“Assessing sustainability impacts of setting aside forest areas in a regional Forest Wood Chain (FWC) in Baden Württemberg (Germany) using ToSIA and a Multi Criteria Analysis (MCA) method”

Master Thesis

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Abstract

In this study the quantitative decision support tool ToSIA (Tool for Sustainability Impact Assessment) is employed to assess sustainability impacts on a regional forest-wood chain (FWC) in Baden-Württemberg (Germany) by using a set of 9 sustainability indicators. ToSIA structures a FWC into processes, the performances of which are characterised by the set of sustainability indicators. Indicator values are generated by simulating the flow of wood material through the processes of a FWC. To enrich the analytical and decision making power of sustainability impact assessments, the multi-criteria analysis method PROMETHEE II is employed to analyse the effects of different hypothetical stakeholder perspectives on overall preferentiality of alternative FWCs.
As examples for change sin regional FWCs it is assumed that (a) forests on steep slopes are set aside, and (b) 5% of total forest area are devoted to nature conservation and taken out of management. The analysis includes the variability in ranking as affected by the different archetypic preference profiles of stakeholders.

Keywords: *sustainability impact assessment, multi-criteria analysis, forest-wood chain, decision support, sustainability indicators.*

Zusammenfassung

In der vorliegenden Arbeit wird ToSIA (Tool for Sustainability Impact Assessment), ein Software-Programm zur Analyse und Bewertung von Nachhaltigkeitsauswirkungen von Forst-Holzketten (FWC) zur Analyse einer regionalen FWC in Baden-Württemberg, Deutschland verwendet. Im ToSIA Programm wird die Forst-Holzkette in verschiedene Prozesse untergliedert. Diese Prozesse und ihre Funktionen werden durch Nachhaltigkeitsindikatoren beschrieben. In vorliegendem Beispiel wurden 9 Indikatoren verwendet. Die Indikatorwerte werden durch Simulierung des Holzflusses durch die einzelnen Prozesse der Forst-Holzkette berechnet. Um die analytische Aussagekraft zu verbessern und die Entscheidungsfindung im Bereich von Nachhaltigkeitsanalysen zu stärken, wird die multikriterielle Entscheidungsfindungsmethode PROMETHEE II eingesetzt. Mit Hilfe dieser Methode wird untersucht, welchen Einfluss verschiedene hypothetische Sichtweisen von Interessensvertretern auf die Vorziehenswürdigkeit von alternativen Forst-Holzketten haben.

In vorliegendem Beispiel werden die Optionen (a) Aussernutzungstellung von Wäldern in Steillagen, und (b) Nutzungsverzicht auf 5% der Landeswaldfläche wegen Naturschutzaspekten, mit der aktuellen Waldbewirtschaftung verglichen. Die Analyse fokussiert insbesondere auf die Effekte unterschiedlicher archetypischer Präferenzprofile von Interessensgruppen auf die Rangfolge der Alternativen.

Schlagworte: *Nachhaltigkeitsanalyse, multikriterielle Analyse, Forst-Holzkette, Entscheidungsunterstützung, Nachhaltigkeitsindikatoren*

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Finally the work is done and my Master thesis is in your hands or on your screen.
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Table of contents

Index of figures

Index of tables

1. Introduction

1.1 General Introduction

The first thoughts towards sustainable forestry rose in Germany centuries ago. Already in 1713 the German tax accountant and mining administrator HANS CARL VON CARLOWITZ mentioned sustainability in context of forestry, but without any specification how to achieve it. Later in 1795 GEORG LUDWIG HARTIG described the principle of sustainability in his manuscript "*Instruction about taxation and description of forest stands*"[1] without mentioning the actual term. Originally, the term sustainability was used in a very simple and narrow application, e.g. the limitation of annual harvests to the amount of annual ingrowths to sustain a constant production of timber. Later, the principles where developed further and used also in other contexts beyond forestry. The World Comission on Environment and Development in 1987 defined sustainability as a term which is still used today in the same way. Thus, the goal of sustainable development was published after the general UN-convention in 1987 (WECD, 1987), "[...] that sustainable development, which implies meeting the needs of the present without compromising the ability of future generations to meet their own needs, should become a central guiding principle of the United Nations, Governments and private institutions, organizations and enterprises [...]". In this definition, sustainability is described quite well, but still it does not show how this goal can be achieved (SVERDRUP AND SVENSSON, 2002).

During the Earth Summit in Rio de Janeiro in 1992, forests and forestry were promoted to the international agenda because of their importance for biodiversity and their role in economic and social development (UNCED, 1992). In the following decade, the sustainability paradigm was expanded to many other sectors including economics (PEARCE ET AL., 1990; KLAUER, 1999; DRESNER, 2003)

As mentioned before, today's interpretation of sustainability in forestry is multi-dimensional. For further expansion, entire sectors should be evaluated for their contribution to sustainable development. This implies for forestry that production chains from the forest to the final consumer should be analysed (i.e. forestry wood chains; FWC). KATILA AND SIMULA (2004) mention that the sustainability of forestry is influenced by many factors which are related to national policies and trade, e.g. full

[1] Translated by the autor. Original: *„Anweisung zur Taxation und Beschreibung der Forstbestände"*

liberalisation would contribute to the long-term trend toward increasing importance of trade in value added products; trade in industrial round wood would decline (*framework of SIA in forestry see Annex 10.1*). This enhances the requirement of integrated sustainability assessments, which evaluate the impact of such policies and offer useful guidance for decision makers (KIRKPATRICK AND GEORGE, 2005; LEE, 2006; NESS ET AL., 2007). Today's sustainability assessment methods are expected to link environmental, economic and social issues (WIHELMSSON, 2001; KATILA AND SIMULA, 2004; GASPARATOS ET AL., 2008). The use of sustainability indicators for analyzing sustainability related questions is today's most often used approach.

So far, just a few sustainability assessments of the FWC have been made and new approaches are currently under development (PÄIVINEN AND LINDNER, 2006).). For example, the Pan-European project EFORWOOD develops a quantitative decision-support tool to assess the sustainability impacts of European Forestry Wood Chains (FWCs), which has not been done so far (EFORWOOD, 2007). This computer based decision support tool (ToSIA – Tool of Sustainable Impact Assessment) for an entire FWC Is innovative with its focus on entire FWCs. FWCs are formed by processes (e.g. thinning, sawing etc…) that convert forest resources into services and products and follows the products until consumers and to demolition or possible recycling. ToSIA will allow to analyse the impacts which external (e.g., oil price, international policies) and internal (e.g., technology development) factors may have on the sustainability of FWCs.

The conceptual approach of ToSIA was already presented in earlier studies (LINDNER ET AL., 2009; WERHAHN-MEES, 2008). These studies where focused on the comparison of single FWCs in context of technology change. It was possible to compare indicators one by one but for none of these studies it was possible to rank the chain alternatives in a consistent and transparent manner with regard to aggregated or even overall sustainability impacts. The approach, of linking different impact assessment methods to overcome the limitations of these former studies was already proposed by LEE (2006). Multi Criteria Analysis (MCA) and Cost Benefit Analysis (CBA) are the most frequently mentioned methods in this context (LEE, 2006; PROKOFIEVA ET AL., 2007).

The software tool ToSIA provides a framework to analyze impacts on the forestry based sector, arising from policy changes and other drivers.

1.2 The German forest sector

The German forestry and timber processing industry occupies a leading position within Europe. The performance of Germanys forestry business is reflected by figures from the second federal forest inventory (cf. BWI II, 2002) as well as the annual report of the central market and price report agency (ZMP, 2008; *see Annex 10.2*). The forest conditions shown in the figures of the BWI II show a development of Germany's forestry over the last centuries from just sustaining the timber supply towards ensuring all forest functions. With the resolution of the "Charta for timber" in 2002, German policy promotes an increased timber harvest as a support for climate conservation, quality of life, innovations and job security (SPELLMANN ET AL., 2008).

Trends towards more nature conservation in German forestry can be seen since the 1980's after an increase of forest damage and the fear of so called "forest dieback". Silvicultural measures changed over the decades and in the early 1990's, the system of ecological forestry was introduced. This strategy includes increasing the share of broadleaved and mixed forests with a diverse structure, target diameter harvesting and to report preference areas for nature conservation (NMfELVL[2], 1991, 2007; ANONYMOUS, 2008). This trend holds on until today and one of the results is the high amount (65% PEFC, 5% FSC) of certified forests in Germany. Germany is one of the 170 countries, which ratified the Convention on Biological Diversity at the United Nation Conference on Environment and Development at the 1992 Earth Summit in Rio de Janeiro. With the ratification of these non-legally binding principles, the partner countries have guaranteed to conserve biodiversity and to use the biological resources in a sustainable way (RICHARDSON ET AL., 2002). Further meetings and conferences like the Framework Convention on Climate Change (FCCC) where the Kyoto protocol was finally adopted followed. A major outcome of these conventions was the identification of forests as a supporting pillar to mitigate the net carbon dioxide emissions by using them as alternative energy source or substituting construction materials (e.g. steel and concrete) (RICHARDSON ET AL., 2002).

The "National Strategy of Biological Diversity" program of the "Federal Ministry of Environment, Nature Conservation and Nuclear Safety" is aiming to sustain

[2] NMfELVL - Niedersächsisches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz und Landesentwicklung – Department of state for food, agriculture, consumer protection and rural development in Lower Saxony.

biodiversity in Germany. One goal of this program is to increase the area of set aside forests to 5% of the total forest area by 2020 (BMU[3], 2007; ANONYMOUS, 2008)

Another trend in this sector is the globalization of the German timber industry over the recent years. Although the timber exports from Germany declined marginally in early 2008, an increase especially for sawn softwood over the recent years can be observed *(ZMP)*. The export development combined with a currently increasing and changing demand within Germany might lead to trade offs towards supply shortfall in certain assortments. The increasing demand of woody biomass for energy purposes will enhance this trend. Currently, the market could compensate this by increased prices and additional harvests from underutilized forests of small private forest owners (SPELLMANN ET AL. 2008). A recent study from MANTAU ET AL. (2007) shows, that the increasing demand in the last years is mostly covered by fresh timber from forests and not from other sources. This shows that timber from forests is obviously the most accessible source of woody raw material now and most probably also in the future (MANTAU ET AL., 2007)

A considerable amount of income and employment in Germany is provided by forestry and forest based sector. Since it is the source for renewable resources, there is a strong focus on this sector in the context of sustainable development (LINDNER ET AL., 2009).
Thus, a conflict arises in the trend of an increasing utilization of timber from German forests on the one hand and sustaining biodiversity on the other hand.
Interest groups of the German forest and timber industry (Deutscher Forstwirtschaftsrat DFWR and Deutscher Holzwirtschaftsrat DHWR) were criticizing and clearly questioning the policy to protect more forest area in Germany (press release DFWR, 2008; SPELLMANN ET AL., 2008).
Therefore, it is of concern to examine the impacts of such policy changes on the sustainability of entire forest wood chains as well as different stakeholder preferences and what influence these may have on decision making in this context.

[3] BMU = Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Nationale Strategie zur biologischen Vielfalt) – Federal Ministry the Environment, Nature Conservation and Nuclear Safety – (National Strategy for Biodiversity)

2. State of the art in sustainability assessment

2.1 Existing tools for sustainability assessment

Sustainability assessment (SA) is a field of research to gain a better understanding of the complex dynamic interactions between environmental, economic and social issues of sustainable development (NESS ET AL., 2007). After a definition given by BUSELICH (2002) SA can be defined as assessment of proposed initiatives, e.g. projects, policies and plans, in terms of sustainability to determine the conditions under which approval would be given. Sustainability assessment should not be mixed up with sustainability impact assessment (SIA), which is a proposed method for SA and described more detailed in this chapter under paragraph (d).

As mentioned earlier there are quite a variety of tools and methods for sustainability assessment that has been developed during the last decades (NESS ET AL., 2007). Some of these methods are briefly described in the following.

a) Forestry Wood Chain[4] (FWC) flow statistics

Many European countries collect information about wood material flows (volume of solid timber) of their FWCs based on forest statistics and production figures (e.g. German flow figure *Annex 10.3*).

These statistics just give information on the amount of wood flows and can not be used to predict anything about sustainability of the FWCs (DIETER, 2005; WERHAHN-MEES, 2008). PAIVINEN AND LINDNER (2007) state that those statistics might possibly be used as basis for further sustainability analysis of FWCs if they are converted to carbon flow volumes.

b) Life Cycle Assessment

Life Cycle Assessment (LCA) is a method to assess the environmental impact of forestry and their products that was introduced in the 1990s (FRÜHWALD, 1995). LCAs have been used to identify environmental impacts caused by the industry. Major focus is to compare the GHG balance of different fabrics to woody products. A major limitation of LCAs is that usually just environmental sustainability aspects are

[4] *A Forestry Wood Chain consists of a set of production processes by which forest resources are converted into products and services, the chain of production processes starts with forest resource management and ends with the end-of-life of a wood product (e.g. combustion).*

addressed (PÄIVINEN AND LINDNER, 2007). Hence, a generalized interpretation of LCA results in term of sustainability needs special caution. There are several examples where LCAs have been applied to analyze FWCs in the context of sustainability impacts, e.g. substitution between wood and alternative materials (PETERSEN AND SOLBERG, 2005), forest production (SCHWEINLE, 2000), sawmilling (SPECKELS ET AL. 2000), bioenergy and wood products (JUNGMEIER ET AL. 2002; JUNGMEIER ET AL. 2003). FRÜHWALD (1995) described the main reasons when LCA can be effectively applied:

i. to quantify consistent information on the environmental impacts and benefits of wood products
ii. to enhance production and recycling techniques by diminish steps with high environmental impact or choose alternative production processes
iii. to reduce environmental impacts or accentuate the compatibility between processing
iv. to stress fields where a lack of information on the environmental impact of products is existing,
v. to allow for comparison of different materials (e.g. various materials can be used for the same purpose – beams for house construction from wood, steel or ferro-concrete)

c) Causal Chain Analysis

Causal Chain Analysis (CCA) is a method which has been applied in the "Sustainability Impact Assessment of Proposed WTO Negotiations" (KIRKPATRICK ET AL. 2005). The CCA method is used to assess the changes of linkages starting from initial trade measures and going towards a change in the production system and ending at its influence on the sustainable development *(Fig. 1).*

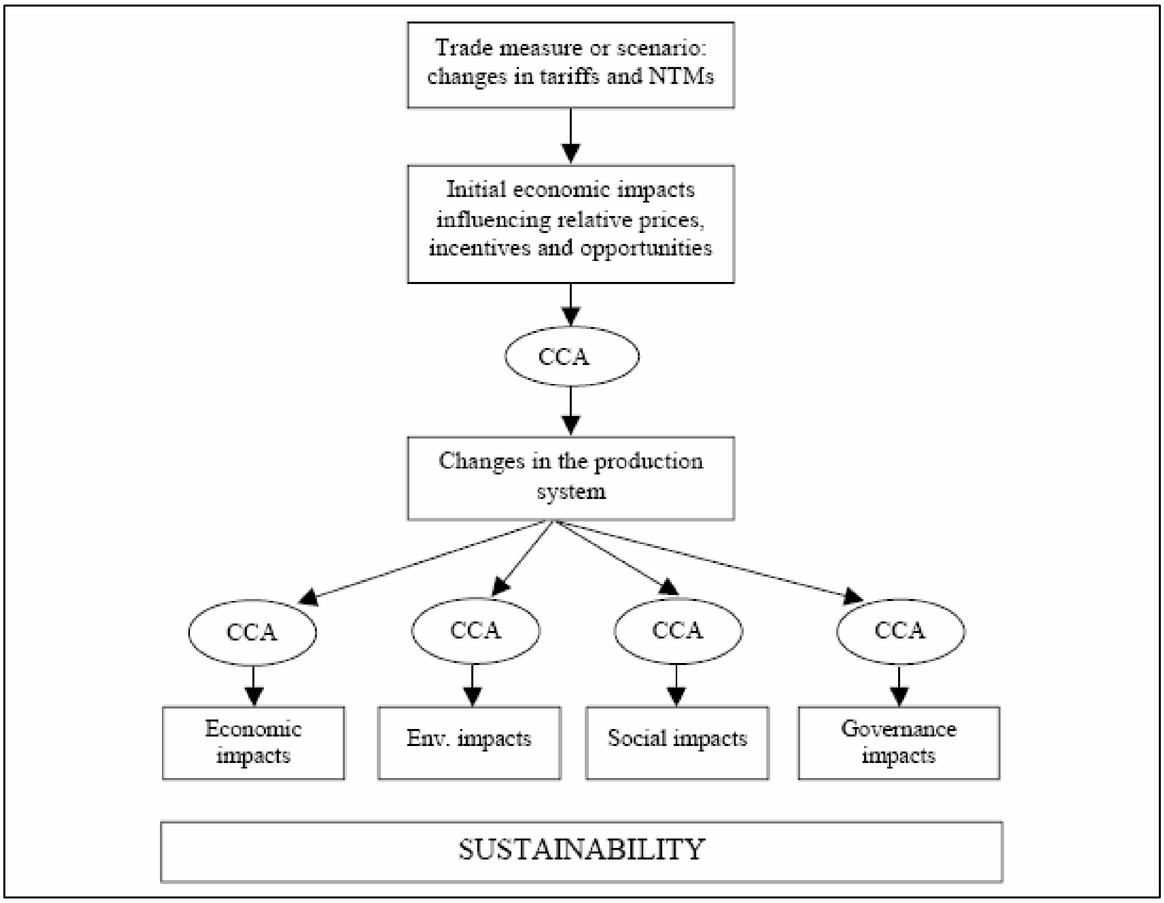

Fig. 1: Basic Principles of the Causal Chain Analysis, (NTM = Non-tariff measures) (KIRKPATRICK ET AL. 2006)

The sustainable development is assessed by using nine core indicators of economic, environmental and social impacts (KIRKPATRICK ET AL., 2006). These nine indicators are: real income, fixed capital formation, employment, poverty, health and education, equity, biodiversity, environmental quality and natural resources.

d) Sustainability Impact Assessment (SIA)

SIA is one tool for sustainability assessment designed to support the European Sustainable Development Strategy (WOLFSLEHNER ET AL., 2006; NESS ET AL., 2007). The goal of SIA in particular is to identify and assess the positive and negative impacts of proposed policies according to criteria consistent to sustainable development. This will allow decision making bodies to make a judgment about them (EUROPEAN COMMISSION, 2002; GEORGE AND KIRKPATRICK, 2003; LEE, 2006; NESS ET AL., 2007).
One early example for sustainability impact assessment is the SENSOR project funded by the EU-Commission in the 6th EU Framework Program

The main goal of this project was to create a sustainability impact assessment tool (SIAT) for an instant assessment of their sustainability impacts in the context of land use change in Europe and is the duty of the program. The tool is created to be a science-based forecasting instrument by designing individual policy scenarios and a decision support tool used by policy makers. . The scope of its application goes beyond forestry but there is a broader approach of multiple land use in sectors like agriculture, forestry, energy, transport, nature conservation and tourism.

SIAT is based on several pre-run models, which were integrated in the framework of the tool.

The dual approach of SIAT can be described as follows:

i. The first step is an analysis of multifunctional land use and related sustainability indicators with the help of "impact identification".

ii. A "sustainability (risk) assessment" to verify if sustainable tolerance limits are fulfilled follows as second step (HELMIG ET AL.,2008)

e) Tool for Sustainability Impact Assessment (ToSIA)

The TOSIA tool is another SIA effort under the 6th EU Framework Program. The objective is to develop a quantitative decision support tool for Sustainability Impact Assessment of the European Forest Wood chain and compartments of it such as, e.g. regional forest wood chains. Such Forest Wood Chains consist of different connected processes which reach from forest regeneration to the end of life of a wood or wood based product. ToSIA as software tool will allow various end users, e.g. forest related industry, policy makers, researchers etc., to analyze the potential impacts of policies (e.g. setting aside forests for nature conservation purposes) and various external drivers (e.g. climate change) on the sustainability of Forest Wood Chains.

2.2 Multi–Criteria Analysis to support sustainability impact assessment

Using multi-criteria analysis (MCA) in sustainability impact assessment can help to convert a rather comprehensive system towards a more practical one. MCA methods are very effectively in supporting the assessment of complex sustainability issues because they can integrate a diversity of multidimensional criteria in a formalized way (KANGAS AND KANGAS, 2002, 2005). As well, MCA will provide an approach to interpret and

evaluate different indicator results in the context of the three dimensions of sustainability.
In the context of SIA multi criteria analysis is one of most frequently mentioned evaluation methods (LEE, 2006) which is expected to enrich the analytical power and provide decision support in the SIA evaluation system (WOLFSLEHNER ET AL., 2009).

Multi-criteria analysis is a term for a set of methods and research models dealing with decision problems under the presence of decision criteria to support the decision making process.
The methods of MCA share common characteristics:

- cope with a conflict among criteria, incomparable units (quantitative/qualitative) and difficulties in the alternative selection,
- apply a comparison of a limited number of alternatives, with the aim to point out the most desirable option
- the alternatives are characterized by indicator sets which cover all dimensions of sustainability
- producing systematic, prescriptive, criteria-based information without being to sophisticated
- participatory approach: inclusion of all stakeholders in the process design and transparency on the final decision making

3. Research objective

The objective of this study is to test and demonstrate the integration of Multi-Criteria Analysis into the approach of sustainability impact assessment as proposed by the FP6 IP EFORWOOD. This should be done by using a test FWC analyzing the effects of changes in forest management on the sustainability indicators of a case study Forest Wood Chain (FWC) in the federal state Baden Württemberg, Germany. In this context, the setting aside of forests on steep slopes as well as setting aside 5% of the total forest area for nature conservation purposes compared to “normal” forest management practices will be analysed.
This study does not focus on the actual indicator values generated for the SIA, but on the conceptual integration of the ToSIA software and a further evaluation with the help

of multi-criteria analysis (MCA). Furthermore, the sensitivity of stakeholder preferences in MCA on the indicator values will be analysed.

The results of different scenarios in the case study should be evaluated with the help of MCA methods.

The primary goal of this study is to show how ToSIA and the selected MCA method can be interlinked. The Baden Württemberg case study data will be used to exemplify and test the functionality of both components. Therefore three forest management scenarios varying in the extent of setting aside forest areas are defined for this purpose.

i. Alternative 1 (baseline) – forest management following current practises
ii. Alternative 2 (steep slope) – all forests on slopes with an inclination >60 % are set aside, on the remaining area "normal" forest management
iii. Alternative 3 (5 % set aside) – 5 % of the total forest area in Baden Württemberg are set aside, on the remaining area "normal" forest management

The following secondary questions should be addressed in this study:

a) What are the effects of varying stakeholder preferences/ indicator weights in MCA on the evaluation results?
b) What are the effects of setting aside forests on steep slopes on the sustainability of the regional FWCs in Baden Württemberg?
c) What are the effects of setting aside forest areas at large scale on the sustainability of the regional FWCs in Baden Württemberg?

4. Methods

4.1 The ToSIA framework

The objective of the ToSIA development is to create a quantitative decision-support tool to assess the sustainability of the forest-based sector in Europe and impacts of possible changes on sustainability, e.g. technology change, change of management strategy.

ToSIA builds on attributes of already existing methods which will be integrated (PÄIVINEN AND LINDNER, 2007).

There are three main characteristics of the suggested methods (PÄIVINEN AND LINDNER 2007):

1. Essential points are the forest wood chain, material flow through production processes from planting to recycling and end-of-life of forest-based products, known also from LCA and optimal allocation models.

2. A second characteristic is the balanced analysis of three pillars of sustainability, i.e. economic, environmental and social aspects by means of indicators

3. The third element is the impact of changes on the FWC; i.e. the comparison of indicators of alternative production chains.

Essential for doing a SIA of the FWC are the definition of the boundaries and the goal of the study. Therefore the spatial, temporal and technical system boundaries have to be specified (location, structure, content, detail). In addition a definition of alternative FWCs has to be done (LINDNER ET AL, 2008).

Transport and trade are two examples for the fact that not all processes of a case study for an entire region like Baden Württemberg are located in that region. Import and export is the result of products leaving and entering the FWC as input and output products of that region. The material flow crossing the system boundaries will be calculated and displayed by ToSIA. Furthermore there will be products where wood is a negligible source of the whole product or there are products excluded because of very low amounts produced (LINDNER ET AL, 2008).

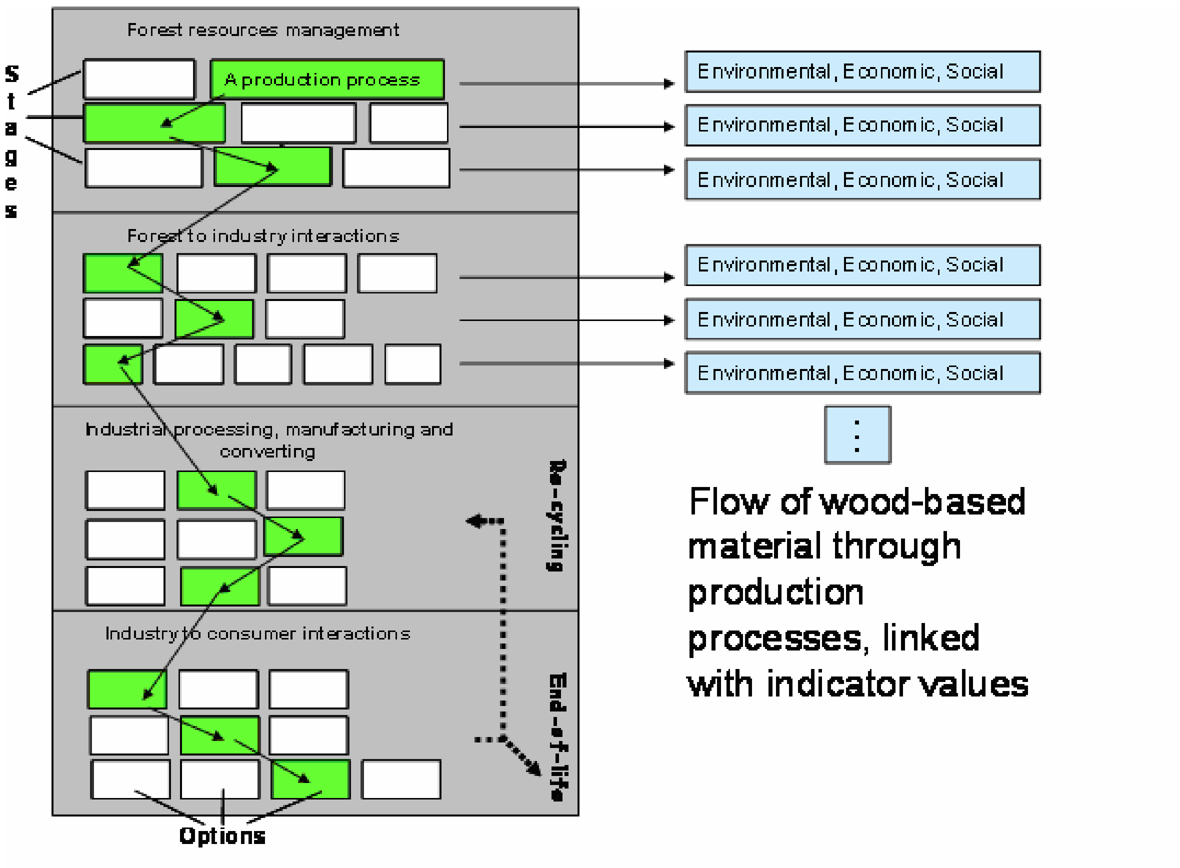

Fig 2: The methodological framework to assess the sustainability of FWCs. The shaded boxes represent processes in one FWC. The green boxes symbolize the processes in a selected FWC and the white ones the alternative processes (LINDNER ET AL. 2007).

Figure 2 shows an example of the structure of a FWC. The topology of a FWC describes the structure and connections between processes and products. The fundamental components of a FWC are: (i) processes, (ii) products and (iii) product shares.

i. ***Processes:*** A process is the most important element of any FWC *(e.g. stand regeneration, harvesting, transport, saw milling, house building, and waste incineration)*. Transformation of raw materials, characteristic change or transports to a new location are the routines which can take place in a process.

ii. ***Products:*** are mass based inputs and outputs of any process. Products are used to link processes to form the FWC structure. Some special processes can be identified: forest regeneration which does not have input products, and processes of material recycling whose output products will form a loop and enter the FWC again in the processing and manufacturing phases.

iii. ***Product shares:*** They are needed if e.g. one output product will enter two or more different follow-up processes to define how much of the product will enter each of these process.

A grouping of processes into four modules is done to enhance an easier analysis and presentation of the SIA results. These modules are: *forest resource management (M1), forest to industry interactions (M2), processing and manufacturing (M3), and industry consumer interactions (M4)* (LINDNER ET AL, 2009)

The ToSIA software calculates indicator values for each single process of the FWC. Values were calculated for more then 100 single processes starting from the forest management until the end of life of each product (see chain description in 5.1). These indicator values from the individual processes were aggregated along the entire chain of each FWC alternative. For the comparison of different FWC alternatives the full chain aggregation of each indicator is the standard approach.

Overall, intensive testing of the tool on different application scales is necessary. In the current study a regional case was chosen. In this approach an analysis of all major material flows of FWCs within the boundaries of Baden-Württemberg will take place. The forest based sector of Baden-Württemberg will be modelled as Forestry Wood Chains (FWCs) which represent the production processes of timber starting with forest resource management and going to the end-of-life of a corresponding wood product (LINDNER ET AL, 2008).

4.2 General data sources and data collection methods

The data collection by experts is divided into different subgroups, modules (M2-M5), where each module is specialised on a certain topic. These modules are *M2 forest resources management, M3 forest to industry interactions, M4 processing and manufacturing and M5 industry to consumer interactions*. To guarantee a transparent way of the data collection, references of the data sources as well as the data collectors identification have to by reported and displayed in the data base client. The main idea of the data collection protocol is to guarantee a common format for each indicator concerning measurement units, system boundaries, sources and means to acquire and calculate values on indicators. There are also spaces for module specific recommendations and key definitions that should be considered in order to have a defined data quality. Further information about these guidelines can be found in the *"Manual for data collection for Regional and European cases"* (BERG S., 2008).

Figure 3 should give an overview about the data collection, further processing of data and the validation system within the project.

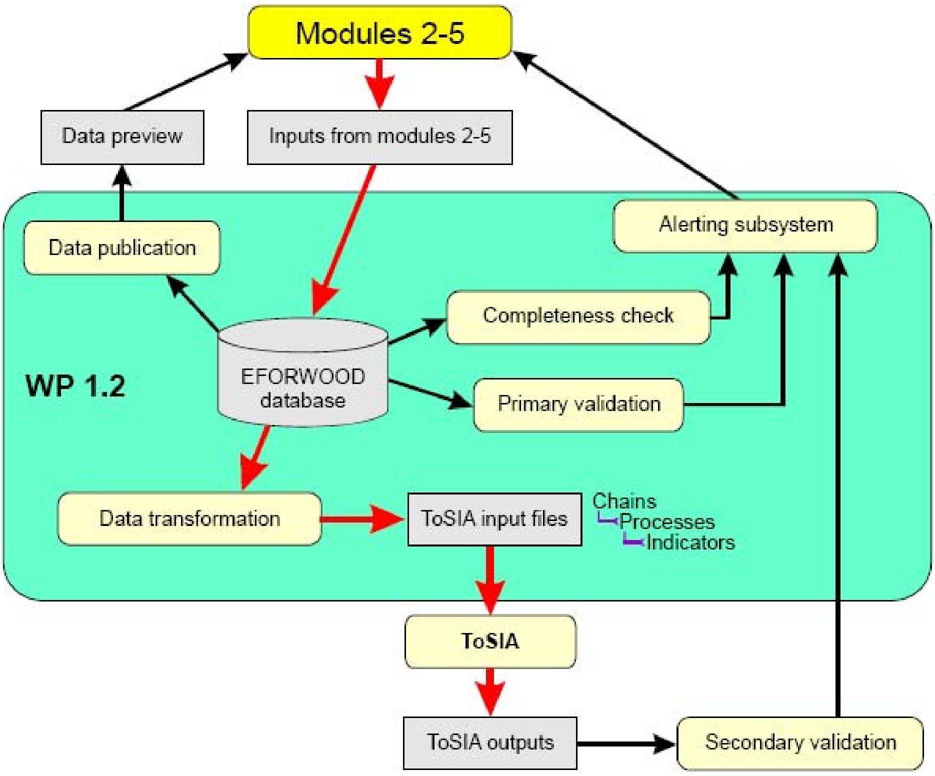

Fig 3: Data is collected in the different modules and provided to the database. Quality checks are done from several points within the project to secure the quality of the ToSIA output results. Work package 1.2 of the EFORWOOD project is responsible for issues like, e.g. validation of the data, providing ToSIA input files etc. (LINDNER ET AL. 2007).

4.3 The Multi-criteria Analysis (MCA) method PROMETHEE

During the last decades MCA has significantly evolved for handling today's complex problems where goal conflicts are prevalent and intuitive, non transparent, decisions are put to question. Yet, MCA is not a tool to provide the a final solution for a decision problem but is a decision making aid instead which is to help stakeholders to classify available information, think of consequences, explore own preferences and tolerances and minimize the possibility of post-decision disappointment (BELTON AND STEWART, 2002). The aim of Multi-Criteria Analysis (MCA) is to explore the preferences of decision-makers, stakeholders, or environmental experts, etc. (in the following referred to as "stakeholders") for indicator weightings and to compare decision alternatives. The aim of MCA is to broaden the decision making perspective of the stakeholders involved. It relies on values assigned to people with multiple points of view. Stakeholders are directly involved and facing a particular decision problem to express their preferences and values regarding the decision criteria. Thus, the gained information better reflects ideas and priorities of persons/groups concerned by decisions about the FWC. Essentially MCA works as an interactive learning process that stimulates stakeholders to think further about conflicts addressed by considering opposing points of view (OMANN, 2000). MCA also helps to structure a decision problem into manageable sub-components, which could be used e.g., to place scientific perceptions on the political agenda (TOMAN, 1998). A considerable advantage of MCA is the ability to deal with complex systems, e.g. a FWC, as well as different perceptions of sustainable development (TOMAN, 1998). The stakeholders involved in a MCA are encouraged to take perspectives and information into account that might go beyond considerations of their main focus. Another advantage of MCA is the possibility to consider a large variety of decision criteria, no matter if they are of quantitative or qualitative nature, independent of the measurement scale (WRISBERG ET AL., 2002). Since it provides the opportunity to include all aspects of sustainability rather than being limited to monetary values MCA is a good approach for comprehensive analysis of sustainability impacts (OMANN, 2000).

The general process of MCA includes: (a) identification of involved stakeholder groups, (b) the choice of a set of indicators, (c) a given amount of alternatives (e.g. different FWC alternatives), (d) the choice of an appropriate method to analyze them, (e) evaluation and comparison of the alternatives with regard to the indicator set and preference information, and (f) make recommendations regarding to the evaluation objectives (WOLFSLEHNER ET AL., 2006).

First of all a stakeholder analysis has to take place. Stakeholders as well as interest groups for the specific area (e.g. Baden Württemberg) have to be identified. Secondly, the preferences of stakeholders towards indicators (indicator selection and weightings) have to be elicited. Finally, the evaluation of the alternatives according to the stakeholder preferences is conducted.

According to earlier research carried out by WOLFSLEHNER ET AL. (2006) the PROMETHEE method meets most of the criteria relevant for the application in this study.

PROMETHEE developed by BRANS ET AL. in the 1980's is a prominent European MCA method. Originally PROMETHEE was used in strategic management or regional planning policies (BRANS ET AL., 1998). Later also other applications where accomplished, e.g. in forestry related issues by KANGAS ET AL. (2001) or KANGAS AND KANGAS (2002).

WOLFSLEHNER ET AL. (2006) proposed the PROMETHEE II method as one appropriate MCA method for further evaluation of ToSIA results.

With the PROMETHEE method it is possible to describe the degree of dominance of one alternative over the other (BRANS ET AL., 1986; WOLFSLEHNER ET AL., 2006; PROKOFIEVA ET AL., 2007).

A standard PROMETHEE evaluation consists of a set of alternatives (e.g. management alternatives, policy alternatives), which will be evaluated with a fixed set of decision criteria. The needed input data can be on ordinal as well as cardinal scale. Additional information is needed to do an analysis with PROMETHEE. First of all information on the relative importance of the indicators (w_j) by e.g. simple rating is needed. Further, the user has to define a preference function for each criterion, in PROMETHEE the user can choose among 6 different preference functions. These preference functions are different with regard to their indifference (q) and preference (p) thresholds (*Figure 4*). The setting of such thresholds accounts for individual preferences in a pair wise comparison of alternatives with regard to an indicator. Depending on the thresholds a difference in the performance of two alternatives with regard to an indicator will be transferred into a dominance value on the scale [0-1].

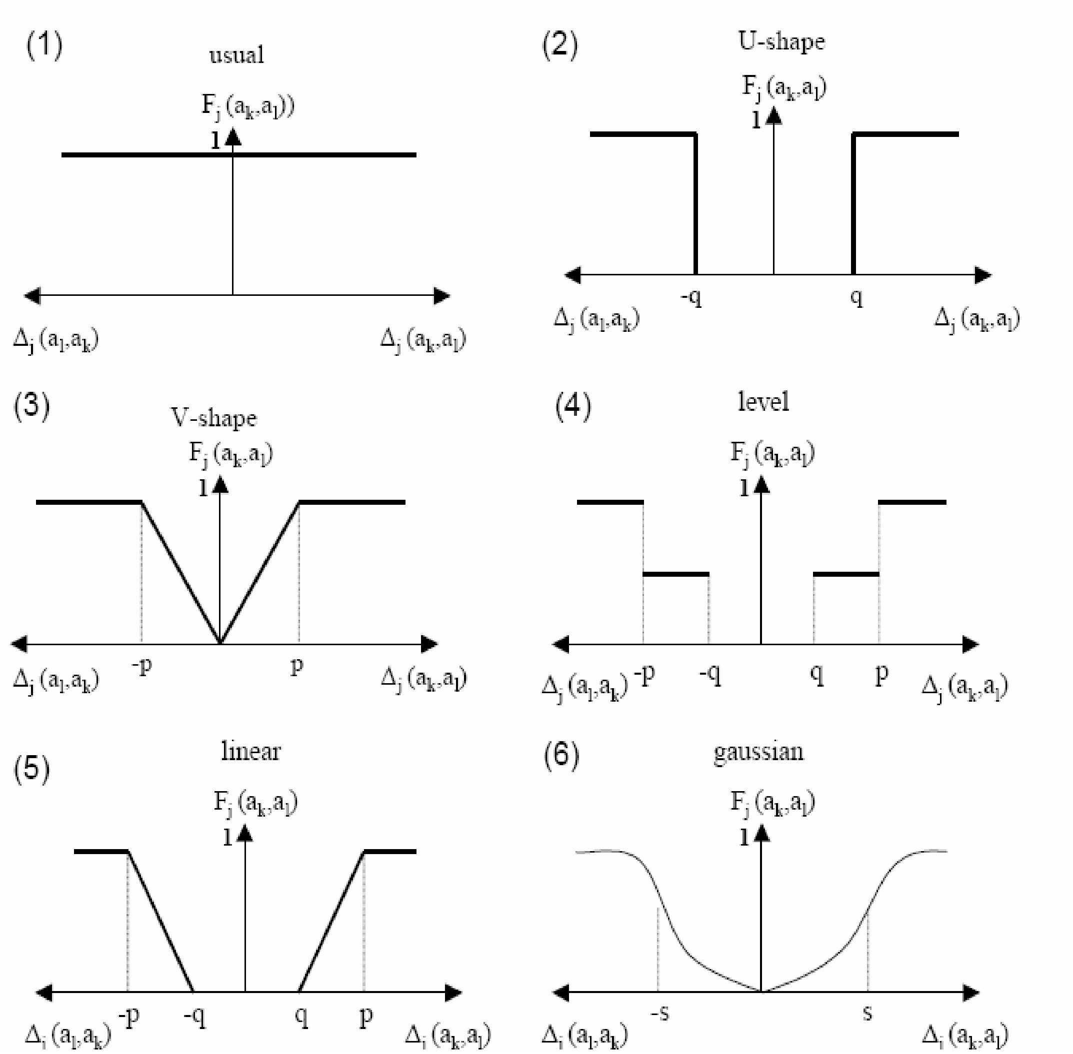

Fig. 4: The six explicit preference functions used in PROMETHEE (BRANS ET AL, 1996).

Positive and negative preference flows are calculated for each alternative whereof the positive shows how an alternative is dominating over the others whereas the negative express the weakness of an alternative.

The flows mentioned above are the basis of the PROMETHEE I parallel ranking from Φ^+ and Φ^-. Here one can see that, e.g. one alternative is clearly dominating all others. Conflicting examples can not be compared with PROMETHEE I.
PROMETHEE II provides a cardinal ranking which is based on a balance between the positive and negative flows. Here information is given on how much favorable an alternative is. Conflicting examples can be compared, by using just one, total dominance value of every alternative (BRANS AND MARESCHAL, 1994). The total net flow Φ of an alternative a_k will be calculated by a subtraction of $(\Phi^+) - (\Phi^-)$. A higher

value of the net flow indicates a higher dominance of this alternative. The alternative with the largest net flow will be the favored one.

Further information on the method can be found in papers of BRANS ET AL. (1984, 1985, 1986, 1992, 1994) or MARESCHAL ET AL. (1986, 1988).

5. Material

5.1 Forest wood chain topology

Generally there are two main strands, which are spruce and beech. The strands are divided into four different modules. Each module is composed of various processes.

In the following section a more detailed description on which processes belong to each module in each strand is provided (compare Figure 5).

Starting with the left side of the FWC one can see the spruce strand. It starts with the forest resources management where the processes of spruce regeneration and further development (young, medium, and adult) are located. From those processes in forest resources management a flow towards processes in forest to industry interactions takes place starting with precommercial operations from young stands to different motor manual and fully mechanized harvesting operations under different slope conditions. From there the chain goes towards processes of forwarding and skidding with different technologies according to the slope steepness (forwarder, skidder, cable crane). Subsequently the different assortments like spruce short and long logs, spruce pulpwood and LDT (Large dimension timber) are transported to different processing mills. At this stage there will be a spruce wood import from outside the FWC (short logs and pulpwood). Transport of spruce fire wood logs and export of spruce pulpwood takes place.

The next step is the measuring and sorting of the different assortments at various mill gates of saw mills or particleboard mills and pulp wood mills.

In the processes of industrial processing, manufacturing and converting the wood material enters soft and hardwood sawmills of different scale or it is processed in particleboard mills. The next step is the transport of sawn timber, saw dust and particle board to further processing where industrial production or manufacturing of construction elements, joinery and furniture takes place. Some wood residues already

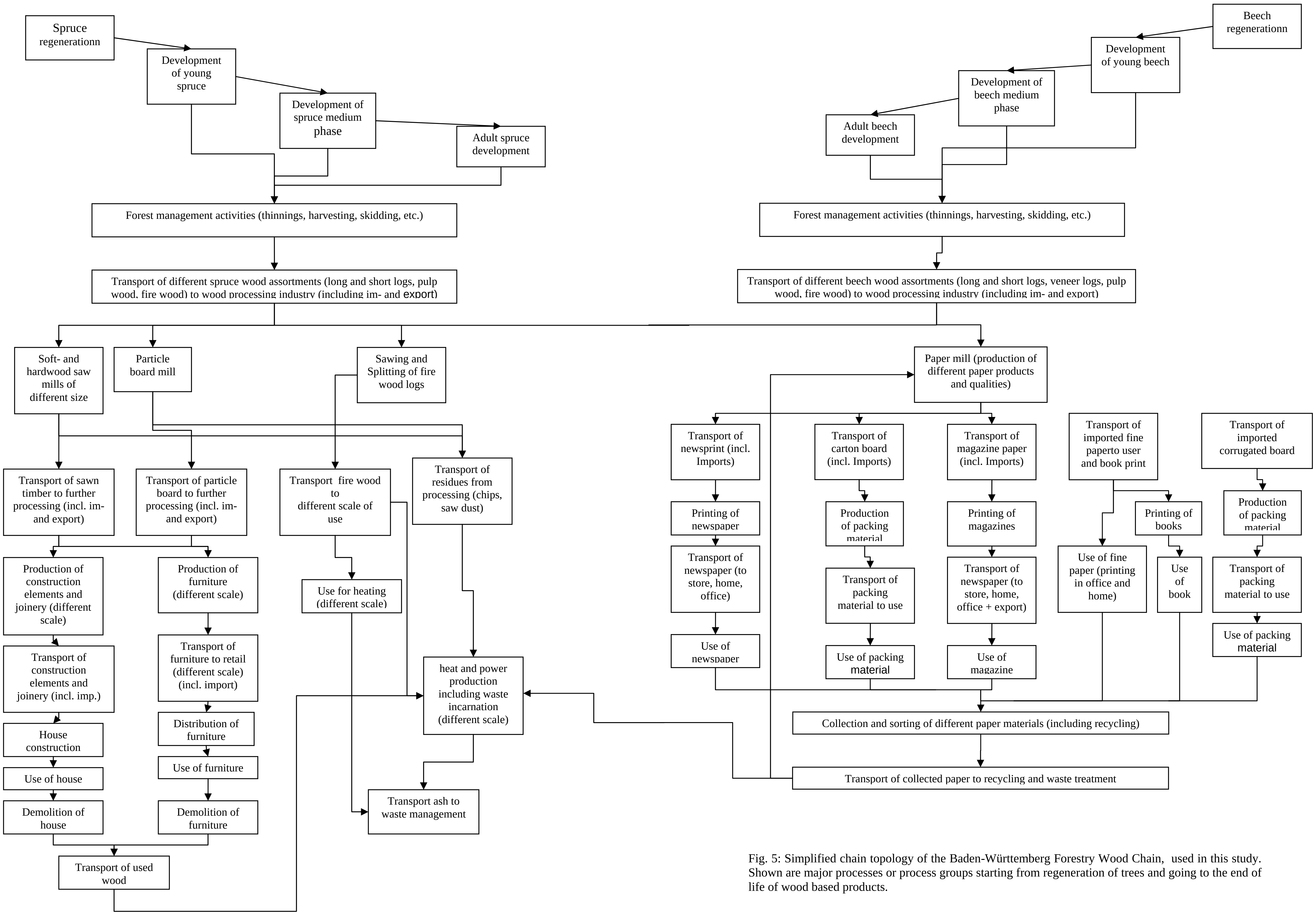

Fig. 5: Simplified chain topology of the Baden-Württemberg Forestry Wood Chain, used in this study. Shown are major processes or process groups starting from regeneration of trees and going to the end of life of wood based products.

go further to processes of industry to consumer interactions and these residues are transported towards power production outside the forest industry.

House construction elements and joinery from the FWC as well as imported ones are transported towards house construction. Furniture and imported furniture are transported towards retail and final destination. Imported packaging material enters the chain and is transported used and finally destroyed and transported towards energy use. Also the houses and furniture are destroyed and transported towards energy production or waste incineration. It can be just heat or combined heat and power of different scales. The final process is the transport of ash towards waste management.

The beech strand starts in the same manner as the spruce chain. There are regeneration and the different development stages followed by harvesting and skidding. Transport of various assortments like veneer logs, beech long logs, short logs, fire wood and pulpwood. This transport takes place within the FWC to various destinations as well as export and import.

The wood is transported to saw mills, particleboard mills, paper mills. There it follows often the same processes which where already described in the spruce strand.

The lower right side (Figure 5) shows the various processes of paper and cardboard production with different transportation processes. Pulp from outside the FWC is entering the chain. Residues are used as pellets or are used directly for energy production.

Various paper and cardboard products are produced and used in magazine printing, book printing, and carton board boxes. All these products are transported and used and partly recycled and reused and finally used as well for energy and power production and end is the ash waste management.

5.2 Forest Wood Chain alternatives

In this study three different management alternatives will be used to identify the impacts of setting aside forest areas on the sustainability of the regional FWC in Baden Württemberg. Since this study is carried out for this regionally defined FWC, only the forest resources, production processes and consumption that occur within the selected region will be analysed.

When this study was conducted, there were no scenario data available yet from EFORWOOD. Therefore it was decided to create alternative options that can be implemented with the 2005 data of the Baden Württemberg Case study of the EFORWOOD project, to avoid the need for collecting new indicator values. On the background of testing the linkage and exploring the sensitivity of the MCA stakeholder preferences the following assumptions and adjustments on the alternatives should be sufficient.

i. **Alternative 1 (base):** The FWC from the Baden Württemberg General structure case study of the EFORWOOD project will be used as reference chain. Some processes that are used in the General structure case study are deleted for this study for different reasons. Some processes are taken out because they where included for purposes not relevant for this study. Another reason for deleting a process from the chain was to break up recycling loops (for simplification). A complete list with all processes and marked processes that have been deleted can be found in *Annex 10.5.* The topology is according to the description above.
This baseline alternative will be the basis for all changes that will occur in the other two alternatives.

ii. **Alternative 2 (steep slope):** Steep slopes are taken out of production compared to alternative 1. Steep slopes are therefore defined as all slopes with an inclination of >60%. The topology and technologies will be according to the baseline alternative. Therefore, no new indicators need to be calculated. There are several assumptions for setting aside the forests in this study. The setting aside process should have taken place in 1995. Since there was no time to carry out a complete new survey for data on the forest in 1995 the approach was to assume the forest in 1995 would have had the same structure as it was given for the forest in the Baden Württemberg General Case Study of the EFORWOOD project. So it was possible to calculate the change of forest area per age class after the 10 years set aside period. This change in the area per age structure will result in different initialization figures compared to the baseline alternative.

iii. **Alternative 3 (set aside 5%):** The fundament of alternative 3 again is the BW-General structure case (alternative 1). 5% of the forest area in alternative 1 is taken out of production and a reduction in material flow will take place. Again it was assumed that this act of setting aside the forest on a large area should have taken place approximately 10 years ago. As a simplification, the effect on indicators of stopping thinnings in the young set aside stands was ignored and no other technology changes were applied in this alternative. Further assumptions are that the set aside forests would have had the same structure as it is given for the total forests in the Baden Württemberg case study of 2005 in the EFORWOOD database. So the same assumptions as in alternative 2 were used for calculating the change in forest area over the 10 years periodThe setting aside of the forest area in this alternative will result in lower amount of forest area in the regeneration phase and a larger forest area in the adult phase.

5.2.1 Forest area for the flow initialization

As mentioned in 5.2 the forest areas are needed to initialize the material flow at the boundary between forest resources management and forestry to industry interactions. The data, productive forest area, for the initialization of the baseline alternative was available directly from the database client. The forest areas of the two other alternatives had to be recalculated according to the assumptions mentioned in the alternative descriptions (see 5.1).

As mentioned in the alternative description the forest should have been set aside about 10 years before the reference year 2005.

During the time period of 10 years the forest is growing older and this has to be considered when calculating the forest areas for the two set aside alternatives of the FWC. In other words forests which where set aside 10 years ago will probably shift to an older age class. The assumption was that the forest should have had the same structure and parameters as the forest given in the database client for the year 2005 at the year they where set aside 10 years ago. To remember the assumption for the 5 % set aside alternative was that 5 % of the total forest area where set aside equally in each age class. Hence due to aging this 5 % are not anymore equally distributed over the age classes.

The “productive” forest areas used for each alternative are shown in Table 1.

Tab. 1: “Productive” forest area (in ha) per tree species and age class, for each management alternative and the reference year 2005.

Tree species age class	Productive forest area baseline alternative in ha	Productive forest area steep slope alternative in ha	Productive forest area 5 % set aside alternative in ha
Spruce			
Regeneration	25.257	25.118	23.994
Young	15.163	14.594	14.405
Medium	278.102	267.535	264.197
Adult	205.928	202.427	195.631
Beech			
Regeneration	6.830	6.718	6.489
Young	11.301	9.080	10.736
Medium	98.605	93.576	93.674
Adult	172.567	164.283	163.938

A reduction of "productive" forest area is achieved by setting aside practices in forest management. In this case productive forest area means, forests, which are used for commercial logging operations. Of course no commercial logging is taking place in regeneration and young stands but those areas are potential commercial areas in the future. One can clearly see that the productive forest areas are decreasing mostly in medium age spruce stands and adult beech stands in both alternatives and additionally a large decrease in adult spruce stands in the 5 % set aside alternative. The younger age classes do not show such a big decrease in forest area. According to the given age class distribution reported to the database the natural age structure in the year 2005 shows as well that most of the forest area is concentrated in the medium and adult age class.

5.1.2 New product split ratios for the steep slope alternative

Product split ratios are values needed in the ToSIA software to be able to calculate how much of the material flow of a certain product, e.g. wood ready for harvesting, has to be distributed to a follow-up process. These values are usually given in the database.

To be able to simulate the steep slope alternative, additionally to the calculation of the adjusted forest area, the product split ratios need to be changed in order to account for the harvesting processes. This is because the steep slope alternative excludes harvesting of forests steeper than 60 % inclination. The processes of harvesting timber on such slopes with more then 60% inclination should not get any more material flow. Thus, the product split ratio from timber ready for harvesting for those processes had to be set to 0. The rest of the harvesting processes need accordingly new product split ratios since the sum of all product split ratios leaving one process has to be 1. The simplest way to calculate the new product split ratios is dividing the old product split ratio by the sum of all old product split ratios minus the old product split ratio towards harvesting slopes with more then 60% inclination. The new product split ratios see Table 2 (spruce medium and adult) and Table 3 (beech medium and adult).

Tab. 2: Product split ratios for spruce ready for harvesting. Black product split ratios for the baseline alternative given by the database client, red new calculated product split ratios for the steep slope alternative.

	harvesting fully mechanised spruce DBH< 35 cm slope <= 30%	**harvesting mototmaual spruce DBH< 35 cm slope <= 30%**	**harvesting mototmaual spruce DBH< 35 cm slope 30%-60%**	**harvesting mototmaual spruce DBH> 35 cm slope <= 30%**	**harvesting mototmaual spruce DBH> 35 cm slope 30%-60%**	**harvesting mototmaual spruce slope > 60%**	**Sum**
Product split ratio spruce medium baseline	0,198	0,143	0,106	0,400	0,115	0,038	1
Product split ratio spruce medium steep slope	0,206	0,149	0,110	0,416	0,120	0	1
Product split ratio spruce adult baseline	0,257	0,200	0,077	0,380	0,069	0,017	1
Product split ratio spruce adult steep slope	0,261	0,203	0,078	0,387	0,070	0	1

Tab. 3: Product split ratios for beech ready for harvesting. Black product split ratios for the baseline alternative given by the database client, red new calculated product split ratios for the steep slope alternative.

	harvesting motormanual beech DBH >35cm, slope <=30%	**harvesting motormanual beech DBH <= 35cm, slope 30%-60%**	**harvesting motormanual beech DBH > 35cm, slope 30%-60%**	**harvesting fully mechanized beech DBH <= 35cm, slope <=30%**	**harvesting motormanual beech DBH > 60 %**	**Sum**
Product split ratio beech medium baseline	0,419	0,093	0,119	0,318	0,051	1
Product split ratio beech medium steep slope	0,442	0,098	0,125	0,335	0	1
Product split ratio beech adult baseline	0,314	0,116	0,150	0,372	0,048	1
Product split ratio beech adult steep slope	0,330	0,122	0,158	0,391	0	1

5.3 The material flow along the FWC

A FWC consists of processes, which are entered and left by material flows. The amount of material that a process in a FWC handles is dynamically calculated based on the amounts of material that the process being examined is receiving from processes that precede it in a FWC (LINDNER ET AL. 2007).

The initialization of the flow calculation takes place between the boundary of the modules Forest to industry interaction and Forest resource management (M2-M3 boundary). To initialize the FWCs for this application the forest area (ha) in the M2 processes are needed. The internal reference unit used in M2 is hectare whereas the reference unit in M3-M5 is tons of carbon. The information flow over the M2/M3 boundary includes the conversion of the area (ha) information to carbon. That is done with the help of transformation factors. Carbon flow and transformation factors are calculated with the following function (eq. 1-2):

$$CarbonFlow_{M2/M3} = \sum (V_i * cf_i) + V_{st} * cf_{st} + V_{hr} * cf_{hr}, \qquad (1)$$

and

$$TransformationFactor = \frac{CarbonFlow_{M2/M3}}{A} \qquad (2)$$

The information that is needed to be collected for this calculation can be found in *Annex 10.6.*

There are imports after the M2/M3 boundary. The initialization of material flow from these processes takes place separately with the use of an import indicator.

Loops of material flow where material, e.g. from recycling processes, enters the chain again at an earlier stage were still a problem for the ToSIA software at the time of this analysis. Therefore the material entering a process from such a loop was initialized in the same manner as for import processes.

Product output shares relative to the input flow of every process are used to calculate material flows consecutively along the entire FWC (*Fig. 6*).

The material flow is necessary to calculate process indicator values. Therefore the material flow will be multiplied by the indicator values per unit of material flow.

Fluctuations in the material flow, which might occur in reality are not considered in the ToSIA calculations. Instead it calculates equilibrium flows along the FWC (LINDNER ET AL., 2009).

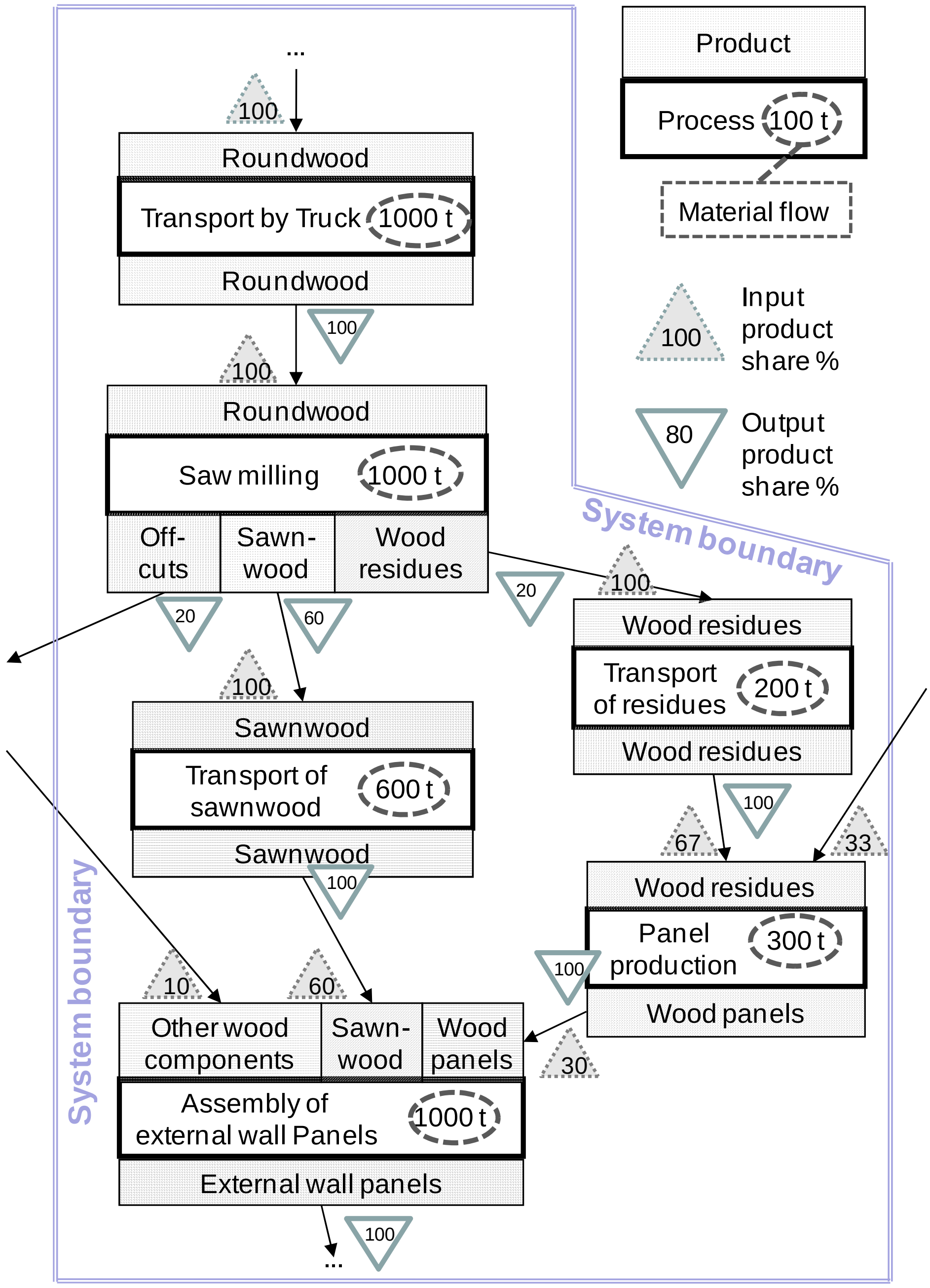

Fig. 6: Extract of the FWC topology showing the selected processes and products and their connections. Product shares for input and output products enable the calculation of material flows along the FWC (LINDNER ET AL., 2009)

5.4 Sustainability indicators

An indicator is a parameter, which provides information about an event, trend or a certain situation. The significance of an indicator goes beyond the strict measure and is used as an approximation of the impact of a change on the sustainable development area, which is analyzed. Indicators can have a direct or indirect relationship with the observed fact. If the observation issue can not be measured directly or conveniently, indicators can be indirect substitute or proxy (for example GDP as an indicator of wealth). Direct indicators measurement of phenomena that directly relate to question asked, e.g. a direct indicator of forest productivity would be measurement of timber yields (UNITED NATIONS, 2007; RAMETSTEINER ET AL., 2008).

Indicators differ from primary data or statistics in a way that they provide meaning beyond the attributes directly associated with them. Hence they offer a possibility to connect detailed data and interpreted information (UN, 2002). Accordingly, evaluation as well as communication of important parameters become instant and easy to understand. Of huge importance therefore is the selection of proper indicators. Another advantage resulting from the use of indicators is that results become reproducible and comparable (HARDI AND BARG, 1997). A consistent methodology allows using indicators to make comparisons over time and space, to find correlations and further to monitor changes and trends (OECD, 1993). Nevertheless, there are also problems, which could occur when using indicators. Indicators always should be chosen carefully and as systematically as possible otherwise they could carry the wrong message and lead to wrong conclusions (BOSSEL, 1999).

5.4.1 Selection of sustainability indicators

The sustainability indicators used for the ToSIA calculations where selected in terms of relevance for the study, which means that they need to have the ability to gather the information on, sustainability impacts of FWCs. Sustainability requires an integrated view of the world and therefore it requires a multidimensional set of indicators that show the links among a community's economy, environment, and society. The selection of sustainability indicators should always be carried out in a way that all three pillars of sustainability will be covered more or less equally. Explicit for this application they need to respond to regional and local needs within the FWC.

Based on already existing indicator sets, like EU-SIA Guidelines[5] (EC 2005), Eurostat-SDI[6] (EC 2005), MCPFE[7] (MCPFE 2003), CSD[8] (United and Nations 2002) and in co-operation with all EFORWOOD partners an adapted indicator set for the utilization in the ToSIA software was developed that is suitable for sustainability impact assessment

[5] Impact Assessment Guidelines of the European Commission

[6] Sustainable Development Indicators for the European Union presented by Eurostat (EUROPEAN COMMISSION 2005b) (EC, 2005)

[7] Improved Pan-European Indicators for Sustainable Forest Management of the Ministerial Conference on the Protection of Forests in Europe (MCPFE 2002)

[8] Indicators of Sustainable Development of the Commission for Sustainable Development of the United Nations (UNITED NATIONS 2002)

(RAMETSTEINER ET AL., 2008). The ToSIA software allows the user to choose among both quantitative and qualitative indicators. Nevertheless quantitative indicators are more feasible regarding processing and evaluation (LINDNER ET AL., 2009).

For the EFORWOOD project 27 main indicators where chosen for demonstration purposes. Each of these 27 indicators has a set of sub-indicators to allow a more detailed analysis. A complete list of all demonstration indicators and sub-indicators can be found in *Annex 10.7.*

For this study nine indicators were selected (Table 4).

Table 4: List of used indicators by category chosen for this application.

IndicatorCategory	IndicatorName
Economic	**Gross value added (at factor cost)** **Production cost** **Productivity**
Social	**Employment - absolute number** **Wages and salaries - total** **Occupational accidents - total**
Environmental	**Energy use** **Greenhouse gas emissions** **Generation of waste in total**

As mentioned before the collection of indicator values followed the clear rules of data collection protocols. As all the other data the indicator data are stored in the database of the EFORWOOD project. This database allows tracking back, who has inserted or changed values and further gives information about the data reference.

The labour productivity indicator (tons/man year) is somehow outstanding from the other indicators because it is calculated by dividing total production in tons (output of ToSIA) by employment absolute number

5.4.2 Calculation of sustainability indicators

The calculation of sustainability indicators in ToSIA (Fig. 7) for each process is done by multiplying the input material flow of the process with the relative indicator values of each process. After this calculation an aggregation of the results for each process can be done for each module or the entire chain by summing up such indicator values. Though indicators that are measured not in absolute numbers, e.g. in relative shares (%), call for a different form of aggregation. Such relative shares would therefore be averaged (LINDNER ET AL., 2009).

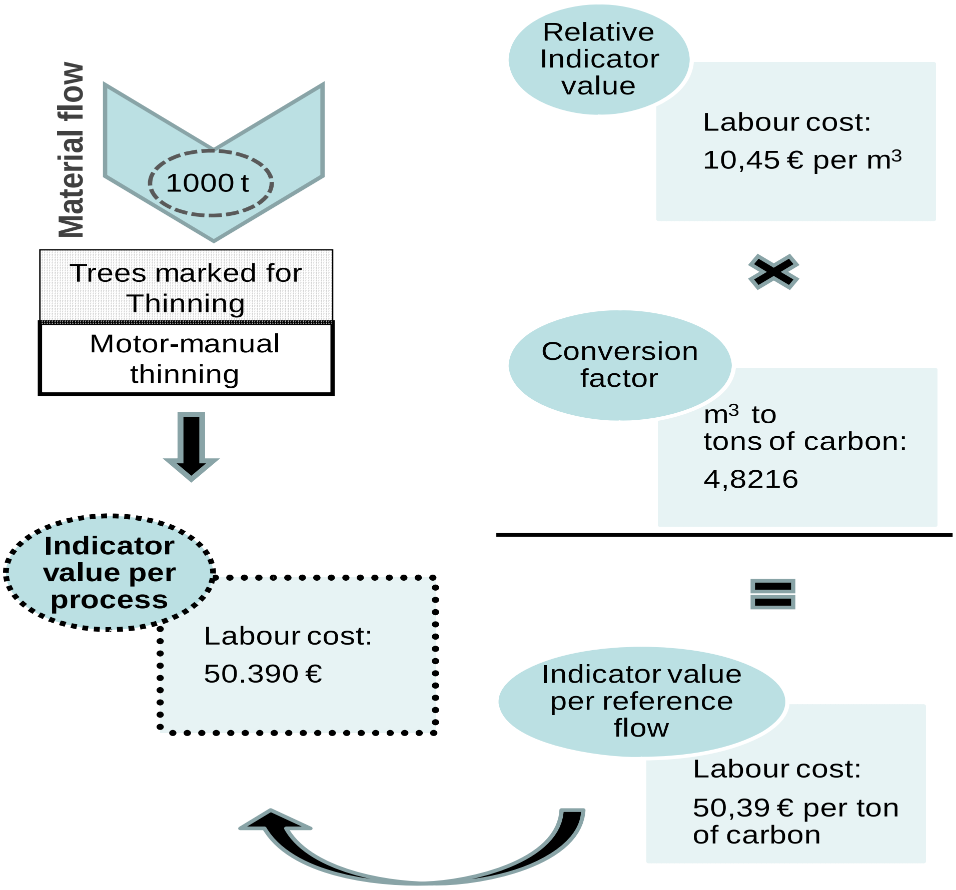

Fig. 7: Calculation example for the labour cost indicator in the thinning process. Indicator data are reported relative to the reporting unit of the process (m3). ToSIA converts this with a conversion factor into the indicator value per reference flow (tons of carbon) and multiplies this with the material flow to calculate the indicator value per process (LINDNER ET AL., 2009).

5.5 MCA set-up

5.5.1 Stakeholder preferences and indicator weighting

Three prototypic stakeholder groups will be the basis for the PROMETHEE analysis in this study. The three stakeholder groups represent different interests with regard to the three pillars of sustainability in a stereotypic interpretation.
The three groups can be distinguished as described below. Resulting from their different views on sustainability different indicator preference profiles will arise.

a) **Representative of the timber industry in Baden Württemberg:**
source: http://www.vsh.de/

This group represents a focus on economic sustainability and working for the timber industry in Baden Württemberg.
The goals of this group are to promote timber products on regional level. The value added should be kept in the region if possible. This should happen if the economic conditions in the region are comparable with other regions and the revenues at roadside are the same. To keep the added value in the area timber exports should just be allowed when the regional market is saturated.

b) **Representative of environmental NGO's in Baden Württemberg:**
source: http://www.lnv-bw.de/

This stakeholder body advances environmental, nature and landscape protection. It informs its members on the development concerning these issues in Baden Württemberg and organizes initiatives to enforce measures concerning issues mentioned above. It represents its interests in front of administration bodies, politicians, political parties, ministries, communal bodies or other interest groups. Further it will inform also the public concerning environmental issues in the federal state. This group advocates forest certification, close-to-nature forest management, biodiversity protection, energy saving, reduction of greenhouse gases, etc.

c) Labor union in Baden Württemberg:

source: http://www.cda-bw.de/

This group represents a body, which will lobby for employee interests in Baden Württemberg. The goals of this group are humane working conditions, equal treatment of men, women and disabled people. Further they try to campaign for a better qualification of employees and fight against tax, subsidy and social misuse.

One key issue of this group is to support local employment in the region of Baden Württemberg.

For the resulting preference profiles (*Table 5-7*) a total of 100 points was distributed according to hypothetic weights for the selected indicators in this application. A higher score for an indicator indicates a higher importance of an indicator with regard to the overall sustainability impact assessment. The points were given by the author based on published statements and opinions of the stakeholder groups.

Tab. 5: Preference table of representative of the timber industry in Baden Württemberg

IndicatorName	Indicator weight
Gross value added (at factor cost)	24
Production cost	21
Productivity	17
Employment - absolute number	12
Wages and salaries - total	7
Occupational accidents - total	5
Energy use	5
Greenhouse gas emissions	4
Generation of waste in total	5

Tab. 6: Preferences representing environmental NGO’s in Baden Württemberg.

IndicatorName	Indicator weight
Gross value added (at factor cost)	5
Production cost	8
Productivity	6
Employment	10
Wages and salaries	4
Occupational accidents	2
Energy use	20
Greenhouse gas emissions	25
Generation of waste in total	20

Tab. 7: Preferences representing the labor union in Baden Württemberg.

IndicatorName	Indicator weight
Gross value added (at factor cost)	12
Production cost	6
Productivity	7
Employment	24
Wages and salaries	20
Occupational accidents	16
Energy use	5
Greenhouse gas emissions	5
Generation of waste in total	5

5.5.2 Evaluation thresholds

Decision Lab, a software tool based on PROMETHEE, will be employed for the analysis. As mentioned before, this software offers six possible shapes of preference functions.

This study will utilize the V-shape preference function (*Figure 8*). The V-shaped preference function requires a preference threshold. Two different thresholds are used. The thresholds will be set with 10% and 50% of the maximum value, given as absolute number.

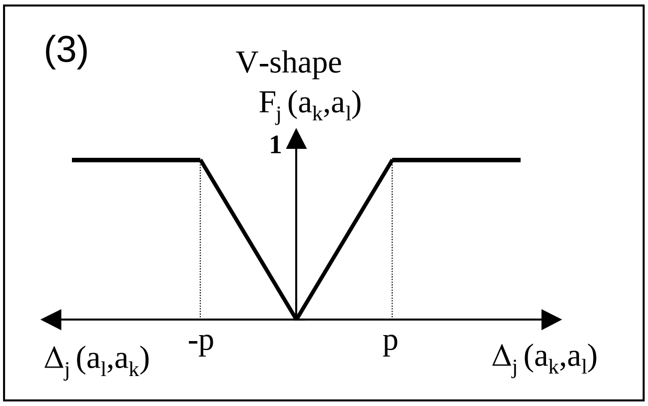

Fig. 8: V-shaped preference function used in this application.

(a_k, a_l) = two alternatives

-p , p = preference threshold

Δ_j = deviation of indicator values

$F_j(a_k, a_l)$= preference function

Since the data calculated in ToSIA can not be used directly for further evaluation with PROMETHEE, a data preparation has to take place.

The evaluation level for the MCA is the whole FWC. Therefore an aggregation of indicator values for the FWC is done. Accordingly, the indicator values of single processes will be aggregated along the chains. This aggregation implies the acceptance of trade-offs among phases of the FWC.

Additionally, the indicator 'total production' will be used to calculate indicator values relative to total production. Both, absolute and relative indicator values will be used for the MCA. This approach was chosen to avoid that differences between the alternatives shown in absolute differences caused by the change in material flow (due to set aside practices), are dominating. Thus dividing absolute indicators by the total productions results in indicator values that are independent of the different productive forest areas.

Further, a sensitivity analysis is conducted, that explores weight stability intervals to demonstrate how sensitive the optimal solution is to changes in the weights of the criteria by the different stakeholders.

6. Results

6.1 ToSIA results

Table 8 shows the aggregated indicator values calculated in ToSIA as absolute values for the three management alternatives. All indicator values are based on the productive forest area (see also 8.1) of each management alternative and the reference year 2005.

As shown in Table 8 one can see that in absolute terms all indicators show a decreasing gradient from the baseline alternative towards the two set aside alternatives. The differences between the chain alternatives are more comprehensible when their relative differences are compared (Table 8). These decreases, which can be seen in the absolute values are obvious but not very high.

Tab. 8: Absolute results of the ToSIA calculations with full aggregation along the chains for the three management alternatives of the Baden Württemberg Forest wood chain (baseline, setting aside forests on steep slopes and setting aside 5% of the productive forest area). All results are calculated for the reference year 2005.

Indicator Name	**values of alternatives**			**Unit**
	baseline	**steep slope**	**set aside 5%**	
Gross value added (at factor cost)	14,37	14,09	13,83	billion Euro
Production cost	11,88	11,70	11,52	billion Euro
Total Production	5,27	5,19	5,10	million tons
Employment - absolute number	273.174	263.641	263.362	man years
Wages and salaries – total	4,31	4,23	4,15	billion Euro
Occupational accidents – total	2,02	1,98	1,93	million accidents
Energy use	12,553	12,42	12,27	TWh
Greenhouse gas emissions	5,26	5,20	5,13	billion tons of CO_2 eqv.
Generation of waste in total	838.381	828.007	816.487	tons

Figure 9 shows the differences in percent for the absolute indicator values. The decrease is usually roughly between 1% and 2 % from baseline to steep slope and between 2% and 4% from baseline to the 5% set aside alternative.

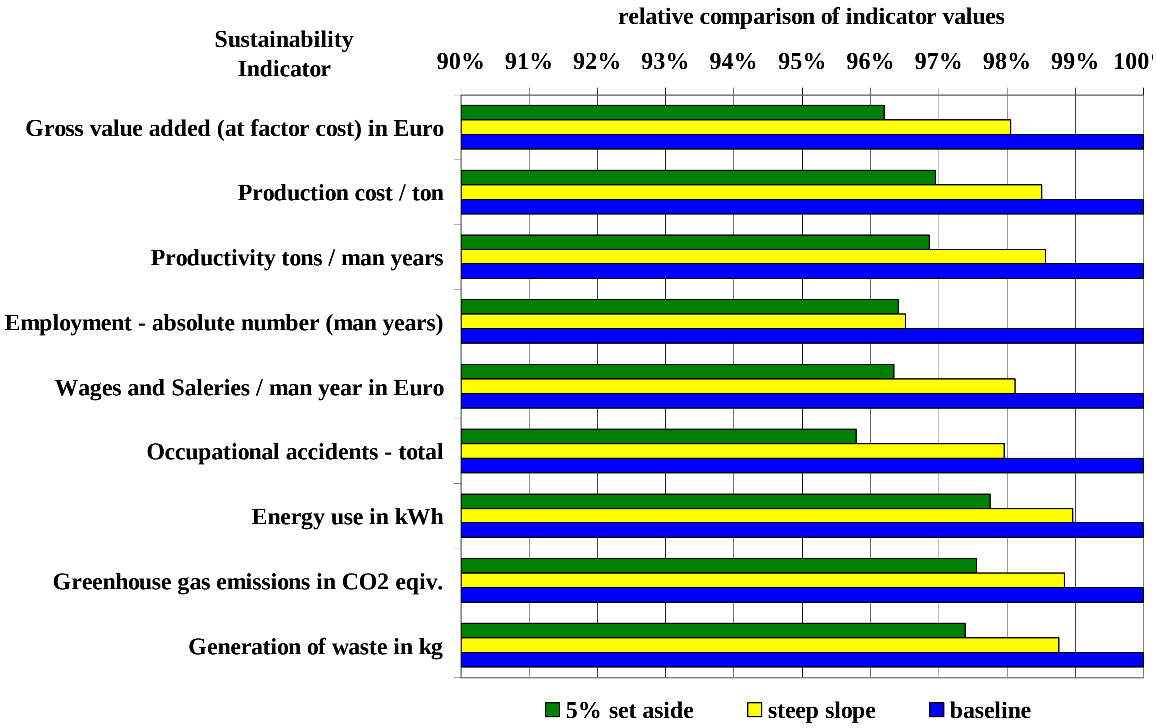

Fig. 9: Relative comparison of absolute indicator values calculated by ToSIA for the three alternatives and the reference year 2005. (100 % = the best/ highest value, the others relative to it).

The "gross value added at factor cost" decreases from the baseline alternative towards the steep slope alternative by around 2 % and towards the large scale set aside alternative by 4 %. The total production costs are about 1,5 % lower in the steep slope alternative and about 3 % lower in the 5 percent set aside alternative compared to the baseline alternative. Pretty much the same differences can be seen for the total production figure.

Looking at the "employment indicator" of the set aside alternatives one can see about 3,5 % lower employment compared with the baseline management FWC. The 5 percent set aside alternative shows very slightly less employment then the steep slope alternative.

"Wages and salaries" (total) are around 2 percent lower in the steep slope alternative and a bit more the 3,5 % lower in the large area set aside alternative in comparison to the baseline. The largest decrease occurs for "occupational accidents" which decrease

more then 4 % for the 5 percent set aside alternative but just about 2 % for the steep slope alternative.
All environmental indicators (energy use, GHG emissions, generation of waste) show all pretty much the same pattern. Their values are about 1 % lower in the steep slope alternative and 2,5 % in the 5 percent set aside alternative compared to the baseline option.

For the evaluation of the ToSIA results with an MCA it was considered as not useful to use just absolute indicator values. Some of the indicators should be related to another to allow a more explicit answer on which alternative would be the best. Especially the indicators “total production” in tons, “production costs” in Euro and “wages and salaries” can be interpreted easier, when set in relation to another factor. Thus, the combined indicator “productivity in tons / man years” was calculated by dividing the “total production” indicator by the “employment” indicator. Further “production costs” where divided by “total production” to obtain the indicator “production costs per ton of material entering the use stage”. Also “wages and salaries” where divided by the “employment” figure to get the complex indicator “wages and salaries per man year”.
The results of absolute and partly complex/combined indicators are listed in Table 9 and Figure 9 which illustrate a much more diverse structure compared to the absolute values.

Tab. 9: Indicator values used for the MCA application as absolute or relative values for the reference year 2005 (later it will be refered to as mixed indicator set).

Indicator Name	**values of alternatives**			**Unit**
	baseline	**steep slope**	**set aside 5%**	
Gross value added (at factor cost)	14,37	14,09	13,83	Billion Euro
Production cost per ton	2255	2254	2258	Euro / ton
Productivity	19,28	19,69	19,37	tons / man years
Employment	273.174	263.641	263.362	man years
Wages and salaries per man year	15.767	16.030	15.757	Euro / man year
Occupational accidents	2,02	1,98	1,93	Million Accidents
Energy use	12,55	12,42	12,27	TWh
Greenhouse gas emissions	5,26	5,20	5,13	Billion tons of CO_2 eqv.
Generation of waste	838.381	828.007	816.487	tons

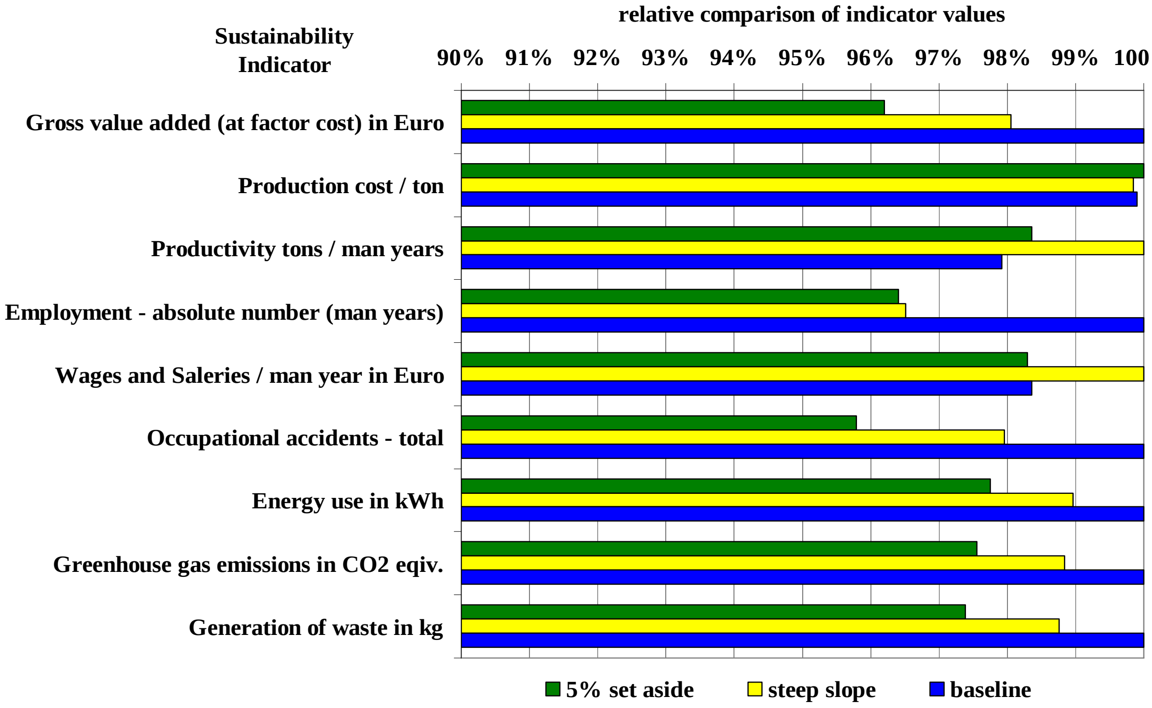

Fig. 10: Relation of decrease and increase of relative indicator values in percentage related to the highest value. (100 % = the highest value, the others relative to it).

Table 9 and Figure 10 draw a different picture at least for those indicator values related to another indicator.

The "production costs per ton of material" becoming merchantable final goods differ only slightly between the alternative chains. The lowest "production costs" are reached in the steep slope alternative whereas, interestingly, the 5 % set aside alternative has the highest "production costs per ton of produced material". The baseline alternative settles between the two others.

The highest "productivity" shown as tons of produced material per man year is reached in the steep slope alternative (alternative 2). The "productivity" in the 5 percent set aside alternative (alternative 3) shows around 1,5 % less productivity. Worst "productivity" reveals the baseline alternative with considerably less then 2 % compared to the steep slope alternative.

The steep slope alternative is also characterized by the highest values of "wages and salaries per man year". The two other chain alternatives show about 1,5 % lower "wages and salaries per man year".

6.2 MCA results

For the data presented in chapter 4.4, a multi-criteria analysis was carried out. The indicator values presented in Table 9 (indicators related to total production) was analysed according to the scheme described in chapters 4.4 and 5.4.

6.2.1 Ranking of the alternatives

According to the evaluation scheme six different rankings were carried out, two for each stakeholder group (Table 10). The first three rankings were done using a 10 % preference threshold whereas the other three rankings where carried out with a 50 % preference threshold (see chapter 4.4).

Tab. 10: For each stakeholder group 2 rankings using different preference threshold were carried out.

	Preference threshold	
Stakeholder group	**10 %**	**50%**
Environmental NGO	ranking of the 3 management alternatives	ranking of the 3 management alternatives
Labour Union	ranking of the 3 management alternatives	ranking of the 3 management alternatives
Timber Industry	ranking of the 3 management alternatives	ranking of the 3 management alternatives

The comparisons of the different rankings accomplished with the 10 % preference threshold can be seen in Figure 11.

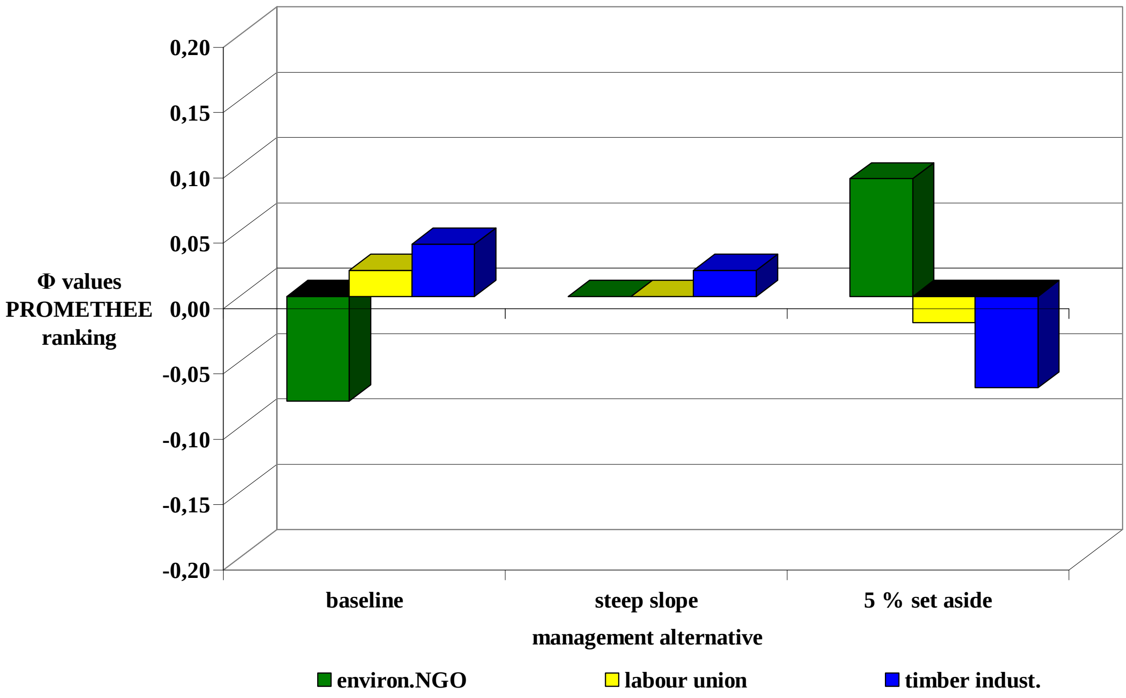

Fig. 11: Comparison of the PROMETHEE 2 rankings. The results are displayed for the three different stakeholder profiles, for the three management alternatives 10% preference threshold. (mixed indicator set)

First of all one can see that although there are differences visible between the alternatives in the different rankings those differences are very small.

The rankings using the weighted preferences of the representative of the timber industry as well as the one of the labour union indicated the baseline alternative is the most preferable choice. An entirely different picture is drawn by the ranking of the weightings of the environmental NGO's representative of in Baden Württemberg. Here the baseline alternative is the least preferable alternative, and the 5 % set aside chain is the best alternative. The ranking value of 0,09 in this case is also the highest one of all obtained ranking values indicating the strongest congruence between the offered management alternatives and all stakeholder preferences.

The steep slope alternative would be the second best alternative for all stakeholders, but it just gets a positive value in the ranking of the representative of the timber industry.

The 5 % set aside alternative is the most favoured alternative of the environmental NGO whereas the other two stakeholders clearly give the lowest preference to this alternative.

The difference between most preferable alternative and least one can be seen in the ranking of the environmental NGO, where the 5% set aside alternative shows a clear dominance over the other alternatives. The differences between the alternatives according the ranking using the weightings of the labour union are the smallest, indicating that none of the offered management alternatives is especially good or bad from the point of view of a labour organization.

Looking at Figure 12 shows the results of the rankings carried out using the 50 % preference threshold, it can clearly be seen that the already small differences between the alternatives when using the 10 % preference threshold are getting even smaller to almost indistinctive.

Still the baseline alternative is the most preferred choice of the timber industry and the worst choice of the environmental NGO's. As well both stakeholders see the steep slope alternative as second best. Looking at the results concerning the 5 % set aside alternative it is still the most preferable for the environmental NGO's and least good option for the timber industry. When it comes towards the ranking of the labour union no clear winner can be seen using the 50 % preference threshold.

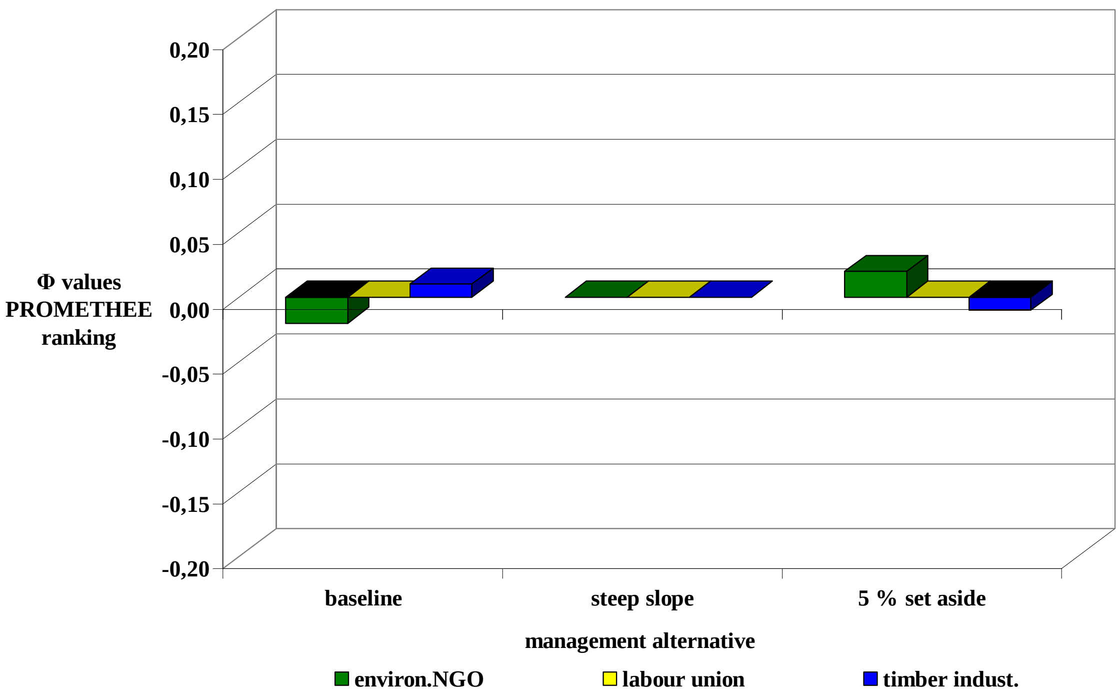

Fig. 12: Comparison of the PROMETHEE 2 rankings. The results are displayed for the three different stakeholder profiles, for the three management alternatives 50% preference threshold. (mixed indicator set)

6.3.2 Sensitivity analysis

Weight stability intervals determining the limits for each criterion within its weight can be modified without changing the result of the complete ranking (MARESCHAL, 1988). In other words checking the weight stability intervals indicates how much each indicator weight can be changed without affecting the total ranking.

The weight stability intervals for all stakeholder profiles and all indicators are shown in Table 10, 11 and 12 (in this case it does not matter which preference threshold is used). For example, wages and salaries in the ranking of the labour union has a weight of 20,00 % given and may be weighted between 10,97 % and 24,39 % without affecting the overall ranking, all other factors remaining unchanged.

Table 11 shows the weight stability intervals for the ranking done with the preference weights of the environmental NGO’s representative of Baden Württemberg. One can see in this case especially the environmental indicators (energy use, GHG- emissions, and generation of waste) as well as the indicator occupational accidents could get any weight and the overall result of the outranking would stay the same. Looking at indicators like for example “employment” one can see that if this indicator would be weighted stronger as 21,95 % the overall result would change. Each indicator could be set to “0” individually and no change in the ranking would occur.

Tab.11: Weight stability intervals from ranking carried out for the representative of environmental NGO’s in Baden Württemberg for the indicator values of the mixed set.

Indicator Name	**% Weight**	**% Interval**	
		Min.	**Max.**
Gross value added (at factor cost)	5,00	0,00	25,46
Production cost per ton	8,00	0,00	78,97
Productivity	6,00	0,00	31,28
Employment	10,00	0,00	21,95
Wages and salaries	4,00	0,00	28,95
Occupational accidents	2,00	0,00	100,00
Energy use	20,00	0,00	100,00
Greenhouse gas emissions	25,00	0,00	100,00
Generation of waste	20,00	0,00	100,00

Table 12 shows also weight stability intervals but for the ranking done by using the preferences of the labour union representative. Here the picture drawn looks different since for many indicators changes in the ranking would result in different overall result. Here, not all indicators could get a preference of “0” without changing the overall result. “Gross value added”, “employment” and “wages and salaries” are these indicators which could not get a significant lower weight as it was given originally given. Changes in the weighting of “productivity” would quickly result in a different result of the outranking.

Tab.12: Weight stability intervals from ranking carried out for the representative of the labour union in Baden Württemberg for the indcator values of the mixed set.

Indicator Name	**% Weight**	**% Interval**	
		Min.	**Max.**
Gross value added (at factor cost)	12,00	7,47	100,00
Production cost per ton	6,00	0,00	70,15
Productivity	7,00	0,00	11,07
Employment	24,00	21,87	100,00
Wages and salaries	20,00	10,97	24,39
Occupational accidents	16,00	0,00	19,73
Energy use	5,00	0,00	13,00
Greenhouse gas emissions	5,00	0,00	12,19
Generation of waste	5,00	0,00	11,79

At last the stability intervals for the ranking of the timber industry representative are shown in Table 13. Here similar to the intervals shown in Table 11 most indicator weights can not be changed much without changing the overall result. Just the weights of the indicators “GVA” “production costs per ton” and “employment” can be changed quite much without influencing the overall ranking. The smallest changes could be done with the weighting of occupational accidents.

Tab.13: Weight stability intervals from ranking carried out for the representative of the timber industry in Baden Württemberg for the relative indicator values of the mixed set.

Indicator Name	% Weight	% Interval	
		Min.	Max.
Gross value added (at factor cost)	24,00	17,87	100,00
Production cost per ton	21,00	0,00	81,54
Productivity	17,00	0,00	22,41
Employment	12,00	8,18	100,00
Wages and salaries	7,00	0,00	14,56
Occupational accidents	5,00	0,00	11,29
Energy use	5,00	0,00	16,68
Greenhouse gas emissions	4,00	0,00	14,65
Generation of waste	5,00	0,00	14,98

7. Discussion

7.1 Comments on forest area calculations

Here the adjustments for the set aside forest wood chain will be commented. Since in this study simplified assumptions had to be made to implement the two optional FWV alternatives no absolute correctness can be expected. As mentioned already in the material description those assumptions have been made to adjust the forest area of the FWC alternatives in order to use the limited amount of available data. Therefore data of the forest area and its distribution in 2005 was used as basis (see 5.2). Of course this does not reflect reality, but since there was a lack in time and resources to do a complete new set-up, it was seen as a feasible assumption.

Further there has been a simplification for the 5 % set aside FWC. Here the statement in the national strategy of biological diversity of the "Federal Ministry of Environment, Nature Conservation and Nuclear Control – BMU" (2007) that about 5 % of the forest area should be achieved was taken as basis. In this study these 5 % where taken out of management equally distributed over age classes and tree species. In reality this distribution would look most probably different. Hence more forests in adult age class and more broadleaved forests would be considered for nature conservation purposes (BMU, 2008). However, for demonstration purposes the assumptions used in this study should be sufficient.

Important to mention is the relation between adult and medium aged forests, which are important for the harvesting processes. Especially in the 5 % set aside alternative there are in relative terms more medium aged forest compared to the two FWC alternatives. This may proof important since it can lead to increasing harvesting costs.

7.2 Discussion of ToSIA results

The hypothesis was that setting aside forest areas would have a positive impact on ecological indicators, represented in this study by energy use, GHG emissions and generation of waste, and a negative impact on social and economic indicators due to e.g. less economic management.

According to the ToSIA results this assumption is only partly correct since not all indicators behave in this manner. In general the decrease of the indicator values in absolute terms from the baseline alternative towards the two set aside alternatives can be logically explained by a decreasing amount of material flow through the processes due to lower amount of harvested wood as a result of the set aside management practice. This can be seen very well when looking at the figures of total production, which clearly show that there is a lower amount of products turned out in the chain. The decreases shown have an irregular pattern following how much forest area in total is set aside. Of course in the 5 % set aside alternative has a reduction of "productive" forest area of 5 %, the steep slope alternative has a reduction of about 3,74 %. Thus, this irregular pattern must be related to the different age class distribution of the set aside area and the resulting "productive" forest area. However, the current example also demonstrates a crucial issue. To test the hypothesis that setting aside forest may improve the environmental domain of a FWC requires an appropriate indicator set, which is sensitive to the changes in the FWC. In our example forest related indicators reflecting biological diversity and conservation would be required.

Gross value added

The indicator "gross value added" shows a lower value in the two set aside alternatives compared to the baseline alternative, because first of all there is lower production in general and second there are pretty much the same investments that are taking place for technology, e.g. sawmilling equipment, but less timber can be processed since less timber is harvested. Such an effect of decreasing gross value added by setting aside forest areas, was already described by DIETER (2008).

Production costs

The production costs in total are decreasing because of the same matter as mentioned already. When looking at the relative figures of production costs per ton of material entering the use stage one can see that there is a small decrease from the baseline alternative towards the steep slope alternative. The reason probably is that excluding harvests form steep slope will reduce costs, since those harvesting operations are cost intensive due to expensive technology, expensive building of infrastructure (e.g. forest roads) and also labour costs (less harvest amount per time unit on steep slopes). In comparison, there is an increase of production costs per ton of material produced in the 5 % set aside alternative. Not all steep slopes are excluded in this alternative from harvesting, so the cost intensive harvesting methods of steep slopes are still needed. The reduction in harvests especially of old spruce stands in the 5 % set aside alternative causes and a not so strong reduction of medium aged stands results relatively larger harvests in the medium aged stands compared to the other two alternatives. According to the "Stück-Masse-Gesetz" (i.e. decreasing cost per unit with increasing average volume per unit) harvesting of smaller diameter trees increases the harvesting costs (ESCHMANN ET AL., 2003) thus also the total production costs are increasing. Furthermore, the same investments for transportation, sawmilling and heat production systems are done which raises the non productive costs.

Labour productivity

The "Labour productivity" indicator shows the production per person year. The highest labour productivity can be seen in the steep slope alternative, which is probably due to the fact that labour intensive harvesting on steep slopes does not take place any longer and thus the overall productivity is increased. Also the 5% set aside alternative shows a slightly higher productivity compared to the baseline alternative. Here motor-manual harvesting is reduced but not as much as in the steep slope alternative.

Employment

The loss of employment is the ultimate consequence of a reduction of production area and thus causes less timber harvested which cascades down the entire FWC. Recent publications state that a reduction of a harvest volume by 1000 m^3 causes a loss in employment of about 10 - 20 person years (DIETER, 2008; HIRSCHFELD, 2009). In this study decreasing harvests according to the area reduction described in 6.1.1 and reduced harvests calculated internally by the ToSIA show a reduction in harvested volume of ~ 497000 m^3 per year in the steep slope alternative. This relates in an employment loss of ~ 9500person years (~ 19 person years per 1000 m^3). In the 5 % set aside FWC ~ 678000 m^3 of wood would be harvested less per year compared to the baseline FWC. Assuming the same this would lead to a loss of employment of ~ 9800 person years (~ 14 person years per 1000 m^3).

Wages and salaries

"Wages and salaries per man year" show a small increase in the steep slope alternative, which might be due to the fact that this alternative causes a loss of low-salary jobs, e.g. forest workers, truck drivers. But generally one can see that the differences are quite small.

Occupational accidents

The figures of "occupational accidents" show lower values in the set aside alternatives, too. This trend is as well quite reasonable since an overall lower production will of course result in fewer accidents.

Energy use / GHG emissions/ generation of waste

Lower indicator values for "energy use" and "greenhouse gas emissions" and "generation of waste" are as well a logical consequence of reduced material flow along the chain since less transportation is needed (reduction of "energy use" and "GHG emissions") and also less energy is needed for the production processes since less timber is delivered to the processing industry. The reduced amount of waste produced is due to the fact that less material is produced which can reach the end of life of the product e.g. furniture at the end of life, ashes from combustion processes, etc.

Nevertheless, the indicator results calculated by ToSIA should not be interpreted as absolute figures. The indicator values produced by ToSIA were compared with secondary literature and statistical information. These cross check of data can be seen in Table 12. Sufficient and applicable information were not available for all indicators.

Tab. 12: Comparison of ToSIA calculated indicator values with findings from secondary literature and statistics.

Indicator / unit	ToSIA results for 2005 (lowest-highest)	findings in secondary sources	secondary source
gross value added (at factor cost) [Billion Euro]	13,83 – 14,37	GVA approx. 291,28 Billion Euro 29,91	GVA for entire Baden Württemberg 2005 - Federal statistical office of Baden Württemberg (online) Turnover 2005 "Cluster Forestry and Timber bases industry Baden Württmberg" (not including waste, energy and transport business) - Bundesforschungsanstalt für Forst- und Holzwirtschaft / Statistical office of Germany 2006 – Waldgesamtrechnung
production costs (total) [Billion Euro]	11,52 – 11,88	-	-
total production [tons]	5100635 – 5266088	-	-
employment [man years]	263.362 – 273.174	210.564	2005 "Cluster Forestry and Timber bases industry Baden Württemberg" (not including waste, energy and transport business) (SEINTSCH, B.; 2007)
wages and salaries / Euro per person year	15.757 – 16.030	32.712 – 43.860	average gross earnings in Baden Württemberg 2005 - Federal statistical office of Baden Württemberg (online)
occupational accidents	1,93 Mill – 2,02 Mill (7 accidents per man year)	0,0263 occ. accidents per man year 1.17 Million	Baden Württemberg total 2004 -Sicherheit und Gesundheit bei der Arbeit 2004 Germany total 2005 - Statistical Office of Germany (Sicherheit und Gesundheit bei der Arbeit 2005 – Unfallverhütungsbericht Arbeit)
energy use / TWh	12,27 – 12,55	448,69 TWh	Baden Württemberg (total) Federal statistical office of Baden Württemberg (online) Monthly statistical report of Baden Württemberg 12/2007
greenhouse gas emissions / tons of CO_2 equiv.	5.130.053.879 – 5.258.434.158	86.693.000 tons of CO_2 equiv.	Total Baden Württemberg Federal statistical office of Baden Württemberg (online) Monthly statistical report of Baden Württemberg 12/2007
generation of waste / tons	816.487 – 838.381	-	-

Unfortunately for some indicators it was not possible to find secondary literature to verify weather they are plausible. For production costs, total production and generation of waste no applicable secondary data was found to check the plausibility of the calculated ToSIA results.

Gross value added shows a quite reasonable figure compared to the values found in secondary literature. The share of the GVA calculated by ToSIA is about 4,75-4,9 % (depending on the management alternative) of the total GVA of Baden Württemberg, listed in the federal statistics (FEDERAL STATISTICAL OFFICE OF BADEN WÜRTTEMBERG, 2005). As reported in the "Cluster study of the Forestry and Wood sector in Baden Württemberg" (SEINTSCH, 2007), the turnover of the forest wood sector (not including heat and energy production, waste treatment of wood products and various transport processes) has a share of about 4% on the total turnover in Baden Württemberg. ToSIA results may very well be slightly higher, because here, heat and electricity production, waste treatment and various transportation processes are also accounted for.
The employment figure calculated in ToSIA shows a higher amount of man years as it was found in the "Cluster study of the Forestry and Wood sector in Baden Württemberg" for the year 2005. Since the figure shown by SEINTSCH (2007) does not include the production of heat and energy as well as the waste management of wooden products and various transport processes, which would account for a considerable amount of employment, the higher ToSIA employment figure seems reasonable.

Wages and salaries give the impression that ToSIA calculated those numbers not correctly. The amount of wages and salaries per person year is about half of the average wages and salaries reported in the statistics of the federal statistic agency of Baden Württemberg. Mistakes in data reporting to the database or calculation errors of the software are possible reasons for implausible indicator results. Perhaps the calculated results reflect that generally, forestry is not a high-income work compared to the skilled work in other industries in Baden Württemberg. Thus I might be that those differences are partly real differences.

Even without referencing it is quite unlikely that the amount of occupational accidents was calculated correctly by ToSIA. Looking at the reference figures from federal statistics, this is getting even more evident, since it is implausible that in the regional forest wood sector of Baden Württemberg twice as many occupational accidents happen as there were occupational accidents reported for entire Germany in the same time period. In other words, this figure would mean that every employee in the FWC would have about 7 occupational accidents per year. Of course one could expect higher rates of occupational accidents for a forest wood chain then the average rate of the whole federal state since harvesting related operations as well as house construction are two branches with a quite high risk of occupational accidents (FEDERAL MINISTRY OF FOOD AND RURAL DEVELOPMENT, 2007; BGBAU, 2006). But a rate like this can be just a miscalculation of ToSIA due to reporting or calculation errors.

The energy use of the FWCs calculated in ToSIA has a value which is roughly about 2,8 % of the total energy consumption in Baden Württemberg. Since there is no figure available how much energy is consumed by the forest sector in total for Baden Württemberg it is just possible to compare it to other industry sectors. Forestry, agriculture and aquaculture together, account for a primary energy consumption of about 3,65 TWh in Baden Württemberg. Hence forestry alone can be seen as not very energy intensive. Figures from other sectors show that e.g. building and construction industry accounts for about 7,51 TWh and manufacturing industry for 106,6 TWh in Baden Württemberg in 2004 (FEDERAL STATISTICAL OFFICE, 2009). The whole forest wood chain involves parts of basically all branches mentioned above like forestry, building sector as well as manufacturing, etc.. Thus, one can assume the energy consumption is a mix out of all these branches. Therefore the energy consumption calculated by ToSIA can be seen as quite realistic figure.

The results of the indicator greenhouse gas emissions seem to be unreasonably high. The calculations for the FWCs show an about 60 times higher value than the emissions in tons of CO_2 equiv. for Baden Württemberg in total (FEDERAL STATISTICAL OFFICE OF BADEN WÜRTTEMBERG, 2005). Another good indicator for an incorrect value of the GHG emissions is the already mentioned energy consumption in the FWCs, which is much lower when compared with the total energy consumption of Baden Württemberg. Consequently the GHG emissions should be lower as well. Hence there are doubts if ToSIA results for GHG-emissions are correct.

The reasons for different and likely incorrect results could be of different origin. The data collection protocol should guide and give information on a common practise of reporting data (indicator data, conversion factors, etc.) to the database client (BERG, 2008). Due to the high amount of different data collectors inconsistent reporting of the data to the database could be one explanation for incorrect values calculated by ToSIA. Another reason could be that due to the high amount of data needed not all data is completely reported for every process or is not even applicable. Also there could have been copying errors while entering data in the database, which could have led to wrong calculations. Although tested previously in an earlier study by WERHAHN-MEES (2008) the ToSIA software is still under development, hence mistakes in the calculation algorithm could be a source of miscalculations as well.

The results calculated by ToSIA do not seem to be correct in every case, especially for the indicators wages and salaries, occupational accidents and greenhouse gas emissions. Nevertheless, since for all 3 alternatives the same dataset was used the values are at least comparable. Decreasing indicator values due to lower amount of harvested wood as a result of the set aside management practice are logical. So this trend seams to be plausible.

Due to the doubts with regard to data quality the presented results do not allow for an absolute interpretation. Nevertheless differences between the chain alternatives are mostly clear and show a consistent picture of impacts on the sustainability of those forest wood chains.

The check of plausibility clearly shows that individual indicator results should be seen as a hint/trend rather than as a very specific picture of reality. The used dataset and system boundaries limit the validity of the results in this special test case. Since the data collection for the Baden Württemberg general case study is still ongoing, simplifications and assumptions (see chapters 5 and 6.1.1) had to be made in order to do this study with limited amount of time. Data quality will always be a limiting factor for the validity of the results produced by ToSIA calculations.

7.3 Discussion of MCA results

Concerning the MCA results, the baseline alternative has the highest utility in the ranking of the timber industry deputy as well as in the ranking of the labour union. In both cases steep slope is ranked second and the 5 % set aside alternative shows the lowest utility among the 3 alternatives. The ranking of the environmental NGO illustrates an opposite picture. Here the 5 % set aside alternative is most preferable, the steep slope is intermediate and the baseline is the least preferable option.

The result is not surprising when looking at the indicator weightings (see 5.5, Tables 2,3, 4). Each stakeholder group allocates most of its 100 points to a certain group of indicators. The representative of the timber industry mostly favours indicators of the economic fraction, the representative of environmental NGO's focuses on environmental indicators and the weighting of the labour union shows highest weights on social indicators.

The performance of the baseline alternative is in most of the cases superior when it comes to economic and social indicators in addition with a high preference given to those indictors. Thus, being the best choice for the timber industry and labour union is a logic consequence. The 5 % set aside alternative becomes superior when it comes to ecological indicators and thus it is the best choice for the environmental NGO, since their preferences are clearly given to environmental indicators. The steep slope alternative performs mostly intermediate. Therefore it is usually second choice no matter which stakeholder preferences where used. The reason for this could be that the indicator values calculated for the steep slope FWC usually are positioned between the values of the baseline and the 5 % set aside FWC.

The overall picture shows that all FWC alternatives perform within a very small range, no matter if one uses the 50 % or the 10 % preference threshold. Thus, assuming the given conditions would represent the reality a compromise for one acceptable forest management alternative between the stakeholder groups could be possible. For instance, the steep slope alternative performance is never superior for any of the stakeholders but it would be the second best alternative for all stakeholder groups. Thus, by choosing this alternative, the interests and expectations of all stakeholder groups could be met somehow.

In this study just a look on values aggregated for the entire FWC was analyzed. The full aggregation of indicator values along the entire FWCs as well as the limited indicator set have to be seen critically. Going into more detail by looking at and evaluating the alternatives on the level of modules would probably draw a different picture and lead to different results for the alternative rankings since indicator weights could turn out to be not stable for the entire FWC (PROKOFIEVA ET AL., 2007). Furthermore, an extended set of decision criteria (larger set of indicators) could probably lead towards a more diverse structure in stakeholder preferences and thus to different solutions in the decision making process. Those facts should be taken into account in further studies. However, an extended set of criteria could also lead to problems since there are no specific guidelines to determine weights. Thus, it can be difficult to weigh for the decision maker if the number of criteria is too large (MACHARIS ET AL., 2003).

The sensitivity analysis by changing the weights of the indicators shows that the rankings are often rather insensitive to weight variations. However, for some indicators the rankings are more sensitive, for example “wages and salaries” and “productivity”. In those cases a rather small change in the weighting would result in a different overall preference of the alternative management options. The reason for such insensitivity is that there is only a limited set of indicators which additionally has strong redundancies, e.g. energy use / greenhouse gas emissions (PROKOFIEVA ET AL., 2007). The sensitivity analysis shows that the choice of the indicator or indicator set may be more important for the overall result then the actual indicator weighting by the stakeholders. Thus, a more diverse indicator set would most likely lead to a more diversified preference structure.

Usually, a multi-criteria analysis should be implemented in an open and interactive procedure. This means that stakeholders are given the opportunity to exchange ideas and perhaps revise their primary preferences. That was not the case in this study since the stakeholder preferences were defined by the author based on secondary information given by statements of the three different stakeholder groups (see 5.4). Hence, it has to be considered that those preferences might be biased by views of the author.

In addition to the limited set of indicators and the simplified assumptions of the test forest wood chains/ alternatives this fact limits the validity of the results.

Nevertheless, the study yielded valuable results with regard to the role of MCA within SIA of forest wood chains.

8. Conclusion

This study demonstrates a test application of the new developed methodology of ToSIA for sustainable impact assessment of Forest Wood chains and post evaluation with a Multi-Criteria Analysis. The proposed methodologies have the potential to provide a significant contribution to the process of environmental decision-making in context of the selection/ranking of different policies. Moreover, future results based on methodologies used in this study could support decision-making bodies such as e.g., the federal government of Baden Württemberg, in making decisions on how to carry out future policies in accordance with a broad range of stakeholder preferences. As well, the different stakeholders could use such results for more consistent lobbying activities when they have an increased information basis given by the combined ToSIA and MCA framework.

Nevertheless, the results of this study clearly show the current limits of ToSIA. To improve the quality of the ToSIA results in the future, data collection and processing needs to be further developed. If this further development can be achieved successfully ToSIA will have the potential to contribute to an increased sustainability and competiveness of the forest based sector.

With the integration of MCA in the ToSIA framework it is possible to make stakeholder preferences visible. Still, there is an obvious demand to improve the post-evaluation of the ToSIA results with MCA methodology. This will be done by using real data on stakeholder preferences. Thus, an interactive development with different stakeholder groups would most probably enrich the procedure. Allowing participants to try different judgements without commitment, to see the results and to foster new perspectives could lead to the generation of new ideas.

9. References

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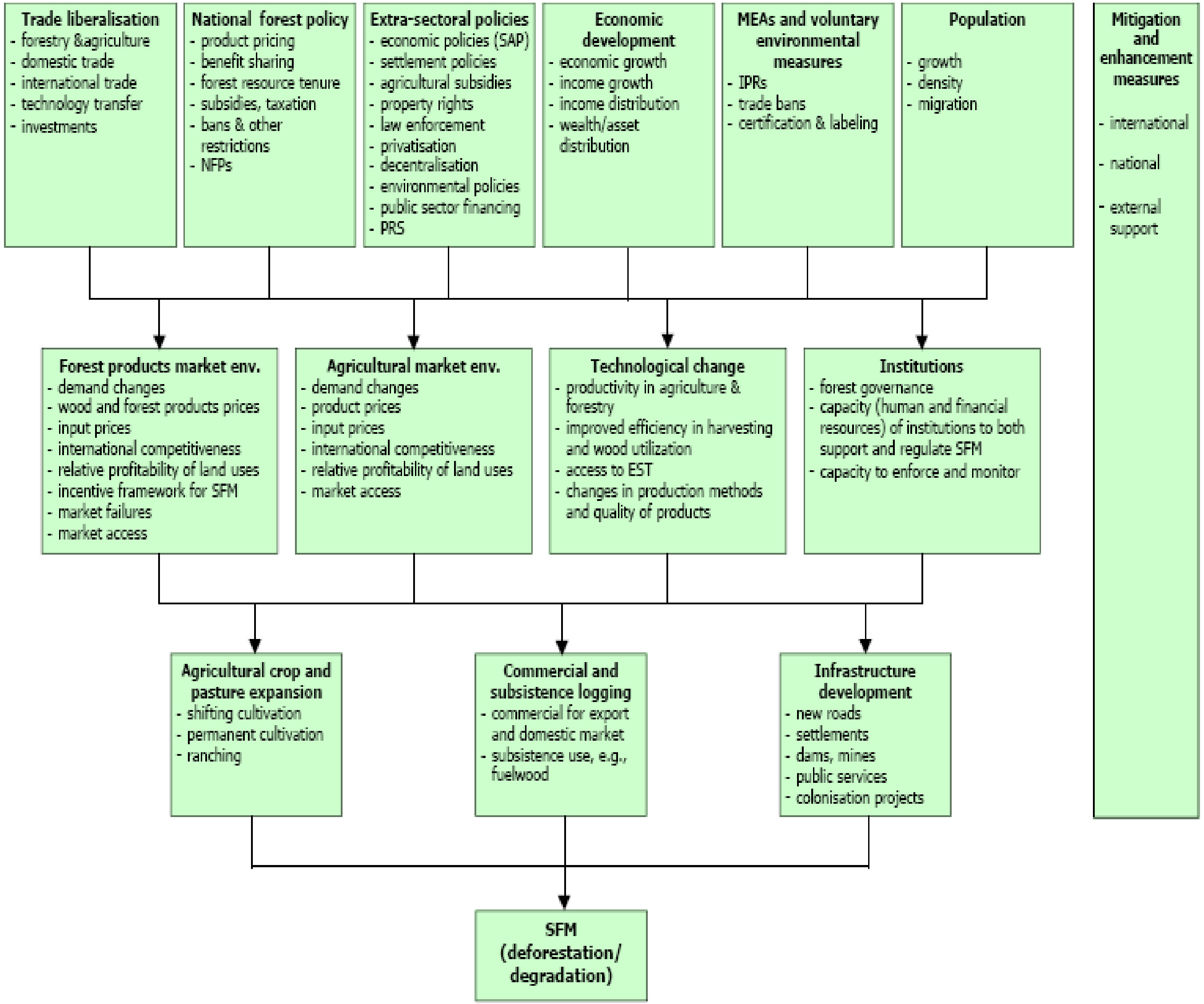
10. Annex



10.1 Conceptual framework for the SIA in Forestry

Source: KATILA AND SIMULA (2004)

10.2 Key figures of the German timber market (in 1000m³)

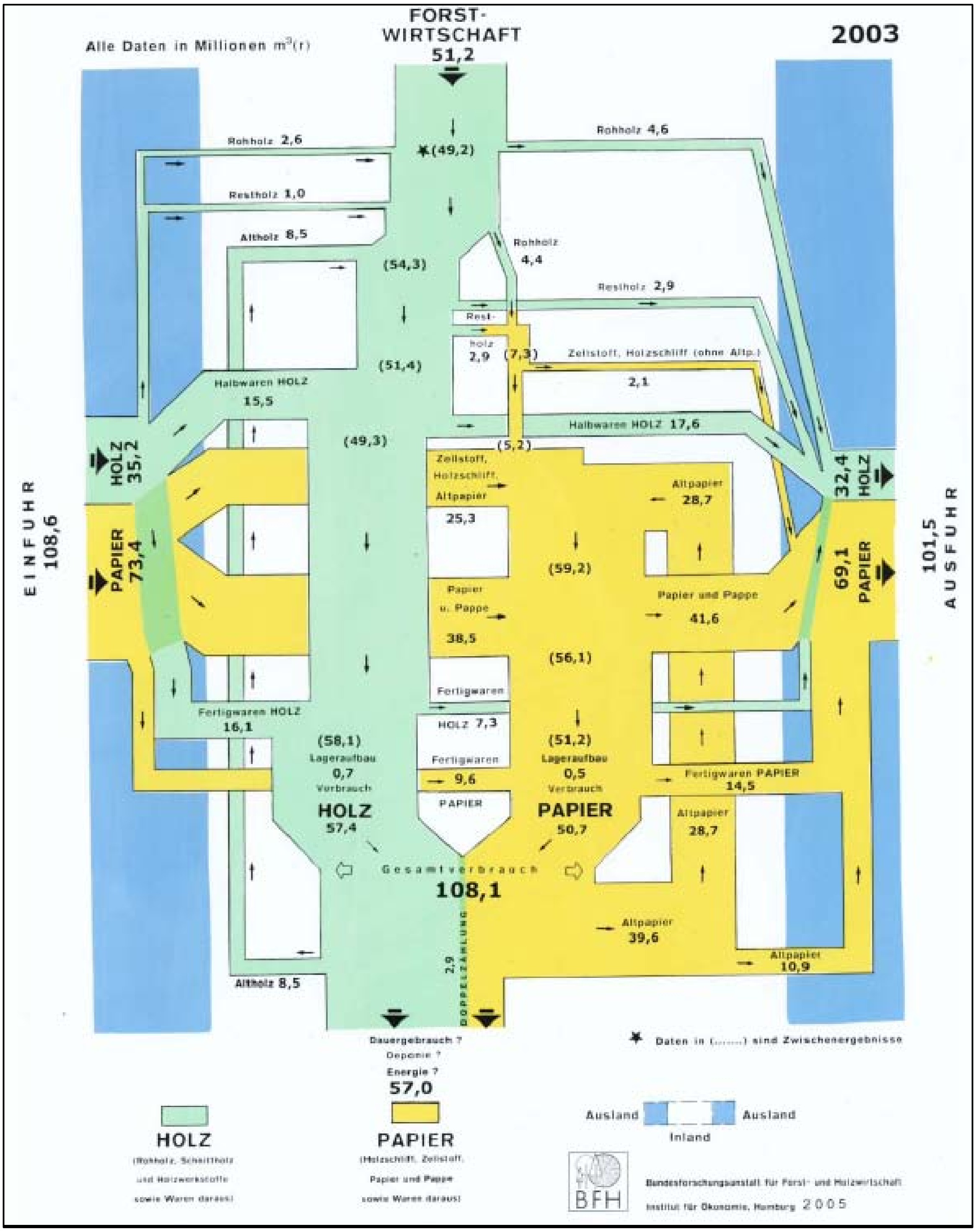
Source: BMELV, BLE, ZMP

	2005	2006	2007
Felling			
Trunk wood (softwood)	30.853	34.451	42.800
Trunk wood (hardwood)	3.569	3.830	3.998
Industrial timber (softwood)	15.079	15.035	20.812
Industrial timber (hardwood)	7.435	8.974	9.118
Produktion			
Sawn softwood	20.806	23.721	23.922
Sawn hardwood	1.126	1.177	1.147
Particle board	10.925	10.840	10.859
Paper and cardboard (1.000 t)	21.679	22.956	23.172
External trade			
Import of softwood	2.707	3.343	3.607
Export of softwood	5.197	5.867	5.310
Import of sawn softwood	4.270	4.863	3.692
Export of sawn softwood	6.471	8.280	8.710
Import of hardwood	284	326	352
Export of hardwood	1.644	1.690	1.350
Import of sawn hardwood	586	592	516
Export of sawn hardwood	750	804	728

Note: sawn softwood including planed wood; figures for 2007 preliminary

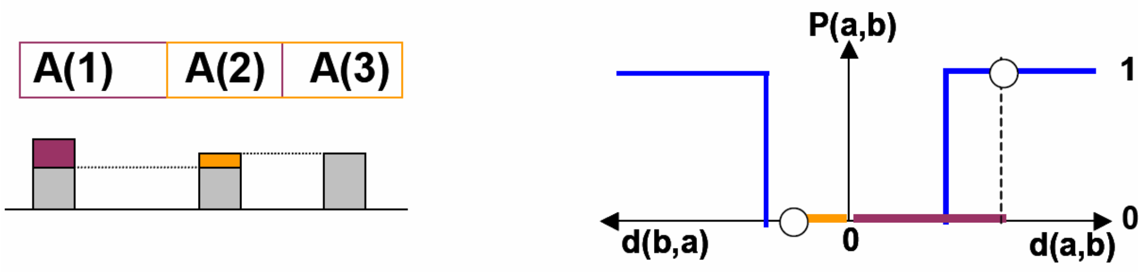
10.3 Annual flow of timber and wood products in Germany 2003(in million m³)

Source: DIETER (2005)



10.4 Example of pairwise comparison in PROMETHEE

Source: PROKOFIEVA ET AL., 2007



In the figure above the purple deviation between A(1) and A(2) exceeds the indifference threshold and leads to strict preference for A(1) (P=1 in a U-shape), whereas the orange deviation between A(2) and A(3) is lower stating indifference (P=0) on the preference scale.

10.5 List of processes used

In this list all indicators used for this study are listed. Indicators marked grey were deleted for different reasons, like not relevant for the study or they are links to loops which lead to material accumulation in the chain.

ProcessName	**Reason for deletion**
Spruce regeneration	
Development of young spruce	
Development of spruce in medium phase	
Adult spruce development	
Beech regeneration	
Development of young beach	
Development of beech in medium phase	
Development of adult beech	
Harvesting fully mechanised (Spruce, DBH <= 35 cm; Slope <= 30 %)	
Harvesting motormanual (Spruce, DBH > 35 cm; Slope <= 30 %)	
Harvesting motormanual (Spruce, DBH <= 35 cm, Slope 30 - 60%)	
Harvesting motormanual (Spruce, DBH > 35 cm; Slope 30 - 60%)	
Harvesting motormanual (Spruce, Slope > 60%)	
Transport of spruce long logs	
Transport of spruce short logs	
Transport of beech pulpwood	
Transport of LDT	
Mill gate: roundwood automated measurements and sorting	
Mill gate: roundwood sorting and transporting car	
Particle board mill gate (paper mill type)	
Paper mill gate	
Harvesting motormanual (Beech, Slope > 60 %)	
Harvesting motarmanual (Beech, DBH > 35 cm; Slope <= 30 %)	
Harvesting motormanual (Beech, DBH <= 35 cm; Slope 30 - 60 %)	
Harvesting motormanual (Beech, DBH > 35 cm; Slope 30 - 60 %)	
Harvesting fully mechanized (Beech, DBH <= 35 cm; Slope <= 30 %)	
Transport of beech short logs	
Transport of beech long logs	
Transport of veneer logs	
Transport of beech fire wood logs	

Transport of imported kraft pulp	
Forwarding with forwarder (Spruce, DBH <= 35 cm; Slope <= 30 %)	
Skidding (Spruce, DBH > 35 cm, Slope 30 - 60%)	
Forwarding with cable crane + skidding (Spruce, Slope > 60%)	
Transport of spruce pulpwood	
Forwarding with forwarder (Beech, DBH <= 35 cm; Slope <= 30 %)	
Forwarding with cable crane + skidding (Beech, Slope > 60 %)	
Skidding (Beech, DBH > 35 cm; Slope <= 30 %)	
Skidding (Beech, DBH <= 35 cm; Slope 30 - 60 %)	
Skidding (Beech, DBH > 35 cm; Slope 30 - 60 %)	
Precommercial operations (Spruce)	
Precommercial operations (Beech)	
Harvesting motormanual (Spruce, DBH <= 35 cm, Slope <= 30%)	
Skidding (Spruce, DBH <= 35 cm; Slope <= 30%)	
Transport of spruce fire wood logs	
Sawing and Splitting of fire wood logs	
Transport of imported spruce short logs	
Transport of imported beech short logs	
Transport of imported beech long logs	
Transport of imported spruce pulpwood	
Transport of imported beech pulpwood	
Transport of exported spruce pulpwood	
Transport of exported beech long logs	
Transport of exported beech pulpwood	
Transport of exported beech short logs	
Transport of wood residues	
Production of wood chips from the forest	not relevant
Transport of spruce wood chips	not relevant
Transport of beech wood chips	not relevant
Transport of wood chips from short term plantation	
Softwood saw mill - L - >150,000m3	
Softwood saw mill - M - 50,000 - 150,000 m3	
Softwood saw mill - S - <50,000m3	
Hardwood saw mill - S - 25000m3	
Particle board mill	
Transport of softwood sawn timber	
Transport of hardwood sawn timber	
Transport of chips	not relevant
Transport of saw dust	loop linkage
Transport of particle board	
Pellet mill	not relevant
Industrial production of construction elements	
Manufacturing of construction elements	
Industrial production of joinery	
Manufacturing of joinery	
Industrial production of furniture	
Manufacturing of furniture	
Cartonboard Model Mill	
Integrated Newsprint Model Mill	
Integrated Magazine Paper Mill	
Transport of imported OSB board	not relevant
Transport of pellets to small scale use	not relevant
Transport of carton board materials	
Production of carton board boxes	
Transport of carton board boxes to industry user	
Filling of carton board boxes	
Transport of filled carton board boxes	
Use of carton board boxes	

Separate collection and sorting of carton board boxes	
Transport of collected used paper	loop linkage
Carton board boxes as packaging material at industry user	
Transport of newsprint	
Printing of newspapers	
Transport of newspapers to store	
Distribution of newspapers to home/office	
Reading / information use	
Separate collection and sorting of newsprint	
Transport of magazine paper	
Printing of magazines	
Transport of magazines to store	
Distribution of magazines to home/office	
Transport of exported magazines	
Transport of exported magazine paper	
Reading /information use (magazines)	
Separate collection and sorting of the magazine paper	
Transport of imported fine paper (woodfree)	
Transport of fine paper to user	
Printing of books	
Reading /information use	
Printing - use	
Separate collectioon and sorting of fine paper	
Transport of imported books	
Transport of imported corrugated board materials	
Production of corrugated boxes	
Transport of corrugated boxes to industry user	
Filling of corrugated boxes	
Transport of filled corrugated boxes to retail	
Transport of filled corrugated boxes to industry user	
Corrugated boxes as packaging material at retail	
Corrugated boxes as packaging material at industry	
Separate collection and sorting of corrugated board	
Transport of construction elements	
House construction	
Use of house	
Demolition of house	
Transport of furniture to retail	
Use of furniture	
Demolition of furniture	
Transport of used wood	
Transport of paper waste	loop linkage
Wood-based combined heat and power production (outside forest industry)	
Wood-based power production (outside forestry sector)	
Transport of ash to waste management	
Transport of beech fire wood to small scale use	
Small scale use for heating	
Municipal solid waste incineration	
Transport of imported construction elements	
Transport of imported newsprint	
Transport of exported carton board materials	
Home scale use for heating	
Transport of pellets to home scale use	not relevant
Transport of spruce fire wood to home scale use	
Transport of beech fire wood to home scale use	
Transport of furniture from generalist to consumer	
Distribution of furniture - specialist	
Distribution of furniture - generalist	

Transport of joinery to specialist distributor	
Distribution of joinery - specialist	
Transport of imported joinery	
Transport of spruce fire wood to small scale use	

10.6 Indicator sets of the EFORWOOD project

10.6.1 Overview of selected main indicators for demonstration of EFORWOOD SIA approach

Indicator	**BWB case study**		**Legend: Selected or not?**
1. Gross value added			Demonstration Indicators
2. Production cost			
3 Trade balance			Not selected for demonstration
4. Resource use	From ToSIA		
5. forest sector enterprise structure			
6. Investment and R&D			
7. Total production	From ToSIA		
8. Productivity	From ToSIA		
9. Innovation			
10. Employment			
11. Wages and salaries			
12. Occupational Safety and Health			
13. Education and Training			
14. Corporate social responsibility			
15. Quality of Employment			
16. Provision of Public Forest Services			
17. Consumer Behaviour and Attitudes			
18. Energy generation and Use			
19. Greenhouse Gas Emissions and Carbon Stock			
20. Transport			
21. Water use			
22. Forest Resources			
23. Soil Condition			
24. Emissions to Water and Air			
25 Biodiversity			
26. Forest damage			
27. Generation of Waste			

10.6.2 Overview of selected sub-indicators for demonstration of EFORWOOD SIA approach

Indicator	**BWB case study**		**Legend: Selected or not?**
1.1 - Gross value added (at factor cost) *			Demonstration Indicators
2.1 - Production cost			
2.1.1 - Average cost - raw materials from FWC			Not selected for demonstration
2.1.2 - Average cost - raw materials from outside FWC			
2.1.3 - Average cost - labour costs			
2.1.4 - Average cost - energy costs			
2.1.5 - Other productive costs			
2.1.6 - Non-productive costs			
2.2 - Share of cost of wood-based materials			
3.1.1 - Imports of wood and products derived from wood - Volume			
3.1.2 - Imports of wood and products derived from wood - Value			
3.1.3 - Imports of wood and products derived from wood - Share of imports in total volume consumed			
3.2.1 - Exports of wood and products derived from wood - Volume			
3.2.2 - Exports of wood and products derived from wood - Value			
3.2.3 - Exports of wood and products derived from wood - Share of exports in total volume consumed			
3.3.1 - Net trade in wood and products derived from wood - Volume			
3.3.2 - Net trade in wood and products derived from wood - Value			
4.1.1 Wood-based material in total (from ToSIA)	From ToSIA		
4.1.2 - Other renewable materials in total			
4.1.2.1 - Other renewable materials - virgin origin			
4.1.2.2 - Other renewable materials - recycled origin			
4.2 - Volume of non-renewable materials in total			
4.2.1 - Volume of non-renewable materials - virgin origin			
4.2.2 - Volume of non-renewable materials - recycled origin			
5.1 - Number of forest holdings and forest-based enterprises in total			
5.1.1 - Number of forest holdings and forest-based enterprises - public			
5.1.2 - Number of forest holdings and forest-based enterprises - private			

5.2 - Average forest holding size		
5.2.1 - Average forest holding size - public		
5.2.2 - Average forest holding size - private		
5.3.1 - Micro and small forest based enterprise (0-49 employees),		
5.3.2 - Medium sized forest based enterpise (50-249 employees),		
5.3.3 - Large forest based enterpise (>250 employees)		
6.1 - Investment (gross fixed capital formation) in total		
6.1.1 - machinery and equipment		
6.1.2 - vehicles		
6.1.3 - the value of land improvements		
6.1.4 - buildings		
6.2 - Research & Development expenditure in total		
6.2.1 - Research & Development - private expenditure		
6.2.2 - Research & Development - public expenditure		
7. Total production	From ToSIA	
8. Productivity	From ToSIA	
9.1 - Share of forest-based enterprises with new or significantly improved goods or services (merged categories)		
9.2 - Share of forest-based enterprises with new or significantly improved production process, distribution method, or support activity for goods o services (merged categories)		
9.3 - Share of turnover from new or significantly improved products as a share of total turnover		
10.1 - Employment - absolute number		
10.2.1 - Employment male - % of total		
10.2.2 - Employment female - % of total		
10.3.1 - Employment on enterprise sites located in rural areas		
10.3.2 - Employment on enterprise sites located in urban areas		
11.1 - Wages and salaries - total		
11.1.1 - Wages and salaries male		
11.1.2 - Wages and salaries female		

11.2.1 - Average wages & salaries per employee relative to country average	From ToSIA		
11.2.2 - Average wages & salaries per employee weighted by purchasing power parity	From ToSIA		
12.1 - Occupational accidents - total			
12.1.1 - Occupational accidents (non-fatal) - absolute numbers			
12.1.2 - Occupational accidents (fatal) - absolute numbers			
12.2 - Occupational diseases - frequency of cases in % per 1000 employees			
13.1.1 - Highest level of education of employees up to lower secondary education			
13.1.2 - Highest level of education of employees - post secondary and tertiary education			
13.2 - Training time per emploee			
14.1. - Forest holdings and forest-based enterprises with third party certified management			
14.1.1 - Forest holdings and forest-based enterprises with third party certified management - Forest certification schemes			
14.1.2 - Forest holdings and forest-based enterprises with third party certified management - Environmental management system			
14.2. - Share of wood sourced from third party certified sustainable production			
15.1 - Persons employed part-time and employees with a contract of limited duration (annual average) in total			
15.1.1 - Persons employed part-time and employees with a contract of limited duration (annual average) - male			
15.1.2 - Persons employed part-time and employees with a contract of limited duration (annual average) - female			
15.2 - Self-employed persons			
16.1.1 Forest area designated for recreational use			
16.1.2 Forest area designated for protective services			
16.2. Number of visits to forests			
17.1. - Apparent consumption of wood per capita			
17.2.1 - Share of population perceiving forest area			
17.2.2 - Share of population perceiving forest biodiversity			
17.2.3 - Share of population perceiving forest health as stable or increasing			

17.3.1 - Share of population perceiving forest industry to be environmentally friendly		
17.3.2 - Share of population perceiving forest industry to be an attractive employer		
18.1 - On-site energy generation from renewables		
18.1.1.1 - On-site heat generation from renewables - residues from process - inputs		
18.1.1.2 - On-site heat generation from renewables - other wood biomass		
18.1.1.3 - On-site heat generation from renewables - non-wood based renewable heat		
18.1.2.1 - On-site electicity generation from renewables - residues from process		
18.1.2.2 - On-site electicity generation from renewables - other wood biomass		
18.1.2.3 - On-site electicity generation from renewables - non-wood based renewable electicity		
18.1.3.1 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - residues from process		
18.1.3.2 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - other wood biomass		
18.1.3.3 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - Non-wood based renewable fuel production		
18.2 - Energy use		
18.2.1.1 - Energy use - Heat from renewable sources		
18.2.1.2 - Energy use - Heat from fossil sources		
18.2.2.1 - Energy use - Direct fuel use - renewable fuel		
18.2.2.2 - Energy use - Direct fuel use - fossil fuel		
18.2.3.1 - Electricity use - from 100% renewable sources		
18.2.3.2 - Electricity use - from 100% fossil sources		
18.2.3.3 - Electricity use - from the grid		
18.3 Energy self sufficiency	From ToSIA	
19.1 - Greenhouse gas emissions		
19.1.1. Greenhouse gas emissions from machinery		
19.1.2. Greenhouse gas emissions from wood combustion		

19.2 - Carbon stock		
19.2.1 - Carbon stock in woody living biomass (above ground)		
19.2.2 - Carbon stock in woody living biomass (below ground)		
19.2.3 - Carbon stock in woody dead wood		
19.2.4 - Carbon stock in soils of forest		
19.2.5 - Carbon stock in wood products	From ToSIA	
20.1.1.1 - Distance by mode - road transport - loaded		
20.1.1.2 - Distance by mode - rail transport - loaded		
20.1.1.3 - Distance by mode - water transport (inland waterways) - loaded		
20.1.1.4 - Distance by mode - water transport (maritime - sea-going ships) - loaded		
20.1.1.5 - Distance by mode - air transport - loaded		
20.1.2.1 - Distance by mode - road transport - unloaded		
20.2.1.1 - Freight volume - road transport - loaded capacity		
20.2.1.2 - Freight volume - rail transport - loaded capacity		
20.2.1.3 - Freight volume - water transport (inland waterways) - loaded capacity		
20.2.1.4 - Freight volume - water transport (maritime - sea-going ships) - loaded capacity		
20.2.1.5 - Freight volume - air transport - loaded capacity		
Ton km	From ToSIA	
21.1 - Water use (freshwater intake by industry) [relevant for industry]		
21.2 - Water use (of the forest ecosystem)		
21.2.1 - Water use (of the forest ecosystem) - Evapotranspiration from the system		
21.2.2 - Water use (of the forest ecosystem) - Groundwater recharge		
22.1 - Forest and Other Wooded Land Area		
22.2.1 Growing stock classified by forest types		
22.2.2 Growing stock on forests available for wood supply		
22.4.1 - Balance of increments and fellings: Net annual increment		
22.4. Balance of increments and fellings	From ToSIA	

22.5.1.1 - Age distribution: number of classes		
22.5.1.2 - Age distribution: coefficient of variation		
22.5.2.1 - Diameter distribution: number of classes		
22.5.2.2 - Diameter distribution: coefficient of variation		
23.1 - Chemical soil properties related to soil acidity and eutrophication (pH, CEC, C/N, organic C, base saturation), classified by main soil types		
23.1.1 - pH		
23.1.2 - CEC		
23.1.3 - C/N ratio		
23.1.4 - organic C		
23.1.5 - base saturation		
23.1.6 - site nutrient budget averaged over total rotation period (N, P, K, Ca, Mg)		
23.2 - Soil compaction from machine operations		
24.1.1 - Water pollution - organic substances (biochemical oxygen demand)		
24.1.2 - Water pollution - nutrients (nitrogen, phosphorus) as Nitrogen or TKN (Total KJELDAHL Nitrogen)		
24.2.1 - Non-greenhouse gas emissions into air - CO		
24.2.2 - Non-greenhouse gas emissions into air - NOx		
24.2.3 - Non-greenhouse gas emissions into air - SO2		
24.2.4 - Non-greenhouse gas emissions into air - NMVOC		
25 Biodiversity		
25.1.1 Area of forest & OWL by number of trees occurring		
25.1.1 Area of forest & OWL by forest type		
25.2.1 Volume of standing deadwood		
25.2.1 Volume of lying deadwood		
25.3. Protection status of area of forest and other wooded land		
26.1.1 - Area with damage classified by damaging agent - biotic		
26.1.1.1 - Area with damage classified by damaging agent - biotic - insects and diseases		
26.1.1.2 - Area with damage classified by damaging agent - biotic - wildlife and grazing		
26.1.2 - Area with damage classified by damaging agent - abiotic		
26.1.2.1 - Area with damage classified by damaging agent - abiotic - fire		
26.1.2.2 - Area with damage classified by damaging agent - abiotic - storm, wind		
26.1.2.3 - Area with damage classified by damaging agent - abiotic - snow, drought, mudflow, avalanche and other identifiable abiotic factors		
26.1.3 - Area with damage classified by damaging agent - human induced		
26.2 - Damage-induced wood supply		
27.1 - Generation of waste in total		
27.1.1 - Not classified as hazardous waste		

27.1.2 - Hazardous waste			
27.2.1 - Waste to material recycling			
27.2.2 - Waste to incineration			
27.2.3 - Waste to landfill			

10.7 Information to be collected for the calculation of the carbon flow over the M2/M3 boundary

Source: BERG, 2008

M2 collects:

Collected data	Unit	Symbol
Area of the managed forest in the process in question	ha a^{-1}	A
Total standing stem wood (conifers) and total wood (broadleaved) volume (over bark) from ground to tip of tree marked to be cut. Volume is reported as solid volume[a]. That is all volume above a certain minimum diameter threshold, e.g. above 7 cm in Baden-Württemberg (V_7).	m^3 ob ha^{-1}	V_S
Volume of tree tops and branches (additional to volumes specified in V_s).	m^3 ob ha^{-1}	V_{tb}

[a] This volume is not used by ToSIA. M3 uses it while calculating and reporting V_i volumes below.

M3 collects:

Collected data	Unit	Symbol
Volume of harvested wood assortments (saw logs, pulp wood, etc.)	m^3 a^{-1}	V_i
Volume of harvest residues[b]	m^3 a^{-1}	V_{hr}
Volume of harvested roots (stump)	m^3 a^{-1}	V_{st}
Conversion factors[c] from m^3 to ton of carbon for all products	tons of carbon m^{-3}	cf

[b] Harvest residues include branches, tops and stumps, unless stumps are extracted and reported as a separate output product. So, if stumps are not harvested: $V_{hr} = V_{tb} + V_{st}$. If stumps are extracted: $V_{hr} = V_{tb}$.

[c] N.B. As M3 uses volumes under bark, the reported conversion factors should be from m^3 (under bark) to ton of carbon including bark.