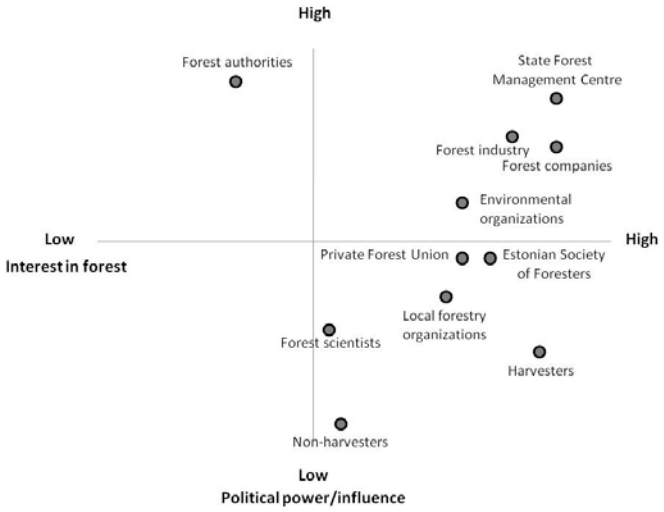

Figure 6 Stakeholders in the power/interest matrix according to their power to influence political decisions and interest in forest issues (based on interviews and literature).

Based on the interviews and the findings from the literature (Ahas et al, 2006) it can be said that according to the prevailing attitude, at the regime level, forest is a source of wood and primarily has an economic function. Ecological and social factors were perceived as important but secondary. Consequently, the dominant regime strives for high harvesting rates rather than other issues of forests. The preferred management practices in the dominant regime is clear-cutting, which is the most profitable and hence the most favored method of harvesting (Ahas et al, 2006, Tullus, 2002).

The stakeholders at the niche level are private forest owners, and environmental organizations. In the interviews it became clear that there is a continuum of forest owners between two groups: those who actively manage their forests (harvesting forest owners or harvesters) and those who are not engaged in forestry activities (non-harvesting forest owners or non-harvesters). Harvesters have better connection with the regime through their cooperation with EPFU and local forest organization and have therefore stronger political influence. Non-harvesters however do not practice regime level management activities and have therefore less power.

Environmental organizations are powerful niche level actors who have high interest in forest issues and their power to influence the political decisions has considerably increased since the beginning of 1990s. That is the opinion shared by all the stakeholders. The environmental organizations are now always included into the

political decision-making process and often their opinion is taken into account but not always (Aitsam, 2009).

6.4 Transition analysis of the forest sector

6.4.1 Predevelopment

The development of Estonian forest sector is explored and analyzed in Paper II and Paper III. The predevelopment phase of transition (Figure 8) in the forest sector started with regaining national independence in 1991 and lasted until 2000. This was a period of rapid and simultaneous changes in the forests sector at all levels (see the events, factors and institutional change in Figure 6. At the societal landscape level the patriotic feelings permeating the whole society were soon replaced by economic wealth oriented ideas. At the same time the regime level factors supported the development of the forest sector. The land restitution process was speeding up. The first Forest Act accepted in 1993 was too weak to regulate the rapid development in forestry (Etverk, 2005) and the new Forest Act entered into force in 1998 was even more liberal, providing forest owners relatively great freedom in management (Ahas et al, 2006, Etverk, 2005). Consequently, a strong correlation between privatization and felling volume could be observed (CFPS, 2008). Simultaneously, the forest industry that was privatised in the beginning of 1990s developed fast and gained considerable importance (Etverk, 2005), which also had an impact on logging and forest management as it provided a necessary domestic market for wood. The interaction of these four processes – the wealth oriented ideology in society, the land restitution process, the forest legislation and the development of forest industry led to a rapid increase of forest logging in late 1990s and the beginning of the new century (see Figure 9). This development was positive from a socio-economic point of view. However, the unsustainable logging rates together with the activities violating legislation and weak enforcement of forest regulations made the forest management ecologically unsustainable. The niche level activities toward sustainability were quite few during the predevelopment phase.

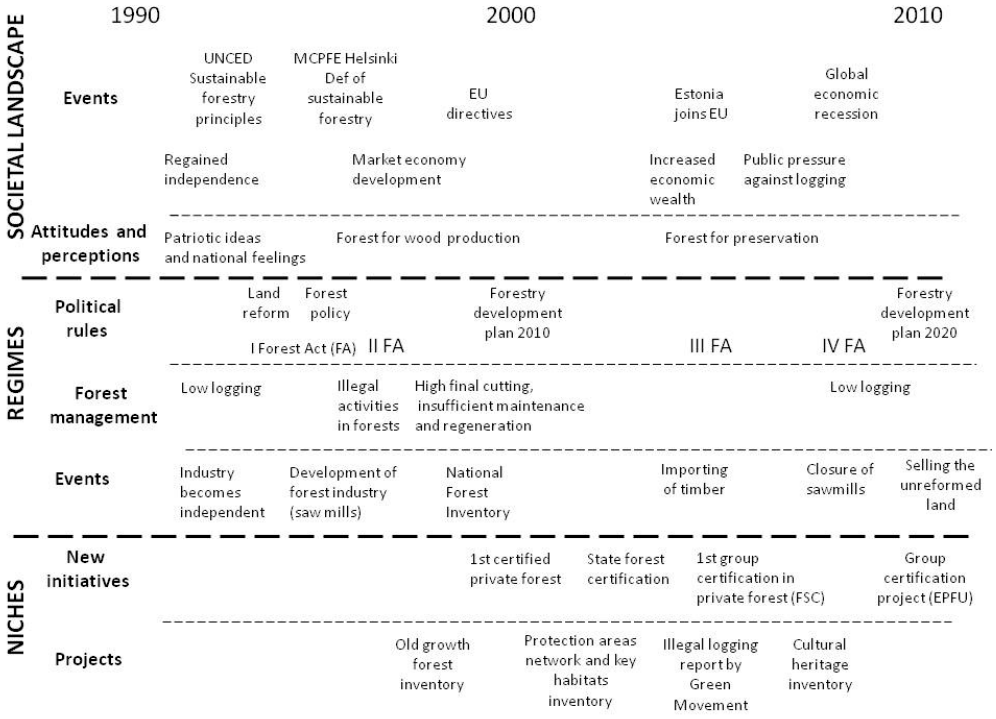

Figure 7 Forest sector related societal, economic and institutional changes at different levels during the period of 1990-2010 (based on interviews and literature). At the societal landscape (macro) level the patriotic feelings were replaced with a purely economic thinking valuing the forest for its wood production, which later gave place to an attitude in favour of preservation which values ecological, social and cultural functions of forest. At the regime level the changes in forestry policy shifted from very liberal to rather restricted regulations that was further influenced by privatisation processes and forest industry development. At the niche level there has been several initiatives towards sustainable forestry including actions against illegal logging and fostering forest preservation and certification.

6.4.2 Take-off

The take-off phase of sustainability transition started around the beginning of the new Millennium. After 2002, harvesting started to decrease due to the events and changes both at the niche and regime level. At the niche level the private forest owners had gained a certain extent of economic wealth through liquidation of their forest. The National Forest Inventories (NFI) started in 1999 revealed that the logging had reached an unsustainable level, which alarmed foresters, the Government, the public and in particular environmental organizations. A report issued by environmentalists (Hain and Ahas, 2004, 2005) claimed that that the extent of illegal forestry in 1998-2003 was 50%, whereas the Ministry of Environment (Lang et al, 2005) concluded that it was 10% [4].

[4] The large discrepancy between the estimates was explained by the different definitions used. The Ministry defined illegal *logging* only as logging that contravened local forestry regulations (Lang et al, 2005). The concept of illegal *forestry* used by environmentalists, on the other hand, included in addition to illegal logging tax fraud and violations of rules for timber trade, transport and processing. It further included so-called *timber laundry,* where illegally felled timber goes

The problem was mainly evident in private forests. The disclosure of the extent of illegal forestry and high logging rates instigated the public authorities to make regulations stricter and improve monitoring to strengthen the fight against high and often illegal logging. Furthermore, public pressure has induced forest companies to take measures to guarantee the origin and legality of wood and good forest management (Kuresoo and Kohv, 2009, Tust, 2009). These measures have led to a decreased rate of illegal logging (CFPS, 2008, WWF, 2006). The increasing awareness of illegal activities together with high logging rates, created a bad reputation for the forest sector, which led to change of attitude towards forestry. It changed from pro-logging to anti-logging and in favour of forest protection (Annus, 2009).

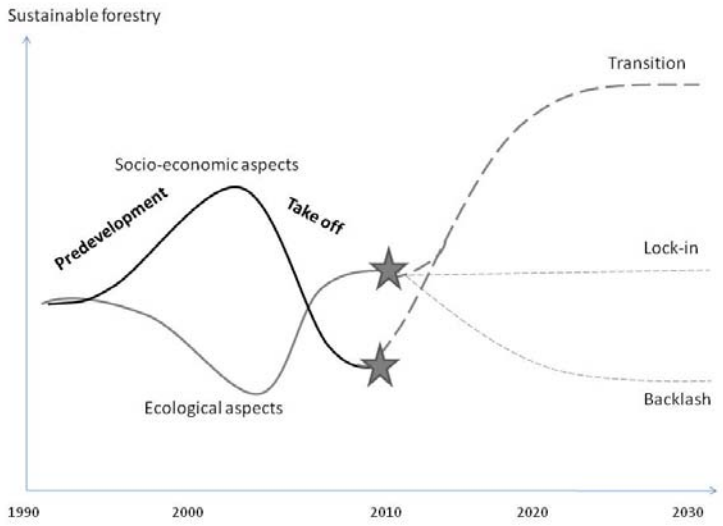

Figure 8 Current path of Estonian forestry from sustainability perspective (solid line) and the future possibilities (dotted line), based on the results of the multi-level analysis (the star represents the present moment). The vertical axis represents sustainable forestry and horizontal axis shows the timeline.

All these events at different levels – initiative to reveal the extent of illegal forestry at the niche level, improvement of statistics to estimate the rates of logging and related change of legislation at the regime level, increased wealth of forest owners and change of attitude at the societal landscape level – induced the decrease of logging since 2003 (see Figure 9). While this has had negative impact on forest sectors' economic indicators, it has been good from ecological aspects. Furthermore, there have been several initiatives at the niche level that support the progress towards an ecological sustainability of forestry. These include mainly activities that increase the protection of forest ecosystems and induce the establishment of forest certification in Estonia. There were several projects that contributed to forest protection. Firstly, the distribution,

through certain schemes to change documents so that the timber appears as legal on the market (Hain and Ahas, 2003).

condition and protection of old growth and natural forests were determined (Leibak et al, 1996). Secondly, the forest protection network was defined (Viilma et al, 2001). Thirdly, an inventory of woodland key habitats (WKH) was conducted in 1999-2002 (Andersson et al, 2003). The mapping of WKH in commercial forests became a basis for a contracting system[5].

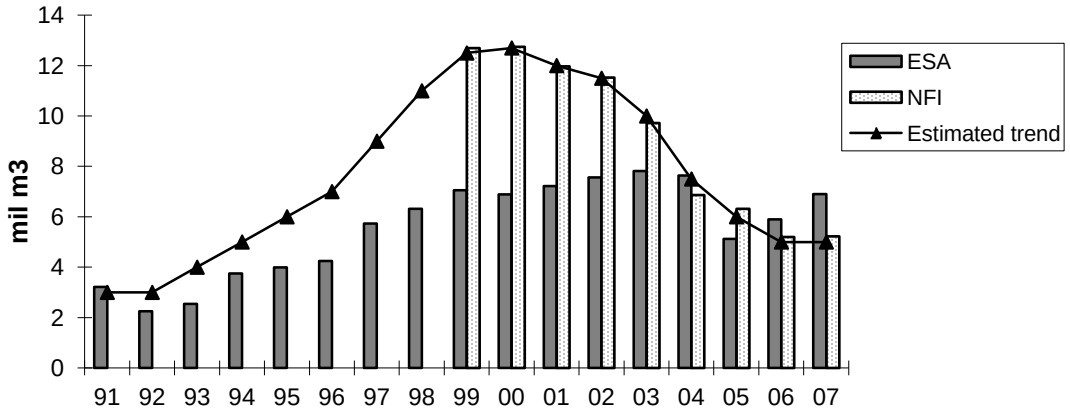

Figure 9 Logging volumes between 1991 and 2007 (in mil m^3). The annual logging volumes provided by the Statistics Estonia (ESA) and the National Forest Inventory (NFI). The dotted line represents the estimated trend of annual logging volume. *(Source: Adermann, 2009, CFPS, 2009)*

Other initiatives at the niche level towards sustainable forestry were related to certification. In 1998-2000 Estonian sustainable forestry standard was developed in a working group. It was an important initiative for the future cooperation between forest stakeholders, (Ahas et al, 2006) even though the document itself was not finalized into official standard until very recently in 2009 (Oja, 2009). In the beginning of the new Millennium several FSC certification cases occurred: all state forests were certified in 2002, which raised the share of certified forest to 40%; the first private forest became certified in 2000 and the first group certification of private forests occurred in 2005 (FSC, 2009). Another group certification was received in 2010 to promote the PEFC scheme that is more favored by small forest owners in Scandinavia (Gulbrandsen, 2005, Schlyter et al, 2009).

Even though after 2002 the economic development of forest sector had decreased, initiatives promoting sustainable forestry started to emerge. These initiatives at the niche level and changes at the societal landscape level demonstrate that there was a pressure to increase sustainability in the forest sector. Environmental organizations proved to be a powerful niche actor that could influence the changes at the regime level. The transition is currently at a stage where there have been several initiatives promoting environmental aspects in forest transition but the logging has decreased to an unsustainable level and the forest owners are expected to become more active and

[5] Woodland key habitat (WKH) contracting is a system to compensate the loss of income for private forest owners for not harvesting but protecting the forest with WKH.

increase management activities again. There are several factors that can induce this. Firstly, sources of imported wood are diminishing due to high export tolls set on Russian wood. Secondly, if the economic situation revives again, the forest industry will require more timber, which will put pressure on domestic resources. Thirdly, the price of timber seems to increase (RMK, 2008) which provides an incentive for forest owners to sell. However, would the new rise of forest sector be more sustainable? Are the initiatives toward sustainability emerging at the niche level enough to enter into acceleration phase and to build a new sustainable forestry regime during that phase? Continuously low harvesting rates as well as overexploitation of forest can lead the sector into a lock-in. At the same time, if the harvesting rates start to increase, the forest sector can enter the acceleration phase. It is then important not to overexploit the forests to avoid ending up with a backlash.

6.5 Scenarios of sustainable forestry

The transition pathway taken in the future depends on how the sustainability is actually envisioned. Paper IV presents two scenarios based on the image of sustainable forestry put forward by interviewed stakeholders. The sustainability impacts of these scenarios are there after assessed. Scenario 1 focuses primarily on timber production while other uses of forest are less important. In scenario 2 the timber production is lower and there is more permanent, and/or old-growth, and protected forest suitable for non-wood products and services. An overview of the scenarios is given in Table 1. Following the scenario typology by van Notten (2003) the scenarios can be characterised as:

- Normative because they explore the preferable future
- Institution-based as the forest sector is a subject for the study
- National according to spatial scale
- Long-term as time scale is 150 years
- Quantitative as sustainability impacts of scenarios are compared in quantitative terms
- Open as there are no institutional constraints
- Snapshots because the scenarios describe the end-state.
- Heterogeneous according to the set of variables.
- Conventional as the scenarios do not differ significantly
- High level of integration as economic, social and ecological impacts are considered

6.5.1 Scenario 1

In scenario 1 the ultimate goal is maximised yield and the intensive management is focused on timber production. It has so called weak sustainability as natural capital can be substituted with manmade capital and the natural capital can be invested in other capitals (Pearce et al, 1994). It is anticipated that intensive forest management is the most profitable, hence sustainable. But the profits may be further invested in forest protection to regain the ecological balance. In this scenario private forests are dominant. To reach the goals in this scenario, it is important to avoid economic losses. Therefore, all commercial forests that reach maturity are targets to final harvesting. Forest is harvested with clear-cutting as this provides the highest return of investments. Regeneration in this scenario is mostly natural as Estonian forests have generally good

conditions for natural regeneration and it is not necessary to invest in cultivation. Forest protection is mainly achieved by private forest owners but in cooperation with the state. The loss of income that private forest owners bear with forest protection is remunerated by the state. It is anticipated that the state forest is highly influenced by political decisions which might lead to decrease of protected forest. Private forest owners on the other hand are considered more reliable in forest protection especially when the costs are covered. Therefore, it is not necessary to create special forest protection areas and the area of protected forest by the State is minimal.

Table 1 Comparison of two sustainability scenarios envisioned by the stakeholders

Area	**Scenario 1**	**Scenario 2**
General goal	Economic sustainability and high profitability	Long term stability and balance in forestry
The main product of forest	Wood	Non-wood products
Logging vs. increment	Removal can temporarily increase increment	Logging does not exceed increment.
Forest regeneration	Mostly natural regeneration, cultivation limited.	Often cultivation in clear-cut areas but natural regeneration in permanent forests.
Type of harvest	Clear-cutting, selection cutting discouraged	Clear-cutting in some areas, selection cutting encouraged
Forest protection	Initiated by private forest owners but supported by the state.	The state owns the protection areas

6.5.2 Scenario 2

The main goal in scenario 2 is to gain long-term ecological and socio-economical stability and balance in Estonian forestry. In order to achieve this it is necessary to look the forest as a whole not at each plot separately. In this scenario the state has a more conservative role. Scenario 2 has strong sustainability approach in which the capitals are not substitutable and none of the capitals (ecological, social or man-made capital) can be reduced in the long run. In this scenario removal should not exceed increment at any time. If there are too many mature forests then the harvest should be stretched over as long time as possible to regain the balance in the forest cover. Clear-cutting is only applied in areas most suitable for that, such as big commercial forests where the land can be divided into many plots. In other areas, such as small private forests, it is more feasible to practice selection cutting which is encouraged as it allows permanent forest. This scenario has a bigger area of forest suitable for non-wood forest product and services. Forest regeneration in this scenario is carried out with the goal of attaining a forest with the same quality as before cutting, or higher. Therefore, the forests are regenerated in the most appropriate way for different conditions. That might in clear-cut areas mean planting, seeding or assisted natural regeneration. Forest protection is mainly State's responsibility. In this scenario the state is considered to be a more reliable manager of protected forest than private owners.

6.5.3 Sustainability impacts of the scenarios

The graphs in Figure 10 illustrate the results of the scenario comparison. In both scenarios the results depend largely on timber production. The fluctuations are steeper in scenario 1 and the sustainability impacts vary accordingly. The oscillations are also evident in scenario 2 but with lower magnitude. Environmental impacts (see GHG emissions in Figure 10) are lower in scenario 2 even during the period of low timber production and it is in some periods of scenario 1 almost three times higher than the impact in scenario 2. The socio-economic impacts (see revenues in Figure 10) are better in scenario 1. The differences between the results from the two scenarios were even bigger concerning revenues. During the low timber production period the revenues differed 20% whereas during the high timber production the revenues in the two scenarios diverged more than three times. In general, it can be claimed that scenario 2 displays impacts that are better for the environment and in scenario 1 the socio-economic indicators show better sustainability.

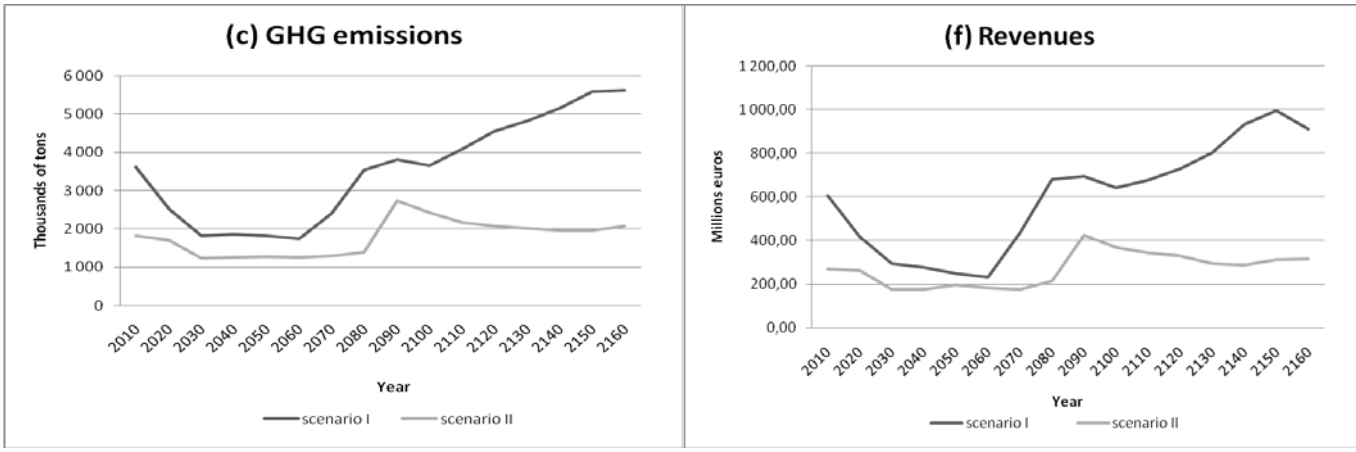

Figure 10 Greenhouse gas emissions (in CO_2 eq.) and revenues (in mil Euros) in the two scenarios.

It is clear from the model results that if the current mature forest is harvested to its fullest extent like in scenario 1, it creates high fluctuations in the economic return in the future and does not allow for a balanced economy in the forest sector while putting higher pressure on environment. However, if the harvesting is prolonged over time in an attempt to smooth the oscillations, it decreases the environmental load but creates considerably lower economic return and less employment opportunities than in scenario 1. In order to avoid the lack of revenues due to decreased harvesting activities, areas of less frequent harvesting must generate revenues from other activities, such as providing berries, mushrooms, hunting, decorative greenery, and recreation. For example, in order to generate as much income as during the peaks of timber production in scenario 1, recreational areas[6] in scenario 2 must produce not less than €690 per ha. That estimation is based on the difference in revenues between the two scenarios that

6 Recreational area includes forests that are under protection, harvested with selection cutting, thus permanent forests, and commercial mature and old forests that are not (yet) harvested.

varies between €35 and €690 per hectare of recreational area. If recreational area generates an average of €340 per ha, it would make the scenario 2 better than scenario 1 only during periods of low timber production.

7 Suggestions

7.1 Main challenges of reaching the sustainability

Based on the transition and scenario analyses it can be concluded that the two main challenges to reach sustainability are a) balancing/overcoming the duality embedded in the sustainability definition that influences the ideology in the forest sector and b) increasing the sustainability of private forest owners' management practices.

The duality of sustainability in terms of diverged ecological and socio-economic impacts is demonstrated both in Figure 7 and Figure 10. One describes the historical development in the forest sector and the other indicates the outcomes of sustainable forestry images envisioned by the forestry stakeholders. It implies that the duality of sustainability is already embedded in the sustainability definition followed by the Estonian forest sector. The similar duality is also seen in the two main forestry ideologies prevailing at the societal landscape level and influencing the events and activities in the forest sector – *forest for wood production* (high economic return but low preservation) and *forest for preservation* (high nature conservation but low economic return). For the transition to sustainable forestry to occur the ecological and socio-economic aspects must be balanced. Forest for wood production is the attitude of the dominant regime even though the forest for preservation attitude, which is prevailing outside the regime, has currently more influence over forest sector. It is important that the understanding of sustainable forestry of the dominant regime balances between the two prevailing perceptions as they represent two extreme ends that in the long-run cannot be sustainable.

State forest management has been stable throughout the years since the beginning of the new Republic of Estonia. The private forests however have induced the unsustainable oscillations in the forest sector (Ahas et al, 2006, CFPS, 2008). At first the logging was too high and often even illegal. Thereafter, it halved, referring that a high number of forest owners are not harvesting their forests. At the same time, the choice of management techniques also determines whether forestry is sustainable. The transition to sustainability in the forest sector only occurs when the private forest owners (harvesters and non-harvesters) adopt an ideology that does not separate between ecological and socio-economic aspects and are able to cooperate, in order to be strong enough to influence the regime and finally become part of it.

7.1.1 Overcoming the duality in the sustainability definition

It is important not to focus on maximizing only one aspect of sustainability (economic, ecological, social, and cultural) but rather strive for balance between all the aspects. Finding such a balance is a continuous challenge and requires tradeoffs between the domains. Some economic profits must be given up in order to sustain the forest ecosystems ability to continuously provide goods and services. Also the economic output from forest must come from various sources not just timber production. The scenario analysis showed that focusing only on timber production does not allow to reach a balanced sustainability. Either socio-economic aspects or ecological balance

suffered. Increased provision of non-wood products and services is a possibility to reach a balance between socio-economic and ecological aspects.

The forest for preservation ideology is largely influenced by the public attitude formed as a result of a number of problems in forestry, such as high and illegal harvesting. Even though both illegality and harvesting rates have decreased the attitude has persisted in the society. On the one side, it is important that the public accepts that wood production is important for the economy and not all forest logging is illegal and a sign of deforestation. The forest sector communication strategy is a good attempt to increase the public knowledge about the forestry situation and improve the reputation of forest sector (MoE, 2006). On the other side, the actors of the dominant regime must acknowledge that not all forest owners are interested in harvesting the forests and low human activity in the forests is not necessarily negative for the economy but can be appealing for foreign tourists that would also support economy.

Estonian forest policy has adopted the definition of sustainable forestry provided by MPCFE (1993), which is all-encompassing but not operational and therefore quite difficult to achieve. The sustainable forestry must be defined in a concrete way, which entails comprehensible and measurable goals for the sector. Moreover, it is necessary to identify indicators by which the goals can be evaluated. The objectives of the current Forest Development Plan are unclear and therefore cannot be gauged (MoE, 2002). Also, there have been no regular sustainability assessments of the forest sector besides a single indicator based assessment carried out seven years ago (Karoles, 2003). Utilization of tools and methods that allow integration of ecological and socio-economic aspects in assessing the sustainability of the forest sector should also be encouraged.

Furthermore, long-term planning in the forestry is necessary. Currently the planning is performed in 10-year cycles, which is not sufficient due to two reasons. First, in sustainability issues we need to consider future generations, where one generation is about 25 years. Secondly, in forestry one logging cycle is 80 years for conifers and 30-50 years for deciduous trees, which grow faster. Therefore forestry has to have at least a 30 year strategic plan. Such long-term planning guarantees more stable forestry regulations as these follow the long-term objectives not the observations of short-term developments in the forestry. This will finally lead to proactive forestry regulations rather than reactive ones. Long-term plans must also be followed up by periodic assessment to ensure that neither ecological nor socio-economic aspects of sustainability dominate.

7.1.2 Increasing the sustainability in private forests

The key to elevate the forest management activities and to increase the sustainability is in the hand of private forest owners. In order to be able to influence the forest owners, one must know the reasons and arguments for their behaviour. Inappropriate taxation system has been claimed to be one of the impediments why private forest owners are reluctant to harvest their forests (Marastu, 2007). Changing the tax system has been under discussion since 2002 and is expected to be one of the most important changes that would induce the forest owners to harvest more actively (Aitsam, 2009, EPFU, 2006, MoE, 2002). So far only minor changes have been made in the tax system, which have not much improved the situation (Aitsam, 2009). However, changing the taxation

system is probably not the only incentive that would encourage an active management in private forests. It will affect only those forest owners who have abandoned the forest management due to the unfavorable taxation system but not those owners who have neglected their forest for other reasons. For example, there are numbers of forest owners who perceive managing their forest rather as a hobby or life style than a business and some forest owners do not even want to intervene in natural processes in forests (Ojala and Tamm, 2006). It is important to find out what are the needs and preferences of private forest owners, especially non-harvesters, regarding the forest management as well as the reasons for lack of management activity. This would help determining the measures that can improve the activity in private forests and increase sustainability in private forests.

At the same time, encouraging all forest owners to harvest in their forest should not be a goal. Rather, it is important that all forest owners make conscious choices regarding their forest management, be it harvesting or non-harvesting. The system must change in a way that lack of knowledge, experience, discouraging tax system or other factors are no longer the reasons for non-harvesting. If forest owner decides to omit harvesting, it must be a result of a conscious decision. Therefore, the small forest owners' awareness of different silvicultural and forest management practices as well as cooperation possibilities must become better. However, the support to increase forest owner's knowledge should not be biased – either towards economic development or towards forest protection. It should ensure that forest owners are aware of the results and impacts of their actions or non-actions and can choose a management method that is the most suitable for their circumstances.

As a significant number of forest owners are non-harvesters, it can be anticipated that these forest owners are not interested in clear-cutting even though the prevalent opinion in Estonian forestry regards clear-cut as the only reasonable way to harvest forest (Ahas et al, 2006, Tullus, 2002). For a typical forest owner who only has a small forest area, a more feasible way to harvest is perhaps selection cutting that allows permanent forest. Still, practicing selection cutting requires high knowledge of forest management and there is a need for help and support of forest experts, which can be provided by the state.

Some forest owners are not interested in any forest management (Ojala and Tamm, 2006). Those forest owners who have woodland key habitants (WKH) identified on their land can take advantage of the WKH contracting system. This will compensate the income loss from protecting their forests instead of harvesting. To guarantee the successful system of WKH contracting, the general awareness of the rights and possibilities of forest owners must be increased. Also, the system has to be improved to overcome all the current deficiencies. It is suggested by environmentalists (Kuresoo and Kohv, 2009) and many interviewees that the WKH areas should become state property to ensure that key habitat areas are not cut down. The pros and cons of this should be weighed and calculations must be made to determine the financially, socially and ecologically better alternative. However, the forest owners with no WKH on their land may also choose to omit harvesting in their forests and focus on forest protection. Many such forest owners live in urban areas where they have jobs and do not need income from their forest (Valgepea and Laas, 2002). The owners living adjacent to their

forest might choose to protect forests or practice selection cutting as they use their forest areas for NWFPS, which can also provide economic benefits.

Regardless of the management choice the forest owner has made, it must be accepted by the regime. It is more problematic when the management method is not in line with the perceptions of the dominant regime. Therefore, the forest owners who have chosen alternative forest management method such as selection cutting or forest protection must in particular communicate the arguments for their choice. The easiest way for that is through cooperation. The need for cooperation in forestry is repeatedly underlined (EPFU, 2006, MoE, 2002, Olesk, 2007). The forest owners who are currently part of local forestry organisations is only 11% but these organisations are part of the dominant regime and appropriate for those forest owners who actively manage their forests. The so-called non-harvesters are more likely not part of these cooperative organisations but they must also cooperate to become stronger niche level actors. This will allow influencing the dominant regime as well as becoming part of it. Also, the forest owners who would like to practice permanent forest management must become stronger to influence the regime.

A possibility to increase sustainability among the harvesters is certification. Currently, the certified forests are mostly public forests whereas the problems in forestry are particularly evident in the private forests (Ahas et al, 2006). Therefore it is especially important that more private forests become certified. Certification allows increasing biodiversity in forests and increases the environmental awareness of private forest owners (Sverdrup-Thygeson et al, 2008). The awareness can also be increased with other measures but certification might have stronger impact as it obligates the forest owners to manage their forests sustainably whereas improved awareness might not bring along the actual changes in management practices. One incentive for stimulating the certification of private forests is via the tax system, either through tax decreases or outright tax exemptions for certified forests. Such systems have shown to be successful in Bolivia (Ebeling and Yasué 2009). Furthermore, the tax exemption can be a good incentive for small forest owners for whom the certification can be too expensive (Ahas et al. 2006). Group certification might be the most suitable way for small forest owners in Estonia to decrease the expenses and it also allows the certification in private forest to become a part of a sustainable regime rather than single initiatives toward sustainability. As there have been a lack of market pressure in Estonia and the market situation will affect the certification in the future, it needs more support from the Government.

8 Discussion

There are several global and local aspects that influence the forest sector and its potential outputs in the following decades, not to mention centuries. These aspects, to name some of them, include climate change, national actors (forest owners, legislation), and market (both world and domestic).

Climate change is expected to impact Estonia in several ways, including increased temperature, precipitation and wind speed as well as frequency and severity of extreme climatic events (Christensen et al, 2007), which further impact forests. According to the findings of Koca et al. (2006) it can be estimated that while the productivity increases

with elevated temperature, it will likely shift the dominance of conifer trees (Norway spruce and Scots pine) to deciduous trees (birch, aspen and alder). Increased net productivity will have positive effects on timber production as profitability increases and the return on investments becomes faster. The shift of dominance from conifers to deciduous species, however, would have a direct effect on the Estonian paper industry. It will reduce the availability of domestic raw material (softwood from conifers) for kraft paper production. The shift from conifers to deciduous trees will also mean that the average life cycle of forests become shorter as deciduous trees grow faster. That can be positive effect on the future of Estonian aspen pulp factory as the production prices will decrease due to higher turnover of aspen.

Another effect of climate change is increased wind speed in northern Europe (Christensen et al, 2007), which will bring heavier storms. Estonia has recently experienced the impact of storms on forest resources as in January 2005 when the storm damaged over 32,000 ha of forests (CFPS, 2007). Increased occurrence of higher wind speed has negative effect both on timber production and on the provision of non-wood forest products and services (NWFPS), as heavy storms can significantly damage forests. The timber from storm-damaged forest can be sold but its economic value is lower. The provision of NWFPS also suffers in storm-damaged forest. Forests are especially vulnerable to storms when selection cutting is practised (Tullus, 2002), which is more suitable in areas where non-forest products and services are offered.

Climate change will also influence forest health as extreme weather events will enhance the susceptibility to disturbances such as insect pests and pathogens (Moore and Allard, 2008). That again can imperil both the productivity of forests and the possibilities to provide NWFPS.

Climatic conditions affect the recreation and nature tourism in Estonia. Even though long days can be attractive during the summer, the long nights and lack of sun are factors that are equally unappealing during the winter. This can create a serious gap in revenues between November and March (Unwin, 1998). Contributing to touristic activities such as skiing can provide income also during the winter time.

Provision of NWFPS is an option for increasing the amount of jobs and revenues in forests, where harvesting activities are low. However, increased provision of NWFPS can also have higher environmental impacts. For example, recreation and tourism become extensive, the nature may become endangered by the people who use the forests (Karoles and Maran, 2008a, 2008b). The private forest owners are particularly reluctant to allow visitors to their forests if their income is not directly related to tourism (Ojala and Tamm, 2006). If more focus is put on recreation and nature tourism, it would also increase the environmental impacts from transporting, feeding and accommodating the tourists. Moreover, if special facilities for recreation are built, it entails environmental impacts. Also intensive picking of berries and mushrooms can damage forests.

Both the domestic market and the direction of forest industry development will shape the forest sector in the future. Furthermore, as the domestic market in Estonia is rather small, it is even more influenced by the world market. For example, recent trends in paper industry show the signs of relocation of the paper industries from Europe to Asia

or South-America, which has resulted in closure of several European paper factories (Pap'Argus, 2007). The demand for paper has considerably increased in Asia and so have the paper production volumes, which have reduced the prices and consequently the orders from European paper mills. This will also affect the paper mill in Estonia, which several times has been forced to temporarily interrupt its production due to lack of production orders. A final closure of the paper mill, however, has not occurred. The advantage of kraft paper produced from local raw material is its strength. Trees that grow in cold climate have longer fibres that allow producing stronger kraft paper. A warmer climate, however, threatens that advantage. Another threat to kraft paper is plastic that is increasingly used for packaging, a trend observed by North American kraft paper producers (2008).

Market, both domestic and international, largely defines which products and services that are provided. As environmental awareness increases the timber as a renewable resource becomes more demanded. That puts more pressure on timber production. With improved awareness the demand for *sustainable* timber may increase and the private forest owners have higher incentive to certify their forests. On the other hand, the increased concern for the ecosystem impacts of timber production puts more emphasis on forest conservation. This might facilitate the provision of other goods and services, such as recreation and nature tourism. As people are increasingly moving to the cities, the possibilities for recreation in the nature become more important, which would increase the economic value of the forests' recreational functions and allow better marketing of NWFPS for private forest owners. Currently the state forest in Estonia provides recreation facilities for free and the public is not willing to pay for such services in the private forests unless some extra benefits are offered. But if the demand for recreational facilities increases, the potential for marketing these services is enhanced.

National actors including forest ownership and political changes also influence the forest sector. For example if the share of public forest is increased, the forest is more influenced by political decisions and legislative changes but if private forest area increases, the economy and market conditions will be more influential. Whereas climate change and its impacts can be predicted to certain extent, the changes of national actors are harder to foresee.

9 Conclusions

9.1 Addressing research questions

There are today a number of tools available for sustainability assessments. Many of them cannot portray the complex nature of sustainability which requires entailing all the sustainability domains including the range of temporal and spatial scales involved in sustainability assessment. However, there are some tools that already correspond to goals set by sustainability assessment. Furthermore, the variety of tools used for sustainability assessment is continuously changing. New tools are developed and the existing ones are elaborated to better address the goals of sustainability. One way to overcome limitations of a single tool is to use a combination of tools that allow a more profound approach to the complex sustainability problems.

In this study a combination of tools was used in a sustainability assessment of the Estonian forest sector. This combined tool allowed for a retrospective analysis of the development of the forest sector, an analysis of the actors involved in forestry and their position of power in the sector as well as a prospective analysis of two alternative visions of sustainable forestry. Multi-level and multi-phase transition analysis together with stakeholder power/interest analysis provided thorough information about the development in the forest sector, which helped to determine where the improvements can be made in order to move toward sustainability. It became evident that private forest owners are the key in achieving sustainability in forestry. Enhancing the private forest management and increasing its sustainability is a challenge that can be met by various measures. These include encouraging the private forest owners to practice alternative forest management techniques, take advantage of the infrastructure already in place (certification, woodland key habitat contracting, financial support, etc.) as well as creating a new boundary organisation for empowerment of the forest owners. Furthermore, the computer modelling by help of a life cycle perspective provided results that facilitated the observation of the duality embedded in the Estonian definition of sustainable forestry. As there are high uncertainties involved in predicting the future, it is important to keep forestry as diverse as possible, allowing for adaption to changes brought along by the variations in climate, market and domestic conditions. Having a clear long term sustainability goal in place will also help to adapt to any disruptions affecting the forest sector. Reaction to short-term fluctuations is important but only to an extent that does not undermine the long-term goals.

9.2 Further research

Several aspects in this thesis need to be further studied in order to advance the sustainability assessments and to improve the sustainable development in Estonian forestry:

- Monetary valuation of Estonian forest ecosystem services is important in order to be able to compare different uses of forest land and to further determine the potential to increase the provision of NWFPS.
- More data about the inputs and outputs of various life cycle stages of non-wood forest products and services are needed to determine both the environmental and socio-economic impacts.
- More information about the needs and preferences of forest owners (especially urban forest owners and non-harvesters) is needed to determine which incentives besides changing the taxation system that would encourage private forest owners to manage their forests in a sustainable way.
- The potential of non-wood products and services for balancing the socio-economic and ecological aspects in sustainable forest management need to be studied.

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Appendix 1

Pan-European Criteria for Sustainable Forest Management

CRITERION 1:	Maintenance and Appropriate Enhancement of Forest Resources and their Contribution to Global Carbon Cycles
CRITERION 2:	Maintenance of Forest Ecosystem Health and Vitality
CRITERION 3:	Maintenance and Encouragement of Productive Functions of Forests (wood and non-wood)
CRITERION 4:	Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems
CRITERION 5:	Maintenance and Appropriate Enhancement of Protective Functions in Forest Management (notably soil and water)
CRITERION 6:	Maintenance of other Socio-Economic Functions and Conditions

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