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INTERNATIONAL TROPICAL TIMBER ORGANIZATION

PRE-PROJECT REPORT

REVIEW OF INFORMATION ON LIFE CYCLE ANALYSIS OF TROPICAL TIMBER PRODUCTS

[PPD 48/02 (M)]

PREPARED FOR ITTO

BY

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Executive Summary

A review was conducted on Life Cycle Assessment (LCA) as applied to temperate and, in particular, tropical timbers. LCA is a tool for analysis of the environmental impact (emissions to air, water or land and resource consumptions) deriving from the lifecycle of products and takes account of activities that go into extracting, processing, transporting, using and disposing of a material/product. It should be appreciated at the outset that LCA, of itself, cannot certify that a particular area of forest is being managed on a good or sustainable basis. There are better, more specific tools and guidelines available for this (see Eba'a Atyi and Simula 2002). Instead, LCA is a systems analysis tool to present the impacts on the general environment resulting from, in this case, wood and wood products. It is equally applicable to any other product or process and, as such, has the capacity to encompass comparative assessments sometimes between very different products that meet the same required function (such as the wood, PVC or Aluminium supporting the glass in a window frame).

The specific objectives of the review were:

- to present a brief overview of the LCA method and to highlight issues of particular relevance to timber, and tropical timber products in particular
- to conduct a search of the literature and LCA reports for information concerning tropical timber species
- to examine the available LCA information on tropical species in relation to that available for temperate species and other materials.
- to present evidence on the advantages and disadvantages of tropical timber over other materials, such as plastic, steel, concrete and temperate timber as documented in LCA studies
- to identify any areas for action to maintain or enhance the position of tropical timbers in the LCA area.

Many reports are available that have included an LCA approach to environmental impacts and related issues of timber and forest products. These were divided into those that focus on non-tropical and tropical timbers. Some of the studies examined were complete or partial life cycle assessments whilst others had more specific objectives and a narrower scope. In order to identify relevant studies, a full literature search was conducted using library and internet facilities and direct contact made with practitioners and researchers in the field between December 2002 and June 2003. In total, 18 relevant reports and studies were included in the review. Where a report included both tropical and non-tropical timbers it was dealt with under the tropical timber review.

The evidence accumulating from LCAs on temperate wood and wood products indicates that they have environmental profiles that are more favourable than other materials (see *inter alia* Hillier and Murphy, 2000; Frühwald et al., 2003; Petersen and Solberg, 2002; Taylor and van Langenberg, 2003). In the context of the present review it was considered important to evaluate how well this type of finding for temperate wood products applied to tropical timbers.

Very few LCA studies on tropical timbers have been conducted to date. Furthermore, only one (VROM, 2002) has been conducted in full accordance with ISO 14040 series of standards. In this, the use of acetylated EU pine timber was compared with the alternative, naturally durable timbers Larch from Siberia and Azobe from West Africa for sheet piling in an urban waterway in the Netherlands. The LCA results showed that the environmental profile of Azobe compares very favourably with that for the softwood species for this product. It was also clear from the LCA that there are higher harvesting and transport requirements and emissions for the tropical wood and

that this is likely to be a general issue faced by tropical timbers in LCA. This factor was investigated further in the review of LCA database information which also showed substantially higher energy consumption to harvest and deliver tropical wood to market in the EU than for 'local' softwoods.

There was found to be a potential for inaccuracy in LCA studies on tropical timbers from attempts to include a Land Use category in the analysis. It is suggested that definitive data on tropical forestry systems need to be made available for land use calculation methods in LCA and these need exemplifying through best practice examples for its use and interpretation. The situation for Land Use impact calculation is also difficult for temperate species but they do not face the same extent of negative outcome. The information and activities in Forest Certification in the tropics could make a significant contribution to addressing this issue and offer scope for synergy and complementarities with LCA studies.

The following conclusions and recommendations can be made:

- In general terms, LCAs show timber-based products to have favourable environmental profiles in comparison with alternative materials.
- The great majority of the LCAs conducted to date on timber products are based on temperate timbers – there are very few available LCAs on tropical timbers. Without action on the part of the tropical timber interests this disparity is likely to increase
- Transparent and complete (to the ISO 14040 standard) LCAs are needed to provide underpinning information for communication of the environmental credentials of tropical timber products in comparison with alternative materials ('green' claims) - these demand best-practice in LCA and high quality data.
- If capacity is not built in tropical countries to develop *local* familiarity and competence in LCA techniques tropical timbers risk being inadequately represented in the market or, even worse, 'external' LCA studies may be done on the basis of inadequate data – especially for harvesting systems and Land Use impacts.

LCA information has a key role to play in supporting the overall sustainability assessment of tropical timbers but a co-ordinated effort is needed to:

1) stimulate further LCA work and training of direct relevance to tropical forests and products, and
2) establish a recognised centre where LCA information for tropical forests and products is collected and made available to LCA practitioners and the wider public, in a web-based form. It is suggested that ITTO could act as a centre for such an effort.

LCA is presently gaining in global significance (see UNEP http://www.uneptie.org/pc /sustain/lcinitiative/). This is an exciting development and it is time for the tropical timber interests to take up the opportunity it presents.

Acknowledgements

The author is grateful to Bill Hillier for much useful discussion on LCA and forestry and forest products during the preparing this report, particularly on the issue of land use. I am also grateful to the many LCA practitioners and interested individuals in the forestry and forest products field who have assisted in completing this review by providing comment, information and stimulation.

GLOSSARY OF TERMS USED IN LCA

By-products: term used as a working definition for economic allocation - re income from the sale of these products is not a significant factor in the profitability of the process, except in offsetting or avoiding waste disposal costs.

Carbon dioxide (CO_2): an atmospheric gas uniformly distributed over the earth's surface at a concentration of about 0.033% (or 330 ppm). CO_2 is released into the atmosphere upon the combustion of carbon-containing fossil fuels such as oil, natural gas, and coal, and it is considered a greenhouse gas.

Characterisation: the second element within the impact assessment phase of an LCA study, in which analysis/quantification, and aggregation of the impacts within the selected impact categories takes place.

Classification: the first element within the impact assessment phase of an LCA study, which attributes the environmental interventions from the life cycle inventory phase, to a number of selected impact categories.

Co-products: term used as a working definition for economic allocation - re the sale of these products is a significant factor in the profitability of the process.

Cradle-to-gate analysis: an LCA study that covers the potential impacts of a product life cycle from raw material acquisition to a defined stage of production or use (often the factory gate).

Cradle-to-grave analysis: an LCA study that covers the potential impacts of a product life cycle from raw material acquisition through production, use and final disposal (or recycling).

Data quality: nature or characteristics of collected or integrated data.

Eco-profile: a general term used to describe the overall environmental impact of a product system over its entire life cycle.

Environment: Entire surroundings and conditions in which individuals, populations and organisations operate and interact. Surroundings include air, water, land, natural resources, flora, fauna and humans, extending from within an organisation's location to the global system.

Environmental aspect: Element of an organisation's activities, products or services which interact with the environment.

Environmental profile (impact score profile): list of impact scores for all impact categories. The term may also be used more generally to describe the overall environmental impact of a product system over its entire life cycle.

Evaluation: the second step within the interpretation stage of a LCA study, which includes a completeness and consistency check.

Externality: a 'hidden' cost, often borne at the expense of the environment.

Feedstocks: raw materials from which other materials are derived.

Fossil reserves: the compressed, fossilised remains of organic matter including crude oil, coal and natural gas, used for their high calorific values in the production of fuels, and also for chemicals and raw materials.

Functional unit: quantified performance of a product system for use as a reference unit in an LCA study.

Global warming potential (GWP): the quantifiable capacity of a greenhouse gas to trap heat within the earth's atmosphere, potentially leading to global warming.

Global warming: rise in the surface temperature of the earth due to the build up of greenhouse gases within the earth's atmosphere (primarily carbon dioxide, methane, and nitrous oxide), much of which is emitted as a result of human activity. Although the heat-trapping property of these gasses is undisputed, uncertainties exist about exactly how the earth's climate responds to this.

Goal and scope definition: activity that initiates an LCA, defining its purpose, boundaries, functional unit of study, procedures and limitations.

Greenhouse gas: primarily carbon dioxide, methane, and nitrous oxide, which trap heat within the earth's atmosphere and are said to be responsible for global warming.

Impact assessment (life cycle impact assessment - LCIA): the third phase of an LCA study aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system.

Impact category: class, representing environmental issues of concern into which inventory results may be assigned.

Impact score: contribution of a product system to one impact category.

Impact: the consequences for the environment attributable to the input and output streams of a product system.

Incineration: a thermal treatment process involving the combustion of waste in a controlled way in order to transform it into less hazardous, less bulky and more inert constituents. Incineration may be used to dispose of a wide range of waste streams including municipal solid waste and may be used to recover energy from the waste.

Indicator: a simplification and distillation of complex information intended as a summary description of conditions or trends to assist in decision-making.

Input: material or energy which enters a unit process through the system boundary, including raw materials, products, water, electricity, etc.

Interested party: individual or group concerned with or affected by the environmental performance of a product system, or by the results of the LCA.

Interpretation: the fourth phase of an LCA study, in which the findings of the inventory analysis and the impact assessment are combined in line with the defined goal and scope, in order to reach conclusions and recommendations.

Inventory analysis: the second phase of an LCA study, involving the compilation and quantification of inputs and outputs for a given product system throughout its life cycle.

Life cycle: consecutive and interlinked stages of a product system, from raw material acquisition through to final disposal.

Life cycle assessment (LCA): compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

Life cycle inventory (LCI): the inventory data on the inputs and outputs for the given product system for its life cycle.

Methane (CH_4): a colourless, odourless gas derived from anaerobic microbial decomposition of organic matter, with a wide distribution in nature. It has a greenhouse gas effect 23 times that of CO_2 on a mass basis.

MJ: mega joules – a unit of measurement for a quantity of energy equivalent to 1 x 10^6 Joules

Output: material or energy which leaves a unit process through the system boundary, including products, emissions, wastes, etc.

Product system: collection of materially and energetically connected unit processes existing within the system boundaries, which perform one or more defined functions.

Sensitivity analysis: a method of data quality assessment - an optional element in the impact assessment phase of an LCA study - which estimates the effects on the outcome of a study on the chosen methods, data, and the uncertainty therein.

System boundary: interface between a product system and the environment, or other product systems, within which the product system is contained.

Valuation/weighting: the final element in the impact assessment phase of an LCA study, in which the results of the characterisation/normalisation element are weighted against each other in order to make the impact information more "decision-friendly".

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1. Introduction

1.1 Context

At its Thirty-first Session in May 2002, the ITTO Committee on Economic Information and Market Intelligence approved a pre-project (PPD 48/02 (M)) aimed at undertaking a review of information on life cycle analysis of tropical timber products. Consideration of LCA is included in the ITTO Work Programme for 2002 as well as in the ITTO Yokohama Action Plan (2002-2006). Under the ITTO Yokohama Action Plan, in the field of Economic Information and Market Intelligence, Action 4 of Goal 2 provides for the Organization to "examine the role of LCA as a potential tool for assisting the competitiveness of tropical timber in the marketplace".

LCA is a tool for analysis of the environmental impact (emissions to air, water or land) deriving from the lifecycle of products and takes account of activities that go into extracting, processing, transporting, using and disposing of a material/product. LCA differs from other methods of evaluating environmental impacts in its wide-ranging approach and because it is based on quantifiable data. On the basis of this, it is seen as an objective way to identify environmental impacts and make useful comparisons among products; assist policy formulation aimed at minimising the impact on the environment and giving consumers the opportunity to compare the environmental and ecological credentials of a range of products; direct a marketing strategy and improve the environmental image of a product, material or company; and inform business decisions to review and improve the environmental performance of the product or material themselves.

1.2 Aims & Objectives

The aim of this review is to summarise the current state-of-the-art in the LCA of forestry and forest products, with special reference to tropical forests and forest products. LCA is becoming well established in the industrial and commercial worlds and a number of LCA studies and LCA information on timber products are available in the literature and in databases. Whilst this is to be commended, there is concern that LCA information on tropical timbers and timber products may not be adequately represented in these sources. This review will examine this concern and summarise the current position for the tropical species.

The specific objectives of the review are:

- to present a brief overview of the LCA method and to highlight issues of particular relevance to timber, and tropical timbers products in particular
- to conduct a search of the literature and LCA reports for information concerning tropical timber species
- to examine the available LCA information on tropical species in relation to that available for temperate species and other materials
- Present evidence on the advantages and disadvantages of tropical timber over other materials, such as plastic, steel, concrete and temperate timber as documented in LCA studies
- to identify any areas for action to maintain or enhance the position of tropical timbers in the LCA area.

1.3 Structure of the Review

The review has been undertaken by web-based literature search, e-mail circulars to numerous organisations and individuals, individual contact with LCA practitioners and database searching. This activity has taken place over several months during 2003 and there has been opportunity to re-visit a number of search sites and organisations in an attempt to acquire further or updated information.

The review is based around an appraisal of existing reports and publications concerned with LCAs on temperate and tropical timber products. Certain aspects of the methodology of LCA are also presented in order to inform the reader of potential pros and cons in the method and to raise awareness of the challenges that will have to be overcome in order to develop LCA information for tropical forest products.

In addition to a bibliography of cited references, primarily web-based sources of LCA information and expertise are included for reference.

2. Timber and Wood Products in an LCA context

Timber products present a number of special challenges when undertaking a Life Cycle Assessment. The development of LCA methodology was dominated by applications to industrial materials and products, and to consumables such as packaging, detergents, nappies, etc. This led to a number of difficulties in the application of a standard LCA to forest products.

The long time-scale of production in forests compared with industrial systems, the extensive rather than intensive nature of wood production, the role of 'non-market' goods like ecosystem services in forestry and the diffuse rather than concentrated nature of emissions and impacts in the timber life-cycle have all provided challenges in applying LCA appropriately to forest products. In spite of this, wood-based products have received favourable assessments, even when the many different types of processing are included. Perhaps the most 'industrial' wood products are packaging of paper, board and card, and yet these materials often also fare well against alternatives under a whole life-cycle assessment (e.g. Tillman *et al.*, 1991).

It should be appreciated at the outset that LCA, of itself, cannot certify that a particular area of forest is being managed on a good or sustainable basis. There are better and more specific tools and guidelines available for this (see Eba'a Atyi and Simula 2002; Anon., 2002). Instead, LCA is a systems analysis tool to present the impacts on the general environment resulting from, in this case, wood and wood products. It is equally applicable to any other product or process and as such has the capacity to encompass comparative assessments sometimes between very different products that can fulfil the required function (such as the wood, PVC or Aluminium that holds the glass in your window frame).

There is much current enthusiasm for LCA as an important tool to help move us closer towards the goal of sustainable development. It is one of the most valuable approaches that we have. However, LCAs are not simple to undertake and as noted, forestry and forest products present some particular difficulties in practice. To perform an LCA requires substantial quantities of data, familiarity with the methodology, time and opportunity for communication and interaction with data providers and resources. These requirements are needed in order to be able to deliver two of the most important aspects of any LCA:

- Completeness – to avoid 'single issue' distortions when trying to understand complex interactions between environmental impacts and compartments, and
- Transparency – to promote confidence and usability in the LCA results

3. Life Cycle Assessment - Overview

3.1 LCA - development

Life Cycle Assessment (LCA) is a rapidly emerging family of tools and techniques designed to assist in environmental management and sustainable development. In the case of a product, the life cycle embraces all activities that comprise extraction of raw materials, design, formulation, processing, manufacturing, packaging, use, (reuse), and disposal.

By the early 1990s, general interest in LCA was being shown by a broad range of industries, who by the time of the 1992 UN Earth Summit, regarded LCA as among the most promising new tools for a wide range of environmental management tasks (Elkington and Hailes, 1993; Jensen, *et al.*, 1997).

By the late 1990s, LCA methodology had become well established. This was facilitated by the introduction of the ISO 14040 series of standards in 1997, which provided a clear overview of the practice, applications and limitations of LCA to a broad range of potential users and stakeholders, including those with a limited knowledge of LCA. While confidence and optimism in the usefulness of LCA has generally grown, some still point to its inaccessibility due to the complexity of the technique. A balance has to be drawn between the competing needs of 'user friendliness' and clarity for the benefit of practitioners and users of the LCA information, and the need for against validity, based on adequate data and scientific rigour to sustain the credibility of LCA results. In recent years, computer software designers have responded to this challenge, resulting in the proliferation of modern LCA software (see Sources of Information).

The key aspects of the LCA framework are presented briefly below.

3.2 Terminology & Definition

Over the course of its development, different LCA approaches and methodologies have given rise to various terminologies, often for very similar concepts. Though the terms *Life Cycle Assessment* and *Life Cycle Analysis* are frequently used interchangeably, other terms are also used to represent similar tools. These include: *Cradle to Grave Analysis*; *Ecobalance*; *Ecoprofile*; *Life Cycle Balance*; *Resource and Environmental Profile Analysis*; *Product Line Analysis*; and *Integrated Substance Chain Analysis*. All these terms refer to studies which analyse and assess environmental impacts of products, processes or activities over partial or entire life cycles. To maintain consistency and consensus with ISO 14040 standards (see section 4.3), the term Life Cycle Assessment (LCA) is used throughout this review.

The International Standards Organisation (1997a) defines LCA as: *A technique for assessing the environmental aspects and potential impacts associated with a product, by compiling an inventory of relevant inputs and outputs of a system; evaluating the potential environmental impacts associated with those inputs and outputs; interpreting the results of the inventory and impact phases in relation to the objectives of the study.*

LCA almost by definition suggests an assessment of the entire life cycle (cradle to grave) of a product, process or activity. In practice however, many studies are restricted in scope to a partial LCA (cradle-to-gate), mostly due to time constraints or limitations in data availability. Some LCA studies are also specifically designed to address specific issues and may not require an assessment of the entire life cycle.

3.3 ISO 14040 Series of Standards for LCA

The first initiative to harmonise the LCA methodology was taken in 1993, when the Society for Environmental Toxicology & Chemistry (SETAC), published a practice for conducting LCAs, based on a three part (Inventory – Interpretation - Improvement) process. The development of internationally agreed standards on LCA were built on this by the International Standards Organisation (ISO) as part of its 14000 series. The ISO Standards 14040 - 14043 now cover the various aspects of the application of LCA methodology (see Box 1).

Box 3.1 Function of ISO 14040-14043 (1997) standards for LCA

ISO 14040: Provides an overview of the practice, applications and limitations of LCA to a broad range of potential users and stakeholders, including those with a limited knowledge of life cycle assessment.

ISO 14041: Details special requirements and presents guidelines for the preparation, conduct, and critical review of life cycle inventory analysis phase of LCA that involves the compilation and quantification of environmental relevant inputs and outputs of a product system.

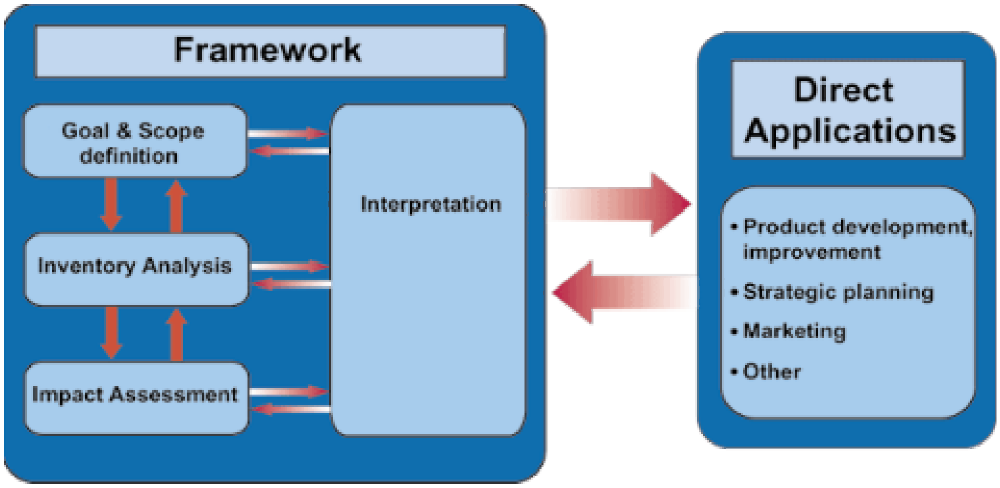
ISO 14042: Offers guidance on the impact assessment phase of LCA - that phase of LCA aimed at evaluating the significance of potential environmental impacts using the results of the life cycle inventory analysis.

ISO 14043: Provides guidance on the interpretation of LCA results in relation to the goal definition phase of the LCA study, involving review of the scope of the LCA, as well as the nature and quality of the data collected.

Source: ISO 14000 Management Group, Altrincham, Cheshire, UK.

According to the ISO 14040 guidelines to the LCA methodological framework, a Life Cycle Assessment shall include four elements a goal and scope definition, inventory analysis, impact assessment and an interpretation of results. Figure 3.1 illustrates the ISO 14040: LCA framework and applications.

Figure 3.1. Life cycle assessment framework according to ISO 14040:1997



Source: http://www.boustead-consulting.co.uk/iso14040.htm

The LCA methodology is a structured framework that specifies the required data, methods of calculation and the procedure for data interpretation. This involves description of the system; production of an inventory of inputs and outputs associated with that system; translation of this inventory data into potential environmental impacts, and finally, evaluation of the results in order to facilitate decision-making.

Phase 1: Goal & Scope Definition

The first phase of the framework, the goal and scope definition, is the planning phase of the LCA. This is a critical part of any LCA as at this stage the specifications of the study are defined. This includes the following main issues: the goal of the study; the scope definition; the functional unit; the system boundaries; the quality of data; the critical review process.

Goal of the Study

The goal of a study clearly states the intended application of the results including the reasons for carrying out the study and the target group or intended audience. Additionally, the goal also determines the complexity of the study and requirements for reporting. An appreciation of these issues is important in order to make the appropriate decisions throughout the study and achieve the stated goal (Jensen, *et al.*, 1997).

Scope Definition

Scoping defines the system boundaries, study assumptions and limitations of a LCA study. It also defines what activities and impacts are included or excluded in the study and why. The scope is defined to ensure that the breadth and depth of the analysis are appropriate to address the goal of the LCA. At this stage, functions of the systems being studied (the functional unit; system boundaries; allocation procedures; data requirements; types of impact; methodology of impact assessment and interpretation; assumptions; limitations; type & format of the report, and type of critical review) must be clearly stated.

Functional Unit of Study

It is important in LCA studies to define the unit to be studied. This functional unit can be defined as *"Specification of the unit size of a product or system, on the basis of which subsequent environmental scores are calculated."* (UNEP1996). Definition of the functional unit or performance characteristics is the foundation of an LCA because this sets the scale for the measure of performance, which a system (product) delivers. In addition, all data collected in the inventory phase (see section 4.4.2) will be related to the functional unit (Jensen, *et al.*, 1997).

System Boundaries

The system boundaries have a significant influence on the outcome and the informative value of LCA studies. They determine the relative assessment area. The system boundaries define the processes and operations, and also the inputs and outputs to be considered in the LCA. At this stage decisions are made about which unit processes would be included and which environmental releases would be evaluated and whether the study would require a complete analysis (Cradle-to-grave) or a partial analysis (Cradle-to gate). Although difficulties associated with data availability, time and resource constraints usually necessitate applying limits to the assessment area, defining the system boundaries is often a subjective process (Nerquaye-Tetteh, 2001).

Data Quality

The quality of data used at the inventory stage is naturally reflected in the quality of the final LCA. It is therefore important that at the goal and scope definition phase, the data used for the LCA is described and assessed in relation to geographical, time-related and technological coverage. In addition descriptions on the sources of the data, whether collected at specific sites or from published sources, and whether the data is measured, calculated or estimated should be outlined. Often, both published and site-specific data are used to develop an inventory (Jensen, *et al.*, 1997).

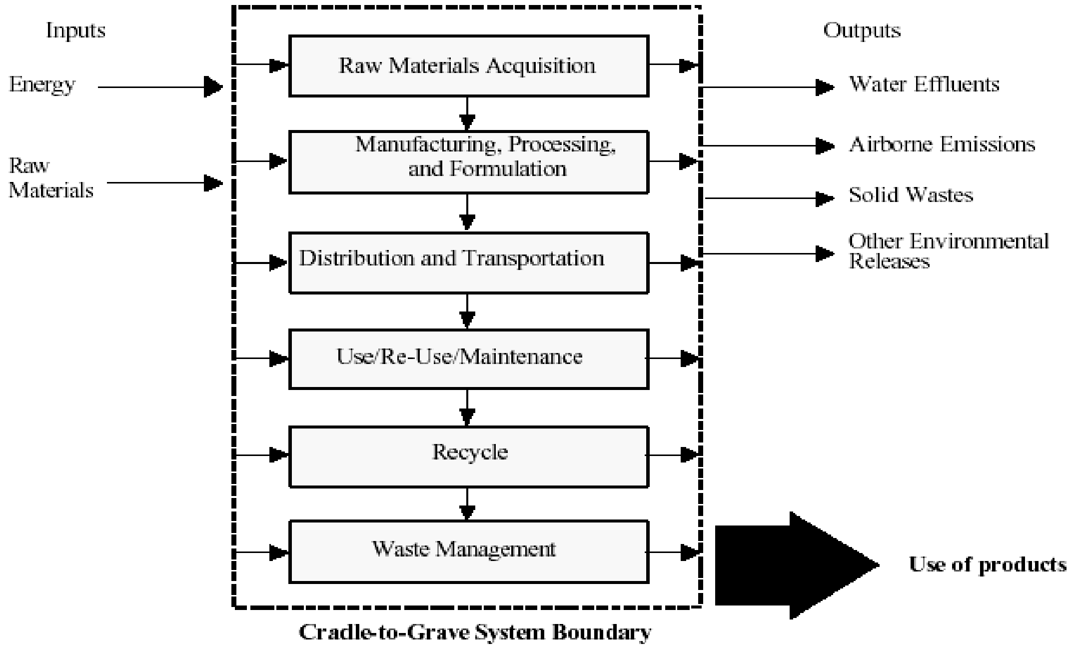
Critical Review Process

Transparency is essential in any LCA study. The purpose of the critical review is to ensure the quality of the LCA. The review can be either internal, external or involve interested parties, as defined within the goal and scope definition phase. This definition clearly identifies why the critical review has been undertaken, what it covers, to what level of detail, and those involved in the process (Jensen, *et al.*, 1997).

Phase 2: Inventory Analysis

Inventory analysis is the second phase of the framework, and is the core of any LCA. At the inventory phase, a process flow diagram of the system is assembled which offers a simple way of representing the linkages between processes or sub-systems involved in a product life cycle, supports data collection and also facilitates reporting and transparency of the LCA. It is crucial to the success of the LCA that all relevant processes are included. Relevant data are then collected; system boundaries are redefined where necessary and calculations are performed in order to quantify the relevant inputs and outputs of the system being studied (Jensen, *et al.*, 1997). Figure 3.2 illustrates a standard life cycle inventory template.

Figure 3.2 Standard life cycle inventory template flow diagram *(Source SETAC, 1992)*



Data Collection
One important stage in the inventory analysis phase is the collection and treatment of data required for inputs (materials and energy) and outputs (products and environmental releases) specified in the process flow diagram. Data collection is generally the most time consuming aspect of an LCA study. Data has to be collected for all single processes in the life cycle. Due to difficulty involved in data collection, both primary (data originally collected specifically for the purposes of that study) as well as previously published data are often used (UNEP, 1996).

Calculation
No formal demands exist for calculation in LCA except for those described for allocation procedures. Various LCA software programmes have been developed for this purpose which can be selected according to the type and amount of data to be managed (Jensen, *et al.*, 1997).

Phase 3: Impact assessment
The purpose of the impact assessment phase is to translate the results from the inventory phase into potential environmental impacts. The life cycle impact assessment specifically uses impact categories and associated indicators to simplify inventory results into environmental issues, for example ozone depletion, climate change and acidification (Nerquaye-Tetteh, 2001). Additional impact categories can be defined to represent specific issues such as noise, odour or casualties.

Classification
At the classification stage, environmental impacts listed in inventory results are assigned to selected impact categories. For example, carbon dioxide and methane are assigned to global warming. The impacts can be classified into global, regional or local scales (Nerquaye-Tetteh, 2001).

Characterisation
Characterisation involves assigning the relative contribution of each input and output to the predefined impact categories. This is mainly a quantitative step based on scientific analysis of the relevant environmental processes and an estimation of their impacts (Jensen, *et al.*, 1997).

Normalisation
Normalisation is an optional element of life cycle impact assessment which involves relating and transforming all impact scores of a functional unit to a reference situation (commonly the total loading of each category). Normalisation can be used to provide a better interpretation of the characterisation data.

Valuation/Weighting
This is an optional element within impact assessment, in which the results of characterisation/normalisation are weighted against each other in order to make the impact information more "decision-friendly". This involves both qualitative and quantitative judgements.

Phase 4: Interpretation of Results
Interpretation is a systematic technique which includes: 1) identification of significant environmental issues; 2) conducting a qualitative and quantitative check and evaluation of information from the results of the inventory analysis and/or the impact assessment phases of the LCA; and 3) formulation of conclusions and recommendations. Interpretation is the phase in which choices and assumptions made during the course of the study and the results of the analysis are judged as to their accuracy, consistency and completeness.

3.4 Special issues for LCAs on Forestry and Timber

A number of special issues exist for LCAs on forestry and forest products. These are strongly related to the extensive and long-term nature of forestry, the ‘non-market’ benefits of forest ecosystems and the multi-product harvesting and processing system. These are dealt with below.

The impact of a process upon Land Use has always been recognised as a potentially critical component of the environmental impact of products and a wide range of potential approaches to establish agreed methods to assess it have been explored as LCA has developed (see Ekvall, 1998; Lindeijer, 1998; Lindeijer, 2000, Köllner, 2000). When the extensive framework for Life Cycle Impact Assessment in the widely accepted CML methodology was revised and improved (the CML 99 method) the treatment of Land Use was also re-examined and has now been revised and applied to a number of case studies.

The European COST (European Co-operation in the Field of scientific Research and Technical Research) Action E9 “Life Cycle Assessment of Forestry and Forest Products” worked from 1997 to 2001, with the aim of developing methods for multi-disciplinary life cycle assessments to cover the whole forestry and forest products chain. This process brought together many of the leading experts in LCA for forestry and forest products, and Working Group 2 of COST Action E9 dealt specifically with the issue of land use in forestry (Schweinle et al., 2002).

Over many meetings and workshops, all of the issues described here were discussed and elaborated. The nature and result of these discussions were synthesised in a final report and a possible methodology was proposed. A key aspect of the general debate within COST E9 was the need for a 'basket' of indicators, which could be applied appropriately to the specific site and ecosystem, but which could also be applied within a common method to all ecosystems. Below is a brief consideration of the main issues surrounding the difficulties in achieving consensus for an environmental impact category for Land Use in LCA.

In assessing Land Use, LCA contrasts with approaches such as Environmental Impact Assessment (EIA), certification or Environmental Management Systems (EMS) since LCA is principally (although not exclusively) directed at products rather than land management as a process. It is also not site-specific, in that any methods developed must be directly applicable in all locations and to all products.

LCA cannot, therefore, deal in such a detailed way with the implementation and testing of principles and indicators as implemented in the certification process. This means that it is of limited value for management planning and assessment at the stand level. It is, however much more useful for planning at the regional level, and for describing and comparing products from different systems and regions.

Furthermore, if sufficient reference is made to sources such as the FSC's principles and criteria in developing and implementing methods, such as those for quantifying Land Use impacts, the synergy between the approaches (and the data needed to support them, see also Appendix 1 in Wessman et al., 2003) can be maximised. The synergies are already quite apparent in some topics, as illustrated by the difficulties encountered in picking historical ecological "baselines" for implementing Principle 6 (Ecological) in developing FSC US National Indicators (Wood, 2001), which mirror those encountered in implementing Land Use in LCA..

The current state-of-the-art for assessment of Land Use impacts in LCA can be summarised as:

- Land Use impacts are significantly different in character from those of pollution that are normally dealt with in LCA but;
- it is at least possible in principle to encompass Land Use Impacts in 'traditional' LCA studies.
- the key characteristics of any effective measure are now clear, and several possible implementations have been proposed, but;
- there is a lack of LCA studies in which the existing methods have been applied *and tested.*
- the possibility of positive scores for land improvement is desirable but is not universal
- Any implementation will be highly data intensive.
- Any method will inevitably be dependent upon value [normative] judgements, especially in the setting of 'reference levels'.
- There is likely to be considerable synergy (or perhaps, overlap) between the application of LCA to Land Use and management-based systems such as certification and EMS.

Overall, it is clear that there is still a great deal of work to do to refine and, in particular, apply the available methods before a final evaluation can be made of the type and value of measures to be adopted. An extended discussion of Land Use in LCA is given in Appendix 3.

Given the state of uncertainty at present over the consistent and general application of Land Use and biotic resource extraction in LCAs, it is clear that different LCA studies may handle these issues in different ways and arrive at very different conclusions even when the essential forestry systems may well be similar and the LCA conducted in accordance with the ISO 14040 standards. This must be assessed carefully in any comparison of overall LCA summary results and at present it is suggested that comparisons of forestry systems e.g. tropical vs temperate, clear fell vs continuous cover should ***not*** be made unless an identical approach to the inclusion of land use and biotic resource extraction is adopted or, alternatively, that these parameters can excluded from the assessment.

4. Existing Studies

Many reports are available that have included an LCA approach to environmental impacts and related issues of timber and forest products. For the purpose of this review these studies have been divided into those that focus on non-tropical and tropical timbers. Several of the studies also include comparisons between timber and non-timber materials and are related to the construction and pulp, paper and packaging sectors.

Some of the studies are complete or partial life cycle assessments whilst others have more specific objectives and a narrower scope. Where possible, the latter studies are included in this review except where the component of LCA was considered to be too minor for useful data or conclusions to be provided with relevance to the LCA context. In order to identify relevant studies, a full literature search was conducted using library and internet facilities and direct contact with practitioners and researchers in the field between December 2002 and June 2003. In total, 16 relevant studies were identified that had been produced for diverse purposes by various authors. Each report is referred to here by an abbreviated title with date and these are summarised in Table 4.1 for non-tropical timbers and Table 4.2 for tropical timbers together with their complete titles and other details. Where a report deals with both tropical and non-tropical timbers the report is dealt with under the tropical timber review.

Table 4.1 Abbreviated and Complete Titles of reviewed LCA studies on temperate timbers (where appropriate URL addresses are shown in the References section)

Abbreviated Title	Complete Title
Taylor and van Langenberg 2003	"Review of the environmental impact of wood compared with alternative products used in the production of furniture" by Taylor, J., and Van Langenberg, K.., Project No PN03.2103, Market Knowledge & Development, Forest and Wood Products Research and Development Corporation, Victoria, Australia 2003
Frühwald et al, 2003 (1 sector, 3 products)	"Comparison of wood products and major substitutes with respect to environmental and energy balances" ECE/FAO Seminar, Strategies for the sound use of wood. Poiana Brasov, Romania, 24-27 March 2003.
ScanForsk 2003 (1 sector)	"Land use in ecobalance and LCA of forest products" by H. Wessman, F. Alvarado, B. Backlund, S. Berg, C. Hohenthal, S. Kaila and E-L. Lindholm, Scan Forsk Report 746, STFI, Stockholm, Sweden, February 2003
Nicoletti et al 2002	"LCA of beech manufactured product" by Nicoletti, G.M., Notarnicola, B., and Tassielli, G. International Conference on "Ecobalance and Life Cycle Assessment in India, MOEF (India)/AIST/APO(Japan)/IDBI(India)/IGIDR, Mumbai, India, 13-15 February, 2002.
COST E9 WG1 2001 (1 sector)	"Energy, Carbon and Other Material Flows in the Life Cycle Assessment of Forestry and Forest Products – Achievements of the Working Group 1 of the COST Action E9 " by T. Karjalainen, B. Zimmer, S. Berg, J. Welling, H. Schwaiger, L. Finer and P. Cortijo, European Forestry Institute, Joensuu, Finland, Discussion Paper 10, 2001
COST E9 WG2 2002 (1 sector)	"The Assessment of Environmental Impacts caused by Land Use in the Life Cycle Assessment of Forestry and Forest Products: Guidelines, Hints and Recommendations. Final Report of Working Group 2 "Land Use" of COST Action E9" by Schweinle, J., Doka, G., Hillier, W., Kaila, S., Köllner, T., Kreiβig, J, Muys, B., Quijano, J. G., Salpakivi-Saloma, P., Swan, G., and Wessman, H. Mitteilung der BFH Nr. 209, Hamburg, Germany 2002.
COST E9 WG3 2001 (1 sector, multiple products)	"Life Cycle Assessment of Forestry and Forest Products – Achievements of COST Action E9 Working group 3 – End of Life: recycling, Disposal and Energy Generation" Ed. G.Jungmeier, Joanneum Research, Graz, Austria, Report No IEF-B-11/01, November 2001
DETR PiT 2000 (3 sectors, multiple products)	"Environmental Assessment of UK Forestry, Sawmilling and Panel Production" by J.S. Mundy, W.M.H. Thorpe, P.W. Bonfield, W. Hillier and R.J. Murphy. Final Report for DETR Partners in Technology Contract C138/19/133D), August 2000, BRE, Watford, UK
Life-Sys Wood 1999 (8 products/sectors)	"Life-Sys Wood: Consistent Life Cycle Analysis of Wood Product" by P.M. Esser and D.J. Robson TNO Center for Timber Research, Delft, The Netherlands (Final Report for EC R7D Contract FAIR-CT05-072), December 1999
FEI 1998 (2 sectors, multiple products)	"Forest industry and the environment: a life cycle assessment study from Finland" by J. Seppälä, M. Melanen, T. Jouttijarvi, L. Kauppi and N. Leikola, Resources, Conservation and Recycling 23 (1998), 87-105
NORDPAP, 1997	"Use of agro fibre for paper production from an environmental point of view" by O. Hedenberg, B. Backlund, T. Pajula, L. Person and H. Wesserman, NordPap DP2/54, SCAN Forskrapport 682, October 1997
Berg 1997 (1 sector)	"Some aspects of LCA in the analysis of forestry operations" by S.Berg, J. Cleaner Production, 5 (3) (1997), 211-217.

Table 4.2 Abbreviated and Complete Titles of reviewed LCA reports on tropical Timbers (where appropriate URL addresses are shown in the References section)

Abbreviated Title	Complete Title
VROM 2002 (1 product)	"LCA for Acetylated Wood : Final Report 2 – Light duty piling in fresh water use" by LCA Group Imperial College London, UK and SHR Timber Research, The Netherlands, Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (VROM), The Hague, The Netherlands, March 2002
Thai Paperboard 2001 (1 product)	"Life cycle assessment of paperboard packaging produced in medium-sized factories in Thailand" by Arunee Ongmongkolkul, MSc thesis, Asian Institute of Technology, School of Environment, Resources and Development, Thailand, August 2001
Parana Pine 2000 (1 product)	"Life cycle analysis of Parana Pine *Araucaria angustifolia*" by S. Alexandridou, MSc Thesis, Imperial College London September 2000
Meranti 1999 (1 product)	"Life cycle assessment of the tropical timber Meranti (*Shorea*)" by I. Rugge MSc Thesis, Imperial College London (and subsequent internal report by I. Rugge, MSc Thesis, Imperial College London September 1999

These reports were subjected to a qualitative review according to the criteria listed in Table 4.3 and this review is summarised in Table 4.4

Table 4.3 Criteria used for qualitative evaluation of LCA reports on forestry and forest products

Review criteria	Description and classification
Specific LCA study	Report presents essentially an LCA driven investigation – Evaluated as Yes or No
Specific research issue	Report uses LCA at least in part to address a specific research issue - specific issue(s) recorded
Forestry or a Forest Products issue	Report is focussed on production of raw material or production of a forest product(s) - Evaluated as Forestry, Forest Product (specified) or Both (specified)
ISO Compliance	Report is based on ISO 14040 series of standards – Evaluated as Full (incl. peer review), Partial (some elements of ISO series missing), Non (does not comply)
Other good practice Compliance	Report is based on other identified good LCA practice (e.g. SETAC) – Evaluated as Full, Partial or Non
Cradle to grave assessment	Report is based on whole life cycle from raw material through to disposal/reuse or recycle – Evaluated as Yes or No
Cradle to gate assessment	Report is based on partial life cycle usually to factory/forest gate – Evaluated as Yes or No
Report availability	Availability of the report to general enquiries – Evaluated as Fully available (published or available from readily identified source), Limited availability (available on a restricted basis or only through specialist routes), Restricted availability (not generally available, confidential)

Furthermore, it should be noted that process data on tropical and non-tropical timbers exists in a number of LCA databases. In a sense, such data represent a special case as they are presented in a form to be deployed readily in ongoing LCA studies. Examples of such data from the Delft University of Technology IDEMAT database are also considered in this part of the report.

Table 4.4 Summary - Qualitative assessments of LCA reports.

Non-Tropical	Specific LCA study	Forestry/Forest Products issue	ISO Compliance*	Other good practice Compliance*	Cradle to grave assessment	Cradle to gate assessment	Report availability
Taylor and van Langenberg 2003	No	Furniture	Non	Non	-	-	Fully
Frühwald et at, 2003	Yes	Forest products, comparative assessment	Partial	-	Yes	-	Fully
ScanForsk 2003	Yes	Land use in forestry Scandinavia	Partial	Partial	No	No	Fully
Nicoletti et al 2002	Yes	Beech chair	Partial	_	Yes	-	Fully
COST E9 WG1 2001	Yes	Energy, carbon & material flows EU forestry	Partial	Partial	No	No	Fully
COST E9 WG2 2002	Yes	Land use in LCA of forest & forest products	Non-	Partial	No	No	Fully
COST E9 WG3 2001	Yes	Wood energy, wood products, end-of-life	Partial	Partial	No	No	Fully
Hillier & Murphy, 2000	Yes	Forest products, comparative assessment	Partial	Partial	Yes	-	Fully
Athanassiadis, 2000	No	Logging machinery emissions Sweden	Non-	Non-	No	Yes	Fully
DETR PiT 2000	Yes	UK forestry, sawmilling and panel production	Partial	Full	No	Yes	Limited
Life-Sys Wood 1999	Yes	Temperate woods, various products	Partial	Full	Yes	-	Limited
FEI, 1998	Yes	Whole forest industry	Non-	Full	No	Yes	Fully
NORDPAP, 1997	Yes	Paper from wood and agro-fibre	Non-	Full	No	Yes	Fully
Berg 1997	Yes	Harvesting systems Sweden	Non-	Partial	No	No	Fully
Tropical							
VROM 2002	Yes	Construction, comp. with EU softwood	Full	-	Yes	-	Limited
Thai Paperboard 2001	Yes	Paperboard, plantation	Partial	-	Yes	-	Fully
Parana Pine 2000	Yes	Solid wood, plywood	Partial	-	No	Yes	Limited
Meranti 1999	Yes	Harvesting, biotic resource extraction	No	Partial	No	Yes	Limited
LCA DATABASES	Yes	LCA Database temperate + tropical wood	Non-	Non-	No	Yes	Restrctd.[1]

** Non compliance includes unknown where this is not specified in the report - = not relevant as previous column supersedes*
[1] = fee payment usually required

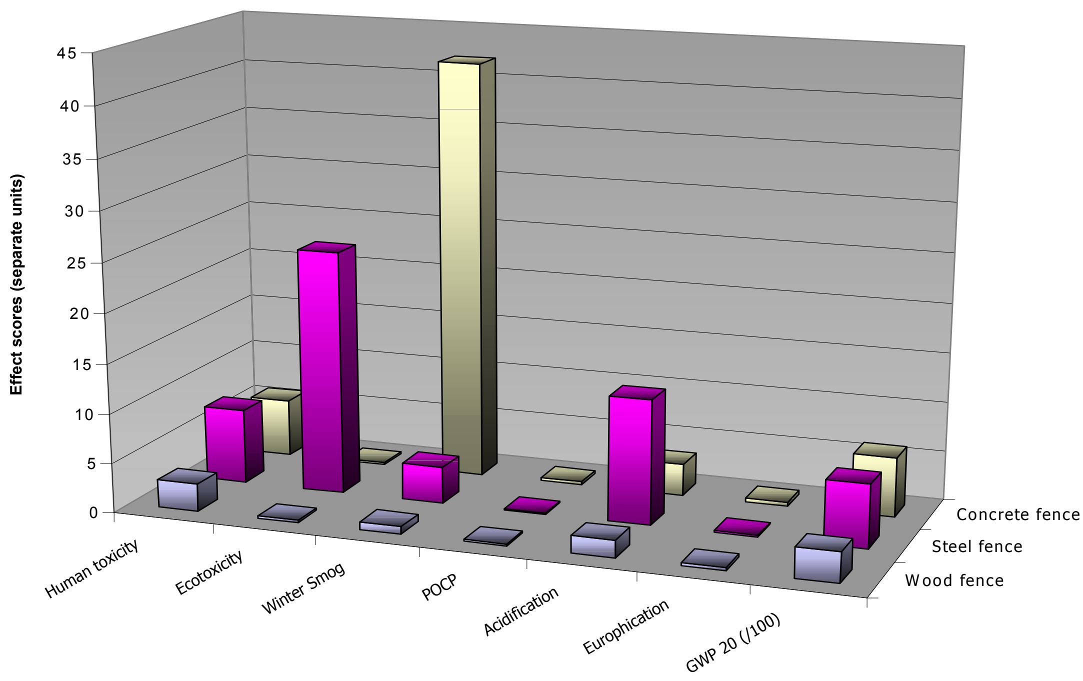
4.1 Qualitative Evaluation

Each of the reports was subjected to critical review (see Appendix 2).

4.1.1 Non-tropical timbers and products

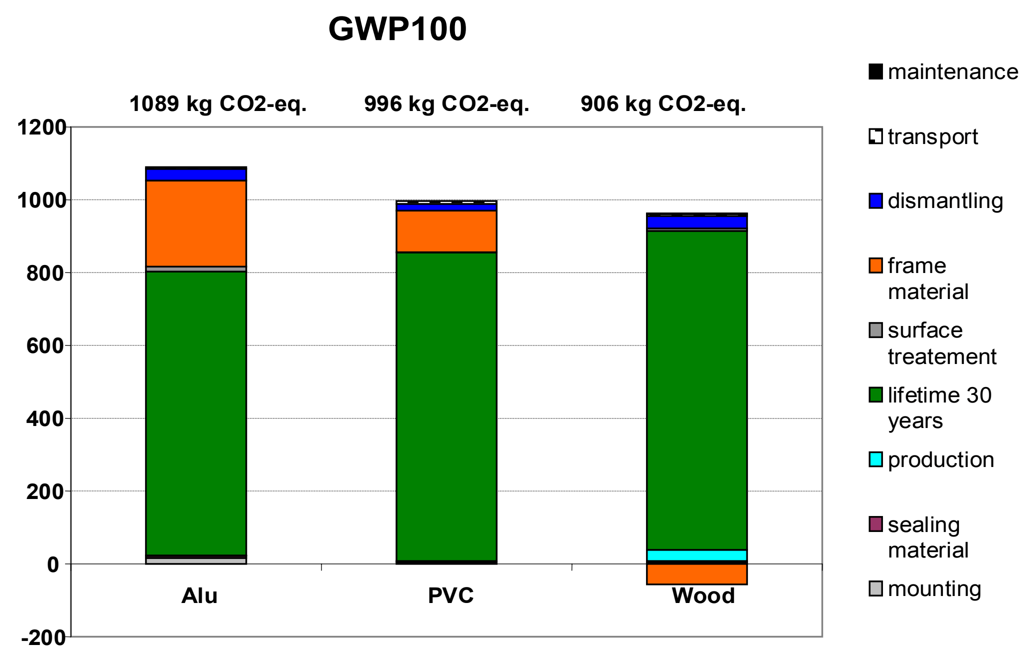
The selected reports present a range of LCA information with the majority being summaries and overviews of full LCA studies conducted on non-tropical timbers over the last 10 years. The majority include examples of data and results from impact assessments with interpretation. Several of the reports are concerned with the important methodological questions that need consideration when applying LCA to forestry and forest products.

Two examples of results in the reports are presented below in Box 4.1 and 4.2. These are 'typical' outcomes of LCAs in that they show that the environmental profile of softwood compares very favourably with that of alternative materials like PVC and metals. All the LCA reports reviewed indicate that sustainably managed wood from temperate forests has environmental profiles that are better than alternative materials. This benefit can also be shown for preservative treated wood although in this case disposal and waste management at the end-of-life exerts a particularly strong influence on the results.



Box 4.1 Summary LCA results from Hillier and Murphy (2000) comparing of timber, steel and concrete for fencing with timber at end-of-life being combusted with energy recovery.

Sawn treated softwood timber clearly has the lowest environmental impact over the 50 year life cycle of the alternative materials for this demanding, high-durability use.



Box 4.2 LCA comparison of the Global Warming potential for materials for window frame (excluding glass) ***from Frühwald et al. (2003)***

Softwood has the least environmental impact in this category and several others analysed over the life cycle of these windows

In the study by Frühwald et al (2003), it can be seen that the wood frame has a slightly higher impact during the use phase of the life cycle through the need for maintenance (Box 4.2). This type of finding is a common feature of cradle-to-grave LCAs and is of considerable value in product improvement. It enables manufacturers and users to target improvement effort to processes and life cycle stages that have the most significant impacts for the product. It also illustrates the importance of considering the whole life cycle of the product. A decision based only on the use phase of the materials would incorrectly favour the Aluminium frame and a decision based only on the material of the frame would represent the extent of the benefits offered by the wood to an unrealistic extent. The positive impact that the use of wood can have in products is shown by the net negative (beneficial) contribution that the wood material makes to global warming through its sequestration of atmospheric CO_2 during tree growth..

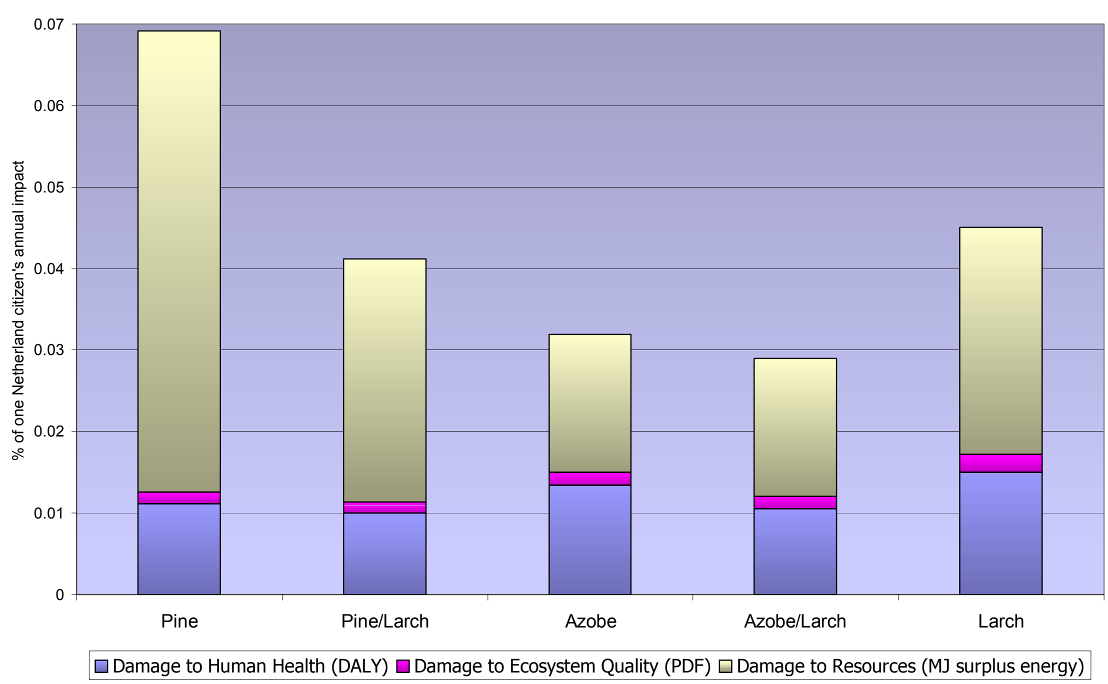
The evidence accumulating from LCAs on temperate wood and wood products indicates that they have environmental profiles that are more favourable than other materials (see *inter alia* Hillier and Murphy, 2000; Fruhwald et al., 2003; Petersen and Solberg, 2002; Taylor and van Langenberg, 2003). Such studies have led agencies such as the Danish Environmental Protection Agency in their study on cleaner products in the wood and furniture industry to conclude that, as a raw material, 'sustainable timber affects the environment minimally' and that 'if the products can be separated, the wood per se can contribute large volumes of energy when incinerated at some subsequent point in the product life-cycle'. In the context of the present review it is important to consider how well this type of general finding applies to tropical timbers.

4.1.2 Tropical timbers and products

Very few LCA studies on tropical timbers appear to have been conducted to date. Furthermore, only one (VROM, 2002) has been conducted in full accordance with ISO 14040 series of standards. In this report the use of acetylated EU pine timber was compared with alternative, naturally durable timbers Larch from Siberia and Azobe from West Africa (see Box 4.3). Though not the primary focus of the study (which was to evaluate the impact of acetylated pine), the LCA results indicate that the environmental profile of Azobe compares favourably with these 2 softwood species in this product. The tropical timber alternative had the lowest overall environmental impact of the materials compared over the whole life cycle.

It is noted in this report that the oil fuel use in forestry for the functional unit (10 m of sheet piling) for the Scandinavian pine was equivalent 13 MJ whereas the corresponding figure for Azobe was 78 MJ. Life cycle transport fuel consumption for the acetylated pine was 100 MJ (3% of total fuel use (about 75% of fossil energy use for pine was consumed in energy and feedstock for the acetylation)) and for Azobe was 310 MJ (31 % of total fossil fuel consumption in the life cycle). It is clear from these values that whilst the overall life cycle profile for Azobe is favourable there are higher harvesting and transport consumptions and emissions for this type of wood. This is likely to be a general issue faced by tropical timbers in LCA.

The VROM study did not include assessment of potential impacts of timber harvesting on Land Use and biotic resource extraction due to the deficiencies in the comparative data and uncertainties over methodology in LCA (see Appendix 3 for a detailed discussion). However, it was considered in the report that was this was a factor that should be incorporated into such assessment and that it was likely that this would be more favourable to the EU pine than the tropical wood or Siberian Larch.

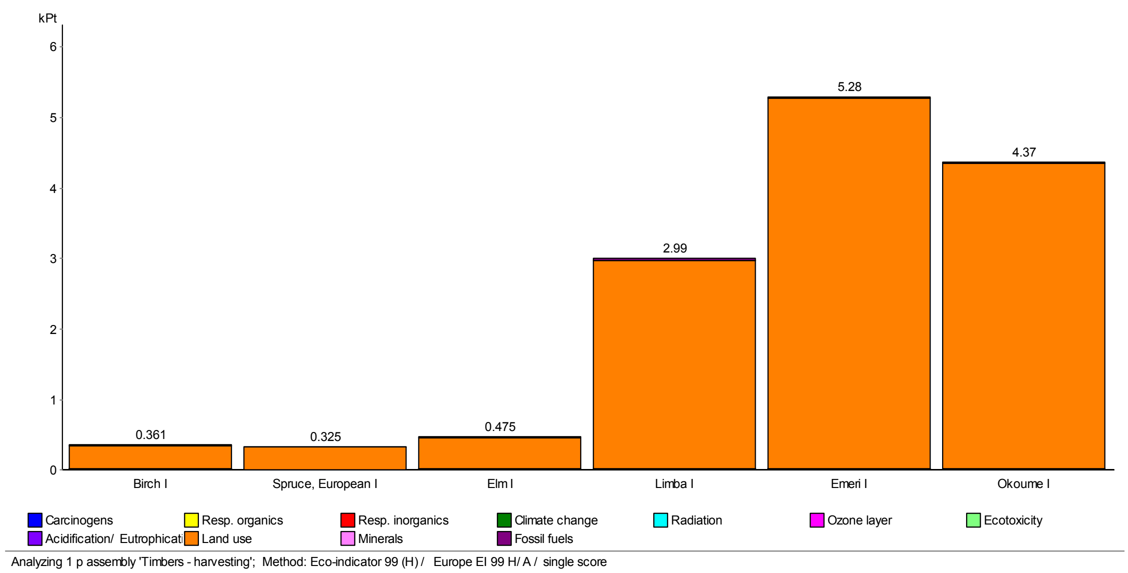


Box 4.3 Summary LCA data from VROM (2002) study with acetylated EU Pine and West African Azobe as sheet piling

These data show that tropical timbers can have LCA profiles that are comparable with temperate species. In this case the good natural durability of the Azobe means that only simple, low energy transformation is needed to enable it to fulfil the function.

Inventory data for LCAs on a number of timbers are available in some LCA databases. As an example, in the database IVAM LCA Data 4, energy consumption values for 1 kg of rough sawn timber delivered to Rotterdam indicate that Scandinavian Birch, Okomue from West Africa and Emeri from Brazil require about 2 to 4 times as much energy as 1 kg of Scandinavian spruce wood. This is similar to the data elaborated in the VROM study and indicates a substantially higher energy consumption needed to harvest and deliver tropical (and temperate) hardwood to market in the EU than for 'local' softwoods.

An important aspect referred to earlier is the incorporation of Land Use in the LCA presentation of environmental impact. Examples of environmental impact under the Eco Indicators 1999 impact assessment methodology (that incorporates Land Use) are shown in Box 4.4 for 1 kg of these timbers delivered to Rotterdam. The dominance of the Land Use category in the overall eco-profile is immediately apparent (orange part of the bar) and substantially to the disadvantage of the tropical timbers. This is due to the way that the tropical forestry and harvesting is considered to impact upon Land Use in the particular datasets. Harvesting is considered to lead to a significant and permanent land conversion. Experience with LCA of Meranti in Malaysia (see Rugge, 1999) suggests that there is a need for definitive and site (or region) specific life cycle inventory data for the tropical timbers to address this matter. In particular, advances with Reduced Impact Logging (RIL) can have substantial effects on stand damage and speed and quality of recovery after logging. Correct data on yield and allocation of harvesting volumes and values to co-extracted species is also required for accurate data for representing Land Use accurately in LCAs.



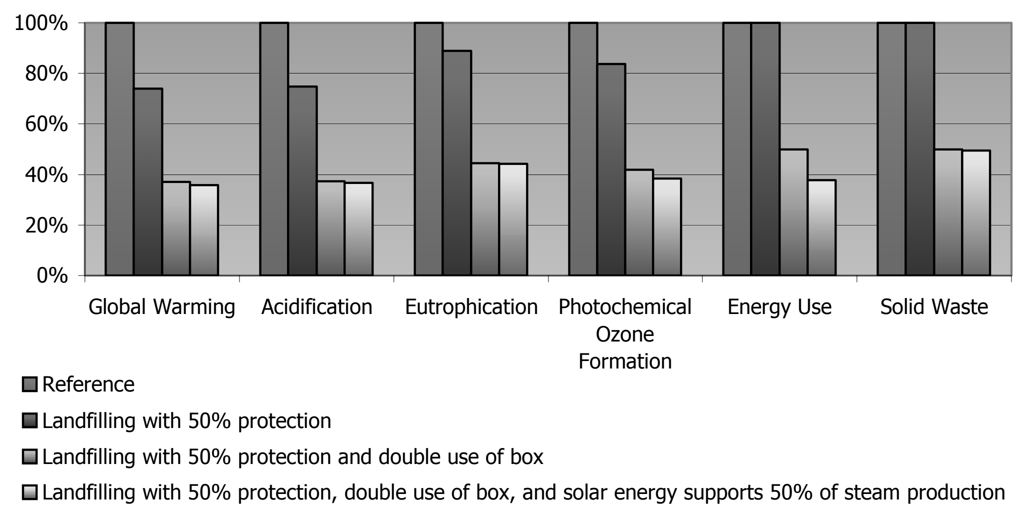
Box 4.4. An example of LCA data from the IDEMAT dataset for 1 m^3 of tropical and temperate timber species

(kPt = a valued/weighted single score in Eco Indicators 1999 method in LCA software Sima Pro)

These data indicate the significance that the Land Use impact assessment (orange bars) can have in an LCA profile for tropical vs temperate timbers. The species harvested from tropical forests are similar to the temperate species in all other impact categories, yet the Land Use category dominates the comparison – however, there is little consensus amongst practitioners on the proper methodology for its calculation and interpretation in LCA.

As a final point, the methodological issues surrounding Land Use calculation also pose serious questions about how to interpret LCA profiles in which this impact category is included as part of the analysis. As indicated in Appendix 3, Land Use indicators cannot be considered as sufficiently mature to permit their use as a *decisive factor* in LCA interpretation. It is clear from Box 4.4 that it would be quite possible for a non-expert reviewer of an LCA to consider that the differences shown represent an unacceptable environmental impact profile for the tropical species. This potential for inaccuracy needs to be removed from LCA studies on tropical timbers by making definitive data available for Land Use calculation methods in LCA and by providing best practice examples of its use and interpretation. The situation for Land Use impact calculation is also difficult for temperate species but they do not face the same extent of negative outcome. The information and activities in Forest Certification in the tropics can be expected to make a significant contribution to addressing this issue and offer considerable scope for synergy and complementarities with LCA studies.

It has already been mentioned that LCA work can be of real value in product improvement and this is as true for tropical forest products as it is for temperate ones. In an excellent study by Ongmongkolkul (2001) this was shown for paperboard packaging from wood and recycled material in Thailand. This identified through an LCA several options for environmental improvement to the life cycle of this product in the local markets (see Box 4.5). This shows the 'internal' benefits that are potentially available through LCA work and provides valuable support for public and corporate policy development.



Box 4.5. Summary LCA results from Ongmongkolkul (2001) on Thailand paperboard

The improvements scenarios indicate that reductions of up to 50% or more of the life cycle impacts and resource consumptions can be achieved in comparison with current practice (Reference end-of life disposal is by conventional landfilling 60% with some recovery 40%)

5. Overview of LCA and Tropical timbers – Conclusions & Recommendations

LCA is an adaptable tool that provides a real opportunity to include the highly positive and the negative aspects forest products in a single framework to assess their overall environmental impact. The accumulating evidence from LCA studies on forest products is demonstrating the strong environmental benefits that occur when timber is used instead of alternative materials for a huge range of products. These benefits occur across all life cycle stages of wood-based materials - from raw material acquisition from a living, renewable and sustainable cradle, through low-energy processing that also provides valuable and environmentally sound by- and co-products (bark, energy, particleboard furnish) to durable, high specific strength, easily modified products to an end-of-life phase that provides secondary raw material, more energy or a mostly benign return through natural cycles to the cradle to be re-borne again. Do any other materials have such a life cycle? There are, of course, areas where timber-based products have negative impacts on the environment and in Table 5.1 the main environmental benefits and disadvantages of timber materials (temperate and tropical) as revealed in LCAs are summarised in overall comparison with non-timber materials.

Life cycle phase	**Advantages for timber**	**Disadvantages for timber**
Raw material origin	CO_2 removal from atmosphere, provision of ecosystem services, renewable with appropriate management	Extensive land use
Harvesting/extraction	Relatively low energy and material needs	Ecosystem damage, greenhouse gas emission due to disturbance, transport distances
Processing	Low energy consumption, useful by- and co-products, potential for energy generation	Low recovery rates (tropical), transport distance
Use	High strength to weight, good thermal properties	Additives needed to enhance durability
End-of-life	Multiple re-use, recycling and energy recovery options, energy recovery can substitute fossil energy needs	Need to segregate contaminated wood, downgrading in recycling.

Table 5.1 Summary of environmental advantages and disadvantages of timber materials in comparison with alternative materials as revealed in LCAs.

Miss-management and human error can result in failure to capture many of the environmental advantages offered by using wood. These mistakes are often caused by ignorance. Life cycle assessment is an extremely powerful tool for combating such ignorance and it is often said that the real benefit of LCA lies not in the specific outcomes (e.g. x is better than y for global warming) but that it nurtures the process of *life cycle thinking*. This demands that we view products and processes as part of larger, inter-connected systems and that we need to understand such systems, particularly the natural systems, in order to achieve a sustainable future. Anyone who has spent even a small amount of time appreciating how LCA addresses environmental questions cannot fail to be engaged by the whole life cycle approach not just to environmental matters but also to a host of other sustainability, economic and materials issues. The concept of Sustainable Development has been rapidly embraced since its exposition *because* of its inherent 'rightness'. It is the same with the life cycle approach to environmental choices.

This review has shown that many temperate forest and forest products enterprises are adopting LCA as a means to understand their environmental profile and for supporting decisions that encompass the environment dimension (see for example Seppälä et al, 1998; Zobel et al., 2002). LCAs of temperate forest products will continue to increase in number and the methodology of LCA will continue to evolve. It seems unlikely that LCA will ever become a 'static' tool because there is a constant need for it to be adapted as new knowledge is gained about environmental processes, environmental priorities are adjusted by society, governments and resources, older studies require updating and refinement and databases and software tools become more sophisticated and automated.

The dynamic nature of LCA at present suggests that, although there are currently very few LCAs available on tropical timber, it is not too late to enter the arena. Many of the methodological issues in the application of LCA to forestry and forest products will benefit from a wider perspective. There is every reason to believe that novel approaches developed through LCAs on the tropical resource will be valuable (for example in Land Use impact assessment or evaluation of the environmental impacts associated with local vs remote markets). There is also a pressing need for the creation and maintenance of good quality life cycle inventories for tropical timbers and products. Such work has to be done locally in the tropical countries and will serve to benefit both producers and consumers of tropical wood. The scope for developing local capacity in LCA and using that to inform both public and corporate policy is enormous. Thus, there are strong reasons to increase the use of LCA for tropical forest products, partly to 'compete' with the LCA information being generated for temperate species and, perhaps more importantly, in order to capitalise on the direct benefits that would accrue from better knowledge of the environmental profile of tropical forest products.

It becomes apparent through using LCA that comparative assessment is desired or expected in order to make a case for the use of one product over another. Experience of conducting and planning LCA research with tropical timbers has indicated that very often there is not direct competition between tropical and temperate timbers at least within specific defined products that usually form the basis of comparative LCA assessments. It is understood that there is competition at the generic level e.g. in the furniture market but, at the level of the individual specific product that is most often the functional unit of an LCA study, often there can be mutual exclusivity. Take a simple, modest priced timber window in Europe for example. This will usually be made from 'locally' sourced softwood. If one wants to model in LCA the use of tropical hardwood for windows one immediately has to move away from this type of window and change the focus of the study to a more highly specified window where issues such as aesthetics begin to play an important part in the marketplace. In many ways this is therefore a different product than the first, softwood one. This suggests that for many products, tropical timber products may not be as directly competitive with temperate species as at first imagined. It is vital in comparative LCAs to compare 'like with like' on a functional unit basis and so questions regarding the relative environmental advantage of tropical timber vs temperate timber must be reserved for products where such comparisons are appropriate.

In summary, the following conclusions and recommendations can be made:

- In general terms, LCAs show timber-based products to have favourable environmental profiles in comparison with alternative materials.

- The great majority of the LCAs conducted to date on timber products are based on temperate timbers – there are very few available LCAs on tropical timbers. Without action on the part of the tropical timber interests this disparity is likely to increase
- Transparent and complete (to the ISO 14040 standard) LCAs are needed to provide underpinning information for communication of the environmental credentials of tropical timber products in comparison with alternative materials ('green' claims) - these demand best-practice in LCA and high quality data.
- If capacity is not built in tropical countries to develop *local* familiarity and competence in LCA techniques tropical timbers risk being inadequately represented in the market or, even worse, 'external' LCA studies may be done on the basis of inadequate data – especially for harvesting systems and Land Use impacts.

It has become evident in conducting this review that LCA information on tropical timbers is vary scarce, in some contrast with the case for temperate species. There is still a shortage of LCA data on timber products, and particularly on tropical timber products, as recognised by the Intergovernmental Forum on Forests (IFF) (UN, 2000). However, whilst there is undoubtedly more LCA information available for temperate timbers, it is also incomplete as yet. Certain centres with interests in temperate timbers are making a concerted effort to acquire and maintain LCA information on timber and its applications in general and, especially, for species of primary interest to their function (e.g. Canadian Wood Council).

LCA information has a key role to play in supporting the overall sustainability assessment of tropical timbers but a co-ordinated effort is needed to:

3) stimulate further LCA work and training of direct relevance to tropical forests and products, and
4) establish a recognised centre where LCA information for tropical forests and products is collected and made available to LCA practitioners and the wider public, in a web-based form.

It is suggested that ITTO could act as such a centre. The organisation is ideally placed for this role which will be to the benefit of both producer and consumer countries. It is expected that those conducting LCA work with tropical forests and forest products would be keen to volunteer reports/publications and information (in agreed formats) for dissemination through an ITTO-hosted mechanism and would benefit greatly from the ease of data and information sharing with related LCA studies which would become readily available and visible.

LCA is presently gaining in global significance (see UNEP http://www.uneptie.org/pc /sustain/lcinitiative/). This is an exciting development and it is time for the tropical timber interests to take up the opportunity it presents.

Sources of Further Information

Examples of LCA software tools and databases

SIMA Pro, Pre Consultants, http://www.pre.nl/
TEAM, Ecobalance UK, http://www.ecobalance.com
GaBi, PE Europe Gmbh and IKP University of Stuttgart, http://www.gabi-software.de
Boustead, http://www.boustead-consulting.co.uk/
PIRA, http://www.pira.co.uk

Organisations

Building Research Establishment (BRE), http://www.bre.co.uk/
COST Action E9 LCA of Forestry and Forest Products, http://www.rrz.uni-hamburg.de/cost/e9/
CML, http://www.leidenuniv.nl/interfac/cml/
Danish Environmental Protection Agency http://www.mst.dk/homepage/
European Commission Environment DG, http://europa.eu.int/comm/environment/
European Forestry Institute, Joensuu, Finland http://www.efi.fi/
Forest & Wood Products Research & development Corporation, Australia. http://www.fwprdc.org.au
International Organisation for Standards (ISO), http://www.iso.ch
IVAM, http://www.ivam.uva.nl/uk/index.htm
Society for the promotion of Life Cycle development (SPOLD), http://lca-net.com/spold/
Society of Environmental Toxicology and Chemistry (SETAC), http://www.setac.org/ and http://www.setac.org/WEB/lca.html
The ATHENA™ Sustainable Materials Institute, http://www.athenasmi.ca/index.html
The Canadian Wood Council, http://www.cwc.ca/
United Nations Environment Programme (UNEP), http://www.unep.org/ and http://www.uneptie.org/pc/sustain/lca/lca.htm
U.S. Environmental protection Agency, http://oaspub.epa.gov

Environmental Product Declaration Information

GEDnet, Global Type III Environmental Products Declarations Network, http://www.gednet.org/

References

Alexandridou, S. (2000). Life Cycle Analysis of Parana Pine (*Araucaria angustifolia*). MSc Thesis, Imperial College London, UK.

Anon. (2002). ITTO guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests. ITTO Policy Development Series No. 13, International Tropical Timber Organization, Yokahama, Japan

BSI (1997) *Environmental management - Life cycle assessment - Principles and framework* (BS EN ISO14040:1997) British Standards Institute, Chiswick, London

BSI (1997) *Environmental management - Life cycle assessment - Principles and framework* (BS EN ISO14041:1997) British Standards Institute, Chiswick, London

BSI (1997) *Environmental management - Life cycle assessment – Life Cycle impact assessment* (BS EN ISO14042:1997) British Standards Institute, Chiswick, London

BSI (1997) *Environmental management - Life cycle assessment – Life cycle interpretation* (BS EN ISO14043:1997) British Standards Institute, Chiswick, London

BSI (2002) *Environmental management - Life cycle assessment – Data documentation format* (DD ISO/TS 14048:2002) British Standards Institute, Chiswick, London

BSI (2002) *Environmental management - Vocabulary* (BS ISO14050:2002) British Standards Institute, Chiswick, London

Corbière-Nicollier, T ., Gfeller Laban, B., Lundquist, L., Leterrier, Y., Månson, J.-A. E., and Jolliet, O. (2001). Life cycle assessment of biofibres replacing glass fibres as reinforcement in plastics. *Resources, conservation and recycling* 33 (4), 267-287.

Eba'a Atyi, R., and Simula, M. (2002). Forest certification: pending challenges for tropical timbers. ITTO Technical Series No. 19, International Tropical Timber Organization, Yokahama, Japan

Ekvall,T. (1998). Land Use in LCA - Existing Characterisation Methods. Chalmers Industriteknik, Goteborg, Sweden.

Frühwald, A.., and Solberg, A.(1995). Life cycle analysis – A challenge for forestry and forest industry. Proceedings of he International Workshop BFH/EFI, *Eds.* Frühwald, A., and Solberg, B., EFI Proceedings No 8, Joensuu, Finland.

Hillier, B., Jonsson, L., and Ryding, S-O. (2002). International Guide to Environmental product declarations. GEDnet, SIS, Sweden.

Howard, N., Edwards, S and Anderson, J. (1999). BRE methodology for environmental profiles of construction materials, components and buildings. BR 370, BRE, Watford, UK.

Jensen, A., Hoffmann, L., MØller, B., Schmidt, A., Christiansen, K., Elkington, J. and van Dijk, F. (1997). Life Cycle Assessment, A Guide to Approaches, Experiences, and Information Sources. *Environmental Issues Series No. 6, Office for Official Publications of the European Communities, Luxembourg. European Environment Agency, Copenhagen.*

Jönsson, Ä., Tillman, A-M., and Svensson, T. (1997). Life cycle assessment of flooring materials: Case study. Building and Environment 32 (3), 245-255.

Köllner,T. 1999. *Assessing Land-Use Impacts on Ecosystem Quality Within Life-Cycle Assessments*. Presented at: 2nd Inter-Regional Conference on Environment-Water 99, 1 - 3 September 1999, Lausanne, Switzerland.

Köllner, T. (2000). Species-pool effect potentials (SPEP) as a yardstick to evaluate land-use impacts on biodiversity. Journal of Cleaner Production 8, 293-311.
Köllner, T. (2001). *Land Use in Product Life Cycles and its Consequences for Ecosystem Quality*. Dissertation Phd 2519, defended March 2001, Universität St. Gallen, Switzerland.

Lawson, W. R. (1996), *LCA and Embodied Energy; Some Contentious Issues*
The University of New South Wales, Sydney, Australia
http://www.ab.deakin.edu.au/Researchinfo/EEseminar/08lawson.pdf (accessed 1/9/2003)

Lindeijer, E.W. (1998). *Biodiversity and Life Support Indicators for Land Use Impacts in LCA*. IVAM/ER/IBN/DLO, for Directorate-General of Public Works and Water management, Road and Hydraulic Engineering Division, Publication series raw materials Nr. 1998/07, Delft.

Lindeijer, E. (2000). *Review of land use impact methodologies*. Journal of Cleaner Production Vol. 8 (4): 273-281.

Marteel A. E., Davies J. A., Olson,,, W. W. and Abraham, M.A. (2003). Green chemistry and engineering: Drivers, metrics, and reduction to practice. Annual Review of Environmental Resources 28, 401-428

Nerquaye-Tetteh (2001) *LCA of Flint Container Glass Production: A Comparative study of Virgin Raw Material & Cullet,* MSc Thesis, Imperial College of Science, Technology & Medicine, London.

Nicoletti, G.M., Notarnicola, B., and Tassielli, G. (2002). LCA of beech manufactured product. International Conference on "Ecobalance and Life Cycle Assessment in India, MOEF (India)/AIST/APO(Japan)/IDBI(India)/IGIDR, Mumbai, India, 13-15 February, 2002.

Ongmongkolkul, A. (2001). Life cycle assessment of paperboard packaging produced in medium-sized factories in Thailand. MSc Thesis, Asian Institute of Technology, Thailand.

Patel, Dr. M. (2002) *Review of Life Cycle Assessments for Bioplastics*, Central Science Laboratory, York.
http://www.chem.uu.nl/nws/www/general/personal/Presentation_York_forEuropoint.pdf

Petersen, A.K., and Solberg, B. (2002). Greenhouse gas emissions, life-cycle inventory and cost-efficiency of using laminated wood instead of steel construction. Case: beams at Gardermoen airport. Environmental Science & Policy, 5, 169-182.

Pré Consultants (2003) *Eco-indicator 99 Introduction*, Pré Consultants bv Plotterweg 12, 3821 BB Amersfoort, The Netherlands. http://www.pre.nl/eco-indicator99-reports.htmn
Elkington, J. and Hailes, JL (1993) *The LCA Sourcebook: a European Business Guide to Life-Cycle Assessment,* SustainAbility for SPOLD, London

Schenck, R. Huizenga, N. and Vickerman, S. (2002). *Draft Report: Testing Habitat Indicators*. Land Use and Habitat Conservation Indicator Workshop June 25-26, 2002. Institute for Environmental Research and Education (IERE), Washington D.C. USA.

Schieck, J., Nietfeld, M., Stelfox, J.B., (1995). Differences in bird species richness and abundance among three successional stages of aspen dominated boreal forests. *Can. J. Zool*. 73, 1417-1431.

Schweinle, J., Doka, G., Hillier, W., Kaila, S., Köllner, T., Kreiβig, J, Muys, B., Quijano, J. G., Salpakivi-Saloma, P., Swan, G., and Wessman, H. (2002). The Assessment of Environmental Impacts caused by Land Use in the Life Cycle Assessment of Forestry and Forest Products: Guidelines, Hints and Recommendations. Final Report of Working Group 2 "Land Use" of COST Action E9. Mitteilung der BFH Nr. 209, Hamburg, Germany (2002).

Scholten, N. (2000). LCA as performance requirement in the Dutch Building Decree by 2001. In Durability of Building Materials & Components 8, Vol 3 Performance, Service Life Prediction and Sustainable Construction, *Eds*. Lacasse, M.M, and Vanier, D.J., National Research Council Canada.

Steventon, J.D., MacKenzie, K.L., Mahon, T.E., (1998). Response of small mammals and birds to partial cutting and clearcutting in northwestern British Columbia. *Forestry Chronicle* 74, 703-713.

Taylor, J., and Van Langenberg, K. (2003). Review of the environmental impact of wood compared with alternative products used in the production of furniture. Project No PN03.2103, Market Knowledge & Development, Forest and Wood Products Research and Development Corporation, Victoria, Australia

UNEP (1996) *Life Cycle Assessment: What it is and how to do it.* United Nations Environment Programme, Industry & Environment, Cleaner Production Programme, Paris, France.

UN (2000). Report of the Intergovernmental Forum on Forests on its fourth session. UN Economic and Social Council, Document E/CN.17/2001/14 (see clause 36), http://ods-dds-ny.un.org/doc/UNDOC/GEN/N00/351/79/PDF/N0035179.pdf?OpenElement

Vink, E.T.H., Rábago, K.R., Glassner, D.A., and Gruber, P.R. (2003). Application of life cycle assessment to NatureWorks™ polylactide (PLA) production. Polymer Degradation and Stability 80, 403-419.

VROM (2002). LCA for acetylated wood Final report 2: Light duty piling in fresh water use. Conducted by the Imperial College London and SHR Timber Research for the Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (VROM, The Netherlands.

Wood, P. (2001). *Additional Reviews of Selected International Forestry Certification Systems*. Government of British Columbia, Ministry of Employment and Investment / Ministry of Forests. Vancouver, Canada.

Zobel, T., Almroth, C., Bresky, J., and Burman J-O. (2002). Identification and assessment of environmental aspects in an EMS context: an approach to a new reproducible method based on LCA methodology. Journal of Cleaner production 10, 281-396.

Appendix 1 ToR

Terms of Reference for PPD 48/02 (M)
"Review of Information on Life Cycle Analysis of Tropical Timber Products"

1. Background

At its Thirty-first Session in May 2002, the ITTO Committee on Economic Information and Market Intelligence approved a pre-project aimed at undertaking a review of information on life cycle analysis of tropical timber products. The background information on this pre-project is outlined in the Annex to these terms of reference.

2. Work Assignment

Conduct a review to compile the work being done on LCA for timber products and for tropical timber products in particular. The consultant shall carry out a review of research and studies undertaken by, among others, The Timber Trade Federation of UK, the Swedish Institute for Wood Technology Research, the Forest and Wood Products Research and Development Corporation of Australia, the Canadian Wood Council, Forintek of Canada, the Malaysian Timber Council, FAO, Imperial College, the University of Sydney as well as all other sources. The following terms of reference are proposed for the consultancy work.

3. Terms of Reference

1. Collect, analyse and report on research results and case studies on LCA for timber products and for tropical timber products in particular, this should include details of the agencies with expertise in the execution of LCA studies.
2. Present evidence on the advantages and disadvantages of tropical timber over other materials, such as plastic, steel, concrete and temperate timber as documented in LCA studies.
3. Prepare a preliminary report for the consideration of the ITTO Secretariat.
4. Prepare a final report incorporating the comments from the ITTO Secretariat and present it to the Committee of Economic Information and Market Intelligence in May 2003 in Panama.
5. Prepare an edited print-ready final report incorporating the comments from the Committee.
6. Prepare an article for possible publication in the ITTO's newsletter 'Tropical Forest Update'. Appropriate photographs should be provided in digital form, if possible.

Appendix 2 Review sheets on LCA reports

This appendix contains single page reviews of the selected reports and publications on LCA of forestry and timber products considered in this report. These studies have been produced for a variety of purposes. Although some focus on particular issues to provide specific results, others undertake complete life cycle assessments with fully classified, characterised and normalised results. However, their essential commonality is that they incorporate or present relevant LCA data and results. To varying degrees, these studies address, explicitly or implicitly, key considerations which can have a fundamental effect on the results derived. In particular, these considerations include land use, products and co-products, transport distances, energy usage and technical performance of wood species in varying products, including durability and preservation. Often comparisons are also made between timber and non-timber alternatives for the same function e.g. window frames from wood and PVC, electricity poles. Particular attention is given to these considerations in the following reviews which are intended to examine their transparency and consistency, and to establish their strengths and weaknesses.

These reviews are presented in 2 groups – non-tropical and tropical timbers – as detailed in Tables 4.1 and 4.2 and are referred to by their abbreviated titles

Review sheets - Non-tropical Timber

Review of the environmental impact of wood compared with alternative products used in the production of furniture

by Taylor, J., and Van Langenberg, K. (2003), Project No PN03.2103, Market Knowledge & Development, Forest and Wood Products Research and Development Corporation, Victoria, Australia
http://www.fwprdc.org.au/content/pdfs/furniture%20review%20WEB.pdf

This is a review report that considers the results of several LCA and other studies related to comparisons of timber-based materials vs alternative materials in the context of furniture manufacture and use. It notes that there are no studies to date that compare wood with other materials for the production of furniture. The review summarises the results of LCA work on non-furniture products e.g. housing, flooring.

The report summarises some LCA data from the studies reviewed e.g. process energy requirements of 3.4 MJ/kg for Kiln dried sawn softwood, 2.0 KJ/kg for kiln dried sawn hardwood, 0.5MJ/kg for air dried sawn hardwood, 8 MJ/kg for particleboard, 80MJ/kg for PVC, 34 MJ/kg for steel. It is also noted in the report that harvesting operations for Australian hardwood form native forests are similar to plantation softwood but that diesel consumption tends to be higher for the hardwoods. The hardwoods require considerable less drying however than softwoods. Extraction of native forest hardwoods were noted as causing an environmental impact on native fauna and depletion of suitable habitat for native plant and animal species.

The study does not include LCA data and, as a review, is not an ISO LCA *per se*.

Overall, this review presents a very positive case for the use of wood products in furniture with a key result being ‘in all the examples studies, wood has been found to have the lowest environmental impact compared with other materials.’. The results of the review ‘form the basis of a compelling argument that the use of timber and timber products for the manufacture of furniture leaves a smaller impact o the environment than other alternative materials such as metals and plastics

Comparison of wood products and major substitutes with respect to environmental and energy balances

by Frühwald, A., Welling, J and Scharai-Rad, (2003), Seminar for the Sound Use of Wood, ECE/FAO, Poiana Brasov, Romania, 24-27 March 2003
(http://www.unece.org/trade/timber/docs/sem-1/papers/r32Fruehwald.doc)

This paper summarises LCA results for a timberframe single family house, a simple 3-storey wood/steel building, wood window frames and wood flooring materials. The use of wood in these products is compared with alternative materials for the same function (some of the construction alternatives also contain elements of wood). The results of LCA are presented for 4 impact categories – GWP100, Acidification Potential (AP), Eutrophication Potential (EP) and Photochemical Oxidant Creation Potential (POCP). This is a reduced list of impact categories from a 'full' LCA, possibly a reflection of the short nature of this paper (a fuller report containing an extended version of this data is presented by Scharai-Rad and Welling (2002), although this also uses the restricted range of impacts).

The paper presents a positive view of the environmental attributes of wood usage for this range of products in comparison with alternative materials. It essentially summarises LCA data available in other reports although it does not clearly provide reference to the underlying nature of those studies with regard to conformity with ISO or other best practice LCA methodology (ISO 14042 is referenced with regard to the flooring study). This is of particular importance with regard to critical review where LCA results are used to support comparative assertions (BS ISO 14040). It appears that data from the other reports has been re-worked in this paper and perhaps 'updated' in a new impact assessment though this should be made transparent if so. This re-working would have been of considerable value as some of the source reports are up to 12 years old and potentially large differences in steel recycling rates, chlorine production processes for PVC etc as well as impact factors in LCA are likely to have occurred since their original production.

The structure of the information presented here and in Scharai-Rad and Welling (2002) suggests that they were conducted with regard to many of the features of the ISO methodology. This is also consistent with the report authors' experience with LCA. The comparative nature of the assessments is interesting, although as indicated above, the results should be used with caution. The paper concludes with an analysis of the substitution pressures faced by wood products even when the results of environmental assessments are strongly in their favour.

Land use in ecobalance and LCA of forest products

by Wessman, H., Alvarado, F., Backlund, B., Berg, S., Hohenthal, C., Kaila, S., and Lindholm, E-L. (2003), Scan Forsk report 746, STFi, Stockholm, Sweden.

This extensive report is based around five main chapters concerned with identifying suitable indicators for use in LCA of forestry in the Nordic countries. Proposals are made for the development of such indicators and their relationship with ongoing forest site and stand-level data collection. The proposals recognise particularly synergistic benefits through optimising the use of already collected data, possibly with some refinements and additions and the benefits that could accrue to forest management and planning from an integration with LCA. Ecosystem driven approaches for biodiversity assessment are considered to still require too much input to incorporated into LCAs for the present.

The report is of methodological interest to LCA practitioners as it addresses the significant issue of Land Use impacts in LCA. However, there is also a very useful dataset and review of energy use and environmental impacts from forestry operations (including transport to mill) in Sweden that indicates that present fossil fuel use varies around 200 MJ m^3 roundwood. Other environmental impacts are also quantified and the data gathering and presentation indicate that it would be suitable for use in full LCA studies in accordance with ISO. These data are useful for benchmarking for other forestry systems and LCA studies.

NICOLETTI et al **2002**

LCA of beech manufactured product

by Nicoletti, G.M., Notarnicola, B., and Tassielli, G. (2002).. International Conference on "Ecobalance and Life Cycle Assessment in India", MOEF (India)/AIST /APO(Japan) /IDBI(India) /IGIDR, Mumbai, India, 13-15 February, 2002.

This conference paper gives a full cradle-to-grave LCA modelled around a beech chair. The life cycle is highly interesting in that it includes production and export of beech (*Fagus sp.*) roundwood from a relatively underdeveloped country Albania to neighbouring Italy where the manufacturing, use and disposal by incineration takes place. The LCA is stated to have been conducted in accordance with the ISO 14040 standard and limited LCI data are presented in the paper. Impacts are assessed for the categories Global Warming, ozone depletion, acidification, photochemical oxidant creation potential, human toxicity and nitrification..

The most burdening phases of the life cycle are identified as being the painting/coating of the chair due to release of volatile organic compounds (VOCs) to atmosphere and the sawmilling due to electricity and fossil fuels. Improvements should be focussed on these elements of the production through energy saving measures and possible change to water-based coatings. The authors take a thoughtful approach to the issue of development in Albania and state that there is a risk in technology transfer to Albania to enable manufacture of semi-manufactured or finished products due to potential transfer also of pollution related to these activities. They conclude that eco-compatible technologies should be transferred to avoid the profits associated with the production of higher added value commodities being at the expense of growing damage to the environment and public health.

Overall, this is a fine and well constructed study containing a wider view.

Energy, Carbon and Other Material Flows in the Life Cycle Assessment of Forestry and Forest Products: Achievements of the Working Group 1 of the COST Action E9

EU-based Consortium under European Co-operation in the Field of Scientific Research and Technical Research (COST) Action E9, 1997-2001.

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Schwaiger, H., Joanneum Research Institute, Graz, Austria
Finér, L., Finnish Forest research Institute, Joensuu, Finland
Cortijo, P., Ecobilan-PriceWaterhouseCoopers, Paris la Défense, France

European Forest Institute, Discussion Paper 10, European Forest Institute, Joensuu, Finland (2001)

This report summarises four years of collaborative work in methodological issues concerning LCA application to forestry and forest products. The results of assessment of 5 case studies on Forestry and 5 case studies on Forest products were used to identify common methodological difficulties in applying LCA to these sectors. These were issues concerned with terminology and definition (e.g. products and wastes, see now BS ISO 14050), large variability in production systems across Europe and beyond and difficulties in comparing different LCA studies due to variable quality of LCI data (note the DD/ISO/TS 14048 (2002) standard for Data documentation format was considered to be a useful development for this). The importance of spatial and temporal issues in forestry/forest products life cycles was emphasises and it was concluded that dynamic modelling was important to enable the temporal changes in forest ecosystems to be included in LCAs. Variability in fuel consumptions and GHG emissions from forest operations around the EU region were analysed and it was determined that GHG emissions from harvesting, hauling and log transport ranged from about 6.5 kgCO_2 equiv./m^3 to about 21 kgCO_2 equiv./m^3 with most countries being in the order of 10 kgCO_2 equiv./m^3. The GHG emissions from harvesting and hauling are considered to be very low at about 0.5% of the carbon stored in the wood. COST Action E9 WG1 also considered the potential impact of nutrient fluxes in forestry/forest products which are not often studied in LC It was concluded that further work is required to identify which are the most relevant nutrient flows and then to determine whether appropriate data can be obtained.

The data reported in this publication are valuable 'complementary' information for LCA studies. The case studies themselves are not presented in sufficient detail to be considered as LCA reports *per se* but several are referenced for further enquiry. The fuel and GHG consumption review for forestry operations around the EU are highly useful for benchmarking and possible sensitivity checks in other LCAs for forestry/forest products.

COST E9 WG2 Study 2002

The Assessment of Environmental Impacts caused by Land Use in the Life Cycle Assessment of Forestry and Forest Products: Guidelines, Hints and Recommendations. Final Report of Working Group 2 "Land Use" of COST Action E9

EU-based Consortium under European Co-operation in the Field of Scientific Research and Technical Research (COST) Action E9, 1997-2001.

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Salpakivi-Saloma, P., Finland
Swan, G, Sweden
Wessman, H., Finland

Mitteilung der BFH Nr. 209, Hamburg, Germany (2002)

This report is concerned with the single issue of Land Use in LCAs for Forestry and Forest Products. It represents between 1/3 and 1/4 of the activity of the COST Action E9 emphasising the significance of this particular aspect of the LCA methodology. The topic of land use impacts within LCA has been intensively studied in Europe. The report presents possibly systems for inclusion of Land Use impacts in LCAs and identifies three groups of possible indicators 1) those suitable for all land use types, 2) those suitable only for forestry, and 3) those that E9 WG 2 considered unsuitable for the assessment of land use impacts. In addition to choices concerning selection of indicators, difficulties were highlighted in the selection of a conceptual/theoretical framework for the development and evaluation of such indicators, the superficial level of assessment of impacts on biodiversity, the selection of appropriate reference systems (e.g. distance from 'nature') and timescales, and the likelihood of being able to get to a universal, transparent and operationally practical assessment for Land Use impacts.

While this report does not present a solution to the problem it is very useful reading for any LCA practitioner aiming to work with LCA in the forest/forest products sector. There are a number of existing Land Use impact assessment approaches available in LCA tools and decision on whether to use them and their appropriate application and interpretation of their output, especially in comparative studies between different timber sources or with non-timber materials, is a necessity for high quality LCA studies. To quote the report on the present state of development:

"due to a lack of knowledge as well as a lack of data, a complete assessment of all impacts caused by land use is impossible for the time being".

It was concluded that the indicators recommended in the report permit a simple assessment of some key impacts of major European land use types and forest management systems. It remains a key decision at the Goal and Scope stage for any LCA including these and other forest types whether to adopt a Land Use impact assessment procedure for the study and if so which one(es).

LCI data or complete case studies are not included in this report.

COST E9 WG3 Study **2001**

Life Cycle Assessment of Forestry and Forest Products - Achievements of the COST Action E9 Working Group 3 "End of Life: recycling, Disposal and Energy Generation".

EU-based Consortium under European Co-operation in the Field of Scientific Research and Technical Research (COST) Action E9, 1997-2001.

Authors	Jungmeier, G, J. (WG2 Leader)	
Berg, S., Sweden	Evald, A., Denmark	Gallis, C., Greece
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Pajula, T., Finland	Petersen, A-K., Norway	Richter, K., Switzerland
Schwaiger, H., Austria	Skodras, G., Greece	Spanos, K., Greece
Speckels, L., Germany	Spitzer, J., Austria	Springer, S., Germany
Voss, A., Netherlands	Werner, F. Switzerland	Wessman, H., Finland
Zimmer, B., Germany		

Report No IEF.2000.AF.012-01 by Joanneum Research, Institute of Energy Research (*Ed*. Jungmeier, G.) Graz, Austria (2001)

This report presents six contributions covering allocations issues in LCA, inclusion of energy generation from wood and fibres in LCA, integration of end-of-life options into LCA studies with wood and LCA assessment of the impacts of using post-consumer wood for particleboard manufacture or energy generation. The principles and procedures of ISO 14041 were examined in detail for system boundary setting and allocation and recommendations made as to how to implement these for LCAs of forestry and forest products. The basis for the recommendations are exemplified using numerous examples to provide a robust demonstration of good practice. The following recommendations for implementation of LCAs for forest products can be summarised :

- A balance of biological carbon and energy is inherent in wood products and should be included and allocated on a mass basis
- Expansion of system boundaries by combining material and energy aspects of wood is favoured (e.g. 1 m^3 of particleboard + 3 KWh energy)
- If avoiding allocation is not possible then the reasons should be documented in the LCA
- Different allocation options should be included in sensitivity analysis for different environmental effects in the LCA
- Allocation options that appear most practical are : Forestry – mass and volume: Sawmilling – mass and market price: Wood industry – mass and market price
- It is important to consider and document aspects of energy and carbon balance, energy generation and substitution potential and other waste management options for wood products in LCA
- The most important benefit of bioenergy is greenhouse gas reduction through fossil fuel substitution (other aspects may not be so beneficial (e.g. particulates, NO_x))
- The waste management option(s) selected in an LCA can have a greater influence on the results than the production of the wooden product through effects on greenhouse gas emissions – this may support product manufacture improvements (design for energy, design for recycling)

The report provides valuable guidance with a strong background in the ISO 14040 standards on approaches to end-of-life options for wood products and very useful benchmarking data on energy values and the effects of using different allocation and end-of-life options. Detailed LCI data or complete LCAs are not presented.

HILLIER and MURPHY Study **2000**

Life cycle assessment of forest products – a good story to tell

by Hillier, W. and Murphy, R.J. (2000), Journal of the Institute of Wood Science 15 (4), 221-232.

This paper presents an overview of the LCA method as applied to forest products. Summarised results are presented (full reports are referenced) from comparative studies on creosote treated wood poles for electricity distribution (including the effects of fugacity modelling of PAH emissions and the use of modelled data in impact assessment) and for preservative treated wood used for fencing. Seven environmental impact categories are used. In both examples, specific LCA issues are addressed, the modelling of hazard and risk and the importance of temporal considerations in the case of creosote treatments and the importance of end-of-life scenarios to LCA outcomes in the case of CCA treated fencing. Overall, the results of the LCA assessments indicate that preservative treated wood products for outdoor applications where high durability is requires can compete favourably with alternative materials like steel, Glass fibre reinforced plastic and concrete – even including the presence of the preservative components in the wood product life cycle. The results can be even more compelling for treated wood products if optimised fate modelling and optimised end-of-life disposal strategies are adopted.

Whilst the ISO methodology is presented and summarised in this paper the results are not declared as being conducted under the full ISO procedure, including peer reviewed although the importance of review is discussed. The data should thus be regarded as unreviewed on the basis of this report. LCI data are not presented.

ATHANASSIADIS Study **2000**

Resource Consumption and Emissions Induced by Logging machinery in a Life Cycle Perspective

by Athanassiadis, D. (2000), Doctoral Thesis, Swedish University of Agricultural Sciences, Umeå.
includes Athanassiadis, D., (2000) Energy consumption and exhaust emissions in mechanized timber harvesting operations in Sweden. The Science of the Total Environment 255, 135-143.

This thesis and paper present LCI data for energy consumption, emissions to air, emissions of hydraulic and lubricant oil and spare part requirements in forest harvesting in Sweden. The data are presented based on a 'functional unit' of $1000m^3$ underbark making them transferable to other studies. They represent a detailed assessment of this topic and although limited in scope provide valuable input to LCA studies. They are not an LCA study in themselves.

An energy input of 82 MJ m^3 was calculated for logging machinery (harvesters and forwarders). The manufacturing phase of the forest machinery was found to be only a small component of the environmental impact of timber harvesting with 6% of the vehicle's life cycle energy consumption due to vehicle production.

DETR PiT Study **2000**

Environmental Assessment of UK Forestry, Sawmilling and Panel Production

UK-based Consortium for DETR Partners in Technology Contract C138/19/133 cc1440

Partners- BRE Ltd, Centre for Timber Technology and Construction (Co-ordinator)
Imperial College London
Forestry Commission
Forest Industry Council
Timber Growers Association
United Kingdom Forest Products Association
Wood Panel Industries Federation
Department of the Environment, Transport and the Regions

Final Report and Summary report 2000, Mundy, J.S., Thorpe, W.M.H., Bonfield, P.W., Hillier, W., and R.J. Murphy. BRE Watford Report Nos. 79714 and 201-393

This report summarises a three year project sponsored by the UK government Department of the Environment, Transport and the Regions (DETR). The work was carried out to quantify the environmental impacts of the UK primary wood processing industries, including UK forestry. It was based on the BRE Environmental Profile methodology (Howard, Edwards and Anderson, 1999) which follows the principles in the SETAC and ISO 14040 LCA procedures. The BRE Environmental Profiles approach recognises 13 LCA Impact Categories with equivalency factors and includes a Normalisation procedure to the impacts of the annual activity of 1 UK citizen. In the Summary Report the results are also expressed in terms of BRE Ecopoints. The Ecopoint system is essentially a valuation of the normalised scores to derive a weighted score based upon a consensus based assessment for sustainable construction issues. It is similar to the approach contained in the Eco-Indicators methodology.

LCA data in the reports are presented as normalised impact scores for the following elements of the UK forest sector:

Forestry (1 green tonne)	***Sawmilling (1 m^3)***	***Panel products (1 m^3)***
Average GB softwood forestry	Sawn green	MDF
Spruce forestry	Sawn & kiln dried	OSB
Pine forestry	Sawn & treated	Cement-bonded particleboard
Softwood Continuous Cover	Sawn, Treated & Kilned	
Oak forestry		
Oak Continuous Cover		

Detailed LCI data are not presented although summary data for transport and energy are. The study is clearly cradle-to-gate. Climate change benefits are recognised for forestry, sawmilling and for particleboard, OSB and cement-bonded particleboard. Forest road construction and maintenance was the major source of impacts in forestry, sawmilling required little energy and kiln drying in addition, though consuming energy and contributing to climate change the net climate change effect remained negative (a benefit). Preservative treatment with CCA was also a low energy requiring process but added to the eco profile in mineral extraction and human toxicity to air.

LIFE-SYS WOOD Study **1999**

Consistent Life Cycle Analysis of Wood Products

Life Sys Wood Consortium for EC R& D Contract FAIR-CT95-0726

Co-ordinator - TNO Centre for Timber Research, Delft, The Netherlands
Partners – Technical Research Center of Finland (VTT); Schauman Wood OY; Imperial College London (IMPCOL); Norwegian Institute of Wood Technology (NTI); Swedish Institute for Wood technology research (TRAETEK); Swiss Federal Laboratories for Materials Testing and Research (EMPA); Forintek Corporation of Canada (FORINTEK).

Final Consolidated Report 1999, *Eds.* Esser, P., and Robson, D. (3 Volumes)

This report summarises a four year project sponsored by the EC FAIR programme. Within the project 2 main activities occurred 1) 8 LCA case-studies on forestry and wood products of EU origin were conducted by the various partner institutes and 2) collaborative work was carried out to use an agreed set of 'Decisions' (18 in total) on LCA methodological approaches in order to develop a consistent approach to the LCA of wood products. The project also attempted to develop a Knowledge Based System for such LCA data and results. The case studies were:

Wood raw material Finland	VTT/Schauman	Finland
Window frame Dutch conditions	TNO	Netherlands
Window frame Swiss conditions	EMPA	Switzerland
Wood flooring	Trätek	Sweden
Preservative treated wood fencing	Imperial College	UK
OSB panel in roof construction	Imperial College	UK
Plywood	Schauman/VTT	Finland
Structural beam	NTI	Norway
Associate partner – methodology	Forintek Corp.	Canada

The project represents a substantial research effort in co-ordinated LCAs for wood products in the EU. The LCAs were conducted with reference to the developing ISO 14040 series standards and CML 1992 Guide. Overall the Life-Sys Wood project generated a list of 18 'Decisions' adopted within the project for conducting LCAs on wood products. The development of a common LSW transport data set within the project was found to exert a strong influence on the LCA results when sensitivity analysis was conducted with local, specific transport data (modes and distances). The decision to exclude aggregated data for processes e.g. electricity generation was found to be a particularly useful outcome of the study.

It should be noted that several of the LCAs were comparative with non-wood alternatives (e.g preservative treated softwood for fencing vs concrete/steel wire and steel box post/steel wire alternatives; wood parquet flooring vs polyolefin). A general conclusion of the LSW LCAs were that : energy use in forestry operations is low compared with manufacturing or service life (of some products e.g. painted window), the wood products chain is highly complex in comparison with other materials, involves extensive rather than intensive impacts in the raw material phase, the choice of service life of the product is of major importance for the results, final disposal options have a major effect on the LCA results, transport processes contribute a significant part to total energy and emissions.

The report contains peer-reviewed LCAs and LCI data for various processes.

FEI Study **1998**

Forest industry and the environment: a life cycle assessment study from Finland

by Seppälä, J., Melanen, M., Jouttijärvi, T., Kauppi, L., and Leikola, N. (1998), Resources, conservation and recycling 23, 87-105.

This paper presents and unusual LCA study in forestry forest products because it considers the entire production system of the mechanical and chemical forest industries in Finland. It is novel in approach to Impact assessment in using decision analysis impact assessment developed in the background project. The report refers to SETAC and CML in terms of other methodology and appears to have been conducted in accordance with their guidelines. It does not refer to ISO standards. The report contains LCI data at the whole industry level – potentially a useful source of data for 'average' benchmarking.

The impact assessment results are subject to a weighting and aggregation procedure to generate value scores that are considered by the authors to be necessary for decision making. Overall the Finnish forest sector was assessed as causing 10 to 15% of domestic environmental stressors. Increasing energy efficiency was identified as a key issue for environmental protection in the forest sector.

Overall the study demonstrates that LCA can be applied to assess not only single products but also whole production systems. The quality of the assessment is subject to uncertainties to do with data and modelling results and it is stated that subjective data must always be used in order to make quantitative impact calculations. This makes sensitivity and uncertainty analysis essential in LCA.

Overall, a highly interesting paper that indicates the scale at which LCA can be applied in the forest sector.

NORDPAP Study **1998**

Use of agro fiber for paper production form an environmental point of view

by Hedenberg, O., Backlund Jacobson, B., pajula, T., Person, L., and Wessman, H. (1997), Nordpap DP2/54, SCAN Forskrapport 682, STFi, SwedenResources, conservation and recycling 23, 87-105.

This is an excellent report on a cradle-to-grave study of the environmental impact of a paper containing reed canary grass agro-fibre to substitute for 40% of the birch fibre in an integrated fine paper as compared with 'conventional' production (50/50 pine and birch pulp). The report presents the goal and scope, assessment methods, inventory data and impact assessment in very clear and comprehensive way. The impact assessment is conducted using five weighting approaches which strengthens confidence in the overall findings. The study goes on to recommend the use of at least two methods for such assessments.

The study meets the requirements for transparency and completeness in a very thorough way – all inventory data and calculations are fully presented. The interpretation of the results has also been undertaken with due regard to the uncertainties in the data and care is taken not to over-emphasise the slightly higher environmental impact of he agro fibre paper. The study seems not to have conducted formal marginal, or sensitivity analysis although this does not seem critical for the conclusions drawn. There is no reference to a formal peer review although the authors state (in connection with a discussion of weighting) that they "do not consider the study describes in this report as a comparative assertion".

Overall, this is a very good example of a high quality LCA report.

BERG Study **1998**

Some aspects of LCA in the analysis of forestry operations

by Berg, S., (1997), J. Cleaner Production 5 (3), 211-217

This paper reports on CO_2 and NO_x emissions from different harvesting systems in Sweden. Motor-manual harvesting, despite the additional transporting of people involved, has lower emissions than mechanized felling (on a per m^3 basis). It illustrates that forest harvesting methods will influence the environmental profile of the harvested wood. The values in this paper indicate that CO_2 emissions from felling and forwarding are in the order of 5 kg/m^3 in clear cutting and about 14% higher for shelterwood cutting.

Review sheets - Tropical Timbers

VROM Study **2002**

LCA for Acetylated wood Final report 2: Light Duty Piling in Fresh Water Use

by LCA Group Imperial College London and SHR Timber Research (2002), Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (VROM) The Netherlands.

This report presents a full cradle-to-grave LCA of the use of acetylated pine wood for use in sheet piling for canal siding. The study is comparative with Azobe from West Africa and Larch from Siberia, Russia. The functional unit is defined as "the amount of material needed to construct and install 10m of sheet piling and to maintain it for a period of 20 years, in an average city waterway or similar type of waterway, and to dispose of the piling at the end of that time". Full details of the product system specification, system boundaries, data, allocation, sensitivity and marginal analysis and impact assessment (using CML 99 and Eco-Indicators 99) methods are given in the report. The report was subject to critical review and minor amendments made in response.

The key findings from the study with regard to its Goal and Scope to examine acetylated pine wood were:

- Compared with the alternative timbers acetylated pine has no significantly greater environmental impacts and its use in freshwater does not lead to pollution hazards
- Mixtures of wood materials that make best use of the durability properties offer the best environmental option
- The consumption of natural gas , as a fuel and a feedstock, is a 'hotspot' in the life-cycle of acetylated pine, reduction through process efficiency improvements or closed loop recycling are worth exploring
- The use of 2 separate impact assessment methodologies adds strength to the conclusions of the study
- There was a lack of data to characterise the effects of harvesting on the ecological quality of the forests in Siberia and West Africa. Due to this lack of appropriate data Land Use impacts were not calculated for any of the timber materials
- The inputs to harvesting in these forests were also based on machinery types and consumptions for North European Forestry. This was not considered to have significantly affected the results.

Although not a focus of this study, the results clearly demonstrated that the sheet piling made from Azobe had the lowest overall environmental impact of the 'pure' woods and that this was further reduced when used in combination with larch. It must be noted that a land use impact could not be included in this study and that this conclusion may change if it had been. However, this requires direct verification and it is also noted that Azobe can be produced under sustainable management conditions and may obtain certification in the future. These LCA findings suggest that there will be value in proceeding with certification for Azobe management so that potentially good LCA profiles can be supported with confidence.

This LCA is produced in conformity with the ISO 14040 series and contains LCA data.

THAI PAPERBOARD Study **2002**

Life cycle assessment of paperboard packaging produced in medium-sized factories in Thailand

by Ongmongkolkul (2001), MSc Thesis, Asian Institute of Technology, School of environment, Resources and Development, Thailand.

This report presents a full cradle-to-grave LCA of a paperboard packaging product (1 tonne) in Thailand. It models the opportunities available to reduce environmental impacts in the life cycle through improvements to landfilling (gas capture and treatment), reuse and recovery of used paperboard, reduced drying fossil energy consumption by use of solar energy and technological improvement by electrical motor upgrades. The paperboard product modelled is made from 15% virgin pulp from plantation Eucalyptus and 85% recycled corrugated containers. The reference disposal option for the manufactured paperboard is 60% landfilling, 40% recovery to recycling based on local data. The study is undertaken in accordance with ISO14040 standards with the exception of absence of critical review and formal sensitivity analysis.

The study includes some primary (site specific) data but also relies to a large extend on secondary data form the Sima Pro 4 dataset, much of which is relevant to the European or Western situation. The inventory data are reported and the Impact assessment was by the Environmental Design of Industrial products (EDIM) methodology. Several scenarios were run with the impact scores to identify potential for environmental improvement.

The key findings were:

- Landfilling was the most serious element in the life cycle accounting for about 50% of the global warming and acidification impacts and 37% of the POCP.
- Reuse of the paperboard box (2 uses) could reduce solid waste generation by 50%
- Technological improvements at the manufacturing plant towards solar energy and upgraded electrical motors would also reduce emissions and energy consumption considerably. The paperboard production in the reference scenario consumed approximately 83% of the total energy for the life cycle.

This is a well conducted and thorough study. The use of scenarios to examine the potential for improvements over the whole life cycle is especially noteworthy. The results suggest that with adoption of several of the improvement options whole life cycle impacts for paperboard usage could be reduced to about 50% or less of current levels.

PARANA PINE Study **2000**

Life cycle analysis of Parana Pine (*Araucaria angustifoila*)

by Alexandridou, S. (2000), MSc Thesis, Imperial College London, UK.

This report presents a cradle-to-gate LCA of production of Parana Pine in southern Brazil. The functional unit was 1 kg of sawn wood or plywood at exportation port in Brazil. A secondary aim of the study was to examine the extent to which there may be a general overlap or complementarity between the data needs of an LCA study and those of a Forest Certification scheme. The report presents a short review of the background to Parana pine forests and the forest products industries in the southern Brazilian states of Parana, Santa Catarina and Rio Grande do Sul. The research involved a field visit and data collection from 3 companies with activities in the sawmilling, pulp and paper and plywood manufacture sectors.

Raw inventory data are presented and impact assessment was by the Eco-Indicators 99 method, including weighting. Differences in environmental profile were noted between the three companies surveyed which were related to their principal focus in sawmilling, pulp and paper (with a small amount of sawnwood production) and plywood manufacture. However, transport distances and forest type (natural vs plantations) and management (e.g. scarification) were also considered to be important sources of difference.

The data calculations were done in Sima Pro 4 using many material and energy production processes and impacts based on European databases. This is of questionable accuracy when applied to Brazil. Data uncertainties were also considered to arise from some difficulties in allocation between Parana pine and other species processed at the companies

The key findings were:

- Variability in data quality and completeness occurred between the companies surveyed. This prevented identification of differences in impact assessment associated with the main product type.
- Absence of readily available energy and transport emission factors was a further obstacle to accuracy in the results.

Overall, this can only be regarded as a preliminary study in which some site specific data have been gathered. Further work with a much wider range of data collection would be required for an accurate LCA of Parana pine forestry and production. Critical review was not carried out.

Regarding the requirements of LCA and Forest certification the study concludes that there was little scope for inclusion of LCA requirements within Certification. Whilst LCA can support the delivery of environmental benefits it was considered that it would probably place too great a burden of added costs on Certification without solving problems such as markets or equity issues.

MERANTI Study **1999**

Life cycle assessment of the tropical timber Meranti (*Shorea*)

by Rugge, I. (1999), MSc Thesis, Imperial College London, UK. (and subsequent Internal Report, Imperial College London.)

This study and its follow up report present LCA data relevant to the forestry system for Dark Red Meranti. Particular attention was given to assessment of the method for biotic resource extraction proposed by Sas et al (1997) using site specific data collected in Peninsular Malaysia. This was considered to be especially important since the original model 'verification' relied on highly derived data for the Meranti in comparison with quite different quality data for European spruce. The results for assessment of the impact of biotic resource extraction are modelled around the quantities of spruce of DR Meranti needed to manufacture a typical window frame in the Netherlands, following the model of Esser and van der Vorst.

The report thus has a relatively narrow focus but provides useful information and supporting data on, for example, species co-extracted with DR Meranti (important for allocation), price information relevant to the time of the study for various species, forestry management cycle and estimates of residual stand damage. Revisions to the model to calculate the impact of biotic resource extraction to better represent the actual forest situation with DR Meranti were then implemented and tested against the data from the original assumptions. This changed the outcome substantially by moving the impact of DR Merati extraction much closer in extent to that for European Spruce from its previous position where it had been nearly x2000 higher for the indicator for risk of species extinction due to ecosystem degradation. The revisions proposed in this report suggest something between a 6 and 30 fold higher risk for DR Meranti extraction as compared with European spruce.

The key findings were:

- The method proposed by Sas et al. (1997) lacks refinement for addressing the environmental issues in forest practices in tropical countries.
- Modifications to account for selective felling practices and more realistic yield values yielded results dramatically different from the original values.
- A proposal is made for a more direct assessment of the impacts of forest management and harvesting based upon quantified effects on soil, hydrology, water quality, nutrients and residual vegetation. This is considered to address better the reality of forestry.

This is an interesting study that makes a number of useful contributions to the issue of Land Use impact and biotic resource extraction for tropical forests in LCA.

LCI data are not presented and compliance with ISO 14040 standards is not relevant to the scope and aims of the study.

Appendix 3 List of Organisations and individuals responding to requests for LCA information

The following individuals and organisations supplied information and comment for the review.

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Appendix 4 Extended discussion on Land use, biotic resource extraction and non-market goods in LCAs of forestry

The impact of a process of life cycle on Land Use has always been recognised as a potentially critical component of the environmental impact of products and a wide range of potential approaches to establish agreed methods to assess it have been outlined and explored as LCA has developed (see Ekvall, 1998; Lindeijer, 2000, Köllner, 2000). When the extensive framework for Life Cycle Impact Assessment in the widely accepted CML methodology was revised and improved (the CML 99 method) the treatment of Land Use was also re-examined and has now been revised and applied to a number of case studies (Lindeijer, 1998). It is to be hoped that this method, and the others mentioned below, might soon be tested in real-world assessments.

The European COST (Co-operation on Science and Technology) Action E9 "Life Cycle Assessment of Forestry and Forest Products" worked from 1998 to 2002, with the aim of developing methods for multi-disciplinary life cycle assessments to cover the whole forestry and forest products chain. This process brought together many of the leading experts in LCA for forestry, and Working Group 2 of COST Action E9 dealt specifically with the issue of land use in forestry (Schweinle et al., 2002).

Over many meetings and workshops, all of the issues described here were discussed and elaborated. The nature and result of these discussions were synthesised in a final report and a possible methodology was proposed. A key aspect of the general debate within COST E9 was the need for a 'basket' of indicators, which could be applied appropriately to the specific site and ecosystem, but which could also be applied within a common method to all ecosystems (and products). Below is a brief consideration of the main issues surrounding the difficulties in achieving consensus for an environmental impact category for Land Use in LCA.

The 'Geography' of Land Use

In Life Cycle Assessment, the changes directly made in the environment as a result of activities in the life-cycle are called 'interventions'. These are the quantities recorded and compiled in the Life Cycle Inventory. The most familiar type of intervention is the emission of x kilograms of pollutant to a specific environmental compartment.

In the Life Cycle Impact Assessment these interventions are ***classified*** according to the type of impacts that they cause, and ***characterised*** as to the extent of that impact.

Unlike the resources it provides, land is only very rarely consumed in use, rather it is temporarily occupied, and sometimes transformed from one state to another. Therefore, there are two related types of intervention that may be recorded in a Life Cycle Inventory - Occupation and Transformation.

Occupation

The occupation of land has two distinct dimensions:

- the area (extent) of the land that is occupied
- the period of time during which the land is occupied

This gives a quantity of 'surface-time', calculated as the total area occupied multiplied by the time of occupation divided by total production (the number of *functional units* provided) over all cycles of production.

In its simplest form, the use of land might be reported simply as *metre-squared-years* (m^2yr) per metre cubed (or tonne, etc.) of wood production. This quantity allows a direct assessment of the degree of *competition for land area as a limited resource*.

It immediately becomes apparent, however, that this quantity treats all *qualities* of Land Use identically. Since the quality of land is at least as important an issue as its availability, this aspect must also be addressed by recording a measure (or measures) of land quality as well as surface-time in the inventory.

It is in describing the quality of the land being used that subjectivity is inevitably introduced into the process. There are many possible aspects and indicators of land quality that may be described. Whilst individual measures can be objectively described and measured, the choice of *which* of those measures are to be applied is a subjective decision made by the particular LCA practitioner conducting the study.

Transformation

Land quality can change at the start of occupation, during the life-cycle, and after occupation has ceased. Therefore, if land transformation is to be included, the inventory must record changes in quality, both the direction and the extent of those changes, for up to three separate stages.

Furthermore, changes during one cycle may be essential in accurately assessing the overall value and effects of a land management regime (e.g. Schieck et al., 1995; Steventon et al,. 1998 for birds in forestry), but these effects have not been adequately recognised or addressed by any of the methods so far developed.

Since Life Cycle Assessment is explicitly concerned with environmental effects, it is the ecological qualities of the land and the ecosystems it supports that are to be analysed and described.

Köllne (1999) analysed land quality impacts for LCA in terms of ecosystem quality (EQ) and identified three distinct aspects of ecosystem quality:

- biodiversity (taxonomic and genetic)
- ecosystem functions and services (robustness and security of ecological processes)
- ecological resources (standing stock, soil productive capacity, etc.)

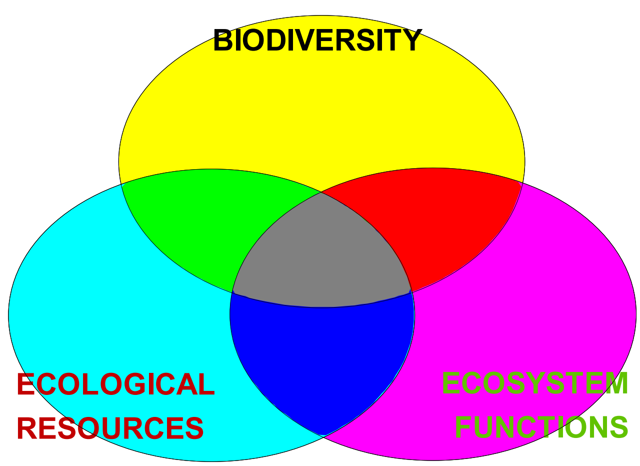

Figure A3.1. The three interdependent aspects of Ecosystem Quality.

These three aspects are not independent, but overlap as illustrated in Figure A3.1. This analysis is (either explicitly or implicitly) fairly general amongst all current approaches, although not all methods address all aspects.

Forestry and agriculture may, of course, continuously occupy land over very long periods of time, and many cycles of production. The selection of how to define ‘before’ and ‘after’ (and the ecosystem qualities assumed at those times) the land use is therefore subjective and at the very least difficult. For tropical forestry it is very clear that both the condition in which land is received and left after the production of a forest product are important defining parameters for land use, as is the actual fate of the land after production. In Figure 2 these aspects of the land use problem are illustrated and described further below.

Time

The Time of Occupation axis in Figure A3.2 covers the whole period of time during which this specific use of the land determines, or is 'responsible for', the quality of the land. This period includes the initial conversion of the land to the new use (0 to v), and the period at the end of this use when the quality of land is returning (or being returned) to a new steady state (w to x). Which of these periods are included in a specific measure, and the way in which they are included varies considerably between land use methods.

The length of time to be assumed for the final relaxation period is the greatest source of uncertainty and subjectivity in this quantity. A number of terms are applied to this final period, mainly according to the type of process taking place, for example abandonment ('relaxation' or 'renaturation') or human modification ('restoration').

The period of conversion at the beginning of occupation is most often assumed to be brief, and is neglected in existing methods. In forestry, however, this period may be long, complex and positive in effect on the ‘quality’ score, such as in the conversion of plantation forestry to a continuous cover system. This area requires more attention in the development of land use methods.

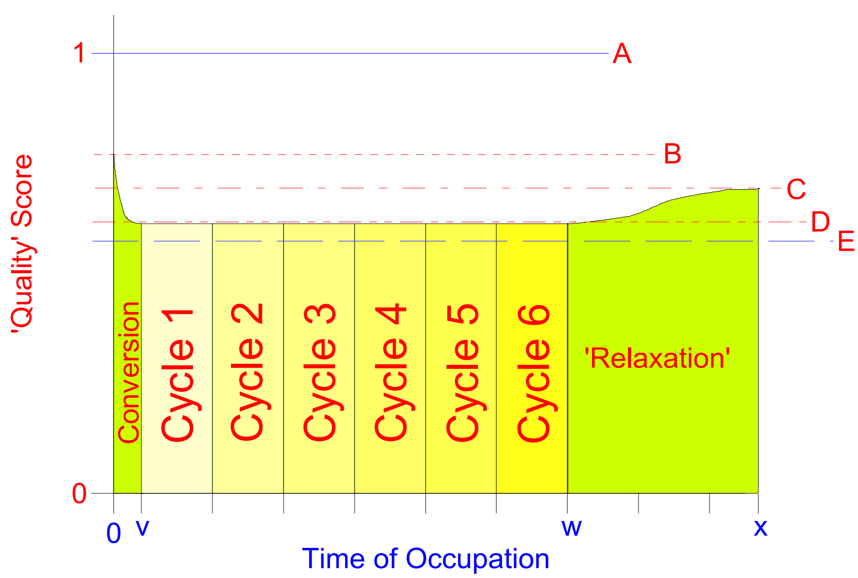

Figure A3.2 Generalised representation of key aspects in land use

Quality

The 'Quality' Score axis in Figure A3.2 can be represented by a variety of indicators in different methods and may be adjusted and modified in a number of ways, which are discussed further below.

The line 'A' is the maximum theoretical quality score (e.g. plant diversity, etc.) for this ecosystem type, or biome.
The line at 'B' is the initial condition of the specific land area occupied.
The line at 'C' is the final steady state of the specific land area occupied for production after relaxation.
The line at 'D' is the quality of the specific land area occupied for production during the period of production.
The line at 'E' represents the actual average quality score for this type of land overall at a local, regional or global average.

An occupation score including land quality is based on the area under the quality curve for the periods included in the method, divided by the total production. The calculation of this score inevitably involves a great many uncertainties and arguable assumptions.

The first uncertainty arises from the selection of exactly which indicator(s) is (are) to be used to represent land quality. Pragmatically, for a generally applicable tool such as LCA, this has to be a quantity that either is routinely gathered, or could feasibly be gathered without excessive cost or technical difficulty. In practice, this eliminates a great many theoretically interesting approaches including soil chemistry and hydrological parameters (e.g. see Schenck et al, 2002) as well as many physical parameters, general biodiversity (including animal and microbiota diversity) or genetic diversity. The only real possibilities are measures already used in land management, or those derived from remote sensing that can be automatically calculated.

There is now fairly general agreement amongst well developed scoring methods that vascular plant diversity is the best practical measure of diversity, and plant biomass together with net primary productivity is the best practical measure of ecosystem function or health. The only radically different approach is the use of ecosystem exergy as a measure of both diversity and function.

In order for different ecosystem types (e.g. desert and rain forest) to be equally treated in such a system, it is necessary to introduce a quality 'baseline' appropriate to each ecosystem type. Scores are then expressed relative to this baseline rather than presented directly as absolute values for diversity or function.

The selection of appropriate baselines is the second large area of uncertainty and subjectivity inevitably involved in any measure of land use impact.

It should also be borne in mind that, in reality, land use impacts can be positive or negative. Just as a process removing atmospheric pollutants (such as the fixation of carbon dioxide in timber) may have a net positive (beneficial) impact, certain land uses may leave land in a better condition at their end than their beginning. Setting an average value as a baseline (as suggested by Köllner, 2001) can show this directly in positive scores. Other approaches, such as the use of maximum possible value (as described by Lindeijer, 1998) as a baseline cannot.

Cyclic production presents a third difficulty; the sharing of Land Use changes between cycles. For example, the conversion of old growth forest to plantation management may represent a significant change in quality in the first cycle, but subsequent cycles may show very small or zero changes. Should the initial change of land use be 'shared' between cycles of production? If so, over how many cycles? In what proportion?

It is also possible to make a further distinction, between the *nature* of land use and the *effects* of land use. Simple classification by measures of quality might adequately describe the nature of land use for management purposes within the site, but the significance of this for biodiversity (both local and global), erosion protection, fire risk, etc. will vary greatly from place to place and time to time.

The Range of Methods Applied

Analysis based on the movement of land from one class to another (such as that proposed in the CML 1992 methodology), whilst simple to apply, cannot realistically be used as a solution to the problem of including land use in LCA.

If the effects of land use are the principal concern, rather than the quality of land itself, then perhaps a selection of direct measures of quality (such as measured biodiversity and soil class) directed specifically at these effects might be applied. There are, however an enormous number of potential measures to be considered for biodiversity alone[1] and no general, objective basis on which to choose between them.

The ecological functions of an ecosystem are somewhat difficult to define and to prioritise. In the Netherlands a list of 12 separate ecosystem functions (called 'life support functions') in 3 categories of importance to humans have been identified[2]. Their direct measurement for each LCA study would, however, be entirely impractical.

Alternatively, perhaps a limited number of well-chosen indicators (such as key species, plant height diversity, productivity, etc.) might be found to integrate these effects. It is this approach that has yielded the existing proposals for land use quality measures.

A measure based on 'bioquality' has been proposed by Swan[3], which integrates biological diversity and productivity, with the maximum 'potential bioquality' of the site as the baseline or reference state. Bioproductivity loss is calculated as the difference between actual and potential production of a range of resources (timber, crops, fish, berries, etc.). Potential productivity has been calculated for a number of climatic zones in Sweden. Biodiversity loss is calculated as the difference between the number of red-listed species actually occurring and the number potentially occurring on the area of land.

The measure of bioproductivity proposed has the advantage of reflecting aspects of ecological resources as well as functional health, but basing bioproductivity purely on production of use to humans may not be acceptable to a number of stakeholders. The use of red-listed species as the measure of biodiversity makes the sensitivity of the indicator very variable between ecosystem types. Proving the presence or absence of very rare species is also difficult (or impossible), and beyond the resources of most LCA studies.

The new CML methodology (CML 99) uses a related approach, but retains two separate indicators; one for biodiversity and one for 'life support function'[4]. The life support function is represented by Net Primary Productivity (NPP). Biodiversity is calculated as a local species density factor for vascular plants (actual species density divided by potential species density at

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[1] Hansson, L. 2000. *Indicators of biodiversity: recent approaches and some general suggestions*, BEAR Technical Report No. 1, Dept. of Conservation Biology, SLU, Uppsala, Sweden.

[2] Voet, E. van der, Klijn,F. Tamis,T.L. and Huele,R. 1997. *Regulatiefuncties van de biosfeer. Aanzet tot een operationalisatie van de life supportfuncties van de biosfeer, toegespitst op de rol van soortenrijkdom*. Ministerie VROM, publikatiereeks SVS no. 1997/33.

[3] Goran Swan (Ed). 1997. *Evaluation of Land Use in Life Cycle Assessment*. Chalmers, Goteborg, Sweden.

[4] Udo de Haes, H.A. and E. Lindeijer. 2002. *The conceptual structure of Life Cycle Impact Assessment*, In: H.A. Udo de Haes (Ed): Towards best practice in Life Cycle Impact Assessment, report of the second SETAC-Europe working group on Life Cycle Impact Assessment, SETAC, Paris, Fr.

the stand level) multiplied by factors for: the species richness of that 'biome (ecosystem type) relative to all biomes, the rarity of that biome and the vulnerability of that biome.

For occupation, both average and maximum-potential plant species density are used separately as baseline levels for biome species richness. For transformation (change) of land use, the condition after recovery is compared to the initial condition. The difference represents the transformation impacts of the process, which are then shared between all products produced during active production.

The use of plant species diversity is advantageous since these do not hide or move significantly, and there is some evidence that plant diversity can give a reasonable correlation with total diversity(e.g.[5]and [6]). However, structural diversity of plant species has also been shown to be a key component of total diversity (e.g.[7]and[8]), and is frequently and relatively easily measured alongside species diversity. None of the land use methods found have considered structural diversity.

Two distinct possibilities for baseline setting, each with their own merits, have been recognised: use of the maximum theoretical quality, or use of the average actual quality. Figure A3.2, with the baseline score (a score of '1') set at line 'A', represents the situation with the maximum theoretical value as the baseline. In this approach, zero is the best score that can possibly be achieved (no damage). If the baseline is set at the average, however (represented by line 'E' in Fig. A3.2), then positive scores (representing improvement in land quality are possible). In the example in Figure A3.2, all of the periods of occupation are at a higher quality than the average level for that ecosystem type, so that the quality score for this land occupation might be interpreted as a positive score, as a land use benefit rather than as damage.

If taking the average background as the baseline can be interpreted as recognition of the realistic alternative quality for that type of land (globally or within that region), then this allows the possibility for much greater recognition of social, economic and developmental constraints on land use than the theoretical optimum quality. On the other hand, including reference to the theoretical optimum allows the setting of aspirational targets for land management, rather than reinforcing a poor average or the status quo. It is likely, therefore, that any successful and useful impact indicator will recognise both types of baseline, as the CML method does.

In the EU LCAGAPS project a similar Land Use methodology was developed[9] based on species density at the local level only, with factors applied for the proportion of indigenous species, as well as the relative species richness of the biome, the rarity and vulnerability of the biome. The measure of life support function was also net primary productivity (NPP). Only land occupation (excluding transformation and the recovery period) were included.

In the EcoIndicator 99 (EI 99) methodology for Life Cycle Impact Assessment[10], a method has been used to describe 'damage to ecosystem quality caused by land-use' at the local level[11]. The

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[5] AUSTIN, M. P. 1991. *Vegetation: data collection and analysis*. Pages 37-41 in C. R. Margules and M. P.Austin, eds. Nature conservation: cost effective biological surveys and data analysis. Australia CSIBO, East Melbourne.

[6] NOSS, R. F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. *Conserv. Biol*. 4:355- 364.

[7] Ambuel, B., and Temple, S.A., 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forests. *Ecology* 64, 1057-1068.

[8] Pretzch,H. 1998. *Structural Diversity As a result of Silvicultural Operations*. Lesnictvi-Forestry, 44, 1998(10): 429-439

[9] Weidema, B.P. 2001. *Physical impacts of land use in product life cycle assessment*. Final report of the Eurenviron-LCAGAPS sub-project on land use. Dpt of Manufacturing, Engineering & Management, Technical University of Denmark.

[10] Goedkoop, M. and Spriensma R. 2000. *The Eco-Indicator 99. A Damage Oriented Method for Life Cycle Impact Assessment*. *Methodology Report* (2nd Edition). Ministerie van Volkshuisvesting, Den Haag, NL. available at http://www.pre.nl/eco-indicator99/ei99-reports.htm.

[11] Köllner, Th. 2000. Species-pool Effect Potentials (SPEP) as a yardstick to evaluate land-use impacts on biodiversity, *Journal of Cleaner Production* 8, pp 293-311.

method also explicitly and separately addresses the effects of land use on the region around the specific local area[12]. Separate factors are also produced for occupation and 'conversion' (transformation). The method allows for the non-linear variation in species density at different scales. It calculates the 'potentially disappeared fraction of vascular plant species', which is expressed as the relative difference between the number of species under reference conditions and the number under the conditions created by the conversion, or maintained by the occupation. For conversion, the time of occupation is modified by a factor for 'recovery time', but the selection of recovery period, and the state recovered to are both essentially arbitrarily set. Lowland Switzerland in 1850 is used as the reference state for the EI 99 factors.

The extreme of the integrated indicator approach is to use a single measure, such as ecosystem 'exergy' (a measure of useable potential energy content) to integrate all significant aspects of land use[13], using maximum potential exergy as the baseline[14].

This approach has the advantages of depending on well-understood scientific measurements, and appearing to be freer of subjective choices than other approaches. This is provided that it is valid to assume:

a) that exergy is a direct and valid representation of all ecosystem aspects of concern, and

b) that it is valid to assume maximum exergy as the 'goal function' of ecosystems.

It is the difficulty in proving these assumptions and the ‘accessibility’ to non-experts of the exergy concept that are the greatest barriers to the wider acceptance of exergy-based measures.

A single example of an *input related* method has been proposed to directly address the third aspect of ecosystem quality[15] - Ecological resources. Output related impacts are calculated as the effects of emissions, input related impacts are calculated as the depletion of resources. Treating biological and ecological entities as resources ('biotic' resources) allows the impacts of Land Use on these to be calculated as a reduction in the availability of these resources.

The separate treatment of the deliberate extraction of biotic resources (such as timber in forestry, or fish from fisheries) appears attractive, since it can be clearly defined and understood (unlike 'land use'), and is analogous to the extraction of 'abiotic resources' such as oil, minerals etc, which is already a well implemented impact category in LCA. There are, however, some serious problems in this approach.

Firstly, the use of an additional, special category of LCA impact singles out the production of all renewable materials as somehow different from, and by implication, even ‘worse’ than industrial production. All production processes should be addressed equally in LCA and it follows that impact categories that only apply to certain industries (like, for example, forestry and tropical ‘natural’ forests in particular) are to be avoided.

Collateral effects on other species and on the ecosystem caused by the extraction of a specific biotic resource has effects that are no different in type or scale to collateral damage to species or ecosystems caused by extraction of non-biotic resources. If a specific LCA measure is required to describe impacts on species and ecosystems then it must be applied equally to all industries – this is the case (at least in theory) under the Land Use approach.

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[12] Müller-Wenk R. 1998. *Land-use - The Main Threat to Species*. IWOE Discussion Paper no. 64, IWOE University of St.Gallen

[13] Muys, B., Wagendorp, T. and Coppin, P. 2001. *Ecosystem Exergy as an Indicator of Land Use Impact in LCA*. In: S. Ulgiati et al. Advances in energy studies: exploring supplies, constraints and strategies. Portovenere, Italy, 275-284.

[14] Bendoricchio, G. and Joergensen, S. E. 1997. Exergy as a goal function of ecosystem dynamics. *Ecological modelling* 102, 5-15.

[15] Sas,H. van der Voet, E., Corten,F.G.P., Huele,R. And Kleijn,R. 1997. *Extraction of Biotic Resources: Development of a Methodology for incorporation in LCAs with Case Studies on Timber and Fish*. CML, Leiden, Netherlands.

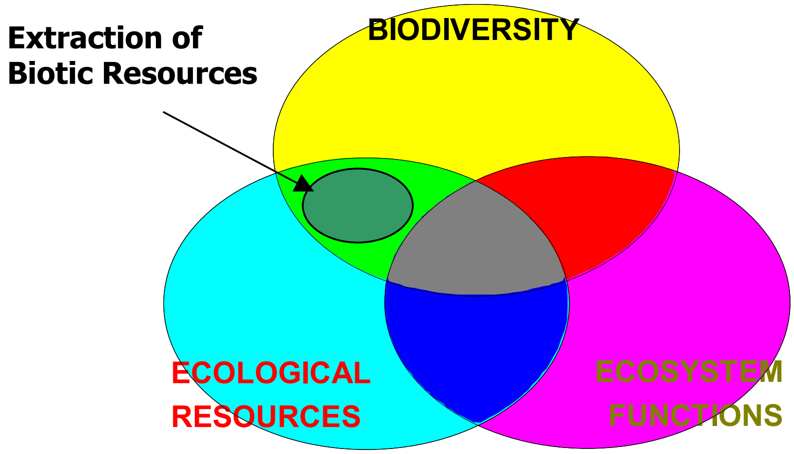

Figure A3.3. The overlap of 'biotic extraction' with other aspects of land use.

Secondly, there is a great risk of double accounting between impacts calculated as part of a 'biotic extraction' impact category and the same impacts (such as 'risk of extinction') that may be calculated as part of a Land Use impact category. The complete overlap of biotic extraction with aspects addressed in other land use impact measures is illustrated in Figure A3.3.

The future Role of Land Use in LCA

In assessing Land Use, LCA contrasts with approaches such as Environmental Impact Assessment (EIA), certification or Environmental Management Systems (EMS) since it is principally (although not exclusively) directed at products rather than land management as a process. It is also not site-specific, in that any methods developed must be directly applicable in all locations and to all products.

LCA cannot, therefore, deal in such a detailed way with the implementation and testing of principles and indicators as implemented in the certification process.

This means that it is of limited value for management planning and assessment at the stand level. It is, however much more useful for planning at the regional level, and for describing and comparing products from different systems and regions.

Furthermore, if sufficient reference is made to sources such as the FSC's principles and criteria[16] in developing and implementing methods, such as those for quantifying Land Use impacts, the synergy between the approaches (and the data needed to support them) can be maximised. The synergies are already quite apparent in some topics, as illustrated by the difficulties encountered in picking historical ecological "baselines" for implementing Principle 6 (Ecological) in developing FSC US National Indicators[17], which mirror those encountered in implementing Land Use in LCA.

General conclusions on the status and potential for the implementation of Land Use in LCA might be:

- Land Use impacts are significantly different in character from those of pollution that are normally dealt with in LCA but;

[16] http://www.fscoax.org/html/1-2.html
[17] Wood,P. 2001. *Additional Reviews of Selected International Forestry Certification Systems*. Government of British Columbia, Ministry of Employment and Investment / Ministry of Forests. Vancouver, Canada.

- it is at least possible in principle to encompass Land Use Impacts in 'traditional' LCA studies.
- The key characteristics of any effective measure are now clear, and several possible implementations have been proposed, but;
- there is a lack of LCA studies in which the existing methods have been applied and tested.
- The use of plant species diversity and productivity as measures of biodiversity and ecological function are quite generally adopted.
- Structural aspects of plant diversity have been neglected so far.
- There is insufficient recognition of the significance of 'within cycle' changes in land quality that are typical of forestry and agriculture.
- The possibility of positive scores for land improvement is not universal
- Any implementation will be highly data intensive.
- Any method will inevitably be dependent upon value [normative] judgements, especially in the setting of 'reference levels'.
- Assessments will, by their nature, be very imprecise.
- There are likely to be considerable synergies between the application of LCA to Land Use and information from management-based systems such as certification and EMS.

Overall, it is clear that there is still a great deal of work to do in refining and (particularly) applying the available methods before a final evaluation can be made of the type and value of measures to be adopted.

Given the state of uncertainty at present over the consistent and general application of Land Use and biotic resource extraction in LCAs, it is clear that different LCA studies may handle these issues in different ways and arrive at very different conclusions even when the essential forestry systems may well be similar. This must be assessed carefully in any comparison of LCA output and at present it is suggested that comparisons of forestry systems e.g. tropical vs temperate, clear fell vs continuous cover, should not be made unless an identical approach with equivalent data to the inclusion of land use and biotic resource extraction is adopted or these parameters are excluded from the assessment.